About the book

The study described here provides a framework for evaluating pest management technologies. The methodology accounts for the effects of pesticides on both production and long-term health of technicians and farmers. When health effects were considered in this study, the net benefits of pesticide use proved to be negative. Technological and policy options for reducing pesticide use are critically assessed. This research was conferred the 1993 M.S. Swaminathan Award for Social Science Research by the Los Baños Science Community.

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Pesticides, rice productivity, and farmers' health an economic assessment

IRRI

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The International Rice Research Institute (IRRI) was established in 1960 by the Ford and Rockefeller Foundations with the help and approval of the Government of the Philippines. Today IRRI is one of the 18 nonprofit international research centers supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is sponsored by the Food and Agriculture Organization of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). Its membership is comprised of 50 donor countries, international and regional organizations, and private foundations.

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The responsibility for this publication rests with the International Rice Research Institute.

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Contents

Foreword

The impact of pesticides on the environment and on human health are topics of special concern for IRRI. The Institute's strategic plan for the year 2000 and beyond identifies the balance of ecological, social, and economic sustainability as a basis for modern rice technology. We initiated a multidisciplinary project in 1989, with funding from the Rockefeller Foundation, to quantify adverse effects of pesticides on the rice ecosystem and the farm household. This book builds on the results of the larger study, which are being separately published by IRRI.

Drs. Agnes C. Rola and Prabhu L. Pingali provide a framework for evaluating pest management techniques, giving consideration to traditional factors such as input prices and production risk, then explicitly adding health effects of pesticides into the analysis. Prophylactic pesticide applications are compared with integrated pest management and natural control practices. When health effects were considered in the study, the net benefits of pesticide use have been negative. This report is a strong endorsement for sustained investment in research that can reduce pesticide use by farmers, such as integrated pest management and breeding for host-plant resistance.

The study received also financial assistance from the World Resources Institute (WRI) as part of its larger study on the economics of sustainable agriculture in several countries funded by the Rockefeller Foundation. WRI is publishing the complete set of case studies in an edited volume that includes an abridged version of this book.

Dr. Agnes C. Rola, a faculty member of the University of the Philippines at Los Baños, was a consultant to IRRI for this study; Dr. Prabhu L. Pingali is on the IRRI staff. Their work exemplifies more than three decades of fruitful collaboration between the two institutions in biological and social science research.

Klaus Lampe
Director General
IRRI

Jonathan Lash
President
World Resources Institute

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This book has benefited from the excellent comments and suggestions of experts in crop protection: Drs. Peter E. Kenmore, Gerald A. Carlson, Herman Waibel, and Dale G. Bottrell, Dr. Cristina C. David's valuable comments on the policy aspects are greatly appreciated. Drs. Mahabub Hossain, Sam Fujisaka, and Sarah Tisch of the IRRI Social Sciences Division made helpful suggestions on our methods and improved our presentation. Comments on the medical aspects of the study were solicited from Drs. Nelia Cortes-Maramba and Carmen P. Castañeda of the College of Medicine of the University of the Philippines. However, whatever errors that remain are solely our responsibility.

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Agnes C. Rola Prabhu L. Pingali

Chapter 1

Introduction and overview of conclusions

Pesticide use in the Philippines cuts rice productivity instead of improving it when the associated health costs are counted as a production cost. Rice pesticides are among the most toxic agrochemicals. Therefore, even though the Philippines' overall use of pesticides may seem insignificant next to worldwide data, the use of pesticides on rice in the Philippines is increasingly problematic.

The pesticide market for the Asia-Pacific region was valued at US$2.53 billion in 1985. Insecticides make up 75.8% of all pesticides used in the Asia-Pacific region. Herbicides account for 13.4% of pesticide use; fungicides for 8.4% (ADB 1987). These aggregates may seem large, but pesticide use at the farm level is actually quite small. Indian farmers, for instance, use about 0.33 kg of pesticide active ingredients per hectare. Pesticide use levels in Indonesia, Vietnam, and Pakistan are comparable. At the other extreme, pesticide use per hectare is high in Japan and the Republic of Korea. Japan uses 14.30 kg of active ingredients per hectare on pesticides while the Republic of Korea uses approximately 10.70 kg of active ingredients per hectare (Barker and Herdt 198.5).

Rice insecticides accounted for nearly 15% of the global crop insecticide market value in 1988. With $2,400 million worth of agrochemicals used in 1988, rice was the single most important crop for pesticides, eclipsing both maize and cotton (Woodburn 1990). Japan is the largest consumer of rice pesticides with a 1988 market share of 59% of the total world market (Table 1.1).

The Philippines has a small share of the total pesticide market, 2.6% (ADB 1987) and a smaller share of the rice pesticide market, 2.0% (Woodburn 1990). More than half of all pesticides sold in the Philippines are insecticides (55%). Herbicides, at 19% of all pesticide sales, and fungicides, at 15%, are the next most important. Over the last decade, about half the insecticides sold have been used for rice. Because the insecticides used in rice are extremely hazardous category I and 11 chemicals, farmer-users are very susceptible to pesticide-related illnesses. The use of category I insecticides has been increasing (Table 1.2) because they are cheaper than other types. Herbicide use for rice has increased dramatically, from 54% of all herbicide sales in 1981 to 82% in 1987 (Table 1.3). This increased herbicide market

Table 1.1. **Market values of rice agrochemicals, by country, 1988 (Woodburn 1990).**

Country	US$ (million)					
	Herbicides	Insecticides	Fungicides	Others	Total	% share
Japan	570	455	375	20	1420	59.2
Rep. of Korea	48	89	95	3	235	9.8
China	11	108	35	0	154	6.4
Taiwan	26	38	18	5	87	3.6
India	18	51	14	3	85	3.5
Philippines	17	28	0	3	48	2.0
Thailand	17	31	1	0	39	1.6
Indonesia	4	24	1	3	31	1.3
Bangladesh	3	14	7	0	24	1.0
Burma/Myanmar	2	8	4	0	14	0.6
Vietnam	2	9	2	0	13	0.5
Pakistan	1	3	0	0	4	0.2
United States	61	22	4	0	87	3.6
Europe	48	24	5	0	77	3.2
Brazil	46	1	3	0	50	2.1
Others	11	15	6	0	32	1.3
Total	885	910	570	35	2400	100.0

Table 1.2. Insecticide use in rice relative to other crops in the Philippines, 1987-90 (APIP 1990).

Insecticide	Hazard category [a]	Insecticide use in rice relative to other crops (%)			
		1987	1988	1989	1990
Endosulfan	II	40.1	49.5	56.4	64.6
Monocrotophos	I	68.5	67.7	76.7	79.4
Cyperrnethrin	II	64.2	44.8	62.9	59.5
Methyl parathion	I	31.0	31.7	41.8	43.2
BPMC	II	80.9	47.8	68.7	51.7
BPMC + chlorpyrifos	II	20.9	20.9	30.5	35.7
BPMC + phenthoate	II	59.4	55.4	97.4	84.4
Diazinon	II	47.7	47.7	48.4	32.2
Carbofuran	I	55.9	72.5	66.7	17.2
Azinphos ethyl	I	38.2	35.7	41.7	46.8
Chlorpyrifors	II	0.7	7.1	7.0	5.8

[a] I = highly hazardous, II = moderately hazardous.

share for rice can be attributed to the substitution of chemical weed control for manual weeding in the irrigated rice bowls and to the growing preference for direct broadcast seeding over transplanting. Fungicide use is high in commercial banana, vegetable, and fruit growing but rare in rice production.

Concern about pesticide use in rice is about injudicious and unsafe use rather than overly intensive use. Injudicious pesticide use especially prophylactic applications at

Table 1.3. Estimated pesticide use, selected crops, Philippines, 1981 and 1987 (APIP 1990)[a]. (in percent of total sales).

Crop	Insecticides		Herbicides		Fungicides		Others	
	1981	1987	1981	1987	1981	1987	1981	1987
Rice	54.0	47.0	54.0	82.0	-	3.8	84.0	-
Maize	2.0	4.2	2.0	-	2.0	-	-	-
Banana	-	0.1	21.0	5.9	60.0	72.0	73.6	-
Pineapple	-	1.2	-	7.3	-	9.0	26.4	-
Vegetables	39.0	19.0	5.0	0.1	38.0	14.7	-	-
Others	5.0	18.5	18.0	4.7	-	0.5	16.0	-
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a] — = no data available.

set intervals and applications early in the crop season disrupt the paddy ecosystem's natural ability to cope with pest infestations, thereby, making it susceptible to pest damage. Dangerous chemicals, unsafe application techniques, and other unsafe pesticide use practices harm rice workers' health (Pingali et al 1991). Impaired health cuts farm household productivity (Antle and Pingali 1991).

1.1 Study objectives

Objectives of the present study were to:

- estimate the relationship between pesticide use and productivity in the irrigated ricelands of the Philippines
- evaluate the benefits of pesticide use when the health costs of pesticide exposure are counted as a production cost
- assess the opportunities and constraints to adopting sustainable pest management technologies
- identify the policy and regulatory environment that will promote sustainable pest management technologies.

1.2 Data sources

This study provides a synthesis of the literature on rice pest control and an analysis of experimental and farm level data on pesticide productivity and choice of pest control technologies. The methodology used is described in Chapters 5 and 6. The literature was reviewed to gather information on the different crop protection technologies, integrated pest management (IPM) and its components, changes in pest ecology, yield loss assessments, pesticide-related health impairments, and current pesticide regulatory policies in the Philippines.

Panel data on experiments by the Entomology Division of the International Rice Research Institute (IRRI) in the Nueva Ecija irrigated rice ecosystem were used to establish productivity relationships between rice yields and crop protection techniques, including prophylactic control, economic threshold, natural control, and farmers' practices. Estimates of these were used to calculate expected net benefits and certainty equivalents, used later to rank stochastic pest control technologies. Health data and other sociodemographic variables of farmers in Nueva Ecija, gathered by the IRRI Social Science Division, were used to assess the health impact of pesticide use. Medical tests included physical examination, cholinesterase determination, chest X-rays, and electrocardiograms (EKGs). Health impact estimates were used to recompute the ranking of alternative pest control strategies. Certainty equivalents were also recomputed, deducting health costs from the net benefit figures.

1.3 Overview of conclusions

- **Pesticide use for rice will remain lower than for other high-value crops.**

For high-value crops such as fruit and vegetables, the price premium for an unblemished physical appearance is substantial. Risk-averse farmers tend to apply pesticides heavily to capture this price differential. Because pesticides do not enhance rice quality in any way, there is no profit differential to capture for higher quality. Moreover, a big part of the pest losses in rice can be controlled by built-in resistance and natural control by predators. In normal years, the expected returns are low on high levels of pesticide use.

- **Researchers'/policymakers' perceptions of pest losses are usually higher than farmers' perceptions of losses which, in turn, are usually higher than their actual losses.**

Despite rapid changes in pest ecology from the intensification of lowland rice production and the perceived importance of pest losses for crop production, surprisingly little systematic work has been done to assess yield-loss relationships. Barring major infestations, less than 10% of yield losses in the Philippines can be attributed to insect pest damage in a normal year. Studies that show very high pest-related yield losses have invariably covered too short a time period to determine true damage distribution or have failed to differentiate adequately between resistant and susceptible varieties.

Both farmer and policymaker perceptions of pest-related yield losses are anchored around exceptionally high losses during major infestations, even when the probability of such infestation is low. Improved farmer experience and education, especially through targeted training courses, could help farmers evaluate pest-related yield losses more realistically. Efforts should be made to improve policymaker perceptions of yield losses as well.

- **Indiscriminate pesticide use leads to larger pest-related yield losses than not applying pesticides at all.**

Applying pesticides routinely, early in the crop season or on a schedule during the growing season (prophylactic application), disrupts the pest-predator balance. Predominant reliance on chemical control often leads to pest resurgence and frequent large-scale infestations. The virulent brown planthopper (BPH) resurgence, for example, was highly influenced by the number of insecticide applications, their timing, and the kind of insecticides used. In this instance, the insecticides decimated the BPH-natural enemy population. National pesticide policymakers should therefore think about putting resurgence-inducing insecticides under stringent restrictions for use in rice production. As acomplement to pesticide regulation, training farmers on judicious use of pesticides could help prevent future outbreaks of BPH.

■ **Where insecticide use is low, poorly implemented IPM programs could increase the amount of insecticides applied.**

The design of IPM programs is influenced by researcher/policymaker perceptions of pest-related yield losses. Where perceived and actual yield losses diverge widely, recommended economic thresholds for spraying are too low, thus reducing the usefulness of IPM. Correcting the application dosages exacerbates the problem. Farmers tend to underdose, using less than the recommended amount of chemicals per application. Upon completion of an IPM training program, most of them adjust their dosages upward. An ill-conceived IPM program could thus lead farmers to spray more often and with heavier concentrations than before.

■ **Frequency of application and use of very toxic chemicals increase risks of farmer health damages due to chemical exposure.**

Farmers often lack accurate knowledge about pests and their control, hence underdosing and frequent applications are generally observed. Current pesticide pricing and regulatory structure plus inadequate storage, unsafe handling practices, short reentry intervals, and inefficient sprayer maintenance taken together provide an environment of greater accessibility/exposure to chemicals not only by the fanner applicator, but the farming household as well. More training and infomiation campaigns on proper pesticide management could mitigate health risks.

■ **Under normal circumstances, the natural control option is often the economically dominant pest management strategy.**

The most common form of biological control practiced is “natural control”—conserving natural enemies by preventing their destruction or by preserving their habitat. This is best achieved by not applying pesticides, thereby sustaining the pest-predator balance. Natural control, in association with varietal resistance, has consistently proven more profitable in a normal year than prophylactic treatment and economic thresholds in long-term experiments. The mean yield was not significantly different between treatments. The standard deviation of yields was lowest for prophylactic treatment and highest for the untreated plots. To be sustainable, natural control should be practiced at community level, where pest-predator dynamics are maximized.

■ **In the choice of pest control techniques, when pesticide-related health impairments are explicitly accounted for, the natural control option is the best one, even for risk-averse farmers.**

Prolonged and frequent exposure to pesticides impairs farmers’ health and hence their productivity. The more frequent the insecticide applications, the higher are the health costs, treatment costs, and opportunity cost of time lost. Explicit accounting for health costs substantially raises the cost of using pesticides. The value of crop lost to pests is invariably lower than the cost of treating pesticide-caused disease. When health costs are factored in, the natural control (“do nothing”) option is the most profitable and useful pest control strategy.

■ Sustainable IPM programs are location-specific and require community participation in design and implementation.

IPM recommendations ought to be spatially and temporally flexible. In other words, IPM recommendations ought to take into account local pest and predator populations, land and farm management practices, and input and output prices. National IPM recommendations, unless adapted to local conditions, could overstate the case for applying pesticides and could cause increases in pesticide applications in cases where a natural control strategy would be more effective. IPM will be successful only if farmers participate fully in adapting and using this technology. Its success also depends on rural communities’ ability to organize against pest infestation, for example by synchronized planting, collective rat control, and communal pest monitoring.

■ Pesticide import, licensing, and pricing policies are essential components of a national IPM program.

IPM will not be adopted if pesticides are subsidized. Farmers would have no incentive to invest time in acquiring IPM skills. Removing all explicit and implicit subsidies on pesticides is essential to reduce pesticide use on farms. Taxes on pesticides can be used to reduce farmers’ health risks. For instance, if governments tax the highly toxic category 1 and 2 chemicals heavily enough, farmers may switch to the less hazardous category 3 and 4 chemicals.

More discretion should be used in importing and licensing agrochemicals. Chemicals that persist in the paddy environment, harm aquatic life, and induce a resurgence of pest populations should be banned in favor of safer chemicals. Judicious pest management is possible only when policymakers and farmers discriminate in their choice of pest control methods and chemicals.

■ Inadequate and underfinanced research and extension services can seriously limit small farmers’ effective use of IPM.

IPM has been the basis of the national plant protection policy and programs in several countries. However, implementation has been constrained by inadequate funding for research, extension, and farmer training needed in an accelerated program. Likewise, a clear demarcation of responsibilities between research, extension, and technical support services presents a major constraint to IPM. This demarcation also means that scientists who generate the knowledge base for IPM may not clearly understand the kind of knowledge extension workers or farmers need.

An accelerated IPM program implementation would need local political support and commitment, as well as funds for on-farm research and extension.

Chapter 2

Pest-related yield losses in rice: reality and perceptions

Farmers' pest control decisions, scientists' research priorities and policymakers' prescriptions are based largely on perceived pest-related yield losses. Actual and perceived pest-related yield losses are often unrelated. Farmers' perceptions of yield losses are based on experience, usually during a year of high pest damage. Researchers perceptions, based on single-season or short-term experiments, become generalized over time and space. Policymakers are often influenced by reports of massive pest damage.

Farmers whose perceptions of expected pest losses are exaggerated often overuse pesticides, disrupting the pest-predator balance and leading to a resurgence of pest populations. Inaccurate perceptions of pest-related yield losses by researchers could lead to a misallocation of research funds due to faulty priorities. Finally, policymakers' judgments on the importance of pest-related crop losses and the efficacy of pesticides could lead to policies, such as pesticide subsidies, that promote pesticide use. Whenever government policies keep pesticide prices artificially low, the incentive is also low for farmers and researchers to invest in knowledge that improves their perceptions.

More accurate crop loss information is likely to improve: farm management decisions that make use of short-term pest information; pesticide regulatory and pesticide pricing decisions using crop loss information; and decisions on allocating research resources using information on relative crop losses.

2.1 Farmers' perceptions and pest management practices

To understand the rationale of farmers' pest management practices, their decision-making process must be understood. Their stock of knowledge regarding pests, natural enemies. and pest management technology should also be assessed.

Farmers' pest control activities reflect their individual perceptions, not necessarily the actual situation (Tait 1977; Mumford 1981, 1983; Norton and Mumford 1983; Pingali and Carlson 1985; Carlson and Mueller 1987). None of these studies explains farmers' behavior because they do not differentiate between actual losses and farmers' perceptions of losses.

Considering the importance of farmers' perceptions in making decisions about pest control, surprisingly little effort has gone into detailed "knowledge, attitudes, and practices" (KAP) studies for developing-country agriculture in general and for rice in particular. The few available KAP studies for rice in the Philippines are summarized below. Their primary conclusions are that farmers generally cannot differentiate between pests and predators; are unskilled in using knowledge-based, pest control techniques in an economically optimal manner; and overuse pesticides and apply them at the wrong times.

In a KAP study of potential IPM farmer cooperators in Laguna, Rola et al (1988) found that about 31% of respondents thought that all insects are enemies of rice. However, a few farmers identified spider, dragonfly, and grasshopper as natural enemies of rice pests (Table 2.1). Most farmers (80%) spray when they see these insects because they believe that the crop will be damaged. Most farmers (73.3%) spray as needed, when they feel that insects may damage their crop, but their idea of need was not related to any economic threshold. For instance, some farmers (53%) spray for even one insect, while others (24.4%) practice calendar spraying. Most farmer-respondents (67%) spray their fields when a neighbor sprays to prevent the pests from transferring to their farms.

To keep pests off rice plants, 40% of the respondents spray pesticides after applying fertilizer. Eighty-two percent of farmer-respondents said they would be amenable to the synchronous planting of rice by all the neighboring farms to prevent pest increases. Farmers who were not amenable said that there may not be enough

Table 2.1. Farmer identification of insect pests and natural enemies of rice pests (Rola et al 1988).[a]

Insect	Sprayed		Did not spray		Did not know	
	Frequency	%	Frequency	%	Frequency	%
Brown planthopper	36	80.0	7	15.6	2	4.4
Lycosa[b]	9	20.0	36	80.0		
Green leafhopper	39	84.4	6	13.3	1	2.2
Microvelia[b]	25	55.6	18	40.0	2	4.4
Rice bug	34	75.5	9	20.0	2	4.4
Caseworm	39	86.7	5	11.1	1	2.2
Leaffolder	43	95.6	1	2.2		
Whorl maggot	35	77.8	10	22.2		
Armyworm/cutworm	41	91.1	2	4.4	2	4.4
Green horned caterpillar	36	80.0	8	17.8	1	2.2
Cyrtorhinus sp.[b]	26	57.8	15	33.3	3	6.7
Long-horned grasshopper	23	51.1	21	46.7		
Short-horned grasshopper	21	46.7	23	51.1		
Apanteles sp.[b]	21	46.7	21	46.7	1	2.2
Stem borer	38	84.4	6	13.3	1	2.2
Beauveria bassiana[b]	37	82.2	7	15.6		
Damselfly[b]	5	11.1	39	86.7		
Coccinellid[b]	29	64.4	15	33.3		

[a] Forty-five farmers were respondents in this survey. [b] Natural enemies of rice pests.

hired workers; irrigating farms at the same time may not be feasible; and they would let other farmers plant first so that their farms will be damaged by insect pests first.

Rola et al (1988) also found the price did not affect farmers' decision of whether to use pesticide inputs (60% of the respondents). Some farmers said that price increases might cause them to delay spraying and use less pesticides. The quantity and price of rice produced did not have any effect on their decision to use pesticides (76.6% of respondents).

Most farmers in Laguna plant pest-resistant rice varieties such as IR64, IR66, and IR42 but still spray as much as they did nonresistant varieties. Some 26% said that they now spray more. Rice yields in Laguna, however, were not related to the number of times insecticides were applied (Marciano et al 1981). Because insect-resistant rice varieties were used, infestations were low, and much of the insecticides applied to rice in Laguna was wasted. A KAP survey of irrigated rice farmers in Iloilo gave similar results (Rola 1989).

Most farmers expected pest losses of more than 35% in the Philippines and more than 50% in Thailand (Waibel 1990). Thai farmers reported one-third higher yield loss from missing an insecticide application than that from not applying any insecticides. However, comparing these farmers' perceptions of pest problems with their actual rice yields, Stone (1983) found no difference in yields of farmers who reported pest problems and those who did not.

Perceptions are influenced by a farmer's socioeconomic characteristics. Age and education could significantly reduce the error in farmers' perception (Garcia 1989). Farmers' experience (age), formal schooling, targeted training, and time spent monitoring pest populations most reduced probability errors and could lead to lower pesticide use (Pingali and Carlson 1985).

2.2 Researchers' perceptions of pest-related yield losses

Researchers' perceptions of pest-related yield loss are based on yield loss experiments or surveys. There are few long-term yield- loss studies, that allow scientists to generate probability distributions of damage. Researchers' perceptions therefore are usually based on generalizations from single-period or short-term experiments. For instance. Pathak and Dyck (1973) found that 25% of the Philippine rice crop was lost to insects, Almost two decades later, this generalization is still being used, despite changes in varieties planted and in crop management practices.

Table 2.2 summarizes the evidence in the literature of rice crop loss attributed to insects, weeds, and diseases in several Asian countries. Most of these crop loss estimates concerned insect pests. Estimates ranged from a low of 6% in Bangladesh (Alam 1961) to a high of 35-44% in the Philippines (Pathak and Dhaliwal 1981). Cramer's results (1967), though predating Asia's Green Revolution and relatively high, are still the most authoritative and widely quoted (Waibel 1986, Teng et al 1990).

Crop loss assessments vary widely by location and by year (Table 2.3). For example, for stem borers, a major insect pest, crop loss estimates vary from 3% in India to 9.5% in Indonesia. Barret al (1981) estimated 6.6% crop loss in the Philippines due

Table 2.2. Crop loss due to aggregate damage of pests in selected countries.

Country	Source of loss	Crop loss estimates (%)	Reference
Asia	Insects	34.4	Cramer (1967)
	Diseases	9.9	
	Weeds	10.8	
	Potential production harvested	44.9	
	Total potential production lost	55.1	
East and Southeast Asia	Insects	23.7	Ahrens et al (1982)
Philippines	Insects	20-25	Pathak and Dyck (1973)
Philippines	Insects	35-44	Pathak and Dhaliwal (1981)
India	Insects	35	Way (1976)
Philippines	Insects	16-30	Way (1976)
Bangladesh	Insects	6	Alam (1961)
Sri Lanka	Insects	20	Fernando (1966)
Philippines	Chronic pests	18.3	Litsinger et al (1987)
Philippines	Weeds	11-65	Moody (1982)

Table 2.3. Crop loss due to rice pests in various countries (Teng et al 1990).

Pest	Country	Crop loss	Reference
Stem borers	Bangladesh (outbreak)	30-70%	Alam et al 1972
	(no outbreak)	3-20%	Alam 1967
	India	3-95%	Glease et al 1960
	Indonesia	up to 95%	Soenardi 1967
	Malaysia (North Krian District)	33%	Wyatt 1957
	Philippines	6.6%	Barr et al 1981
Leafhoppers and planthoppers	Bangladesh (leafhoppers)	50.80%	Alam 1967
	Malaysia (brown planthopper)	M$10 million	Leris et al 1988
	India	1.1-32.5%	Jayaraj et al 1974
Rice bugs and gall midge larvae	India	10%	Pruthi 1953
	India	12-35%	Reddy 1967
	Vietnam	50-100%	Reddy 1967
Blast	India	1% loss (1960-61)	Padmanaban 1965
	Japan	3% (1963-60)	
	Korea	at epidemic lands (mid-1970s)	
	China	8.4% in 1980 14% in 1981	Teng 1986
	Philippines	50-60%	Nuque 1963 Nuque et al 1983
	Philippines	70-85% in BPI 76 and C4-63 cultivars (1969-70)	Nuque 1970

Table 2.3 **continued**

Pest	Country	Crop loss (%)	Reference
Tungro	Malaysia	1% (1981-84)	Heong and Ho 1987
	Malaysia	17,628 ha in 1982 worth M$21.6 million	Chang et al 1985 Reddy 1973
	Indonesia	21,000 ha in 1969-71	Reddy 1973
	Bangladesh	40.60%	Wathanakul and Weerapat 1969
	Thailand	50%	Serrano 1957
	Philippines	30% or 1.4 milllon t rough rice	Ling et al 1983
	Philippines	456.000 t rough rice in 1971	
Bacterial blight	Japan	300-400 thousand ha of riceland 20.30%	
	India	6.60%	Srivastava 1967
	China	6% in 1980 4.9% in 1981	Teng 1986
Sheath blight	Japan	24-38 thousand t rice in 1954	National Institute of Agricultural Sciences
	Japan	20% 25%	Mizuta 1956 Hori 1969
	Philippines	7.5-22.7% loss In high-N plots planted to a susceptible variety and 0.4-8.8% and 2.5-13.2% loss in moderately resistant varieties	Ou and Bandong 1976
	Sri Lanka	10% sf rice tillers	Abeygunawardane 1966
	Mainland Chins	12% in 1980 9.1% in 1981	Teng 1986

to stem borers. Estimates of crop losses due to leaf and planthoppers, another major set of insect pests, also vary widely, from 1% in India to 80% in Bangladesh.

Pest-related yield losses depend on agroclimatic conditions, cropping intensity, varieties used, land crop management practices, and pest control methods. Single-period assessments clone at one spot cannot be generalized over time and place. Long-term loss assessments have generally shown modest yield losses to insect pests.

In addition, no standard loss assessment method is used. Data in the literature vary significantly from one method to the other. Using a direct field survey method, Cramer (1967) evaluated crop loss from insects at 31.4%. Ahrens et al (1982). using pesticide-evaluation trials, came up with a 23.7% yield loss from insects. Only standardized methods enable comparison of different assessments, remove observer bias, and allow the value of different methods to be studied and tested (Walker 1990).

2.2.1 Evidence from multiperiod, multilocation studies

At least four sets of data could give an indication of yield losses due to rice insect pests in the Philippines. These include pesticide evaluation trials, yield-constraint experiments at IRRI, Litsinger's experiments, and Waibel's trials in collaboration with the Philippine regional crop protection centers. In these trials, crop loss is derived from the yield difference between the most heavily infested and the least infested plots.

2.2.1.1. Pesticide evaluation trials

Crop losses due to insect pests in nonresistant and resistant varieties were computed from long-term trials conducted by IRRI and the Bureau of Plant Industry (BPI) of the Philippines. Each experiment station represents a major agroclimatic zone.

To obtain adequate infestation levels, the IR22 variety was used since it is regarded as being susceptible to all major pests. On small plots of 20-30 square meters, the level of attack by major pests was assessed and grain yields were determined. Crop losses were computed from the difference between the respective maximum yield and the untreated control plot. Losses from the untreated plot would be minimized by the presence of natural enemies. Table 2.4 summarizes crop losses due to insect pests and virus for nonresistant and resistant varieties taken from the pesticide evaluation trials. Even without carbofuran, the yield loss with nonresistant varieties ranged from 33 to 35%. In the dry season, crop losses were lower than in the wet season. The failure of carbofuran to stimulate growth during the dry season was probably due in part to the higher use of fertilizer (Waibel 1986). In resistant varieties, recorded losses of 5.12% in the dry season and 10.1 % in the wet season indicated the high benefits gained from built-in resistance of cultivars. Trials in farmers' fields showed losses of 11.74% in the dry season and 5.49% in the wet season.

2.2.1.2 Constraint experiments at IRRI

IRRI conducted a cross-country research project between 1973 and 1977 to identify the major constraints limiting yields on farmers' fields. The primary objectives of this work were to identify and quantify the factors contributing to the yield gap between farmers' field and the yields at the experiment stations. Trials were conducted using farmers' fertilizer, herbicide, and insecticide inputs and two additional input levels, intermediate and high. Table 2.5 shows the insect control and weed control contribu-

Table 2.4. Summary of crop loss (%) due to insect pests and viruses, by variety, Philippines, 1969-81.

Period	Nonresistant varieties[a] 1969-81		Resistant varieties[b] 1976-80	Farmers' losses[c] 1980-81
	Without carbofuran	With carbofuran		
Dry season	32.7	33.0	5.12	11.74
Wet season	35.2	40.0	10.1	5.49

[a] Based on results from pesticide evaluation trials. [b] Source: Waibel (1986). [c] Based on results from field trials (Waibel 1986).

Table 2.5. Farmers' and researchers' yields, and the contribution of three factors to yield gap in a constraints experiment on Philippine rice farms, 1973-79 (Herdt et al 1984).

		Yield (t/ha)			Contribution (t/ha) of		
Trials (no.)	Province	Farmers' inputs	Researchers' inputs	Difference	Insect control	Fertilizer	Weed control
				Wet season trials			
57	Laguna	3.6	5.3	1.6	0.8	0.6	0.3
78	Nueva Ecija	3.9	4.8	0.9	0.5	0.4	0.1
47	Camarines Sur	3.9	4.7	0.8	0.1	0.2	0.1
38	Iloilo	3.9	5.2	1.3	0.5	0.7	0.3
220	All sites	3.8	5.0	1.1	0.5	0.5	0.3
				Dry season trials			
57	Laguna	4.4	6.5	2.1	1.0	0.4	0.2
60	Nueva Ecija	5.0	6.9	1.9	.7	1.0	0.2
40	Camarines Sur	4.3	5.8	1.5	1.1	1.1	0.2
32	Iloilo	4.1	5.3	1.2	.3	1.1	0.2
189	All sites	4.5	6.3	1.8	0.8	0.9	0.2

tion of yield gap for four places in the Philippines for the wet and dry seasons. The figures represent yield differences between fields worked on by farmers and the plot with the highest insecticide inputs. These yield-constraint trials showed that an additional 0.5 ton per hectare in the wet season and 0.8 ton per hectare in the dry season are obtained with higher levels of insect control (Herdt et al 1984). In relative terms, yield loss would be 10-20% (based on a yield level of 4-5 tons per hectare). Weeds in rice contributed less to the yield gap than did insects.

2.2.1.3. Insecticide check method

Litsinger et al (1980) generated further data for assessing crop loss from trials conducted to develop pest control recommendations for different parts of the Philippines. Trials started in 1976 in two provinces, the rainfed sites of Iloilo and Pangasinan. They were later extended to Nueva Ecija and became, in modified form, part of the applied research activities of the pilot projects on integrated rice pest control (Waibel 1986). Litsinger (1980) defined yield loss as the relative difference between the yield obtained under maximum protection and no treatment.

Table 2.6 shows yield losses as determined by the insecticide check method in farmers' fields in three rice environments and two plant types from 1976 to 1986. Traditional varieties in both upland and rainfed wetlands have lower yield losses than the modern varieties. The lower yield loss in longer maturing varieties is explained by compensation: early- maturing rice has less time to compensate for pest damage, while longer maturing cultivars can photosynthesize and tap energy reserves to overcome the detrimental effects of pest injuries. Modern varieties in irrigated environments had an 18% yield loss due to the insect pests, as computed from trials in 1976-86.

Waibel (1986) conducted trials in collaboration with the Regional Crop Protection Centers (RCPC) following Litsinger's methods. He also included as variants local

Table 2.6. Yield losses determined by insecticide check method in farmers' fields, by rice environment and plant type, Philippines, 1976-86 (IRRI 1986). [a]

Environment	Plant type	Sites (no.)	Crops (no.)	Yield (t/ha)		Yield loss	
				Treated	Untreated	t/ha	%
Upland	Traditional	1	5	2.90	2.85	0.05	2
	Modern	2	5	4.20	3.21	1.0	23
Rainfed wetland	Traditional	2	5	2.21	1.83	0.38	18
	Modern	3	12	3.74	3.03	0.71	21
Irrigated	Modern	5	33	3.86	3.29	0.57	18

[a] Lower yield loss in longer maturing crops is explained by compensation. Early-maturing rices have less time to compensate for pest damage, while longer maturing cultivars can photosynthesize and tap energy reserves to overcome the detrimental effects of pest injuries.

farmers' typical pest control practices and measured infestation intensity at weekly intervals. In the IRRI trials (Litsinger's method), assessments of infestation levels were made on predetermined dates. Trials were also carried out on fields using farmers' own varieties. In 6 out of the 10 trials, no significant difference was found between the control measure and the unsprayed field: crop losses were 8.9%. Average losses due to insects in IRRI trials during the same period (1976-80) were almost identical, 8.6%.

Waibel (1986) concluded that the lower yield losses were due to the relatively high proportion of trials with insignificant yield differences and that a somewhat decreasing trend was observed moving from experiment station to farmers' field trials.

Table 2.7 summarizes the data on crop loss due to pests in the Philippines as cited in Waibel (1986). Over a long time trend, estimated crop loss decreases. Thus, Pathak and Dyck recorded a crop loss of 22.5% during 1968-72, but more recently, both Litsinger and Waibel recorded only 8.6 and 8.9%, respectively. This could be attributed to widespread use of resistant varieties in farmers' fields after the mid- 1970s. Both Litsinger and Waibel observed no significant yield differences between treated and untreated plots in more than half the trials. In other words, half the time farmers need not spray.

The individual crop loss data are too heterogeneous to permit direct comparison. Several factors could affect these estimates because infestation intensity and the size of experimental plots vary both in time and place. Due to interplot interference, untreated plots may be subject to an intensity of infestation unlikely to occur under farm conditions (Waibel 1990).

Economic analysis of available crop loss data depends on many assumptions, the most important ones being costs and effectiveness of alternative control measures. Economic loss is based on net return rather than on yield. Thus, economic loss is calculated as the difference between net returns for treated and untreated fields, weighted with the probabilities of infestation. Economic loss then depends on the pest situation and the control method used. If farmers practice calendar-based pesticide application and the probability of infestation is low, the economic loss will be high.

Table 2.7. Crop loss due to pests, Philippines (Waibel 1986).

	Pathak and Dyck's method (1968-72)	Pesticide evaluation trials (1972-81)	Yield constraints trials (1975-79)	Litsinger's method (1976-80)	Waibel's method (1980-81)
Proportion of trials without significant yield differences (%)[a]	-	14.0		57.0	60.0
Maximum loss (%)	32.0	91.0	27.1	40.3	27.5
Average loss (%)	22.5	34.0	11.1	8.6	8.9

[a] Proportion of trials in which significant yield differences between treated and untreated were not found to exist.

Waibel (1990) argues that the value of crop loss assessment is in predicting loss rather than in proving that losses are intolerable. He further states that crop loss assessment studies have to be done at farm level where on-farm trials need only three treatments: farmers' pest control practice, recommended practice, and no control or natural control.

2.3 Policymakers' perceptions

Policymakers commonly perceive that intensification of rice cultivation and modern variety use necessarily lead to increased pest-related crop losses and that modern rice production is therefore not possible without high levels of chemical pest control. This perception is based on the high crop losses from the early modern varieties that were susceptible to pest damage. Most varieties released since the mid-1970s are highly resistant to a broad spectrum of pest infestations, yet the perception of a close link between modern varieties and pesticides persists. This perception has led to the promotion of pesticide use through subsidies and credit programs. Pesticide mismanagement, disruption of the pest-predator balance, and increased pest losses are the result. The case of the brown planthopper (BPH) illustrates how pesticide policies can aggravate pest infestations.

Due to unilateral chemical use and crop intensification, epidemics of BPH and green leafhopper and their associated viral diseases spread throughout the rice-growing Philippines (Litsinger 1987). BPH (*Nilaparvata lugens*) is the preeminent insect pest of the modern Green Revolution (Kenmore et al 1984). Planthoppers, by eating rice plants, cause a symptom known as "hopperburn" (Heong 1991). These pests were major threats to rice cultivation in the 1960s and 1970s and still are in many rice-growing areas. They are still considered the single most important insect problem in rice today (Teng 1990). Among the factors contributing to the increase and severity of BPH outbreaks, insecticide-induced resurgence is of major importance. Many commonly used insecticides for rice insect control in Asia caused the BPH resurgence. For instance, Reissig et al (1982a) found that 16 of the 39 insecticides tested caused BPH resurgence.

BPH built up enough to cause hopperburn in all but test 1 (Table 2.8). Despite the high percentage of hopperburned plants in most insecticide treatments, very little hopperburn occurred in the untreated check plots. The degree of BPH resurgence was highly influenced by the time and number of insecticide applications (Heinrichs and Moshida 1984), and foliar sprays caused the most BPH resurgence. Only plots that received the foliar applications had significantly more BPH and hopperburned hills than the check (Table 2.9, test 1). In test 2, all carbofuran application methods caused BPH resurgence, but it was highest in the foliar spray treatment (20-fold greater than the check population.)

Chelliah and Heinrichs (1980) showed that methyl parathion sprayed on rice plants stimulated plant growth by increasing tiller and leaf number (Table 2.10). The increased growth may have made the plants more attractive to adults. Over time, most BPH outbreaks occurred after periods of heavy insecticide use and plantings of nonresistant rice varieties. The highest outbreaks came during most intensive insecticide use (1973-76) because of government programs. By then, IR8, introduced in 1966, had built up enough to cause BPH outbreaks.

Kenmore et al (1984) also showed that disruption of population-regulating factors such as natural enemies, especially by insecticides, can induce tropical BPH population

Table 2.8. Insecticides that cause BPH resurgence,[a] 39 field tests, International Rice Research Institute, Los Baños, Philippines (Reissig et al 1982b).

Insecticide	Formulation[b]	BPH insecticide treatment/ BPH in check	Hopperburn (%)[c]
Azinphos ethyl	40% EC	4.6	0 a
Quinalphos	25% EC	5.3	0 a
Penthoate	50% EC	6.0	0 a
Methomyl	19.8% EC	9.3	0 a
Check			0 a
Diazinon	5% G	33.2	100 a
Isazophos	5% G	36.7	100 a
Carbofuran	3% G	35.2	80 a
Check			0 b
Tetrachlorvinphos	75% WP	14.5	12 d
Methyl parathion	50% EC	32.6	65 b
Monocrotophos	16.8% EC	2.2	2 e
Pyridaphenthion	75% WP	14.5	29 c
Cynophenphos	40% EC	71.5	91 a
Check			0 e
Triazophos	40% EC	5.5	78 b
Decamethrin	31% EC	5.5	100 a
Check			10 c
Penncap M	25% EC	2.3	91 b
Fenvalerate	38% EC	2.8	99 a
Check			13 c

[a] Insecticide treatments which had significantly higher BPH populations than the untreated control at the last sampling date, based on DMRT at the 5% level. BPH = brown planthopper *Nilaparvata lugens.* [b] EC and WP formulations applied as a spray at 0.75 kg ai/ha and G formulations broadcast at 1.0 kg ai/ha. [c] In a column, means followed by the same letter are not significantly different at the 5% level by DMRT.

Table 2.9. Effect of carbofuran on BPH population and degree of hopperburn, by treatment method (Heinrichs et al 1982a)[a].

Treatment[b]	Test 1[c]		Test 2[d]	
	BPH (no./hill)	Hopperburn (%)	BPH (no./hill)	Hopperburn (%)
Root zone	87 b	14 b	1196 ab	19 a
Broadcast	44 b	4 b	541 bc	16 a
Foliar spray	749 a	97 a	2456 a	25 a
Check	120 b	8 b	123 d	18 a

[a] In a column, means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test. [b] In test 1, root zone application was made once with a basal application at 5 DT at 1 kg ai/ha; broadcast applications made at 1.0 kg ai/ha and foliar sprays at 0.5 kg ai/ha, both at 5, 25, 45, and 72 DT. In test 2, all applications made at 0.75 kg ai/ha at 25, 45, and 72 DT. [c] *N. lugens* counts taken at 78 DT and hopperburn recorded at 92 DT. [d] *N. lugens* counts at 71 DT and hopperburn recorded at 84 DT.

Table 2.10. BPH response to insecticide sprays and plant growth (Chelliah and Heinrichs 1980).

Treatment	Adults that alighted[a] (%)	Tillers (no./plant)	Leaves (no.)	Height (cm)
Methyl parathion	31.5 a	9.8 a	32.4 a	75.3 a
Decamethrin	28.6 b	7.6 b	27.4 ab	75.4 a
Diazinon	23.2 c	6.8 b	23.5 b	71.6 ab
Ethylan	23.4 c	7.2 b	23.5 b	69.6 b
Control	24.3 c	7.2 b	23.5 b	74.7 a

[a] Transformed angular values. In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

outbreaks. Neither varieties per se nor fertilizer levels have been shown to induce BPH outbreaks, but destruction of natural enemies by insecticides does so consistently if enough BPH are active in the vicinity. Kenmore (1980) reported that nearly every recorded outbreak of BPH in the tropics has been associated with prior use of insecticides.

On the whole, the direct effect of an insecticide on BPH and its indirect effects via the host plant and natural enemies depends on the type of insecticide and on the rate, timing, number, and method of application. The direct effect of the insecticide on BPH depends on the toxicity of the insecticide to BPH, the subsequent percentage mortality, and the response of survivors that have received a sublethal dose. The combination of both, percentage of hoppers surviving the insecticide application and the extent of reproductive stimulation of survivors, are two important determinants of the degree of resurgence. Maximum resurgence is caused by an insecticide treatment that allows a high BPH survival and causes a high degree of reproductive stimulation in the survivors (Heinrichs and Mochida 1984).

BPH could be managed via the use of resistant varieties and selective use of insecticides. However, because BPH populations adapt quickly to newly bred resistant varieties, a rapid breakdown of resistance is expected. Heinrichs and Mochida (1984) concluded that the only effective means of preventing BPH resurgence in tropical Asia is for national insecticide evaluation programs to identify the most active resurgence-

Table 2.11. Insecticides banned for use on rice, Indonesia, 1986 (unpublished Presidential Executive Order, 1986).

Agrothion 50 EC: fentirothion
Bassazinon 45/30 EC: diazinon + BPMC
Basmiban 20 FC: klopirifos
Basminon 60 EC: diazinon
Basminon 60 EC: diazinon
Basudin EC 60
Bayrusil 250 EC: kuinalfos
Bayrusil 5 G: kuinalfos
Basudin 10 G: diazinon
Brantasan 450/300 EC: diazinon + BPMC
Carbavin 85 WP: karbaril
Cytrolane 2 G: mefosfolan
Dharmasan 60 EC: fentoat
Dharmathion 52 EC: fenitrothion
Diazinon 60 EC: diazinon
Dicarbone 85 S: karbaril
Dimaphen 50 EC: fenitrothion
Dimecron: fosfamidon
Dursband 20 RC: klorpirifos
Dursband 15/5 E: klorpirifos + BPMC
Dyfonate 5 G: fenofos
Ekalux 25 EC: kuinalfos
Ekalus 5 G: kunalfos
Ekamet 5 G: etrimfos
Elsan 60 EC: fentoat
Elstar 15/30 EC: fentoat + BPMC
Eumultion TM: triklorfon + azinfosmetil
Folimat 500 SL: emetoat
Fomadol 50 EC: malathion
Gusadrin 150 WSC: monokrotofos
Azodrin 15 WSC: monokrotofos
Hostation 40 EC: triazofos
Karbathion 50 EC: fenitrothion
Lannate 25 WP: metomil
Lebaycid 550 EC: fention
Lirocide 650 EC: fenitrothion
Lirocide 650 EC: fenitrothion
Miral 2 G: Isasofos
Monitor 200 LC: metamidofos
Nogos 50 EC: diklorfos
Nuvacron 20 SCW: monokrotofos
Ofunack 40 EC: pinidafention
Padan 50 SP: kartap
Pertacide 60 EC: fentoat
Petroban 20 EC: klorpirifos
Phy,lodol 50 eC: diklorfos
Reldan 24 EC: metil klorpirifos
Sematron 75 SP: asefat
Sevin 5 D: karbaril
Sevin 5 G: karbaril
Sevin 85 S: karbaril
Sumibas 75 EC: BPMC + fenitrotion
Sumithion 50 EC: fenitrotion
Sumithion 2D: fenitrothion
Surecide 25 EC: sianofenfos
Tamaron 200 LC: metamidofos
Thodas 35 EC: endosulfan
Trithion 4 E: karbofenotion
Trithion 95 EC

inducing insecticides and to prohibit their use by farmers. However, a survey of farmers in the Philippines (Pingali et al 1990, Rola et al 1990) and in Vietnam (Heong 1991) found that the common insecticides used by farmers are usually organochlorines and organophosphates (for example, methyl parathion, monocrotophos) and pyrethroids (for example, cypermethin, deltamethrin) whichinduce BPH resurgence (Chelliah and Heinrichs 1980; Heinrich et al 1982a,b; Reissig et al 1987: Heinrich and Mochida 1984).

National pesticide policies should therefore consider putting these insecticides under strict restrictions for use in rice production. Indonesia, in 1986, banned 57 insecticides known to induce BPH resurgence (Table 2.11). Developing alternative strategies with a broad ecological approach would be another route to pest management, taking into account crop rotation, timing of pesticide application, and other factors that will minimize outbreaks and losses from insect pests.

Chapter 3

Crop protection technologies

Unilateral use of chemical control was the main recommendation for crop protection in the 1960s and 1970s because the effectiveness of other pest control measures had not been tested in modern plant varieties. To give an idea of the range of choices now available, several pest control strategies are described here. The economics of these crop protection practices is also discussed.

3.1 Prophylactic chemical control

Prophylactic chemical control involves calendar-based pesticide application, with no consideration for pest density or anticipated crop loss. Prophylactic control recommendations for rice were set in the early 1970s when the modern varieties then grown were susceptible to most insect pests and diseases. Since then, despite improved varietal resistance and management practices, these recommendations have hardly changed. Prophylactic chemical control has been associated with destruction of other beneficial (predator) species: resurgence of the treated pest populations: outbreaks of secondary pests: residues in feed, food, and the environment, and farmer illnesses from prolonged exposure to pesticides. These problems rule out prophylactic chemical control as a sustainable pest management strategy.

Japan found that long-term dependence on pesticides is unsustainable. Energy input in terms of fertilizers, machinery, fuel, and pesticides increased 4-, 12-, 23- and 33-fold in 1950-74, while the rice yield rose by only 1.5-fold (Kiritani 1970). Pesticides had the highest energy increase. In 1976, for instance, Japanese rice growers spent $230 per hectare on pesticides, including insecticides, fungicides, and herbicides. By 1986, they were spending US$670 per hectare.

Prophylactic chemical control may have caused brown planthopper (BPH) outbreaks. Abnormal increases in BPH populations occurred in Japan after 1957 when insecticide application reached a high level. Prophylactic control caused an imbalance in the pest-predator equation and the resurgence of pests. More recently, strategic insecticide application technique (SIAT), prophylactic control, has involved spraying insecticides 30 days after transplanting (DAT) and again at 60 DAT, regardless of pest density.

3.2 Natural control

The continuous use of insecticides in ricefields affects insect pests and natural enemies as well (Medina and Justo 1990). Intensive application of broad spectrum insecticides could also be a factor (Kenmore et al 1984). The disturbance by insecticides of the balance between insect pests and natural enemies has contributed to the development and application of integrated pest control and has prompted studies of insecticide selectivity in relation to natural enemies.

Natural control is the conservation of natural enemies by preventing their destruction or preserving their habitats. Choice of plant varieties, maintenance of alternative hosts, and proper soil management are among the tactics employed to keep beneficial species active and populous enough to control pests. Some evidence also suggests that increasing crop diversity through intercropping or polyculture reduces damage from insect pests by providing habitat for natural enemies.' To be successful, natural control should be practiced at community level, where predator populations are maximized.

3.3 Varietal resistance

Varietal resistance to rice pests is an effective means of controlling yield losses. Over the past two decades, plant breeders have been successful in generating varieties that are resistant to major insects and diseases in Asia. Most modern varieties released after the mid-1970s are resistant to BPH and green leafhopper and have some resistance to stem borer (Table 3.1). The problem has been that this resistance has not lasted since pests tend to evolve around it. Thus, resistance can be retained only by constantly breeding new varieties. Recent advances in biotechnology can help improve the durability of host plant resistance.

Two approaches are being used for improving yield stability through durable resistance to diseases and insects: 1) the alien gene transfer, and 2) the use of novel genes. Useful alien genes are being transferred for resistance to diseases and insects from wild species into cultivated rice. Useable technology from these more durable resistance genes should be available within the next three years. Novel genes such as the *Bt* gene for insect resistance and coat protein genes for tungro resistance are likely to become available within the next five years. When introduced into rice, they should impart high levels of resistance (Pingali 1991).

The interaction of resistant plant varieties and natural control is also being investigated because these two pest control tactics are thought to be compatible. For example, because of high resistance to BPH in most modern, high-yielding varieties, the immediate impact of calendar-based insecticide treatments on natural enemies may not be detected. In the absence of natural enemies, BPH adapted to these resistant varieties and the "biotypes" developed. When used in association with varietal resistance, natural control could be just as successful as judicious pesticide use, except in disaster years.

Table 3.1. Resistance of IRRI varieties to insect pests.[a]

Variety	IRRI Acc. no.	Year of re-lease	Matu-rity (DAS)	Plant-height (cm)	BPH 1	BPH 2	BPH 3	GLH	WBPH	ZLH	YSB	SSB	LF	RWM	CW	Thrips
IR5	10321	1967	130	135	S	S	S	MR	S	S	S	S	S	S	S	S
IR8	10320	1966	125	98	S	S	S	MR	S	S	S	S	S	S	S	S
IR20	11355	1969	121	112	S	S	S	MR	S	S	MR	R	S	S	S	S
IR22	11356	1969	119	95	S	S	S	S	S	S	S	S	S	S	S	S
IR24	19907	1971	118	100	S	S	S	MR	S	S	S	S	S	S	S	S
IR26	24154	1973	121	105	R	S	R	MR	S	S	S	MR	S	S	S	S
IR28	30411	1974	104	105	R	S	R	R	S	S	S	S	S	S	S	S
IR29	30412	1974	112	95	R	S	R	R	S	S	S	S	S	S	S	S
IR30	30413	1974	105	100	R	S	R	R	S	S	S	MR	S	S	S	S
IR32	30414	1975	130	105	R	R	MR	MR	S	S	S	MR	S	S	S	S
IR34	30415	1975	122	125	R	S	R	R	S	S	S	MR	S	S	S	S
IR36	30416	1976	110	85	R	R	MR	MR	S	S	MR	R	S	S	S	S
IR38	32536	1976	123	100	R	R	MR	MR	S	S	S	MR	S	S	S	S
IR40	36958	1977	130	100	R	MR	S	MR	S	S	MR	R	S	MR	S	S
IR42	36959	1977	132	100	R	R	S	MR	S	S	S	MR	S	S	S	S
IR43	32615	1978	120	100	S	S	S	MR	S	S	S	MR	S	S	S	S
IR44	39341	1978	123	95	R	R	MR	MR	S	S	S	R	S	S	S	S
IR45	47675	1978	120	100	R	S	R	MR	S	S	S	S	S	S	S	S
IR46	32695	1978	112	110	R	S	R	MR	S	S	S	S	S	S	S	S
IR48	53432	1979	127	115	R	R	S	MR	MR	S	S	S	S	S	S	S
IR50	53433	1980	107	95	R	MU	R	R	S	S	MR	R	S	S	S	S
IR52	53434	1980	117	105	R	R	MR	R	MR	S	S	MR	S	S	S	S
IR54	53435	1980	120	121	R	R	S	R	S	S	MR	MR	S	S	S	S
IR56	63491	1982	106	100	R	R	R	R	S	-	S	MR	S	S	S	S
IR58	63492	1983	108	90	R	R	R	R	S	-	S	MR	S	S	S	MR
IR60	63493	1983	110	97	R	R	R	R	MR	-	S	MR	S	S	S	MR
IR62	66969	1984	110	98	R	R	R	R	MR	-	S	MR	S	S	S	R
IR64	66970	1985	115	103	R	MR	R	R	S	-	S	MU	S	S	S	-
IR65	66971	1985	115	100	R	R	R	R	MR	-	MR	MR	S	S	S	-
IR66	72550	1987	110	93	R	R	R	R	S	-	R	MR	S	S	S	-
IR68	76328	1988	127	114	R	R	MR	R	S	-	MR	MR	S	S	S	-
IR70	76329	1988	129	101	R	MR	MR	R	S	-	MR	MR	S	S	S	-
IR72	76330	1988	117	96	R	R	R	R	S	-	R	MR	S	S	S	-
IR74	76331	1988	130	92	R	R	R	MR	S	-	MR	MR	S	S	S	-

[a] – no data available: R = resistant; MR = moderately resistant; S = susceptible; SSB = striped stem borer: L = leaffolder: RWM = rice whorl maggot; CW = caseworm: WBPH = whitebacked planthopper; MAT (DAS) = maturity (days after sowing): BPH = brown planthopper: GLH = green leafhopper; ZLH = zigzag leafhopper; YSB = yellow stem borer.

3.4 Cultural control

By definition, cultural control includes the physical manipulation of insect environment and excludes application of chemical pesticides or introduction of resistant varieties or natural enemies of pests. Many cultural control techniques work best when cooperation extends over a large area. Cultural controls overlap with legislative control because broad cooperation may be brought about by directives from the government and local authorities.

Practices for cultural control include cultivation and rotation, timing of planting and harvesting, and variation of plant density and nutrient use.

3.4.1 Cultivation and rotation

Preparing a seedbed suitable for planting is the main purpose of soil cultivation. Other functions include weed and pest control; incorporation of manures, fertilizers, and crop residues; and control of temperature, aeration, and water content. The pest control components may harm the pest directly, or they may promote plant growth that minimizes the effects of the pests.

Crop rotation is used partly for pest control but also for increasing or maintaining soil fertility or for spreading labor requirements out evenly throughout the year. An unbroken sequence of any single crop allows large populations of associated pests to develop, especially nematodes such as the potato root eelworm (Woods 1974).

Though cheap, rotation cannot be relied upon to control every pest, and it is not always economic. The sequence of cropping and the associated cultivation vary with the pest complex and life histories of individual pests in an environment.

3.4.2 Timing of planting and harvesting

Most plants are susceptible to pests only during certain stages of growth, and many pests are present only for a few days or weeks of the year. Therefore, by modifying the planting date, pest attacks can be avoided. The harvest time can also be adjusted in some cases to minimize pest damage. For example, the timing of alfalfa cutting has been found to influence insect fauna in the United States. Early cutting of the first and second crops is effective against the alfalfa weevil (Woods 1974).

3.4.3 Variation of plant density

Dense planting increases humidity within a stand and encourages the spread of many diseases. The spacing of trees in plantations and crops in fields is important in controlling pests and diseases.

3.4.4 Nutrient use

anuring with potassium and phosphates can reduce the incidence of some pests (Wood 1974). Fertilizers can sometimes help create a stand of uniform density, which can discourage pests. The benefits of some organic manures result not merely from the nutritional factors but from the antibiotic effects of microorganisms in the manures.

Cultural control methods are needed to help reduce insect pest populations because resistant varieties and pesticides alone are inadequate. Certain farmoperations can be modified to make the environment hostile to insect pests but favorable for crop production. Techniques such as modification of crop planting, cultivating, or harvesting aim at preventing insect damage rather than at destroying live insects. Plant spacing, the cropping system, and fertilizer management may prevent buildup of certain populations.

These techniques should be compatible with other control methods and with agronomic needs of the crop. Farm-level methods that prevent insect pest buildup include minimizing fertilizer use by splitting applications or using organic slow-release materials. Planting methods also influence pest abundance. Leaffolder and BPH are particularly favored by high nitrogen rates (Litsinger 1987), especially in the absence of natural enemies. Direct seeding prevents whorl maggot colonization.

Community wide cooperation in synchronizing planting schedules to create rice-free periods during the year is an important way to deny pests the opportunity to multiply all year. Farm communities could time rice planting to conserve irrigation water and to take advantage of low seasonal occurrence of insect pests. Another good cultural practice is limiting rice crops to two a year and plowing rice stubble to improve the soil's organic content and kill the virus-carrying ratoon. The most promising cultural methods for BPH control is synchronized rice cropping and rotation with other crops.

3.5 Integrated pest management

Integrated pest management (IPM) is a new approach to crop protection within the context of the crop-production system. Many components of the IPM concept were developed in the late nineteenth and early twentieth centuries. Their integration at research level came in the early 1970s (Smith et al 1976). As now conceived, IPM is unique. Based on ecological principles, it integrates multidisciplinary methodologies in developing agroecosystem management strategies that are practical, effective, economical, and protective of both public health and the environment (Smith et al 1976).

IPM is based on the idea that below a certain pest population density or economic threshold, the cost of control measures exceeds the value of losses from pests. At farm level, pest management decisionmaking is determined by at least three factors (Headley 1972): the nature of the pest attack and the damage it causes, the range of protection measures and information available to farmers, and farmers' objectives.

To determine the economic threshold, information is needed on the extent of a pest attack (estimated by taking field samples of the pest population) to guide farmers' decision on whether or not to apply control: the damage function, relating the level of attack to crop loss; the control function, relating the reduction in attack to the control strategy applied; the estimated price of the crop; and the cost of the control strategy and its application.

With this information in hand, let

h = the level of pest attack;
d = the damage coefficient; in yield per hectare, lost for each pest present per unit area;
k = the mortality coefficient associated with the control strategy;
p = the price of the crop; and
c = the cost of applying the control.

The loss in revenue associated with the attack is equal to $p(dh)$. The reduction in loss associated with applying the control is equal to $pdhk$. It will then be profitable to apply control where $pdhk > c$; hence, the economic threshold (h^*) is equal to $h^* = c/pdk$.

IPM was pronounced the national crop protection policy of the Philippines in 1986. It is associated with the need-based insecticide applications rather than the traditional or prophylactic chemical treatments. The Philippine IPM method involves scouting the field for incidence of pest attack, comparing the pest population to a predetermined threshold level, and applying insecticides only when the actual population exceeds the predetermined threshold level. (For examples of action threshold levels, see Table 3.2.) IPM also involves use of pest-resistant varieties and improved cultural management.

On-farm studies have been conducted to determine if IPM has any effect on the number of pesticide applications, yields, costs, and pest populations in farmers' fields. According to IRRI data in Nueva Ecija in 1984-85, farmers who practiced IPM applied insecticides an average of 1.8 times a season, compared to 2.9 for non-IPM farmers. IPM fields yielded 0.49 tons per hectare more and cost P190 a hectare less to maintain than non-IPM fields. A more extensive study conducted during the 1984 wet season on 43 farms in 5 regions showed further that IPM farms average P158 per hectare versus the non-IPM farms with P351 per hectare in insecticide costs with respective yields of 5.1 tons per hectare and 4.9 tons per hectare. In the IPM farms, IPM had maintained yield levels while reducing insecticide expenditure by about 55% (Teng 1990a).

Some questions are raised about whether IPM has reduced the gap between attainable yield and actual yields after pest damage. Teng (1990a) concluded after a comprehensive survey of the literature that no data set exists for evaluating whether IPM programs cut crop losses and raise marketable yields.

The impact of IPM on human health and the environment will require long-term studies. Field data are also needed on the impact of IPM in reducing the rate of decrease in the population of aquatic and terrestrial wildlife (Teng 1990a).

IPM programs can be implemented and developed effectively through research and training. They can be adapted to different geographical locations only through

Table 3.2. Pest action thresholds for rice, Philippines, 1988 wet season.

Pest	Conditions	High	Low
	Vegetative stage		
Whorl maggot	Number of eggs/hill per m^2 Trap crop planted 1 week earlier	1	0.5
Defoliators	Number of live larvae/hill Do not spray if 25% parasitized Cluster of cotesia pupae is counted as one larva	1	0.5
Caseworm	Percent damaged leaves (20 hills)	2	1
Leaffolder	Number of live larva/hill Do not treat if 25% parasitized	2	1
Stem borer		3[a]	0.5[b]
	Reproductive stage		
Leaffolder	Number of live larva/hill	1	0.5
Stem borer		1	0.25
	All growth stages		
Planthoppers, WBPH, BPH	No./tillers by tapping Spray when mature nymphs are present	1	0.5

[a] Number of moths/min by disturbing the plants using an elbowed Stick. [b] Number of egg masses/m^2. If threshold is reached, collect egg masses and rear. If parasitism exceeds 50%, do not spray.

Table 3.3. Added cost and added return on heavy fertilizer and insect control, farmers' fields, 1974-77 wet season (Herdt 1979).

Location		Average increase of high level compared with farmers' level ($/ha)					
		Fertilizer			Insect control		
	Trials (no.)	Cost	Net return	B:C	Cost	Net return	B:C
Joydebpur. Bangladesh	20	23	68	3.96	7	24	4.43
Yogyakarta, Indonesia	14	35	–12	0.66	43	–42	0.02
Subang, Indonesia	8	19	–10	0.47	27	93	4.44
Dry zone, Sri Lanka	32	9	15	2.67	53	–27	0.49
Taiwan	1.2	23	49	3.13	nt[a]	nt[a]	nt[a]
Central Plain, Thailand	17	63	23	1.37	135	103	0.24
Laguna, Philippines	41	15	59	4.93	160	–34	0.79
Nueva Ecija, Philippines	39	35	7	1.20	81	–10	0.88
Camarines Sur, Philippines	20	52	–56	–0.08	76	-43	0.42
Iloilo, Philippines	23	45	17	1.38	95	52	1.55
All	226	30	20	1.67	86	–16	0.81

[a] Factor not tested.

research in those locations. The lack of trained extension personnel and lack of training for farmers are the major deterrents to successful implementation of IPM (Shepard and Isa 1987).

Farmers in the Third World do not adopt IPM easily because it is a demanding control measure (Goodell 1984). Because it is labor-intensive, it would be less attractive in high-wage areas. More research and effective extension must be done for a wider IPM adoption. For IPM research to succeed, it must be a cooperative effort by a multidisciplinary team (Goodell et al 1981).

In summary, nonchemical approaches to pest control may have some effect on some pest populations. Unfortunately, few of these methods can be applied by a simple rule of thumb. Timing must be precise, and labor may not always be available when needed. Hence, in some situations, farmers may still use pesticides which often give complete control over pests when most other controls have lost their effectiveness.

3.6 Economic analysis of crop protection technologies

Several research studies have delved into the question of profitability of different pest management strategies. Herdt (1979) compares prophylactic chemical control with farmers' practice. Herdt et al (1984) compares prophylactic versus economic thresholds (ET), the lowest level of chemical applications using resistant versus nonresistant varieties. Smith et al (1989) compares prophylactic versus economic thresholds (as in IPM that monitors insect pest populations and sprays only if economic thresholds are reached) versus natural control.

Herdt et al (1984), using yield-constraint experiment data, shows that rice yields in farmers' fields could often be raised almost a ton per hectare (Table 2.5). However, farmers do not take advantage of that yield potential because the returns are not high enough during the wet season (Table 3.3). The higher level of insect control added

Table 3.4. Added cost and added return on heavy fertilizer and insect control, farmers' fields, 1974 77 dry season (Herdt 1979).

Location		Average increase of high level compared with farmers' level ($/ha)					
		Fertilizer			Insect control		
	Trials (no.)	Cost	Net return	B:C	Cost	Net return	B:C
Joydebpur, Bangladesh	29	31	42	2.35	5	10	3.00
Yogyakarta, Indonesia	10	63	121	2.92	22	3	1.14
Subang, Indonesia	4	36	8	1.22	4	-4	0
Subang, Indonesia	40[a]	nt[b]	nt[b]	nt[b]	7	60	9.57
Dry Zone, Sri Lanka	16	50	–24	0.52	95	-77	0.19
Taiwan	12[a]	24	68	2.83	nt[b]	nt[b]	nt[b]
Central Plain, Thailand	6	84	67	1.80	151	–121	0.20
Central Plain, Thailand	10[a]	33	135	5.09	nt[b]	nt[b]	nt[b]
Laguna, Philippines	18	18	113	7.28	170	–74	0.56
Nueva Ecija, Philippines	19	38	124	4.26	87	34	1.39
Camarines Sur, Philippines	20	82	68	1.83	116	–34	0.71
Iloilo, Philippines	11	66	62	1.94	109	–79	0.28
All	195[a]	45	71	2.58	65	12	1.20

[a] Fertilizer or insect control (but not both) was tested in these cases. Total number of trials for fertilizer experiment was 155; that for insect control was 173. [b] Factor not tested.

Table 3.5. Average performance of insecticides[a] tested at Philippine research stations, 1972-74 dry season (Herdt et al 1984).

Treatment[b]	Moderately resistant rices			Nonresistant rices		
	Added cost (P/ha)	Added return (P/ha)	MBCR	Added cost (P/ha)	Added return (P/ha)	MBCR[c]
ET	80	767	9.5	95	819	8.6
NH	82	–77	Neg	85	365	4.2
MP	1446	1337	0.9	1386	1895	1.4

[a] Shows added cost and added return compared with lower treatment (ET) compared with control, (NH) compared with ET and (MP) compared with NH. [b] ET=economic threshold; NH=next higher; MP= maximum protection: MBCR = marginal benefit cost ratio.

more to costs than returns in 6 out of 10 locations in the wet season in 1974-77 in several Asian countries. Dry season results were somewhat more favorable because high input raised yield more then than in the wet season (Table 3.4). High insect control or prophylactic treatments reduced net returns in six cases and barely covered its cost on average, yielding a benefit-cost ratio of 1.2:1.

On average, only the lowest application level was economically profitable in experiments at several Philippine research stations (Herdt et al 1984). Table 3.5 further shows the economic analysis of the insecticide trial experiments conducted at the four research stations during the 1972-74 dry seasons for moderately resistant and nonresistant rices. The return on ET is most attractive on both rice types, but the difference between moderately resistant and nonresistant rices is clear. There is no incentive to go above

ET with the moderately resistant rices but applying even the maximum protection level on the nonresistant rices brings some profit.

Table 3.6 presents the added costs, added returns, and marginal benefit-cost ratio (MBCR) for three levels of insecticide treatments in farmers' field experiments with resistant rices in five provinces. According to these data, only the economic threshold level of treatment (ET) would be economically attractive in all five sites. However, with inclusion of natural control plots as a check in these experiments, ET became an inferior technology in normal years. Average MBCRs for the maximum protection (MP) treatment and even the next higher (NH) to the economic threshold treatment are less than 1.0 in all sites and are negative in most cases. The same analysis is presented in Table 3.7 for nonresistant varieties. Again, the ET treatment was uniformly best. Comparing MBCRs of maximum protection in resistant versus nonresistant varieties, MBCRs in nonresistant varieties are positive and greater than one in dry season trials, while MBCRs of maximum protection in resistant varieties are negative and less than one. Because the productivity effect of pesticides on resistant varieties is minimal, a more profitable strategy will be to plant resistant varieties and use pesticide only if needed.

Even though the total yield loss in farmers' field trials with resistant rices was 0.8 tons per hectare in Iloilo and 1.3 tons per hectare in Nueva Ecija in the wet season, the ET treatment, which saved 0.4 tons per hectare in lloilo and 0.9 tons per hectare in

Table 3.6. Added costs, added returns, and marginal benefit-cost ratio of insecticide use on resistant rices in farmers' fields, Philippines, 1976–81 (Herdt et al 1984).

	Wet season[a]			Dry season[a]		
Location/treatment	Added cost (P/ha)	Added return P/ha)	MBCR	Added cost (P/ha)	Added return (P/ha)	MBCR
Laguna						
Economic threshold	311	759	2.4	217	868	4.0
Next higher	254	–341	Neg	338	–512	Neg
Maximurn protection	1000	791	0.8	740	884	1.2
Nueva Ecija						
Economic threshold	333	1442	4.3	201	–1178	Neg
Next higher	1086	–140	Neg	964	–527	Neg
Maximum protection	942	775	0.8	589	1240	Neg[b]
Cagayan						
Economic threshold	0	–47	nd[c]	0	558	nd[c]
Next higher	1504	744	0.5	1202	–279	Neg
Maximum protection	310	124	0.4	861	698	0.8
Iloilo						
Economic threshold	140	573	4.1	254	780	3.1
Next higher	311	432	Neg	355	–25	Neg
Maximum protection	880	68	0.1	519	1236	2.4
Pangasnan						
Economic threshold	215	186	0.9	242	660	2.7
Next higher	522	148	0.3	252	18	0.1
Maximum protection	1038	–21	Neg	705	145	0.2

[a] Compares ET with control. NH with ET, MP with NH. [b] MP gives a lower net return than the control, ET, or NH. [c] MBCR concept not defined.

Table 3.7. Added costs, added returns, and marginal benefit-cost ratio of insecticide use on nonresistant rices in farmers' fields, Philippines, 1976–81 (Herdt et al 1984).

Location/treatment	Wet season[a]			Dry season[a]		
	Added cost (P/ha)	Added return (P/ha)	MBCR	Added cost (P/ha)	Added return (P/ha)	MBCR
Laguna						
Economic threshold	451	2403	5.3	217	1891	8.7
Next higher	76	–1333	Neg	338	-977	Neg[b]
Maximum protection	816	1441	1.8	740	1643	2.2
Solana/Cagayan						
Economic threshold	0	1271	nd[c]	74	264	3.6
Next higher	1732	-449	Neg	747	-62	Neg
Maximum protection	331	46	0.1	365	496	1.4

[a] Compares ET with control, NH with ET, MP with NH. [b] MP gives a lower net return than the control, ET, or NH. [c] nd = not defined.

Table 3.8. Mean and standard deviation of marginal net benefits, variable costs, and benefit-cost ratios determined for insect control treatments in rice, Zaragoza, Nueva Ecija, 1978-80 and 1982-84 wet seasons (Smith et al 1989).

Item	Untreated	Economic threshold		Prophylactic
		High wage	Low wage	
Net benefit (P/ha per crop)	7988	8093	8168	8019
Standard deviation of net benefit (P/ha per crop)	1221	1910	1910	2455
Variable cost (P/ha per crop)	0	1276	1202	2027
Benefit-cost ratio	-	6	7	4

Nueva Ecija, was the most attractive economically (Herdt et al 1984). These results also suggest that in both experiment station and Laguna farmers' field trials (which enable a comparison of insecticide use on resistant and nonresistant rices), there is less economic incentive to apply insecticides heavily on resistant rices than on nonresistant rices. This highlights the important advantage of built-in insect resistance—the lower economic incentive to apply insecticides heavily saves farmers money, conserves natural enemies, reduces the potential for environmental problems, and reduces the likelihood of developing pesticide- resistant insects (Herdt et al 1984).

More recently, Smith et al (1989) compared ET (spraying only when economic thresholds are reached) with prophylactic and natural control tactics. ET treatments had a more favorable benefit-cost (B-C) ratio than the prophylactic treatments (Table 3.8). Without typhoons, the untreated check or natural control had a lower net benefit per crop of ₱7,988 per hectare, compared to the ET treatments with high (₱8,093 per hectare) or low (₱8,168 per hectare) wage rates. The prophylactic treatment has a profit of ₱8,019 per hectare. The difference in net profits between all treatments is only 2% of net profit, ₱180 per hectare.

On the whole, economic threshold treatments were better than other types under certain conditions. Smith et al (1989) found the B-C ratios for ET treatment more profitable at low wage rates for monitoring. When pest populations are low, natural control is profitable. When pest infestation is high, highest net benefits are obtained from prophylactic or ET treatments. Hence, research on economic crop loss assessments may not only concern absolute losses, but can also predict future losses so that pest control investment or returns can be maximized (Smith et al 1989). One way of reducing pest populations is to minimize insecticide use so as to give natural enemies a hospitable environment.

In terms of yield stability, the standard deviation in yield over six seasons was highest in plots with scheduled spraying and lowest for untreated (natural control) plots (Smith et al 1989). The standard deviation of net benefit (pesos/hectare/crop) was also lower in threshold plots than in plots with scheduled spraying, indicating less risk for the ET technique.

To summarize, for profitable pesticide decisions, farmers have to be able to predict pest populations to reduce the year's chance of a problem. In low pest-population years, natural control is the most profitable. Natural control is more appropriate to maximize profits in the wet season while ET could be profitable in dry seasons (Smith et al 1989).

Chapter 4
A profile of pesticide use for rice

Pesticide use in lowland ricelands has become a regular feature of farming even if most rice farmers do not fully understand the hows and whys of such use. Because farmers often lack accurate knowledge about pests and their control, their spraying decisions are sometimes non-optimal. Constantly changing pest complexes, a widening range of insecticide products, and the absence of a unique and specific control recommendation against insect pests all contribute to farmers' confusion regarding the type of chemical to use, the rate of application and timing of control (Huelgas 1989). Despite this confusion, farmers with enough cash are willing to invest in chemical control measures with the thought that using lower than recommended dosages is better than no control at all.

In addition, farmers generally lack knowledge about proper pesticide management, including safe pesticide handling and storage. Training Filipino rice farmers on pesticide safety has not been adequate and thus exposed farmers unnecessarily to risks of pesticide poisoning. Unsafe pesticide practices have been documented in several farm level studies (Pingali et al 1990, Rola et al 1992).

This chapter describes the pesticide use practices of rice farmers in the study site of Nueva Ecija in Central Luzon. Results of rice farmer surveys by the International Rice Research Institute (IRRI) Social Sciences Division in Nueva Ecija during crop years 1979 and I991 were used to determine patterns of use and kinds of pesticides used. A one-shot IRRI survey during the 1989 dry season also revealed information about safety practices, storage and disposal of pesticides, and the incidence of farmer poisonings. Information generated from these surveys provides further background information on farmers' pest control technologies as described in Chapter 5 and the evidences of farmer exposure to pesticides as discussed in Chapter 6.

4.1 The study site

The study site, Guimba, Nueva Ecija, is located in the Central Luzon region, the rice bowl of the Philippines. Because of its proximity to Manila, Nueva Ecija supplies most of the rice requirements of the metropolis. Farm gate prices of rice are higher than in the other regions of the country, and input prices are relatively lower (Rola et al 1990). Thus, it is more profitable to produce rice in commercial quantity in Central Luzon than in any other region of the country. Central Luzon produced about 12% of all Philippine-grown rice in the 1979 wet season, but 18% by the 1991 wet season (Table 4.1).

About 300,000 hectares are under rice in the wet season and about half of that in the dry season. In general, mean yield per hectare in Central Luzon is higher than the national average yields. Yields in the dry season are consistently higher (3.54-4.55 tons per hectare) than in the wet season (1.87-2.96 tons per hectare). The yield per hectare had been increasing, despite decreasing farm-level use of insecticide, as discussed below.

4.2 Pesticide use profile by rice farmers

4.2.1 Frequency of insecticide applications

Insecticide application patterns by rice farmers have not reflected current pest situations. Even with no serious pest attacks, farmers applied insecticides frequently during 1979. However, the average frequency of application has decreased in the early 1990s (Table 4.2). Possible reasons for this reduction may be increases in farmer awareness of pest thresholds or in host plant resistance. The variance of the frequency of application likewise decreased over time. Hence in 1991, no farmers were observed spraying more than six times, in contrast to earlier years. This implies that farmers are moving away from calendar spraying.

4.2.2 Quantity of insecticide use

Rice farmers in Nueva Ecija use more organochlorines and organophosphates than carbamates and pyrethroids. On the whole, a decrease was observed from 1.07 kg ai/ha to 0.5 kg in the wet seasons 1979 and 1991, respectively (Table3.3). The same trend was seen during the dry seasons where the quantity of insecticide used decreased from 1.29 kg ai/ha to 0.6 kg. The farmers are known to underdose their insecticide application. Hence in dry season 1991, the 0.6 kg dose was sprayed more than twice.

Table 4.1. Production, area and yield, Central Luzon and Philippines, 1979-91.

Time		Production		Area		Yield (t/ha)
		000 t	% of total	000 ha	% of total	
Wet season						
1979	Central Luzon	604.67	12	245.00	10	2.5
	Philippines	4903.00		2371.00		2.1
1991	Central Luzon	982.53	17	331.48	17	3.0
	Philippines	5622.24		2004.00		2.8
Dry season						
1979	Central Luzon	729.80	26	165.60	14	4.4
	Philippines	2782.00		1170.00		2.4
1991	Central Luzon	765.96	19	168.39	12	4.6
	Philippines	4047.51		1418.64		2.9

Table 4.2. Frequency of insecticide applications by Nueva Ecija rice farmers, 1979-91.

Applications (no.)	Frequency			
	Wet season		Dry season	
	1979	1991	1979	1991
0	28	7	32	10
1	29	33	32	15
2	38	28	24	41
3	25	14	26	19
4	13	5	15	7
5	4	6	7	2
6 and above (no.)	8	0	7	1
Mean	2.11	1.95	2.11	2.08
Variance	3.04	1.62	3.48	1.44
Total respondents	145	93	143	95

Table 4.3. Insecticide use (kg ai/ha), Nueva Ecija farmers, 1979-91.

Insecticide type	Insecticides (kg ai/ha)			
	Wet season		Dry season	
	1979	1991	1979	1991
Organochlorines				
Mean	.33	.43	.84	.53
Range	.01-1.24	.18-1.05	.09-4.42	.11-2.45
Organophosphates				
Mean	.67	.43	.85	.47
Range	.06-2.98	.07-1.74	.13-7.8	.05-2.88
Carbamates				
Mean	.85	.39	.81	.36
Range	.02-5.13	.007-1.13	.01-6.8	.03-.70
Pyrethroids				
Mean		.04		.07
Range		.008-.17		.008-.28
Total				
Mean	1.07	.50	1.29	.60
Range	.14-5.4	.008-1.88	.03-7.8	.008-2.95

Farmers obtain their knowledge about pesticide dosage from government technicians, pesticide sales people, pesticide labels, and other farmers (Table 4.4). Proper training about correct dosages is imperative for government technicians because industry sales people may tend to convey a message of higher dosages and frequent application to increase their sales. The instructions on pesticide labels are too nebulous for farmers to understand and apply, which also causes incorrect dosages. In addition, farmers may experiment on their own and may deliberately underdose. Especially without pest pressure, farmer investments in chemical control would result in a negative return. However, compared to other crops, insecticide use on rice is low (Table 4.59), and will likely remain low because so much more research on host plant resistance is being done on rice than on other crops. Insecticide use on rice will also remain low because it neither enhances rice quality nor improves yields in the absence of pest pressures. In contrast, the use of fungicides, which do improve the appearance of high-valued fruits and vegetables, will increase.

4.2.3 Timing of insecticide applications

Critical in farmers' timing of insecticide applications are the presence of pests, the perceived intensity of infestation, transplanting date, and such other factors as fertilizer application dates and neighbors' recommendations (Table 4.6). Fifty-eight percent of farmer respondents in the survey stated that they spray when pest infestation is heavy. About 42% of the respondents said they spray whenever pests are present, irrespective of pest density. Other criteria mentioned by respondents (such as date of transplanting and date of fertilization) were reminiscent of the recommended calendared spray schedules or complete protection treatments.

Table 4.4. Sources of rice farmers' knowledge regarding rates of pesticide application, Nueva Ecija, 1989 dry season.

Source[a]	No.	%
Government technicians	39	65
Pesticide labels	16	27
Fellow farmers	13	22
Pesticide salesmen	9	15
Others[b]	11	18
Total	60	—

[a] Multiple responses. [b] Includes ratio advertisements, store dealers, seminars.

Table 4.5. Mean pesticide usage (kg ai/ha), various crops, Philippines (Rola et al 1992). [a]

	Usage (kg ai/ha)				
Crop	Insecticides	Herbicides	Fungicides	Others [b]	Total
Vegetables					
Cabbage	2.9590	1.9990	2.0820		7.0400
Onion	1.5090	0.2270	1.9970		
Fruit					
Mango	0.3183	0.0079	0.5101	1.2597	2.0960
Banana	0.1610	0.3060	1.3060		1.7730
Pineapple	0.3000	3.2940	0.2519		3.8459
Grain					
Rice	0.5050	0.5220	0.2350	0.3060	1.5680
Maize	0.4663	0.5167	0.1755		1.1585
Others					
Tobacco	0.3730		0.0530		0.4260

[a] These are the results of a survey of 460 farmer respondents in selected Philippine provinces. [b] Includes molluscicides, rodenticides, and flower inducers. [c] In kg ai/tree.

Table 4.6. Factors that farmers consider in timing of insecticide application, Nueva Ecija, 1989 dry season.

Factor[a]	No.	%[b]
Presence of pest	25	42
Degree of pest infestation	35	58
Date of transplanting	13	22
Others[c]	14	23
Total respondents	60	100

[a] Multiple responses. [b] Total responses per item over total respondents [c] Others include date of fertilizer application, neighbors recommendation, and spraying even without pest or damage.

Table 4.7. Types of insecticide applied by season, in percent of farmers reporting, Nueva Ecija, 1979-91.

Insecticide	Category[a]	Farmers reporting (%)					
		Wet season			Dry season		
		1979	1985	1991	1979	1985	1991
Organochlorines							
Endrin	I	11	1	0	10	0	0
Endosulfan	II	6	4	31	4	9	27
Organophosphates							
Methyl parathion	I	12	8	5	8	9	5
Monocrotophos	I	36	59	33	33	55	36
Azinphos ethyl	I	7	4	2	12	4	1
Diazinon	II	9	0	0	15	3	0
Carbamates							
Isoprocarb	II	26	10	20	36	10	33
Isoprocarb + lindane	II	4	29	0	3	33	0
BPMC + chlorpyrifos	II	54	40	7	54	26	14
Carbofuran	I	9	3	3	9	1	0
Methomyl	I	9	3	0	12	3	1
Pyrethroids							
Cypermethrin	II	0	24	14	0	20	16

Category I = highly hazardous, II = moderately hazardous.

4.2.4 Types of insecticides used by rice farmers

Filipino rice farmers use mostly category I and II insecticides that the World Health Organization (WHO) classifies, respectively, as extremely and moderately hazardous (Table 4.7). Laws regulating the use of hazardous chemicals have been lax in the Philippines, which increases farmers' health risks from exposure.

Organochlorines (OC) and organophosphates (OP) are in the WHO hazardous categories I and II. Among the OCs, endrin and endosulfan were most widely used in 1979 in the Philippines. However, endrin was banned in the early 1980s and was totally out of use in 1991. On the other hand, the use of endosulfan as a molluscicide is increasing because it controls golden snail on rice. Endosulfan is registered only as an insecticide, hence this misuse by farmers became a ground for regulation. A proposal to prohibit importation of endosulfan is currently being reviewed by pesticide policymakers.

Filipino farmers prefer OPs to OCs. Organophospahates such as methyl parathion, monocrotophos, and azinphos ethyl are cheaper, widely available, and known for wide-spectrum toxicity. The Philippine regulatory agency has proposed to reserve these extremely hazardous chemicals for exclusive use by certified applicators. Chemicals popular in the Philippines have been banned or severely restricted in the United States (Table 4.8). The United States, for instance, forbids use of monocrotophos in knapsack sprayers. Lately, the Philippine government has announced an impending ban on these three chemicals. Chemical companies have been invited to present evidences of absence of harmful effects of their products.

Rice farmers also use carbamates which, together with pyrethroids such as cypermethrin, are classified in the moderately hazardous category. However, current prices, almost twice as high as those for OCs and OPs (Table 4.9), discourage farmers from using pyrethroids. Policies geared toward making pyrethroids competitive with OPs and OCs could mitigate farmer health risks associated with pesticide use.

Table 4.8. Registration status in the United States of insecticides commonly used by Filipino farmers (US. Environmental Protection Agency 1992).

Insecticide	Registration status in the United States
Organochlorines	
Endrin	No longer registered
Endosulfan	For general use
Organophosphates	
Methyl parathion	For restricted use
Monocrotophos	No longer registered
Azinphos ethyl	Not registered
Diazinon	For general use
Malathion	For general use
Fenitrothion + malathion	Not registered as a mixture
Chlorpyrifos	For general use
Phosphamidon	For restricted use
Triazophos	Not registered
Edifenphos	No information
Proferofos	No information
Carbamates	
Isoprocarb	Not registered
Isoprocarb + lindane	Not registered
BPMC + chlorpyrifos	Not registered
Carbofuran	For restricted use
Methomyl	For restricted use
Carbaryl	For general use
BPMC	Not registered
BPMC + chlorpyrifos	Not registered
BPMC + endosulfan	Not registered
BPMC + penthoate	Not registered
Formetanate	No information
Pyrethroids	
Cyperrnethrin	For general and restricted use
Deltamethrin	Not registered
Fenvalerate	For general and restricted use
Deltamethrin + endosulfan	No information
Cypermethrin + monocrotophos	Not registered
Cyhalotrin	No information

Table 4.9. Average retail prices of chemicals (P/liter or kg), urea (P/kg), and rough rice (P/kg), Nueva Ecija, Philippines (1979 = 100).

	Dry season		Wet season	
	1979	1991	1979	1991
Chemical				
Organochlorine	41	54.75	42	50.88
Organophosphate	47	60.86	49	52.51
Carbamate	51	57.60	48	55.57
Pyrethroid	nd [a]	84.47	nd	92.81
Urea	1.91	1.07	1.91	1.07
Rough rice	1.05	.92	1.05	.92

[a] nd = no data, pyrethroids were not in the market In 1979.

4.3 Safety and storage practices

Acute poisonings in Philippine rice farm households can be traced to unsafe practices in handling, storing, and disposing of pesticides for several reasons. First, even if farmers are aware of the hazards, they cannot afford adequate storage and disposal systems. Other farmers do not know about the consequences of mishandling chemicals. Hence, farmer training on proper pesticide handling could minimize unnecessary exposure to chemicals. Surveys have revealed how urgently needed such training programs are.

4.3.1 Handling and reentry intervals

Most farmers spray chemicals away from the wind, but one in five still sprays into the wind (Table 4.10). Although almost all applicators are partially covered with protective clothing, few of them wear masks, and the probability of poisoning through inhalation of chemical particles is high. The more frequent the application, the higher their exposure.

Table 4.10. Pesticide handling practices and kinds of protective cover as reported by farmers, Nueva Ecija, Philippines, 1989 dry season.

Item	Farmers reporting	
	No.	%
Direction of spraying		
Toward the wind	40	63.5
Against the wind	11	17.5
Both	12	19
Kind of protective cover		
No protective clothing[a]	1	1.6
Partial protective clothing[b]	60	95.2
Full protective clothing[c]	2	3.2

[a] Short pants and T-shirt. [b] Short pants/long sleeves or T-shirt/long pants. [c] Long pants, long sleeves, mask and gloves.

A reentry interval is the time needed to allow a chemical to dissipate in the environment. Most OPs and OCs need an interval of at least 72 hours, but farmers usually go back the same day to see if the spray has worked (Table 4.11). It is also suspected that few manual weeders (traditionally women) know about the reentry interval requirement. In any case, no danger signs are posted on newly sprayed fields. Thus, weeders as well as children and other household members in or near newly sprayed fields are also directly exposed to pesticides.

4.3.2 Pesticide storage and disposal practices by farmers

Pesticide storage and disposal practices of farmers show high probability of accidental exposure to the chemicals as well. Only 13% of respondents mentioned safe storage practice (Table 4.12). Any practice but placing dangerous chemicals in a locked cabinet inside the house is considered unsafe. Most farmers' houses do not have cabinets, but if they do they are used to store clothing and other personal effects. A popular storage space is an improvised cabinet under the house flooring. This is, however, accessible especially to children.

Seventy-two percent of respondents sold their empty pesticide containers, and a few (7%) disposed of them in the paddy ecosystem. Piling empty pesticide bottles in one, unfenced place on the farm is another common mode of disposal. Again, small children could get containers from this garbage heap.

Table 4.11. Reentry periods[a] as reported by rice farmers, Nueva Ecija, Philippines, 1989 dry season.

Number of hours	No.	%
< 48	45	75
48-72	8	13
>72	7	12

[a] Recommnded reentry period is 72 h for category I chemicals and 48 h for other categories. Reentry period is dissipation time for chemicals and tells farmers when it is safe to reenter newly sprayed fileds.

Table 4.12. Farmers' practices regarding pesticide storage and disposal of empty containers, Nueva Ecija, Philippines, 1989 dry season.

Practice[a]	Farmers responding	
	No.	%
Pesticide storage after procurement[b]		
Safe storage practices	8	13
Unsafe storage practices	52	87
Disposal of empty pesticide bottles[c]		
Sold	43	72
Disposed of in the ricefield	4	7
Others[d]	13	21

[a] Multiple responses. [b] Safe storage practice = the bottle is placed in a locked cabinet inside the house; unsafe = all other practices. [c] Eighty-three percent of respondents return the cover of the empty pesticide bottles before disposing of them. [d] Sold and disposed of; piled and sold.

4.3.3 Sprayer use and maintenance

Knapsack sprayers with a 16-liter capacity are widely used by rice farmers (Table 4.13). Although 83% of the respondents own a sprayer, they are not much concerned about sprayer maintenance. This creates no demand for sprayer repair shops. Sprayer leakage is common, and farmers know about it but do nothing.

About 83% of respondents wash sprayers after use. Wash water is usually dumped in the irrigation canal or in the ricefield. Eventually this pesticide contamination poisons the microorganisms in the paddy ecosystem and surface water systems. In addition, contaminated irrigation water could also come into contact with the human skin, leading to pesticide poisoning.

4.4 Incidence of insecticide poisoning among rice farm households

Due to use and unsafe handling of hazardous pesticides, a number of on-farm poisonings have been recorded in the national statistics. Of the 4,031 acute pesticide poisonings reported by Department of Health hospitals, 603 resulted in death from 1980 to 1987 (Castañeda and Rola 1990). The number of poisonings is likely underestimated, since most cases do not reach the hospital, and rural health officers may not always correctly diagnose pesticide poisoning.

For acute pesticide poisonings reported at the national level, death rates ranged from 13 to 21 %. National data likewise show that most pesticide poisonings were suicidal (64%), accidental (16%), and occupational (14%) [Castañeda and Rola 1990]. Acute pesticide poisoning cases involved both males (54%) and females (46%). In the Central Luzon case study, farmers have reported cases of acute pesticide poisoning with headaches/dizziness, vomiting, and stomach pain, among other symptoms (Table 4.14). A detailed health examination of sample farmers in the study site included physical examination, cholinesterase determination, chest x-rays, and electrocardiograms (EKGs). The results of this study are reported in Chapter 6.

Table 4.13. Sprayer use and safety practices by rice farmers, Nueva Ecija, Philippines, 1989 dry season.

Item[a]	Farmers	
	No.	%
Type of sprayer used[b]		
Knapsack sprayer	59	98
Automatic sprayer	1	2
Wash sprayer after using		
Yes	50	83
No	10	17
Disposal of wash water used		
In the irrigation canal	36	72
In the ricefield	12	24
Others[c]	2	4

[a] Multiple responses. [b] Eighty three percent of respondents own a sprayer with 16-liter capacity. [c] Include both Irrigation canal and ricefield.

Table 4.14. Number of poisoning cases as reported by 60 farmers, Nueva Ecija, Philippines, 1989 dry season.

Symptom [a]	Farmers reporting	
	No.	% [b]
Headache, dizziness	35	69
Vomiting	12	24
Unconscious	8	16
Stomach pain	5	10
Weak	3	6
Others	3	6
Total victims [c]	51	

[a] Multiple responses. [b] As reported by respondents. [c] Cases reported/total victims.

A related study by Rola (1989) has shown that about 50% of rice farmers in rainfed and irrigated ricelands claimed sickness due to pesticide use. The incidence of sickness, however, is higher among vegetable farmers, who are heavy users of pesticides. Vegetable farmers and tree farmers display patterns similar to those of rice farmers in pesticide safety, handling, disposal, and storage practices (Rola et al 1992). Because this wider population uses more pesticides than do rice farmers, a higher probability of poisoning cases is expected. However, compared to rice farmers, farmers of other types of crops have fewer nonchemical pest control alternatives (see Chapter 3).

Although pesticides are considered a panacea for the farmers' pest concerns, their use is creating another set of problems. Frequent applications of highly toxic chemicals increase risks of health damage from chemical exposure. Current pesticide pricing and regulatory structure combined with inadequate storage, unsafe handling practices, too short reentry intervals, and inefficient sprayer maintenance expose not just farmer applicators but their whole household to an increased risk of chemical poisoning.

Chapter 5

Choice of crop protection technologies under risk: an expected utility maximization framework

The uncertainty of pest attacks warrants the use of stochastic models in measuring the impact of crop protection technologies on agricultural productivity and income. Many of the stochastic elements, risks, in pest control stem from variations in agricultural biology, including variations in pest numbers and types over time and space: crop susceptibility to pest attack across crops, varieties, and crop growth stage; and pest susceptibilities to chemical, mechanical, and other controls (Carlson 1984).

Pesticide, labor, and other pest control inputs have an important effect on risk and uncertainty in agricultural production. Since most uncertainty in pest control is due to uncertain pest infestation levels, and chemical inputs act on these infestations, randomness enters the production function through the productivity of the pesticides. Taking production risk and producer risk attitudes into consideration, this chapter presents an assessment of the various crop protection technologies, including complete control, economic threshold (ET) levels, and natural control as well as farmers' technologies.

An expected utility function is used to rank technologies where expected utility is based on decisionmakers' subjective probability distributions of the random variable in profit. Profit or net benefit variability is directly related to yield variability, which is directly related to insect damage variability, among other variables.

Two models of yield distribution function were specified, where first and second moments were estimated and used in estimating the expected utility function. Farmers' expected utility was assumed to follow a negative exponential function. Risk aversion parameters were taken from Sillers (1980) for Nueva Ecija.

The data on input use of the different pest control strategies were generated by the International Rice Research Institute (IRRI) Entomology Department. These experiments were done in farmers' fields in Guimba, Nueva Ecija, Philippines. Input cost data were gathered by the IRRI Social Sciences Division.

5.1 Background literature

Farmers face different kinds of risks. They face production risks from natural phenomena and economic risks from market fluctuations and related economic phenomena. If all relevant variables were known with certainty, farmers would face the classical maximization problem: maximizing profits. However, after decisions are made, natural and economic conditions change, and with this new setup, previously optimal decisions become suboptimal.

Along this line, Antle (1983) advanced the hypothesis that risk matters primarily because production is a dynamic phenomenon and that production and price uncertainty therefore affect expected productivity and expected income. The analysis of dynamic, uncertain models shows that farmers' optimal decisions are affected by risk whether they are "risk neutral" or "risk averse." This suggests that dynamic, risk neutral models may be more useful than conventional static risk averse models (Anderson et al 1980) for understanding the role of production risk in farm management.

The modern approach, as described in the literature (Antle 1988, Antle and Goodger 1984, Just and Pope 1979), is based on the assumption that farmers, as decisionmakers, behave as if they maximize the mathematical expectation of utility, where utility is assumed to be a function of profit and possibly other variables. In this sense, expected utility is based on the decisionmaker's subjective probability distributions of the random variables in profit. To formulate expected utility functions, mean, variance, and higher moments of the distribution will be needed as well as the functional specification of the utility function. First, second, and higher moments could aptly describe the nature of probability distributions of random variables. In technology evaluation under risk, an adequate production function specification should include two general functions: one that specifies the effects of input on the mean (the first moment) and another that specifies the effects of inputs on the variance of output, that is, the second moment.

Few researchers have used this moments-approach method to estimate production relationships under risk. Early research based on this method utilized experimental data (for instance, Day [1979], Anderson [1974]. and Roumasset [1974]) and found systematic relationships between fertilizer use and the mean and higher moments of output. Antle (1988) used flexible moments-based functions to estimate optimal pest management decisions.

Econometric production models have also been used to estimate moments of output (de Janvry 1972, Moscardi and de Janvry 1977). However, Just and Pope (1979) showed that the usual multiplicative-error economic production function specifications may be inappropriate because they restrict the effect inputs can have on output variance. They argue that the characteristics of conventional agricultural production models are such that, if an input has a positive effect on output, a positive effect is also imposed on the variability of output. The effects of input on output should not be tied to the effects of input on the variability of output a priori. To attain this generality, an adequate production function specification should include two general functions: one specifying the effects of input on the mean; the other specifying the effects of input on the variance of output. Just and Pope then proposed an additive-error heteroscedastic model, which overcomes the limitation of the multiplicative-error model.

Practically all new technologies likely to be adopted increase expected outputs or yields, that is, shift and/or change the shape of the yield distribution to increase expected yields (Binswanger 1980). Furthermore, few shifts resulting from new technologies increase yield risks very much. What happens to riskiness of net returns depends on two factors: the investment levels associated with the new technologies (the smaller, the less risky) and the shift or change in the shape of yield distribution.

Roumasset (1979) has also concluded that, despite the small number of empirical attempts to determine the effects of various inputs on crop yield distribution, some inputs in some situations increase variation in returns (for example, application of nitrogen to drought-prone maize), and some inputs reduce variance (for example, pest management). If variance reduction is an important element in farmers' decisions, situations should not be too difficult to find where farmers underuse the variance-increasing input and simultaneously overuse the variance-reducing input in relation to the input quantity that would maximize expected profits.

Most empirical analyses of production under risk have been applied to fertilization. Among them are studies by de Janvry (1972) using Argentine data on maize and wheat. Anderson (1974) using response of wheat data to nitrogen and phosphorus in Australia. Just and Pope (1979) with data of several crops in the United States, and Roumasset (1973) who estimated rice response to nitrogen in the Philippines. In most cases, risk optimal fertilizer rates were determined under various assumptions about an expected-utility objective function and specified in terms of moments of distributions of farm profits derived from the yield distributions. Antle (1988) estimated optimal pest control decisions on tomato production in California using the expected-utility framework.

The expected-utility of profits can be estimated in at least two ways. One is the elicitation of objective output distribution (Scandizzo and Dillon 1979). The other is by specifying utility functions and taking expected utilities (Anderson et al 1980) using Taylor series approximation (Antle 1988). However, utility functions are difficult to establish for farmers in a certain location. Attempts were made by Binswanger (1980) in the semiarid region of India and Sillen (1980) in the Central Luzon region of the Philippines. Both studies used experimental methods to elicit risk attitudes of farm household heads in each location. Hardaker and Ghodake (1982) applied Binswanger's estimates of risk attitudes in modeling farmers' choices of technology, that is, their choice of cropping pattern. Similarly, Walker and Subba Rao (1982) validated these risk-aversion parameters in their study of choices of cropping systems in the Akola region of India.

Sillers (1980) estimates of risk aversion parameters are used in this chapter to define an expected utility function for farmers to be used in ranking stochastic pest control technologies.

5.2 Methodology

The concepts of production risk, defined in terms of randomness in production, and farmers' risk attitude, defined in terms of the utility function, can be used to generalize the neoclassical efficiency and welfare analysis. The distribution of output, conditional on managment decisions, replaces the neoclassical production function. The maximization of expected utility of profit replaces the profit-maximization postulate of the neoclassical model. Expected utility is maximized by choosing the level of input at which an additional or marginal unit of input gives no higher utility.

5.2.1 Theoretical framework

It is assumed that in production decisions farmers behave as if they maximize the mathematical expectation of utility and that utility is a function of profits, among other variables. Expected utility is based on the decisionmaker's subjective probability distributions of the random variable in profit. It is further assumed that profit variability is directly related to output variability which is directly related to insect-damage variability among other variables.

Hence, the objective is to maximize

$$Eu(p,s) = Eu[(py - wx), s] = u(x,a,w,s) \tag{1}$$

where:

$Eu(p,s)$ = the decisionmaker's expected utility function;
p = profit or net benefit;
s = risk parameter;
p = output price, assumed to be predetermined and constant across experimental treatments;
y = yields, a random variable, whose distribution is conditionally defined on the input vector x;
x = input vector to be chosen;
w = a vector of input prices, usually predetermined; and
a = a vector of parameters which with x define the probability distribution of y.

The solution to the expected utility maximization problem is $x^* = x^*(a,s,w)$.

5.2.2 Estimation procedure

5.2.2.1. Yield distribution function

Two models were used to derive for probability distribution of yields, y.

Model 1: Just and Pope (1979)

The Just and Pope model specifies the following relationship:

$$y = f(x) + h(x)^{1/2} e^{u}, \tag{2}$$

where:

y = yield;
$f(x)$ = deterministic component of the production function and
x_1 = log fertilizer (in kilograms);
x_2 = insecticide (in dosage level);
x_3 = season dummy (0 for wet season and 1 for dry season);
$h(x)$ = stochastic component of the production function, and
e^{u} = error term, where $u \sim N(0, s^2)$

where both f and h follow a popular log-linear form the Cobb- Douglas. The function f(x) could be estimated using the nonlinear regression estimation and h(x) is estimated using the ordinary least squares.

The second moment or variance of the distribution was computed via a weighted regression of the inputs of production by the square of the error term in (2). Means and variance of yields and net benefits were estimated using the Just and Pope model fitted to the raw data.

Model 2: Log-linear equation with treatments as intercept shiftors

The second model that was used to estimate for yield distribution is a log-linear model where each technology is represented by a treatment dummy. Hence:

$$\ln Y = f(\ln N, SD, TD_1, TD_2, TD_3, TD_4) \tag{3}$$

where:

Y = yield of rice per hectare;
$\ln N$ = log of nitrogen;
SD = season dummy, where $SD = 0$ for wet season and $= 1$ for dry season;
TD_1 = dummy for complete protection;
TD_2 = dummy for economic threshold;
TD_3 = dummy for natural control; and
TD_4 = dummy for farmers' practice.

5.2.2.2. Net benefit or profit function

Once the yield distribution function is estimated, a net benefit function could be defined by the following standard form:

$$p = pY - wx, \tag{4}$$

where:

p = price of the output,
Y = stochastic yield,
w = vector of input prices, and
x = vector of input use.

Moments of net benefits are directly related to moments of yields because p, w, and x are assumed to be predetermined variables, and Y is the only stochastic component of the equation. In addition, the yield distribution function reflects the stochastic effects of insect damage on production and hence indirectly on yields.

5.2.2.3. Expected utility function

To implement welfare and efficiency analysis, a utility function must be specified over a range of farmer population. If utility depends only on a single attribute, the utility function can be respecified as an expected utility function defined in terms of the moments of the probability distribution of that single attribute.

Following Anderson et al (1980), the basis-of-the-moment method is a Taylor series expansion, with the equation of the expected utility function expressed as follows:

$$E[U(\pi)] = U[E(\pi)] + U_2[E(\pi)]M_2(\pi)/2 + U_3[E(\pi)]M_3(\pi)/6 \qquad (5)$$

where:

U = functional form of the utility function;
U_2, U_3 = the second and third derivatives of the utility functions; and
M_2, M_3 = the second and third moments of the probability distribution functions of the attribute, say profit (π).

Empirically, it could be shown that terms beyond the first three moments of the distribution add insignificantly to the precision of the approximation.

To translate these estimates to expected utility framework, Sillers' (1980) values of partial risk aversion parameters were used. He obtained these values experimentally from rice farmers in Nueva Ecija, the same province as the farmers in this study. The elicitation method consisted of a series of experimental games, in which subjects were confronted with choices among sets of alternative prospects or gambles, involving real money pay-offs. The rounds, at first, involved small amounts of money, and the pay-off scale increased in later rounds. In the final round, the subjects faced potential pay-offs comparable to returns on major agricultural investments and annual incomes for most farm households in the area at that time.

Parallel experimental games were conducted in two villages with similar socio-economic characteristics. One set involved only gains to the subjects; the other involved both gains and losses. The games were designed with different odds for winning or losing to test the importance of probability preferences. Sillers' results showed that the higher the pay-offs, the more risk averse the farmer becomes.

To compute for expected utility of net benefits, it is assumed that the farmer operator's utility function is negative exponential. Following Sillers (1980), this can be expressed as:

$$U(\pi) = (1-S)\ \pi^{(1-S)} \qquad (6)$$

where:

$U(\pi)$ = utility of net benefits, and
S = risk aversion parameter.

The expected utility function can then be expressed as:

$$EU(\pi) = \left[(1-S)E(\pi)^{(1-S}\right] + \left[(1-S)^2\pi^{-S}\frac{V(\pi)}{2}\right] - \left[S(1-S)^2\pi^{-(1+S)}\frac{M_3(\pi)}{6}\right] \qquad (7)$$

where:

$EU(\pi)$ = expected utility of net benefits,
$E(\pi)$ = mean of net benefits,
$V(\pi)$ = variance of net benefits, and
$M_3(\pi)$ = third moment of net benefits.

The third fragment of the equation (that is, containing M_3) was not included in the computations because the values derived from it were negligible.

Certainty equivalents CE were computed as follows:

$$CE = \left[\frac{EU(\pi)}{1 - S}\right]^{1/(1 - S)} \tag{8}$$

where:

CE is the amount exchanged with certainty that makes the decision-maker indifferent between this exchange and some particular risky prospect.

5.2.3 The data set and methods of collection

To be able to rank stochastic pest management technologies, data collected by the IRRI Entomology Department from the ongoing experiments on farmers' fields were used. These experiments aimed to develop chemical control technology based on economic thresholds for rice insect pests. The project started in the wet season of 1984 and was conducted in four irrigated lowland sites in the Philippines. This study used the data set generated from the Guimba, Nueva Ecija, site for 1985-88.

The process leading to the development of need-based use of insecticides includes field trials that quantify yield losses to insects, determine key pest groups, and test action threshold levels. These results are compared with doing nothing (no treatment or natural control), complete protection method, and farmers' current practice. The agronomic practices for the trials are those of the farmer; pest control varies for the different treatments.

The research treatments in the field trials take up 1,000 square meters, and farmers perform insect control practices on adjacent fields of 500-1000 square meters. Variety, tillage, planting method, fertilizer, water, and weed control are equal in both researcher and farmer practice fields. Hence, only insecticide use differs. The study site, Guimba, Nueva Ecija, is located in the Central Luzon region where most of the irrigated environment is found. Post-typhoon flooding of these undulating lands depletes zinc and therefore makes them low in rice yield. Land classification in the site is known as “turod” where fields are slightly elevated and soils are lighter textured and easily drained: and “lungog” where fields are lower, soils are heavier textured, and water accumulates earlier in the wet season and longer in the dry season. The wet season lasts only four months (June-September); the dry season extends up to six months (November-April). Natural rainfall is supplemented by water from electric pumps.

Four treatments are considered in this analysis as mentioned: complete protection; economic threshold; natural control or untreated plot, and farmers' practice.

Complete protection requires an average of nine sprays; three each for the vegetative, reproductive, and ripening stages of crop growth; and sometimes two sprays during seedbed. Economic thresholds would require treatment only when the preset threshold level has been reached. This preset threshold varies from season to season and from year to year.

Natural control or untreated field serves as a check. Farmers' practice is whatever methods local farmers use, ranging from no insecticide control to three or four insecticide sprays. Table 5.1 shows the frequency of spraying per treatment during the study period.

Table 5.2 shows the mean input usage per treatment as well as input cost and rice price. Nitrogen use is the same for all treatments and refers to farmers' current practice. Hence, an average of 68.50 kg of nitrogen was used per hectare in the wet season and about twice as much, 127.50 kg/ha, in the dry season. The insecticide dose was computed as the ratio of total active ingredients (ai) used to recommended ai. This allowed values to be standardized to recommended dosage. For complete protection, the insecticide dose is 15.43 kg in the wet season and 17.47 kg in the dry season. The ET treatment had one dose for wet season and 1.93 doses in the dry season. Eighty-four percent of the plots in the wet season and 52% in the dry season were not sprayed because the threshold level was not reached. Monitoring time in the ET plots was estimated at 60 hours per season. Farmers' practice used an insecticide dose of 0.96 kg in the wet season and 1.11 kg in the dry season.

The cost of nitrogen varied during wet and dry seasons, but the cost per insecticide dose was constant in both seasons. Monitoring time has a low wage of ₱15.00 per hour and a high wage of ₱22.50 per hour and were constant in both seasons. The farm price of paddy used in the analysis was the actual price in 1988, ₱3,500 per metric ton. However, both input and output markets for rice in the Philippines are regulated. Floor and ceiling prices exist in the output market; government price usually uses subsidies in the input market, more significantly in the fertilizer market.

5.3 Analysis of findings

5.3.1 Regression results

Tables 5.3 and 5.4 present the regression results for models 1 and 2. Using the Just-Pope model, Table 5.3 gives the estimates of the regression equations for the first and second moments of the yield distribution. The first moment function shows significant estimates for all independent variables. Hence, both fertilizer and insecticide use have

Table 5.1. Frequency of insecticide application, by treatment and season, Guimba, Nueva Ecija, Philippines, 1985-88 (IRRI 1988).

Frequency	Farmers reporting (no.)					
	Wet season (1985-87)			Dry season (1986-88)		
	Complete protection	Economic threshold	Farmers' practice	Complete protection	Economic threshold	Farmers' practice
0	0	27	4	0	21	0
1	0	5	3	0	1	5
2	0	0	8	0	18	10
3	0	0	1	0	0	3
4	0	0	0	0	0	1
5	0	0	0	0	0	1
a	12	0	0	6	0	0
9	4	0	0	8	0	0
10	0	0	0	6	0	0
Total	16	32	16	20	40	20

Table 5.2. Mean input usage, by treatment, input costs, and palay price[a], Guimba, Nueva Ecija, Philippines.

	Wet season	Dry season
Input use		
Complete protection		
Nitrogen	68.50	127.50
Insecticide dose (no./ha per season)	15.43	17.47
Economic threshold		
Nitrogen (kg)	68.50	127.50
Insecticide dose (no./ha per season)	1.00	1.93
Monitoring time[b] (h/ha)	60	60
Natural control		
Nitrogen (kg)	68.50	127.50
Insecticide dose (no./ha per season)	0.00	0.00
Farmers' practice		
Nitrogen (kg)	68.50	127.50
Insecticide dose (no./ha per season)	0.96	1.11
Input costs		
Nitrogen (P/kg)	5.80-9.48	7.07-11.19
Insecticide dose (P/dose)	234.0-401.00	234.0-401.00
Monitoring cost (P/h)[b]	15.00-22.50	15.00-22.50
Output price		
Palay price (P/t)	3500	3500

[a] Input costs and palay price refer to 1988 dry season figures. [b] Cost of monitoring is assumed to be P15.00 = P22.00/h for 60 ha (Smith et al 1988).

Table 5.3. Estimated yield distribution functions, in logarithms and using Just-Pope model, Guimba, Nueva Ecija, Philippines, 1985-88.[a]

Parameter	Moments	
	1st	2nd
Constant	1.02[b]	4.01
	(6.32)	(4.29)
Log nitrogen	0.096	0.009
	(2.38)	(1.24)
Insecticide dosage	0.007[b]	4.002[c]
	(2.72)	(-1.85)
Season dummy	-0.087[c]	0.042[b]
	(-1.76)	(2.46)
F-value	4.39[b]	31.15[b]

[a] Figures in parentheses are t-values. [b] Significant at 1% level. [c] Significant at 5% level.

a positive effect on production, and fertilizer contributes more than insecticide use in terms of marginal productivity. The season dummy coefficient is negative and does not follow the usual pattern that higher yields are attained in the dry season. It was observed, however, that the lower yields in dry season during these experiments were caused by irregular and late delivery of irrigation water to some plots.

The second moment equation shows a positive coefficient value for nitrogen, which implies increasing risk as this input increases. This supports findings of most studies on risk due to nitrogen use (Roumasset 1979, de Janvry 1972). On the other

Table 5.4. Estimated yield distribution functions, in logarithms with treatments as intercept shiftors, Guimba, Nueva Ecija, Philippines 1985-88.[a]

Parameter	Moments	
	1st	2nd
Log nitrogen	0.09[b]	0.006
	(2.73)	(0.62)
Season dummy	-0.08	0.028[c]
	(-1.84)	(2.30)
Dummies for		
Complete protection	1.16[b]	-0.016
	(7.99)	(-0.39)
Economic threshold	1.02[b]	0.014
	(7.17)	(0.34)
Natural control	0.99[b]	0.010
	(6.86)	(0.23)
Farmers' practice	1.02[b]	-0.003
	(7.09)	(-0.08)
R2	0.98	0.40

[a] Figures in parentheses are t-values. [b] Significant at 1% level. [c] Significant at 5% level.

hand, insecticide use is found to be risk-reducing with coefficient equal to −0.002. Again, this result supports the hypothesis, although few studies have shown this (Antle 1988). The season dummy coefficient in the second moment equation is positive and highly significant. This result is again as expected.

Table 5.4 shows results of the log-linear function (model 2) where pest control treatments were specified as dummy variables. Comparing estimated coefficients of this model to the Just-Pope model shows that:

1. the value of the coefficient of nitrogen is identical at 0.09;
2. the value of the coefficient of the season dummy is likewise identical at −0.087; and
3. the value of the intercept in the Just-Pope model is equal to the values of intercept of the ET treatment and that of farmers' practice. These results imply that farmers' practice approximates the ET treatment to a significant degree.

The coefficient of the dummy for natural control is a little lower than ET. The complete protection coefficient is the highest among the four treatments. The second moment function has significant coefficient only in the season dummy variable. Coefficients of treatment dummies are all insignificant, with negative values only for complete protection and farmers' practice.

5.3.2 Analysis of yield estimates

The estimates of mean yield from the two regression equations and from the raw data set itself (model 3) show that, in terms of physical quantity, the four treatments do not give significantly different values for wet and dry seasons. The values of yield range from 3.94 tons per hectare for natural control to 4.71 tons per hectare in complete protection for the wet season; and 3.84 tons per hectare for natural control to 4.81 tons per hectare in complete protection for the dry season. The yields in complete protection consistently has the highest values, and natural control consistently has the lowest.

Table 5.5. Estimated mean of expected benefits of treatments [a], by season, Guimba, Nueva Ecija, Philippines, 1985-88 (P/ha).

Treatment	Estimates of expected net benefits (₱/ha)		
	Model I [b]	Model II [c]	Model III [d]
Wet season			
Complete protection	11,532	12,337	12,477
Economic threshold	12.469	12,679	12,819
Natural control	13,498	13.393	13,708
Farmers' practice	13,497	13,637	13,917
Dry season			
Complete protection	11,846	10,936	11,931
Economic threshold	12,797	11,607	12,377
Natural control	14,009	12,539	13,169
Farmers' practice	13,847	12,692	13,252

[a] Total gross return minus fertilizer and chemical costs. [b] Just and Pope. [c] Treatments as intercept shiftors. [d] Raw data means.

However, the difference between the estimates is less than 1 ton. Farmers' practice and ETs almost always have the same values for both wet and dry seasons.

On the other hand, estimates of yield variances show distinct differences in variance or levels of risk attached to each treatment. This variation is especially distinct in dry season. Thus, wet season variances will range from 0.48 ton per hectare in complete protection to 0.6 ton per hectare in farmers' practice. Dry season variances would range from 0.79 ton per hectare in complete protection to 1.36 tons per hectare in ET treatment. These values suggest that complete protection gives the minimum risk to farmers, while ET and natural control give a higher risk of more than a ton per hectare in the dry season. Although risk is low in complete protection treatment, this treatment may not be attractive to farmers (Herdt 1979) because the investment cost is too high. The same conclusion will be attributed to this study as well.

Complete protection requires almost double the ET and a significantly greater investment than the natural control treatment. Current farmers' practice costs less than ET but slightly more than natural control. This implies that farmers use pesticides not as a measure against risk but as a response to their perception of pest attack. ET may not be attractive if local monitoring costs are high, especially if farmers have off-farm jobs or local wage rates are high.

5.3.3 Analysis of net benefits and certainty equivalents

On the whole, farmers' practice and natural control are more economical treatments than complete protection and ET (Table 5.5). From the profitability perspective, farmers' current pest control practices would give higher net benefits than the recommended ETs. This observation is true in both wet and dry seasons, which implies that higher farmers' thresholds are more profitable. Hence, recommended threshold levels should be reinvestigated. They may have to be location-specific and consider several pests simultaneously. The estimated variance of net benefits (Table 5.6) supports the lower risk inherent in complete protection than in the other three treatments.

Table 5.6. Estimated variance of net benefits of treatments, [a] by season, Guimba, Nueva Ecija, Philippines, 1985-88 (P/ha).

Treatment	Estimates of variance (P/ha)		
	Model I[b]	Model II[c]	Model III[d]
Wet season			
Complete protection	2744	2793	938
Economic threshold	3542	3591	1736
Natural control	3605	3605	1925
Farmers' practice	3494	3511	2006
Dry season			
Complete protection	2726	2726	1997
Economic threshold	3392	3532	4547
Natural control	3605	3885	3710
Farmers' practice	3448	3553	2993

[a] Total gross return minus fertilizer and chemical costs. [b] Just and Pope. Treatments as intercept shiftors: [d] Raw data means.

Table 5.7. Certainty equivalents' of net benefits of treatments (P), by season, Guimba, Nueva Ecija, Philippines 1985-88. [b]

Treatment	Certainty equivalents					
	Model I		Model II		Model III	
	S_1=1.37[c]	S_2=0.72	S_1=1.37	S_2=0.72	S_1=1.37	S_2=0.72
Wet season						
Complete protection	13,024	12,964	13,849	13,791	12,958	12,952
Economic threshold	14,427	14,332	14,664	14,568	13,728	13,708
Natural control	15.479	15,389	15,376	15,284	14,719	14,695
Farmers' practice	15.411	15,327	15,560	15,476	14,972	14,946
Dry season						
Complete protection	13,324	13,266	12,449	12,384	12,453	12,422
Economic threshold	14,660	14,575	13,575	13,472	14,970	14,805
Natural control	15,983	15,897	14,708	14,592	15,219	15,120
Farmers' practice	15,729	15,650	14,654	14,560	14,872	14,810

[a] Certainty equivalent is the amount exchanged with certainty that makes the decisionmaker indifferent to this exchange and some particular risky prospect. [b] Model I =Just and Pope: Model II =treatments as intercept shiftors; Model III = estimated from raw data. [c] S_1 = more risk averse; S_2 = less risk averse.

The expected utility and certainty equivalents of net benefits for the different treatments are computed using the risk parameter values of 1.37 for more risk averse and 0.72 for less risk averse (Table 5.7). In absolute terms, technologies could be ranked by their expected utility and hence, the certainty equivalents. The results suggest that in the wet season, farmers' practice is preferable to the other three treatments, complete protection being the least desirable. During the dry season, however, natural control would be preferred to the other treatments. The estimated certainty equivalents in Table 5.7 are a little higher than the expected net benefits. These results suggest that farmers are willing to take on risk in pest control. This is because they cannot predict pest population dynamics, and their yield losses over time are likewise unpredictable. If farmers have the resources to minimize this perceived risk, they would be willing to spend less on pest control.

5.3.4 Sensitivity analysis

To quantify the impact of policy changes or price fluctuations on the estimates of net benefits and certainty equivalents, a sensitivity analysis was conducted.

Sensitivity of the estimated expected net benefits and certainty equivalents were investigated for changes in the price of insecticide (P_I) and monitoring cost (P_M); the price of rice (P_Y); and a simultaneous input and output price changes. The low and high prices of insecticides are based on actual figures in Guimba, Nueva Ecija. Monitoring cost is assumed to take on values of zero (no cost), a low price of ₱900 per season: and a high price of ₱1,350 per season (Smith et al 1989). The P_Y was assigned the following values, expressed in pesos per metric ton: a low price of ₱3,500, the actual price in 1988 in the study area; a medium price of ₱5,000, the price of rice in early 1990; and a high price of ₱6,000, the farm gate price during the second half of 1990.

Table 5.8 presents the results of sensitivity analysis of net benefits in response to changes in input and output prices.

5.3.4.1. Input price change

With input price changes, farmers' practice and natural control still dominate the other two treatments in terms of net benefit values. Removing insecticide subsidies would imply increased insecticide costs to farmers and further decreases the net benefits of complete protection by ₱3,000 in both wet and dry seasons. Subsidizing monitoring costs of ET treatment would make its net benefits almost equal to natural control. A high insecticide price and high monitoring cost would likewise make ET less attractive than natural control and farmers' practice. Farmers' practice is most attractive with low

Table 5.8. Sensitivity analysis[a] of expected net benefits due to changes in input and output prices, by treatment, wet season.

Changes due to	Expected net benefits			
	Complete protection	Economic threshold	Natural control	Farmers' practice
Input price				
Low P_1 and low P_M[b]	11,812	12,749	13,813	14,057
Low P_1 and no P_M	11,812	13,649	13,813	14,057
Low P_1 and high P_M	11,812	12,299	13,813	14,057
High P_1 and low P_M	9,236	12,582	13,813	13,957
High P_1 and no P_M	9,236	13,482	13,813	13,957
High P_1 and high P_M	9,236	12,132	13,813	13,957
Output price				
Low P_Y[b]	11,812	12.749	13,813	14,057
Medium P_Y	18,592	18,869	19,903	20,312
High P_Y	23,112	22,949	23,963	24,482

[a] P_1 = Insecticide price. P_M = monitoring costs, and P_Y = palay price with the following values (in P), low P_1 = 234. high P_1 = 401. no P_M = 0, low P_M = 0. low P_M = 900, high P_M= 1350. low P_Y = 3500, medium P_Y = 5000. and high P_Y = 6000. [b] First entries are benchmark figures, estimated with Model I computed as the means

Table 5.9. Sensitivity analysis [a] of certainty equivalents due to changes in input and output prices, by treatment, wet season.

Changes due to	Certainty equivalents			
	Complete protection	Economic threshold	Natural control	Farmers' practice
Input price				
Low P_I and low P_M [b]	13,250	14,614	15,698	15,893
Low P_I and no P_M	13,250	15,508	15,698	15,893
Low P_I and high P_M	13,250	14,167	15,698	15,893
High P_I and low P_M	10,399	14,429	15,698	15,757
High P_I and no P_M	10,399	15,488	15,698	15,757
High P_I and high P_M	10,399	13,982	15.698	15,757
Output price				
Low P_Y [b]	13,250	14,614	15.698	15,893
Medium P_Y	20,810	21,540	22.595	22,955
High P_Y	25,850	26,158	27.192	27,664

[a] See Table 5.8 for entry definitions. [b] All first entries are benchmark figures, estimated with Model I computed at the means and S = 0.72.

insecticide prices but would have almost equal net benefit.; with natural control in a high insecticide price regime.

5.3.4.2. *Output price change*

The sensitivity of expected net benefits to output prices shows significant changes in absolute values. Hence, liberalizing the rice economy, which could mean an increase in rice prices, would imply higher net returns in all treatments. The variance of' net returns among treatments would be less significant than those when insecticide prices change. Thus, in the medium P_y regime, the difference in not returns between complete protection and ET is roughly ₱300; between natural control and ET about ₱1,034; and between farmers' practice and natural control about ₱409. The gap between farmers' practice (highest net benefit) and complete protection (lowest net benefits) is about ₱1,720 in the wet season. Under high palay price, high insecticide price, and no monitoring cost regime, ET and natural control have almost the same net benefits; but net benefits due to farmers' practice is still higher by about ₱400. Under the medium rice price, high insecticide price, and no monitoring costs, ET also approximates natural control, but farmers' practice still wins.

The same could be concluded by analyzing certainty equivalent for sensitivity to output price and input price changes (Table 5.9). Even with free monitoring cost to farmers, farmers' practice and natural control would still yield higher net benefits. A high pesticide price would decrease profits for complete protection and ET and would make natural control even more attractive. However, a high output price and a low insecticide price would make complete protection more competitive, especially for risk-averse farmers. Lower risk is attained in the complete protection treatments.

Chapter 6

Pesticide exposure, farmers' health, and choice of pest control technologies

Prolonged exposure to pesticides could lead to cardiopulmonary disorders; neurological and hematological symptoms, and skin disease (Davies et al 1982, Smith et al 1988, Pingali et al 1997). Any of these symptoms could lower productivity due to a farmer's absence from work during treatment and recuperation and impaired capacity to do a full load of work, or both. Farmers who do not know about the harmful effects of pesticides sometimes overvalue their benefits and use more than is good for them or their communities.

This chapter illustrates how exposure to pesticides affects net benefit estimates of the different pest control technologies described in Chapter 5. A health cost function is estimated using the medical and socioeconomic data from a set of rice farmers in Nueva Ecija where experimental data on the different pest control treatments were generated. The health cost estimates are then deducted from net benefit estimates of the treatments in Chapter 5. The expected utility of benefits is likewise recomputed incorporating health costs. Finally, the recomputed certainty equivalents, based on the expected utility figures, are presented and compared with estimates in Chapter 5.

6.1 Health problems and long-term exposure to pesticides

Chronic health effects in almost every part of the body are associated with prolonged pesticide exposure (Pingali et al 1997). (See Table 6.1 for detailed references to the medical literature.)

6.1.1 Eye effects

The eye is very vulnerable to physical and chemical hazards in the agricultural setting. Some pesticides like 2,4-D and acetamides are known eye irritants (Morgan 1977). Nueva Ecija farmers have been using acetamides and 2,4-D for at least five years. A chronically, irritated eye can lead to the formation of a pterygium, a vascular membrane over the cornea, usually affecting older people and people exposed to dust and wind. With increasing severity, the vascular membrane may encroach on the pupil, diminishing visual acuity and requiring surgical removal to improve eyesight. Pterygium can therefore reduce farmers' productivity, initially because of bothersome symptoms, and later because of diminished vision.

Table 6.1. Hypothesized health effects of chronic exposure to pesticides.

System	Effects	Critical signs and symptoms/laboratory findings	Source
Eye	Pterygium	Vascular membrane on eye, decreased visual acuity	
Skin	Eczema	Lichenification and fissuring	Morgan (1982) WHO (1982)
	Nail destruction		FPA findings
Respiratory (pulmonary tract)	Bronchial asthma	Wheezing cough, bronchospasm dyspnea	Hock (1987) Morgan (1982) Nemery (1987)
Cardiovascular	Electrocardiograph (EKG) changes, high blood pressure		Morgan (1982)
Gastrointestinal tract	Chronic gastritis	Epigastric pain, nausea, vomiting	WHO (1982)
Kidneys	Asymptomatic urinary abnormalities	Albuminuria, hematuria, elevated blood urea nitrogen (BUN), creatinine	WHO (1982) Hock (1987)

6.1.2 Skin effects

Pesticides enter the body mainly through the skin, not the respiratory tract, contrary to common belief. Mixing and transferring concentrates, not applying the pesticides, poses the greater health hazard to farm workers. For spray operators, dermal exposure levels were higher than those recorded by inhalation. The degree of contamination is proportional to the concentration of the chemical and proximity to the source of emission (Dennis 1982). Spraying or dusting on pesticides deposits on exposed skin 20-1700 times the amount reaching the respiratory tract. The quantity varies with working conditions, application techniques, protective equipment, and duration of exposure (Bainova 1982).

Dermal contamination is greater when spraying with a knapsack sprayer than with a spinning disc applicator or an electrodyne sprayer (Durand et al 1984). The hands and forearms have the highest potential for pesticide contamination (Castaneda et al 1990, Zweig et al 1985).

Among the pesticides used by the rice farmers, 2.3-D, organochlorines, and acetamides are considered mild to moderate skin irritants and potential sensitizers (Morgan 1977). Eczema, a chronic allergic dermatitis characterized by lichenification and fissuring, is a dermatologic health indicator of pesticide exposure. The skin appears thickened with accentuated markings. Other health indicators are the destruction of the distal portions of the toe nails, giving it an “eaten-up” appearance.

6.1.3 Respiratory tract effects

Some pesticides such as pyrethrum and 2,4-D severely irritate the lungs and upper respiratory tract (Pingali et al 1992). Long-term exposure to chemical irritants like pesticides can cause respiratory symptoms such as cough, cold, sputum formation, wheezing, rales, tenderness, and decreased chest expansion. Incipient lung disorders can be detected by a thorough physical examination and adequate medical history. Bronchial asthma and other abnormal lung findings are the two respiratory tract indicators of pesticide exposure.

6.1.4 Cardiovascular effects

In acute pesticide poisoning, the heart may be damaged either by direct action on the myocardium or as a result of low tissue oxygenation. Hardening of blood vessels causes blood pressure elevation. High blood pressure was noted among pesticide handlers in a health survey conducted in seven formulating plants in the Philippines (Maramba, UPCM. pers. commun.). Hence, one health indicator is elevated blood pressure.

Organophosphates and 2,4-D have been implicated as causes of myocardial injury or injury to the conducting system, as reflected in electrocardiogram (EKG) changes (Morgan 1977).

6.1.5 Gastrointestinal tract effects

Pesticides usually enter the gastrointestinal tract accidentally through the mouth. For example, a farmer applying pesticides who smokes or wipes sweat off near his mouth may unknowingly ingest pesticide particles. Carbamate insecticides formulated in methyl alcohol and ingested may cause severe gastroenteritic irritation (Morgan 1977). Given in large doses to experimental animals, 2.4-D and organochlorines are moderately irritating to the gastrointestinal lining, causing vomiting, diarrhea, and mouth ulcers (Morgan 1977). Organophosphates and copper salts also irritate the gastrointestinal tract, manifesting as intense nausea, vomiting, and diarrhea. The health indicator chronic gastritis is clinically characterized by epigastric tenderness and pain associated with nausea and vomiting.

6.1.6 Neurological effects

Organophosphorus compounds and 2,4-D are known neurotoxicants (Morgan 1977). Both have been implicated as causative agents for polyneuropathy, a neurologic disorder that manifests typically as motor weakness in the distal muscles and sensory deficit with a “glove-and-stocking” distribution (Braunwald 1987). Absence of deep tendon reflexes in the early stages may be the only sign, but neuropathy may be purely motor or purely sensory.

Diabetes is highly prevalent in the Philippines and must be considered in the differential diagnosis of polyneuropathy. Isolated hyporeflexia, another neurologic index, is a known sensitive indicator of chronic exposure to organophosphorous pesticides (WHO 1990).

6.1.7 Hematologic effects

A Philippine study of 371 workers, including 100 farmers, showed that 38% of the farmers had anemia and 41% of the applicators had a high platelet count (Maramba et al 1957). Insecticides accounted for 21 out of 70 cases of aplastic anemia admitted to the Hematology Section of the Philippine General Hospital. Twelve of the 21 were farmers (Giongco-Baylon et al 1982). Aplastic anemia is manifested as a pancytopenia depression of all formed elements of the blood. Lymphocytosis, eosinopenia, neutropenia, and hypochromic anemia have also been reported (WHO 1986). Chlordane, an organochlorine, has apparently induced a few cases of megaloblastic anemia after protracted low level exposure; recovery followed termination of exposure (Morgan 1977).

6.2 Evidences of health impairments among rice farmers due to pesticide exposure

Pingali et al (1992) compared the health status of farmers exposed to pesticides and those who had not been exposed to these agrochemicals. Table 6.2 shows the health impairments per organ system among the Quezon farmers, the nonexposed group, and Nueva Ecija farmers, the exposed group. Investigating the health status differences given by the health indicators enumerated above would show evidence of eye, skin, lung, cardiovascular, and neurological diseases.

6.2.1 Eye effects

Because the farmers in the Quezon group were older, more cases of pterygium (perhaps unrelated to pesticides) were expected than in Nueva Ecija. Contrary to expectations, however, more statistically significant cases were found in Nueva Ecija (66.67%) than in Quezon (10.55%).

Table 6.2. Prevalence of health impairments (by organ system) among farmers of Quezon and Nueva Ecija, Philippines (Pingali et al 1992).

Effect parameter[a] (health indicator)	Quezon, control group (39 farmers)		Nueva Ecija, exposed group (57 farmers)	
	no.	%	no.	%
Eye (pterygium)	4	10.25a	38	66.67 b
Dermatologic system (nail pitting, eczema)	0	0.00a	26	45.61 b
Respiratory system	9	23.07a	26	45.61 b
Cardiovascular system (elevated BGP, EKG)	18	46.20a	2	49.12 b
Gastrointestinal tract (chronic gastritis)	0	0.00a	5	8.77 b
Kidney (albuminuria, hematuria, elevation of creatinine)	6	15.00	15	26.32 b
Neurologic system (polyneuropathy, isolated hypo/hyper/areflexia)	10	25.64a	20	35.09 a
Hematologic system (low hemoglobin, thrombocytopenia, lymphocytosis)	29	74.35a	51	89.47 b
Cholinesterase baseline	0	0.00a	0	0.00 a

[a] For each effect parameter, percentages with the same letter are not statistically significant at P = .05 using chi-square or Fischers' exact test.

Pesticide-related pterygium, though not specifically recounted in available literature, can come about from pesticide irritation of the conjunctivae. For at least five years, the farmers in Nueva Ecija have used phenoxy herbicides and acetamides, both known to be moderately irritating to the eye. Nueva Ecija farmers have applied both 2.4-D and acetamides at a high frequency and active ingredient concentration.

6.2.2 Skin effects

Almost half (45.61%) the farmers from Nueva Ecija showed dermal impairments compared to none from Quezon. One third (36.84%) of Nueva Ecija farmers, but none from Quezon, exhibited nail destruction. This may be due to the use of organotins as molluscicide. Snails pose a major threat in Nueva Ecija. Organotins have in fact been banned in the Philippines, and replaced by endosulfan, a substitute molluscicide. Eventually, endosulfan was prohibited for use in golden snails as it is not registered for such use.

6.2.3 Respiratory tract effects

No significant number of farmers (7.02%) in Nueva Ecija had bronchial asthma compared to none in Quezon (Pingali et al 1992). Other abnormal respiratory findings were significantly more prevalent in Nueva Ecija (40.35%) than in Quezon (23.08%).

6.2.4 Cardiovascular effects

There was no significant difference in the results of the EKGs among the farmers at the two sites (Table 6.2.) Stratifying results to account for differences in age and drinking gives a totally different picture. These two influencing factors known to adversely affect cardiovascular outcomes are unequally distributed in the study group, and they can be confounders.

To unmask confounding, stratification for drinking and age was done. When age was held constant, nobody under 40 years of age in Quezon had abnormal EKG findings, but 38.89% in Nueva Ecija did. Normally, EKG changes would be more prevalent among people over 40. Holding drinking constant, 11 % in Nueva Ecija had functional EKG impairments but none in Quezon. Further stratifying by sex, all but two cases of cardiac abnormalities were males. Because young males generally apply the pesticides, they face an abnormally higher risk of cardiac problems than older males. No significant difference in blood pressure elevation between the two groups was reported.

6.2.5 Neurological effects

No one in Queson had polyneuropathy; 10.53 percent in Nueva Ecija did. There was a significant difference between the results of Quezon and Nueva Ecija. Taking drinking into account, 7.69% of farmers from Nueva Ecija had polyneuropathy; none from Quezon.

Forty percent of the control group had one pesticide-related impairment; 32% of Nueva Ecija farmers had four impairments (Table 6.3). The maximum number of health impairments in the Quezon group was four: in the Nueva Ecija group, seven. Farmers and agricultural workers thus face chronic health effects from prolonged exposure to pesticides. Eye, skin, nail, pulmonary, neurological, and renal problems are significantly associated with long-term pesticide exposure.

Making farmers and other pesticide users aware of the importance of safe use could significantly reduce overall health costs for farm households. An attempt is made in the following section to estimate farmers' health costs from chemical-related impairments.

6.3 Reestimating expected utility function incorporating health costs due to pesticide exposure

6.3.1 Theoretical framework

Incorporating health costs into the expected utility function would entail a shift of this function to the left. Hence, the objective function in Chapter 5 can be rewritten as:

$$EU(p) = EU(py - wx - HC) = u(x. a, w, s),$$

where:

U = U(p ,s), the decision maker's utility function;
p,s = is profit or net benefit and s is the parameter vector defining the utility function;
p = output price, assumed to be predetermined and constant across experimental treatments;
y = output, a random variable, whose distribution is conditionally defined on the input vector x;
x = input vector to be chosen;
w = a vector of input prices, usually predetermined;
a = a vector of parameters which with x define the probability distribution of y; and
HC = health cost as a result of illness due to pesticide exposure.

HC estimation is described below. The values of HC are used to recompute for the values of net benefits and certainty equivalents by treatment and by season (Chapter 5).

Table 6.3. Frequency of farmers with multiple health impairments among farmers of Quezon and Nueva Ecija, Philippines (Pingali et al 1992).

Health impairments (no.)	Quezon		Nueva Ecija	
	no.	%	no.	%
0	3	5.3	0	0.00
1	23	40.4	3	5.26
2	19	33.3	7	12.28
3	10	17.5	16	28.07
4	2	3.5	18	31.58
5	0	0	8	14.04
6	0	0	3	5.26
7	0	0	2	3.51

6.3.2 The health cost model and estimation procedure

Health costs from pesticide use would be associated with total pesticide use; pesticide exposure (the number of times the farmer comes into contact with pesticides); pesticide hazard category (category I and II pesticides which include most organophosphates and organochlorines have a greater health effect than category III or IV pesticides); and "other" farmer characteristics (weight over height, age, smoking, and alcohol consumption).

The log-linear equation in the following form was used in the estimation:

$$\text{In HC} = f(\text{LAGE, WTHT, DS, DD, LOG TOT DOSE,} \\ \text{L DOSEI, LDOSEH}).$$

where:

In HC = log of health costs, in pesos;
LAGE = log of farmers' age;
WTHT = farmers' weight by height;
DS = dummy for smoking (0 for nondrinkers and 1 for drinkers);
DD = dummy for drinking alcohol (0 for nondrinkers and 1 for drinkers);
LOG TOT DOSE = log of total dosage of pesticides used including insecticides, herbicides, and other pesticides (ai/ha);
LDOSEI = log of insecticide dosage used (ai/ha); and
LDOSEH = log of herbicides dosage used (ai/ha).

Pesticide category was not included in the equation since most insecticides used are in category I or II: most herbicides. in categories III and IV. Pesticide exposure is also reflected in the pesticide dose variables. Total dosage, insecticide dosage, and herbicide dosage were standardized by using the strength of formulation (recommended active ingredient) as the weights.

6.3.3 Data set and method of collection

The data used in estimating the health cost function were taken from a farmer survey by the International Rice Research Institute (IRRI) Social Sciences Division in the 1991 dry season. In particular, two sets of information were available from the 42 farmer respondents in Nueva Ecija: a detailed physical and laboratory examination of each farmer, including a documented personal history of health and habits like drinking and smoking; and technology use practices with special emphasis on pest management practices, including safe handling (Pingali et al 1992).

Total health cost computations were based on the medical tests conducted. These tests provided an assessment of each farmer respondent's ailments and their seriousness. Such ailments may or may not be related to pesticide exposure. The treatment required to restore the farmer's health was assessed. Treatment costs (including medication and physicians' fees) plus the opportunity cost of farmers' time lost in recuperation formed a measure of the health cost per farmer.

The medical assessment was done by a medical team of a physician, a nurse, an X-ray technician, and a medical technologist. The nurse interviewed the farmers about their personal, family, and occupational histories, and their drinking and smoking habits. The doctor performed a complete physical examination on every farmer. Cholinesterase determination was done by the medical technologist; chest X-rays and electrocardiograms were handled by the X-ray technician.

Other survey data were gathered by researchers from the IRRI Social Sciences Division. The actual pesticide use data were converted into dosage by dividing total active ingredients by the recommended active ingredient per hectare.

6.3.4 Analysis of results

6.3.4.1. Health cost function

According to regression equation estimates, insecticide dose significantly influences farmer health costs (Table 6.4). Herbicide dose has a positive but insignificant coefficient. These results likewise reflect the hazard category effect on health, as most insecticides used by farmer respondents are in catezory, I or II; most herbicides, in category III or IV. Costs increase by 0.74% for every 1% increase in insecticide dose.

Weight by height is not a significant factor in estimating health costs, but age and smoking habits are in the three specifications of the model. The coefficient of the drinking variable, though significant, has a negative sign. Some measurement deficiencies may influence this result; that is, some farmers might have stopped drinking because they already have a disease or ailment. This kind of information would reflect a high health cost in a nondrinker respondent in the data set.

Table 6.4. Estimated health cost distribution for rice farmers of Nueva Ecija, Philippines, 1991 dry season.[a]

Independent variable	Equation 1	Equation 2	Equation 3
Intercept	-0.23 (-0.06)	-2.28 (-0.63)	1.33 (.36)
Log of age	1.97[c] (2.22)	2.35[b] (2.67)	1.82[c] (2.17)
Weight by height	-0.03 (-0.57)	-0.02 (-0.50)	-0.05 (-1.06)
Dummy for			
Smoking	1.15[b] (2.62)	0.97[c] (2.21)	1.10[b] (2.65)
Drinking	-0.80[d] (-1.73)		-0.77[d] (-1.72)
Log of total dose			0.62[c] (2.31)
Log dose of insecticide	0.74[d] (1.75)	0.72[d] (1.65)	
Log dose of herbicide	0.46 (0.47)	0.53 (0.52)	
R^2	0.40	0.35	0.43

[a] Dependent variable is log of health cost; figures in parentheses are t-values. [b] Significant at P = 0.01. [c] Significant at P = 0.05. [d] Significant at P = 0.10.

Table 6.5. Estimated mean health cost for rice farmers of Nueva Ecija, Philippines, 1991. [a]

Treatment	Mean cost (P per insecticide dose)	
	Wet season	Dry season
Complete protection	6735	7450
Economic threshold	647	1188
Natural control	0	0
Farmers' practice	623	720

[a] Based on estimates of Equation (1), Table 6.4 for nonsmoker/nondrinker farmer population: and assuming an average age of 48.69 years, a weight/height ratio of 24.79, and an average herbicide dose of 1.79. See Table 5.2 for mean insecticide dose by treatment.

Equation 1 regression results were used to estimate expected health cost values per treatment in the experiments described in Chapter 5. The mean cost per treatment of insecticides (Table 6.5) is based on estimates for a nonsmoker, nondrinker farmer population. It assumes an average age of 48.69 years, a weigh- height ratio of 24.79. and an average herbicide dose of 1.79. These figures represent expected values of health costs, corresponding to the insecticide dosage per treatment (Table 5.2).

With natural control, health costs due to insecticide exposure would be zero. Using farmers' practice for pest control would increase health costs associated with pesticides by ₱623 in the wet season and by ₱720 in the dry season. On the other hand, ET treatments would result in an incremental increase in health costs of ₱647 in the wet season and P1,188 in the dry season. The high dosage levels in complete protection treatments would also increase health costs by ₱6,735 in the net season anti ₱7,450 in the dry season.

Thus, using more pesticides, especially insecticides, would raise the expected value of health costs. This would shift the net benefit function to the left, as health costs would increase the total cost of production. Once farmers are aware of the costs incurred due to pesticide exposure, the threshold levels that they use as decision rules to spray would increase further.

6.3.4.2. New estimates of net benefits and certainty equivalents of treatments

Accounting for health costs due to pesticides in the net benefit equation, the values in Table 5.5 would decrease in all treatments. The complete protection treatment would have the highest decrease, ₱12,000 to ₱5,000 per hectare (Table 6.6). On average, for all three models, wet season net benefits from complete protection would be only ₱5,380; for ET, ₱12,009; natural control. ₱13,533; and fanners' practice ₱13,061. Dry season results showed that expected net benefits from each treatment would average ₱4,121 for complete protection, a decrease of ₱7,450; ₱11,072 for ET, ₱13,239 for natural control, and ₱12,544 for farmers' practice. These results imply that natural control consistently has the highest net benefits. Complete protection would have net benefits of more than 50% less than the other three treatments.

Recomputed certainty equivalent figures would decrease the same trends as in net benefits (Table 6.7). Natural control would be the best. with certainty equivalent values ranging from ₱14,635 to ₱16,029. Certainty equivalent values for complete protection treatment would be reduced by more than half by taking health costs into account.

Table 6.6. Corrected mean of net benefits of treatments, incorporating health costs for rice farmers of Nueva Ecija, Philippines.[a]

Treatment	Mean of net benefits[b]		
	Model I	Model II	Model III
Wet season			
Complete protection	4797	5602	5742
Economic threshold	11822	12032	12172
Natural control	13498	13393	13708
Farmers' practice	12874	13014	13294
Dry season			
Complete protection	4396	3486	4481
Economic threshold	11609	10419	11189
Natural control	14009	12539	13169
Farmers' practice	13127	11972	12532

[a] Model I = Just and Pope model, Model II = treatments as intercept shiftors, Model III = raw data means, [b] Based on estimates of nonsmoker/nondrinker farmer population and assuming an average age of 48.69 years, a weight-height ratio of 24.79, and an average herbicide dose of 1.79. Models are as defined in Chapter 5.

Table 6.7. Certainty equivalents[a] **of net benefits of treatments incorporating health costs (₱), by season, Nueva Ecija farmers.**[b]

Treatment	Certainty equivalents					
	Model I		Model II		Model III	
	S_1=1.37[c]	S_2=0.72	S_1=1.37	S_2=0.72	S_1=1.37	S_2=0.72
Wet season						
Complete protection	6490	6316	7277	7128	6238	6225
Economic threshold	13830	13725	14066	13961	13118	13095
Natural control	15523	15429	15420	15325	14759	14733
Farmers' practice	14848	14754	14996	14903	14398	14369
Dryseason						
Complete protection	6110	5918	5355	5079	5654	5562
Economic threshold	13500	13405	12422	12304	13831	13643
Natural control	16029	15938	14755	14635	15265	15162
Farmers' practice	15055	14967	13983	13879	14195	14127

[a]Certainty equivalent is the amount exchanged with certainty that makes the decisionmaker indifferent to this exchange and some particular risky prospect. [b]Model I =Just and Pope model, Model II =treatments as intercept shiftors, Model III = estimated from raw data. [c]S_1 = more risk-averse, S_2 = less risk-averse.

Without health costs, certainty equivalent values for complete protection would be about ₱12,742; certainty equivalent values with health costs would only be ₱5,706. Certainty equivalents have higher values than expected net benefits, implying that farmers with cash resources would be willing to invest more than the expected net benefit values in pest control. Again, this is basically due to the unpredictable extent of yield losses when infestation occurs.

In the presence of health costs and if pest pressure is low, natural control would be the most profitable treatment. As insecticide dose increases, health costs increase significantly.

Chapter 7

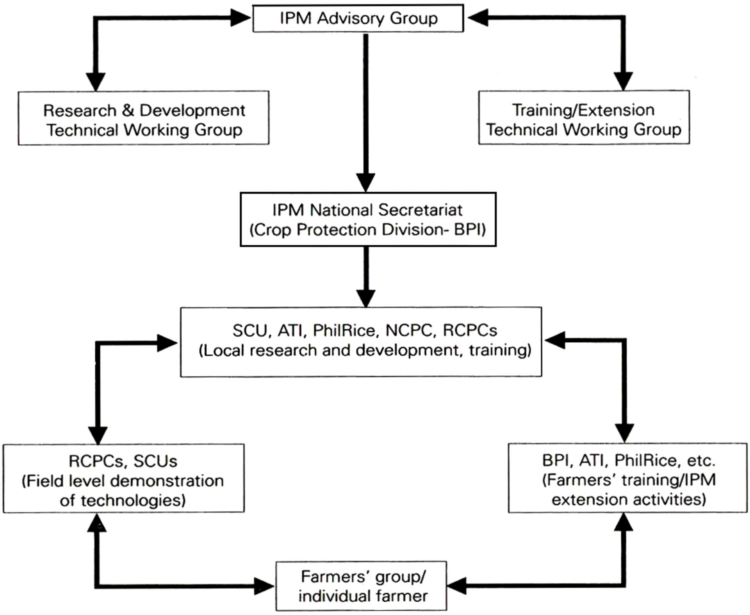
IPM implementation in the Philippines: a policy overview

The social costs of current crop protection technologies, once recognized, made the search for sustainable pest management technologies imperative. In developed countries, the damage done by conventional pest management technologies to the environment has triggered the development of integrated pest management (IPM). In developing countries, the shift from polyculture to the more modern monoculture has opened up the need for chemical control of pests, especially in the rice world. Development of pesticide resistance and the increasing health risks to users may have created initiatives for developing sustainable pest management technologies in developing countries. However, for sustainable technology to be adopted, it will have to fit the management capabilities of farmers.

The institutional and economic structure in the rural sector of developing economies is such that some policy intervention would be needed to reconcile long-term societal objectives and short-term individual objectives in pest control. Farmers are focused on family survival and general well-being and may use practices and resources in a way that is unsustainable from society's perspective. Government seeks self-sufficiency in food, but at a minimal social cost. Its role, therefore, is to provide farmers with appropriate policy incentives to use sustainable practices.

7.1 IPM in rice in the Philippines

IPM activities in rice in the Philippines was initiated by the Food and Agriculture Organization (FAO) in the late 1970s. Backup research by the International Rice Research Institute (IRRI) has been translated into useable thresholds, resistant varieties, surveillance programs, and identification and definition of the role and importance of natural enemies. Although most research has focused on insects, weeds and diseases are also being studied intensively. In recent years, the Philippine Rice Research Institute (PhilRice) has become active in research, extension, and farmer's training in IPM. In 1986, the Philippine government issued a directive to make IPM technology the core of its pest control policy in agriculture. The Department of Agriculture (DA), with the help of the FAO intercountry program in pest control, has pursued this objective.



7.1. Institutional structure of the National Integrated Pest Management (IPM) Program. Philippines. 1991. ATI = Agricultural Training Institute, BPI = Bureau of Plant Industry, PhilRice = Philippine Rice Research Institute, RCPC = Regional Crop Protection Center, NCPC = National Crop Protection Center, SCU = State Colleges and Universities.

In rice farming, IPM is a set of rules for making decisions. They may advise farmers to plant a variety resistant to locally prevalent pests, to flood and plow fields earlier than usual, to join neighbors in community wide rat hilling, or to use a higher seeding rate and fertilize optimally rather than maximally. In the Philippines, most IPM training is devoted to identifying pests and natural enemies, recognizing preset thresholds, and recommending chemical control when pest populations exceed threshold levels. The benefits of resistant varieties and other cultural controls are also discussed but on a minor scale. Indigenous biological control agents could also be utilized. However, little attention has been given to biological control. Quantitative information about the efficacy of biocontrol agents is also lacking.

7.1.1 Institutional structure relating to IPM

Figure 7.1 shows the institutional structure relating to IPM in the Philippines. An IPM Advisory Group (IPM-AG) wascreated in 1986 to provide operational policy guidelines for regional and provincial program implementation. It decides on policy issues affecting the program, facilitates the availability of resources that may be necessary in its implementation, and approves research and development proposals for funding by the program.

The IPM-AG is chaired by the DA Undersecretary tor Regional Operations with the Assistant Secretary for Research, Extension and Training as Co-chairman. Members include representatives from the different government and private organizations including the DA, the Bureau of Plant Industry (BPI), the Agricultural Training Institute (ATI), the Fertilizer and Pesticide Authority (FPA), and PhilRice; the National Crop Protection Center (NCPC), University of the Philippines at Los Baños (UPLB); the Association of Pesticide Industries of the Philippines (APIP); the Society for the Advancement of Vegetable Industries (SAVI); the Hybrid Corn Seed Industry and the Banana Industry (Sumangil et al 1991).

The Advisory Group has ex-officio members from institutions such as the FAO. Integrated Pest Control for Rice Program for South and Southeast Asia: IRRI; and the Philippine-German Biological Plant Protection Project.

Two technical working groups lend support to the advisory group: 1) the research and development committee; and 2) the training and extension committee. Committee members are recruited from government agencies, state colleges and universities, and other sectors that have expertise in pest management.

Aside from NCPC-UPLB, other state colleges and universities in 13 regions and some private universities conduct region-based research programs or studies on their respective crop priorities. The Regional Crop Protection Centers (RCPC) test IPM research and recommendations prior to their use in farmers' fields. Training and extension, one of the most critical parts of IPM, is done by the ATI, PhilRice, BPI, IRRI, NCPC-UPLB, and the RCPCs. The IPM National Secretariat, based at the BPI Crop Protection Division, orchestrates all activities pertaining to IPM program implementation, including research and development and extension and training.

Major deterrents to successful implementation of IPM are lack of trained extension personnel, lack of support for extension services, and lack of training for farmers. Training farmers, extension agents, and others is slow and expensive. Only 189,386 farmers nationwide were trained from 1984 to 1991, according to available statistics With an estimated 3 million rice farmers, this constitutes only 6% of total farmer population (Table 7.1). Other approaches therefore ought to be considered for equipping farmers with pest management technologies. So far, no in-depth studies have been done into the economic as well as social aspects of more efficient methods of tranferring technology (for example, through the mass media).

In addition, research is far ahead of implementation (Shepard and Isa 1987), possibly because of the weak link between researchers on the one hand, and extension agents and farmers on the other hand. Farmer participation in research into IPM technologies would be one way of assuring a package tailored to the needs of farmers and local communities.

Table 7.1 Integrated pest management training accomplishment for rice, Philippines, 1984-91 (Sumangil et al 1991).

Clientele	Number
National trainers	98
Subject matter specialists	1,474
Extension agents	11,260
Farmers	183,386
Total	202,281

7.2 Redesigning IPM programs

This study has shown that natural controls give the greatest economic returns under low pest population levels. A similar economic analysis of data from a nearby town also showed that a do-nothing is the most profitable decision in light pest infestations (Smith et al 1989). On the other hand, IPM technology yielded higher profits from insecticide use in heavy pest infestations. Thus, doing nothing each crop season without monitoring results carries the risk of high economic losses on future crops because pest outbreaks are unpredictable and could occur anytime (Litsinger 1990).

Economic threshold levels that would maximize farmers' expected utility of yields and profits must therefore be recognized. The cornerstone of ET levels is the damage function, which is highly dependent on the presence of crop stresses and yield potential, both site-specific. The damage function is the relationship between pest abundance and yield loss. This relationship becomes more complex with the knowledge that thresholds may change if several pest species damage the crop at the same time and if natural enemy species that feed on the pests are abundant. Current IPM technology is still oriented toward dealing with a single pest; further work needs to be done to produce the knowledge farmers need to manage pests in an integrated manner (Rosegrant and Pingali 1991). The synergy of dealing with several pests simultaneously may mean that ET levels could be set higher. Because crops are often infested by groups of insect pests, thresholds that account for multiple pests are more appropriate gauges for insecticide use as they account for the cumulative damage (Palis et al 1990). The challenge therefore lies in determining a site-specific damage function from multiple pest incidence.

Farmers' insect pest thresholds, guiding their decisionmaking, should also be investigated because they are different from researchers' thresholds. This study showed empirically that farmers' practice may be economically rewarding under local conditions. This brings into focus the farming systems approach, characterized by on-farm testing with farmer participation and adapting technology to local conditions. This approach may be well-suited to generating and verifying IPM technology (Litsinger 1990).

Aside from the damage function, several other variables influence ET levels (Chapter 3). Economic threshold levels are directly related to the cost of control and inversely related to the price of rice and the bioefficacy of the control measures. Incorporating positive health costs into the ET function makes ETs higher than does considering only the impact on the damage function. If the price of rice goes up, ETs would decrease. If control costs go down, ETs would go down as well. If the efficacy of the control measure is high, then ETs would be low. At this point, efficacy just refers to insecticides, because quantitative information about the efficacy of biocontrol agents is generally lacking. Scarcer still are data on the impact of resistant varieties on pest populations, physical and mechanical control measures, and cultural control practices such as synchronous planting and planting time adjustments.

Research and extension/training are the keys to effective IPM programs. Aside from additional research on ETs, some of the Philippines' research and training needs are discussed

7.2.1 Research needs

7.2.1.1 Varietal resistance/durable technology

In genetic research, varietal selection aimed at increasing daily productivity and multiple resistance for pests and diseases (that is, stability of performance) must be as important as increasing yields per se. Over time, once-resistant varieties become moderately resistant or susceptible to other pests or to new pests that evolve in the crop environment. Research then should be geared toward improving hybrid vigor to stand the test of insect pests over a longer period. Moreover, performance of resistant varieties in farmers' fields must be systematically monitored. Currently, mass-produced new varieties pass through the Seed Improvement Program of the Philippines DA. The PhilRice/DA/BPI procures certified seeds from recognized seed growers and distributes or sells them to farmers. Government then must be able to monitor the distribution of insect-resistant varieties.

Heinrichs et al (1984) suggested that to prevent pest outbreaks, the government should release adequate quantities ofresistant varieties if the area planted to susceptible varieties is judged too large or requiring more diverse genetic backgrounds to prevent the buildup of new biotypes.

7.2.1.2. Biocontrol

More effort is needed on research into the different biocontrol strategies. Much of the research in progress seeks to identify biocontrol agents. A knowledge gap exists in terms of the social and economic aspects of biocontrol as a pest management technology.

Furthermore, more studies could be done on the bioefficacy and cost effectiveness of other forms of biocontrol such as the inoculation release, or classical biocontrol, and the inundative, or augmentative, release. Classical biocontrol has a remarkably high success rate in some countries (Dover 1985), mainly because the pests most likely to be controlled biologically are targeted. Since most of these target pests are themselves introduced species, researchers can efficiently study and search the pest's original habitat for biocontrol agents.

Inundative or augmentative release, on the other hand, involves rearing and periodically releasing large numbers of natural enemies to temporarily suppress pest populations. Beneficial species, used as living pesticides, are applied as needed to bring pest numbers down to tolerable levels. Several microbes, such as the insect pathogen *Bacillus thuringiensis* (Bt) have been registered and used as pesticides in many parts of the world to control various species of caterpillars.

7.2.1.3. Botanicals as alternative to chemicals

A shift from chemicals to botanicals would help to attain balanced, self-regulating agricultural systems. Some Filipino farmers already use botanicals (BAR 1989), and many others are convinced of their beneficial uses. Homever, just like biocontrol, not enough study has been done on the social and economic impact or on ways government can help to promote these alternative pest control agents.

Some popular botanicals are makabuhay (*Tinospora rumphii* /T.Crispa: madre de cacao or kakawate (*Gliricidia sepium*), and the neem tree. Others being studied include garlic leaves and, for its nicotine content, tobacco to control stem borers and cutworms (BAR 1989). A host of other botanicals long used by farmers is being documented by state colleges and universities and by research institutions.

The extensive investigation and documentation of botanicals in the Philippines and elsewhere may eventually lead to their popular use as standard pesticides. However, government has to promote them to farmers actively and widely. These strategies are both more economical and environment-friendly.

If pesticides must be used, IPM complementary research should also be done into handler and user safety and on-farm residues.

7.2.1.4. Pesticide handler/user safety research

Handler/user safety research should be directed toward setting minimum standards for protective covering suitable for the tropics. The safe minimum waiting times for reentering treated fields must also be established. The regulatory agency must require an antidote to be available before registering any pesticide.

7.2.1.5. On-farm analyses of residues

Residue analyses should be done on farms. For a given amount of pesticide used, a corresponding tolerable residue should be determined, based on a transformation function. Research also is needed to relate toxicity and residue levels.

7.2.2 Extension delivery system in support of IPM

Dissemination of research results to farmers is a crucial responsibility and must be undertaken by well-trained extension agents. IPM, for instance, is designed to suit a particular local situation for optimum impact. It cannot succeed without a marked improvement in training farmers in each locality.

One agency involved in IPM training programs is the National Integrated Pest Control Program under the BPI Crop Protection Division in collaboration with the FAO Intercountry Programme on Integrated Pest Control in Rice. The program has individualized training of farmers' groups in the different regions. Their record has been impressive, but there are still too few trained farmers and technicians. In another venture, the Philippine-German Crop Protection Program (PGCPP) piloted a radio campaign on IPM and supported construction of over a hundred farmers' centers where crop protection information can be distributed. The effectiveness of these different extension strategies has not been studied.

The key issues for crop protection extension are quality control and accountability. Even the latest locally validated research results remain mere academic or bureaucratic exercises if they are not passed accurately to extension agents and on to farmers. Currently, IPM research extension linkage is weak, such that IPM component technologies are not effectively disseminated to farmers. High-quality, decentralized crop protection resource centers should be set up as close as possible to farmers, at the municipal level. These centers would form the key link in at least three areas of information exchange on problems farmers identify to researchers, research results conveyed to farmers, and local adaptation of IPM among farmers and technicians.

Existing agencies should support these resource centers through their ongoing activities. The NCPC should continue to train subject matter specialists to pass on research results to local resource center s and farmer- identified problems to researchers. Extension agents, trained by subject matter specialists and through programs of the BPI Crop Protection Division, would rely on these centers as their first-line resource in answering their farmer-clients' questions and needs. Regional crop protection centers would form the next line of information resources, including backstopping local adaptation trials for results coming from local agricultural universities and the NCPC. The Surveillance and Early Warning System (SEWS) would use the centers to alert local farmers and extension agents about pest problems and to get information on suspected pest problems. IPM municipal trainers would use these centers as bases, getting new ideas and materials for training through the center network. Most important, these centers would be close enough to farmers so that farmers could hold them accountable for the quality of crop protection information. Standard field skill evaluations of all technical staff and assessments of farmers' training needs could be done through these centers.

The eventual goal is to build up the problem-identifying and problem-solving capacities of every barangay in the country. Innovative research, development, and extension methods with greater farmer participation and initiatives should be explored and encouraged. Pest and pesticide problems are intrinsically local in nature. National policy should nourish rather than squelch every rural community's capacity to handle these problems effectively, profitably, and equitably.

7.3 Community action

No pest management program will be successful without full participation by farmers. Farmers' indigenous practices as well as institutional and structural arrangements should be considered when planning pest management programs.

A relevant issue is how farmers as a community could collectively organize against pest infestation. Because pest management is a common property resource just like land and water, social pest control tactics may even be more sustainable and more profitable. This aspect, however, has not yet been empirically investigated.

Pest management, as a branch of resource management. could he tackled by recognizing the problem to be a Commons Dilemma (Hardin 1968). A certain sector can be group rational about a situation and decide that preserving the commons (that is, an environmental resource or a resource pool) is more important than personal gratification. In this sense, farmers may find forming groups to jointly control pests worthwhile. Grouping could be done in two ways. First, an organization could be formed along political or governmental units, that is, the barangay, with mandatory participation in pest control programs. A second grouping could be done via private cooperatives or groups where participation is usually voluntary. Both public and private groups may benefit from such community action because of mobile pests, pesticide drift, or pest control information. Moreover, group economies of size may lower costs to members and aid in delivery of new pest management techniques.

Rooh and Carlson (1985) have shown that uniformity of pest control demand was a strong determinant of participation and that the probability of participation increased as farmers' opportunity cost of time increased. The study further revealed that farmer participation in pest management groups is significantly affected by the percentages of their area planted in a time-competing crop, farm size, group price, extension service subsidies, and expected crop yield.

In the rice sector, where farms are uniformly small and farmers are nearly homogeneous, collective action for pest control seems quite attractive. Two types of action could be explored: synchronizing planting and other cultural management practices and monitoring pests through an institutionalized scouting program.

7.3.1 Synchronizing cultural management practices

Synchronizing cultural management practices involves planting at the same time to take advantage of hostile environmental conditions for pests at the stage new plants are most susceptible to insect attacks. It also implies farm cleanliness and proper sanitation practices that would not clog or pollute irrigation canals. Synchronization would be ideal in cases where product price is nonfluctuating (regulated) and irrigation water is available all year round. In rainfed areas, planting is synchronized around rainfall, and harvesting dates are common to almost all farmers. Few rainfed farmers are market oriented, however, so output prices are not a crucial factor in their rice farming decisions. Prices of cash crops are more significant.

Several factors may constrain synchronization. Loevinsohn et al (1982 and 1985) investigated the causes, extent, and effects of synchronous rice cultivation in Nueva Ecija. These include:

Irregularities in water distribution and drainage or variation in the date irrigation water arrives at farms; and unavailability of tractor or custom hire work during land preparation, unavailability of labor during transplanting, and lack of access to credit; and asynchrony reducing the fallow period between crops or increasing the duration of standing crops.

Asynchrony is significantly related to a pest species' maximum rate of increase. Because synchronous planting can prevent pest buildup and crop damage, it could greatly improve rice yields. Loevinsohn et al (1982 and 1985) also proposed that the pattern of synchrony should be by waves. Ricelands could be mapped to demarcate the synchronous rice area (called waves), no smaller than 0.75 hectare or an area of 1-kilometer radius.

The extent of synchrony would be based on the minimum period in which pests can complete one life cycle. Therefore, ricefields have to be planted within three to four weeks and adjacent waves will have to be planted no more than three to four weeks apart (Heinrichs et al 1984).

Heinrichs also pointed out, however, that synchronous cropping can lead to two unfavorable repercussions. First, it endangers landless workers' continuity of employment and creates labor shortages in the rice labor market. Most farm operations involved in irrigated rice production utilize temporary, landless workers. With synchronous cultivation, their employment periods are shortened and their incomes cut. In addition, because the number of landless workers does not vary, labor shortages may arise during periods of peak demand. Labor shortages are common in the wet season and wages are higher because most of the lands (rainfed and irrigated) are cropped to rice. Synchronization would aggravate labor shortages unless nonrice employment opportunities, vertical mobility of labor (from rice to nonrice jobs), and horizontal mobility of labor (from one synchronous wave to another) are deliberately enhanced.

Another unfavorable consequence of synchronization as cited by Loevinsohn et al (1982 and 1985) is that it undermines the existence of "informal" crop insurance against natural disasters. In case of a typhoon, for example, some crop would have been harvested, and others would be young enough to recover. The scheduling of waves would influence the extent to which this informal insurance is compromised.

Constraints to the practice of synchronization could be removed if farmers organized their wave-planting schedules so as to have maximum impact on pest life cycles: government agencies like the National Irrigation Administration cooperated for effective water delivery: more nonfarm jobs were made available to diversity rural employment: and price risks were minimized. Most of these solutions could be tackled by the public sector.

7.3.2 Scouting program to enhance IPM

In countries where IPM is institutionalized scouting as main feature is usually done by government pest control services or privately owned scouting services. A potato IPM program for instance, would hire university graduates to monitor pests and advise groups of potato growers. Employment is generated whenever a group of enterprising experts (usually extension entomologists) establish a service bureau or firm to meet the needs of the growers' group. Some growers use a computer-based expert system for advice on the need for pest control actions whenever enough information exists about the pest and crop cycles.

In Third World countries like the Philippines, farms are small and farmers are individualistic and poorly educated. Information on pest and crop cycles is scant, and creation of service groups may not be feasible. In addition, training the 3 million rice farmers would take a very high budget, where a favorable benefit-cost ratio may be uncertain. So far, IPM training has had a sizable budget, but the proportion of farmers trained is still insignificant. Training scouts to monitor several farmers' fields would solve this problem.

Ideally, pest management programs begin with thorough scouting and monitoring before undertaking any control activities. Scouting provides information for farmers to use when considering pest control, be it chemical, biocontrol, or other means. Using this strategy, fields are periodically sampled for pest population levels and a decision to spray or act is made if the pest population level surpasses the recommended critical level. This contrasts with decisionmaking criteria under the conventional chemical strategy which usually results in higher insecticide applications. The criteria involve setting a routine date for applying insecticide, without reference to fluctuations in pest populations.

Government could help by institutionalizing scouts for hire by a group of farmers. Several alternatives could be pursued. Incentives could be offered for enterprising agriculture/entomology graduates to form a scouting business. This enterprise could be a conduit for government to spread research results on alternative pest management strategies to farmer cooperatives. Farmer cooperatives would pay this firm a collectively agreed price. The government could subsidize biocontrol agents and could provide the firm with consultant services.

If a private firm is not feasible, an alternative strategy is training the better educated farmers in cooperatives to do the scouting. Training would be intensive, and trainees would take on scouting as a secondary job to farming. How many trained scouts are needed per area of land is still a research question. The strategy of training out-of-school youths in the community could also be pursued. However, trainees should be committed to doing the scouting. In a Calamba, Philippines, case study, IPM- trained, out-of-school youths gave up scouting activities when they found more lucrative jobs (Adalla et al 1990).

This raises the issue of how much to pay scouts. If farmer cooperatives could pay scouts at least the standard wage, the scouting business would flourish. Using agricultural wage rates to determine scouting fees may be relatively unattractive because a person with at least a college degree should do the scouting. Furthermore, scouts have to be alert to new technologies and information about pest management. They could be educated to predict pest attacks from pest crop cycles.

Other open questions include: who will pay the scouts—government, as a form of subsidy to IPM, or the farmer cooperatives? How much will they pay per visit, per hectare, per farm, or per hour? Scouts-for-hire is a potentially good business in areas where pesticide use is high. Scouts would identify pests and natural enemies in different crops, with different growing seasons, and would be able to stay in business all year. Vegetables are farmed all year, and vegetable farmers spray most of the time.

Chemical companies could likewise be a vehicle for sustainable pest management strategies for farmer cooperatives. These companies could package and sell biocontrol agents, for instance, to farmer groups and do scouting for a fee. Selling custom-made packages to an individual farmer may be unwise in as much as positive externalities or beneficial spillover effects do exist in using biocontrol agents for pest control.

On the whole, treating pests as a common property resource (or a public liability) would entail collective action by constituents and support from the public sector. Recognizing both positive and negative externalities that pest control agents possess, group action could be much more effective than individual action. The challenge to government is to create an environment that promotes these strategies in ways that achieve growth, equity, and environmental sustainability.

7.4 Pesticide pricing policies and IPM

Even with a solid IPM program, pesticides may have to be kept as a technology-of-last-resort. A good IPM program should therefore include measures to minimize pesticide hazards. The judicious use of pesticides in IPM recognizes and stresses the importance of correct application timing and dosage. The pesticide used should be as safe and selective as possible, targeting the pest with minimal harm to other organisms. Although some research has been done into selective chemicals, they are not generally available. A chemical useful for only one pest would have a small market and be unlikely to repay its development costs (Bull 1982).

Essentially, the idea of pesticide use in IPM is to spray only when imperative, using the smallest amount possible to do the job. This means that pesticide management is an essential part of pest management. Pesticide management includes every aspect of safe, efficient. and economic handling and use of pesticides. Both the agricultural and medical disciplines must be involved to achieve this. Such an “agromedical“ approach means imbuing agricultural extension workers with a broad concept of conmunity care, including preventive health care. In terms of pesticides, community health practitioners and extension workers should, together, teach people how to use pesticides safely and recognize and help to treat cases of pesticide poisoning (Bull 1983).

Over 55% of all insecticides used in the Philippines are applied on rice. The most common insecticides used in rice (monochrotophos, methyl parathion, and azinphos methyl) are all classified as “extremely” hazardous (Oudejans 1982). Available and cheap, these insecticides also show clear knockdown toxicity in the field. Many countries restrict their use, but the Philippines has been an easy market. Other effective insecticides against rice pests but less toxic to people include triaziphos, carbaryl, and cypermethrin. Slightly to moderately hazardous (Oudejans 1982), these chemicals are neither as cheap nor as commonly available as the more dangerous materials.

A comparison of pesticide retail prices in several Asian countries shows that the Philippines has one of the highest average price levels in the region (Table 7.2). Carbaryl costs more in the Philippines than in Thailand and Korea. Such high prices

Table 7.2. Retail price of selected pesticide products, selected countries and years (US$) (FPA 1988).

Product	Unit	India (1982)	Korea (1982)	bangla-desh (1983)	Pakis-tan (1983)	That-land (1983)	Sri Lanka (1982)	Philip-pines (1983)
Carbofuran 3% GR	kg	2.49	1.02	2.14	1.56	0.97	1.07-1.17	0 75
Monochrotophos 36%	liter	18.93	7.10	15.94	14.46	10.63	88.84-24.46	5.78
Carbaryl 85% WP	kg	8.42	5.16	10.00	9.45	6.94	10.3	8.69
Endosulfan 35% EC	liter	7.68	7.78	7.14	11.42	5.86	5.42-13.88	7 28
Fenmothion 50% EC	liter	10.26	8.26	11.90	10.27	7.16	6	6 21
Paraquat 24% EC	liter	10.53	9.04	6.19	9.45	4.12	3.71-5.22	na
Mancoreb 75% WP	kg	6.57	na	na	6.16	3.47	3.58-7.59	6.45
Diazinon 20% EC	liter	6.32	6.56	13.60	12.49	9.54	7.35-11.46	9.69
Penthoate 30% EC	liter	8.84	8.06	na	11.58	7.59	11.2	na
Dimethoate 30% EC	liter	6.53	na	8.50	10.27	3.69	5.44-10.17	na
2,4-D-Ester	liter	4.74	na	4.24	na	4.34	na	3.00
Captan 75% WP	kg	11.58	5.26	na	5.92	4.56	5.56	10.50
Malathion 50% EC	liter	4.75	4.58	3.99	5.42	4.77	na	4.29
Diazinon 10% GR	liter	na	0.65	na	1.81	na	na	0.73
Methyl parathion 50% EC	liter	9.49	6.04	na	5.18	6.07	8.75	5.01
Zinc phosphide	kg	6.42	na	6.69	9.86	5.20	na	5.10
Cypermethnn 25% EC	liter	63.16	12.76	na	43.14	36.96	na	na
Fenthion 82.5% EC	liter	16.63	7.22	13.00	11.17	6.50	10.6	na

[a] GR = granule. SC = suspension concentrate, WP = wettable powder. EC = emulsifiable concentrates.

Table 7.3. Tariff structure (%) for pesticides, Philippines (Tariff Commisssion 1991).[a]

Material	Jan 1965-Dec 1970	Jan 1971-Dec 1972	Jan 1973-Dec 1989	Jan 1990-Jun 1991	Jul 1991-present
Raw material	10	10	10	10	10
Intermediate material	10	15	20	10	5
Finished product	10	15	20	20	10

[a]Domestic tax for agricultural pesticides is zero percent.

in the Philippines are often attributed to the high tariff rates imposed on pesticides because they are not classified as essential agricultural items (Table 7.3). Domestic sales taxes for agricultural pesticides are zero. To encourage the use of safer pesticides, only chemicals classified as slightly and moderately hazardous should be given tariff relief. High tariffs should be retained on chemicals in the very and extremely hazardous categories to encourage purchasers to select compounds of lower intrinsic toxicity to people. Standard classification systems such as those adopted by the World Health Organization or the Economic and Social Commission for Asia and the Pacific (ESCAP) should be used to group pesticides. In the 1980s, there was no significant change in c.i.f. value of imported finished pesticide products. In fact, due to devaluation, inflation, and high interest rates, the retail price of pesticides has steadily risen.

To make IPM more attractive, pesticides would never be subsidized. However, the public sector should have access to adequate amounts in cases of severe pest infestation. An unfavorable pricing system for highly toxic chemicals is one way to discourage use. Category I chemicals (extremely, hazardous) could be taxed much higher than the moderately and less hazardous ones. What rate of tax will deter purchasers has not been determined. Since it will be difficult to estimate the optimal consumption tax by level of toxicity and to monitor the payment of such tax by different types of chemicals, a direct ban would be preferable to differential taxation at this time.

7.5 Constraints to IPM implementation

IPM appears to present so clearly preferable an approach that it may seem strange that it has not been universally adopted. The most common explanation is that IPM requires knowledge, expertise, and infrastructure that most Third World countries lack. To implement an IPM program, farmers need assistance from specialists, analogous to doctors who can diagnose and treat complaints. Lacking such specialists, many people in the Third World see IPM merely as a hope for tomorrow (Rull 1982). Bull also points out that a true IPM program requires research and extension infrastructure as well as some degree of community organization. Inadequate and underfinanced research and extension services can seriously limit small farmers' effective use of IPM.

Teng (1990b) listed several constraints met in IPM implementation and assessed their severity (Table 7.4). They are institutional, informational, technological, sociological, economic, and political.

7.5.1 Institutional constraints

Government agencies responsible for different aspects of a national IPM program often lack a common view about the objectives and operational aspects of IPM. This constraint prevented effective implementation of IPM in Indonesia (Teng 1990).

The clear demarcation of responsibilities betweem research, extension, and technical support services presents a major constraint to IPM. This organizational constraint, compounded by interinstitutional rivalry, impedes the timely flow of information between the key players. This demarcation of responsibilities also means that scientists who generate the knowledge base for IPM may not clearly understand what kind of knowledge extension workers or farmers need. Institutional barriers to on-farm research scientists in national programs in Asia are real and need to be addressed.

7.5.2 Informational constraints

Lack of useful IPM information for farmers and extension workers is still a major constraint in many countries. Training materials must be geared to farmers' educational attainments (now Grade 6, up from Grade 2, 25 years ago). In the past, for example, posters may not have been designed in a way that conveys the message to farmers. The lack of experienced IPM teachers poses another constraint.

7.5.3 Technological constraints

Technology for IPM that recognizes the receptivity of different farmer groups has been developed but is not widely available. More constraining than the availability of technology is the lack of facilities and support services for extension personnel to do their work. Many countries do not have functional IPM extension programs because the people who would participate in them have no means of travel to farms or field demonstration sites.

In a related problem, few national programs have scientists who can generate the IPM technology themselves. Few scientists have been exposed to contemporary knowledge on IPM, and few guidelines exist on the extrapolation domain of IPM technology generated at one locality for use in another.

Table 7.4. Assessment of severity of constraints in integrated pest management implementation (Teng 1990).

Type	Information flow[a]			
	Research	Adoptation	Dissemination	Adoption
Institutional	2	3	3	2
Informational	2	3	3	1
Technological	3	3	3	2
Sociological	1	3	3	2
Economic	1	2	3	1
Political	1	1	1	1

[a] 0 = none, 3 = very severe.

7.5.4 Sociological constraints

Past conditioning of farmers by industry or public workers regarding unilateral approaches to pest control is a real constraint, especially with regard to insecticides. Many farmers and extension workers still favor technology that is simple to use, like insecticides.

7.5.5 Economic constraints

The issue of economic risk and positive returns from using IPM rather than conventional, scheduled practices appears to be present in the minds of many extension workers and farmers. Despite abundant research and demonstration plot evidence that IPM works (Smith et al 1989, Kenmore 1989), doubt lingers about its reliability. Some of this reticence may be traced to the knowledge requirements of IPM, where each decision has to fit the prevailing conditions. A "package" approach, in contrast, seems to remove uncertainty from the decision process. The uncertainty constraint could be removed by improving educational programs and knowledge. This last point is important as the extrapolation domains of IPM techniques has not been adequately researched (Teng et al 1990).

National IPM programs definitely pay for themselves in terms of savings on resource inputs for production. However, IPM must be viewed as an investment, which always requires an initial outlay. Several countries have made IPM the basis of their national plant protection policy and program and provided the financial resources to implement it, but many others have done neither. Funding for the research, extension, and farmer training needed in an accelerated program is a major constraint, even if IPM is adopted in principle.

7.5.6 Political constraints

The relatively low status of plant protection workers in the administrative hierarchy, especially extension, was considered a major constraint in efforts to improve plant protection generally. Associated with it is the morale and financial standing of these workers. Many workers have impressive programs on paper but do not have the funds to travel and execute those programs. These programs are often outside the scope of external funding agencies. A more logical approach may be to generate the right policy environment and local political support and commitment to IPM.

Environment-conscious groups such as PAN International have stressed the interrelationships between the sectors involved in the pesticide trade and have questioned whether these connections are not the real constraints to any attempt to reduce pesticide misuse. As one commentator puts it: "One of the reasons the underdeveloped governments don't do anything about the pesticide problem is that the people who use pesticides, the people who import pesticides, and the people who regulate pesticides are the same people. It's a tight little group in each developing country" (Anonymous 1984 as cited in Teng 1990b). This may be an extreme view, but many vested interests are undeniably associated with the pesticide industry. Many of them could be addressed by an explicit government policy on IPM (Teng 1990b).

Chapter 8

Regulating pesticide use in Philippine agricultural production: some policy considerations

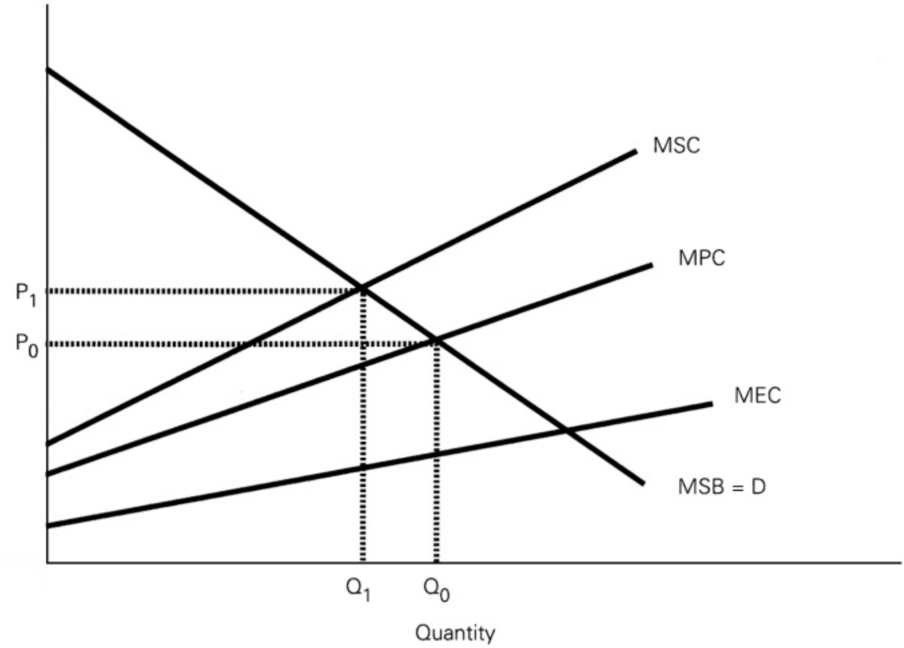
Pesticide use in agriculture is heavily regulated due to its externality effects. Pesticide regulations restrict or prohibit the use of particular pesticides and set quality standards for chemicals and tolerance levels for chemical residues on output. Through their effect on production costs, these regulations alter the production possibilities set and the supply curve.

Policies for regulating pesticides should maximize the benefits of using this input. In the Philippines, pesticide policies should be redesigned to consider the externalities such as harmful health and environmental effects.

8.1 Agricultural productivity and pesticide regulations: an analytical framework

Regulating pesticide use to make farmers face the external costs of production may increase costs as higher cost inputs are substituted, or output may be reduced when such substitutes are not available (Archibald 1988). The extent to which productivity is affected depends upon opportunities for input substitution, possibilities for "abatement" technology, and the specific regulatory mechanism employed. When no abatement possibilities exist and the externality generated is proportional to the agricultural output produced, production falls if producers are forced to internalize the externalities.

Following Archibald (1988), Figure 8.1 shows price-output combinations under competitive and socially efficient scenarios. When externalities exist in a competitive economy, allocation of resources are no longer Pareto optimal. For production decisions to be Pareto optimal in the presence of externalities, marginal social benefits must be equated to marginal social costs. Hence, in Figure 8.1 (p_0q_0) is the price-output combination that results from a competitive equilibrium when marginal external costs (MEC) are excluded. If MEC are added to marginal private costs (MPC), so that the producer faces marginal social costs (MSC), the socially efficient price-output corn-bination will be (p_1q_1).



8.1. Price-output combinations under competitive and socially efficient scenarios.

Regulation can lower productivity. However, in the long run, environmental and resource policy should aim to achieve the economic growth consistent with environmental protection and socially efficient uses of natural resources, including human resources. Choosing the right regulatory strategy may be difficult and costly.

8.2 The Philippine pesticide regulatory policy: current status

The agency tasked to regulate the use of agricultural pesticides in the Philippines is the Fertilizer and Pesticide Authority (FPA). It was created in 1978 by Presidential Decree 1144 and was originally given the control of the importation, manufacture, formulation, distribution, sale, transport, storage, labeling, use, and disposal of pesticides and fertilizers.

Today the FPA is mandated to register new pesticides, regulate pesticide availability and use, license handlers, set residue limits on foods and feeds, monitor compliance with FPA policies, supervise imports, and design pesticide training programs.

8.2.1 Registration of new pesticides

Registration is intended to ensure that pesticides will be effective and efficient for the purposes claimed when used according to registered label directions. This does not cover externalities that can ensue from its use. Registering new pesticides is a lengthy process. Patent owners must submit data on toxicology, bioefficacy, environmental fate, and residues. These data may be generated locally or else where. Experts evaluate the data and recommend registration or rejection of the pesticide to the FPA Administrator. To reregister a product, new research data must be presented.

The registered label must show hazard category (imprinted in color codes), common names, directions for use by crop, quantity/formulation. pest: and reentry interval.

In the Philippines, as elsewhere, some farmers read labels regarding pesticide use and some do not. The proportion who do ranged from 32% among banana growers to 100 percent among rice growers in the Philippines. Rice farmers are aware of manufacturing dates (100%), color-coded hazard category (80%), common names (52%), and mode of use (85%), but only 52% knew the safe reentry interval (Table 8.1). Onion growers knew the least about label information (Rola et al 1992).

Even among farmers who attended a training course on pesticides and safety, only 2 out of 10 gave pesticides the same hazard ranking as the color code on the label. Among untrained farmers, fewer than 3 in 10 were aware of hazard ranking and color code (Table 8.2). This shows that information in the labels of pesticides may not be functional. Hence, regulatory strategies ought to be reformulated to be useful to Filipino farmers.

8.2.2 Restrictions on availability and use

FPA is empowered to restrict or ban the use of any pesticide or pesticide formulation in specific areas or during certain periods upon evidence that the pesticide is an imminent hazard or has caused or is causing widespread serious damage to crops, fish, livestock, public health, or the environment. The Administrator through the Pesticide Technical Advisory Committee (PTAC) could classify the pesticide, or particular uses.

Table 8.1. Percent distribution of farmers who read labels, Philippines, 1991 (Rola et al 1992).

	Grains		Fruits				Vegetables			
	Rice	Maize	Mango	Banana	Pineapple	Tobacco	Cabbage	Potato	Onion	All farmers
Percent distribution of farmers who read labels	100.00	89.33	97.00	32.00	47.50	88.00	78.00	82.00	80 00	79.13
Percent distribution of farmers who are aware of										
Hazard category	80.00	88.06	92.78	75.00	36.84	47.73	84.62	100.00	37.50	79.40
Common names	52.00	62.69	76.29	25.00	42.11	34.09	17.95	95.12	12.50	56.04
Mode of use by										
crop	88.00	85.07	98.97	100 00	89.47	100.00	79.49	100.00	93.75	91.48
quantity	84.00	88.06	98.97	93.75	89.47	100.00	71 79	100.00	93.75	92.31
pest	80.00	92.54	96.91	87.50	84.21	100.00	69.23	100.00	93.75	91.48
Re-entry interval	52.00	49.25	70.10	12.50	31.58	34.09	61.54	60.98	6.25	51.37

Table 8.2. Pesticide hazard ranking, Nueva Ecija, Philippines, 1991.

	Sample A[a]		Sample B[b]		Total	
Item	no.	%	no.	%	no.	%
Persons interwewed	55	(100.0)	103	(100.0	158	(100.0)
Men	54	(98.2)	100	(97.1)	155	(98.1)
Women	1	(1.8)	3	(2.9)	3	(1.9)
Hazard ranking agreed with color code	11	(20.0)	3	(2.9)	14	(8.9)
Hazard ranking agreed with color code except for lower categories (blue and green)	7	(12.7)	7	(6.8)	14	(8.9)
Participant chose too few pesticides to rank them	0	(0.0)	2	(1.9)	2	(1.2)
Hazard ranking did not agree with color code	37	(67.3)	91	(88.3)	128	(81.0)
Color code mentioned as a reason for hazard ranking	17	(30.9)	6	(5.8)	23	(14.6)
Actual ranking	7	(12.7)	0	(0.0)	7	(4.4)
Actual ranking agreed with color code except lower categories	3	(5.5)	0	(0.0)	3	(1.9)
Actual ranking differed from colored code	7	(1.7)	6	(5.8)	13	(8.2)

[a] Sample A is a random sample of farmers and laborers who attended a 2-day IRRI training course on pesticides and safety. [b] Sample B is a random sample of farmers and laborers who did not attend the same 2-day training.

for restricted use. However, before a restriction or a ban is imposed, the company is given a chance to show proof that the product is safe and may not need restrictions. Renewal of registration also depends upon the chemical's local performance. Too little effort has been put into post-registration monitoring of local performance. No formal system or office handles this function.

8.2.3 Pesticides for institutional use only

The Philippines has limited some pesticides to institutional use only. An institutional user, unlike a farmer, can closely supervise every phase of pesticide application. This means that occupational exposure can be limited to smaller and more homogeneous group. Prohibitions and protective clothing requirements, exposure times, and other factors in applicator safety can be more readily managed. Such simple expedients as limiting exposure time of workers to nil-exposure situations may prevent some effects.

8.2.4 Licensing

All pesticide handlers must be licensed by the FPA. Handlers include importers, manufacturers, formulators, exporters, repackers, distributors, warehouse personnel, and sales people. A separate license is required for each establishment or place of business subject to these rules, and it must be conspicuously displayed on the premises.

FPA license permits are needed to sell pesticides at costs ranging from ₱140 to ₱2,200 (Rola et al 1992). However, only half the pesticide dealers hold permits, perhaps because the application and renewal processes are so cumbersome.

8.2.5 Maximum residue limits on foods and feeds

To protect the public from hazardous pesticide residues on food, FPA is mandated to establish a system of maximum residue levels (MRLs), applicable to both domestic and imported raw agricultural produce. Because of the large number of pesticide-crop combinations, FPA must establish MRLs only for existing pesticide registration uses. However, as a statement of policy for future food uses of pesticides, registration will not be granted without the concurrent establishment of an MRL to cover pesticide residues on each commodity for which registration is requested. FPA must prepare a list of proposed MRLs based on extrapolation and estimation of allowable daily intake (ADI) of pesticide residues from calculations taking into account food factors, dietary intake studies, ADI, and existing Codex MRLs.

To this day, however, FPA has not yet established this system, partly for lack of funding. Some market-basket and farm level monitoring of residues in crops has been done for FPA use as a regulatory measure. These data were to be compared with the WHO/FAO Codex Alimentarius. However, FPA does not have policing power to enforce the standards. The residue problem is more serious in fruits and vegetables than in rice.

8.2.6 Postregistration activities

FPA is authorized to conduct four types of postregistration monitoring to ensure observance of its policies. First, FPA and cooperating agencies are to provide an overview of potential and actual environmental contamination harmful to fish and wildlife. However, because several agencies are mandated to monitor pesticides in the environment, none has made a serious effort. Second, FPA has the authority to monitor pesticide residues on food to assess safety levels, detect residues from illegal or improper use, and protect the credibility of exporters with their customers. Again. no functional system has been created to conduct this activity. Third, FPA has the authority to monitor pesticide use to assure compliance with label directions for training, informational needs, and other regulatory purposes. Practically nobody is doing this type of activity. Fourth, FPA has the authority to monitor pesticide poisoning cases in collaboration with physicians and paramedical practitioners trained in the Agromedical Program. No complete program has been developed for nationwide gathering of poisoning data. For lack of resources or perhaps lack of political will, FPA fulfills few of these monitoring activities.

8.2.7 Import restrictions

FPA processes import permit applications according to registration and licensing policies, especially the list of banned and restricted pesticides. The Philippine list is shorter than those of other Asian countries as well as those of WHO, World Bank, and the Asian Development Bank (ADB). From time to time. special cases can result in import restrictions or temporary waivers, for example, to facilitate international loans involving pesticide procurement or to implement conditions agreed upon with other governments or organizations.

To encourage local entrepreneurs to manufacture pesticide technical materials or active ingredients. FPA prohibits imports of any product that is manufactured locally as long as local manufacturers can prove that their prices are competitive with world market prices. The only FPA-protected technical material manufactured locally is 2,4-D.

8.2.8 Training programs

FPA places great emphasis on training programs and has designed appropriate courses for different target audiences. Scarce resources, however, prevent their full realization. Agromedical training, agropesticide dealer training, and training technicians in the DA form the core of FPA training programs.

Agromedical training is designed to educate medical and paramedical practitioners to recognize and manage pesticide poisoning cases. Most training programs are conducted only in areas of intensive pesticide use. However, other areas may have a high incidence of poisoning due to unsafe use, but these statistics are not recorded because of misdiagnoses. Distribution of pesticide poison control kits of supplies and antidotes to various rural health centers and hospitals has been recommended but not done. Another integral part of the training is monitoring pesticide poisoning cases by rural health centers and hospitals participating in the training course. Reports are to be sent to FPA on a monthly basis and collated annually.

Agropesticide dealers are thought to be important channels for informing farmers about the safe handling and effective use of agropesticide. For a license, prospective dealers are required to attend an FPA course on the efficient use and safe handling, storage, transport, and disposal of pesticides. Few dealers comply with this requirement. Moreover, out of 460 farmer respondents in a recent nationwide survey, only 8% considered dealers an important source of information on pesticide use (Rola et al 1992).

DA technician training is intended to make technicians aware of pesticide hazards and to promote their efficient use and safe handling. The technicians, in turn, train farmers. So far, practically no technicians have completed their training. This component could be subsumed in the periodic IPM trainings.

Explicit policy statements notwithstanding, pesticide dealers, farmers, and government technicians in the Philippines see much room for improvements, according to a recent survey (Rola et al 1992). Compliance with regulatory policies is poor and few farmers are aware of safety practices and judicious use of chemicals. More important, the extension infrastructure (by the local DA) is inadequate to advise farmers on proper pesticide use and alternative crop protection technologies. With this seemingly dim picture, it suffices to say that the Philippines is challenged to put more substance into the current regulatory policy statements.

8.3 Policy options in promoting safe pesticide use

For lack of viable alternatives, Filipino farmers will still use pesticides in the short term. Therefore, the government should strictly enforce its regulatory policy. So far, implementation has been short of expectation. Cases of farmer poisoning are increasing, pesticide residues in their food crops are high, and groundwater/well-water pollution is worsening. To mitigate environmental risks from pesticide use, several strategies are thus proposed.

8.3.1 Regulatory policies

Pesticides that pose acute and chronic health effects and persistent environmental contamination should be banned. There are too few data to determine the impact of a pesticide ban on crops other than rice, but a ban on insecticides used on rice would not result in a significant yield decrease, as shown in this study. The productivity coefficient for insecticides in rice was estimated at 0.007. Recently, three chemicals were recommended for banning: monocrotophos, azinphos ethyl, and methyl parathion; the use of endosulfan was severely restricted.

Local MRLs should be set for food, feeds, and drinking water. Food safety is paramount in crops consumed domestically and for export. The tolerable levels must be determined for pesticide residues in food and water through a multidisciplinary effort by nutritionists and physicians.

In monitoring regulations, local government officials could he invested with FPA policing power. Hence, local government officials could do spot checks to see, for example, whether dealers have undergone training and secured a business licence, whether pesticide stocks are within the effective shelf life, and whether pesticides have been repackaged. Monitoring use of banned pesticides could also be done locally. As a prerequisite to this effort, lists of banned and restricted pesticides should be made and posted in public places.

A constraint on effective monitoring/implementation of regulatory policies at the local level has been the authorities' susceptibility to bribes and familial influences to overlook infractions.

To renew their registration, pesticide companies must be required to furnish data on local conditions, based on inspections of farmers' fields, concerning bioefficacy, health impact, and environmental impact. For comparison, an interagency team of investigators should have independent data sets with the following assignments: DA for bioefficacy, Department of Health for health impact, and Department of Environment and Natural Resources (DENR) for environmental impact. Together with food residue data from BPI, FPA could already establish benefit-cost and risk-benefit assessments by integrating the different data sets. Currently, environmental impact and ecological disruption are not considered in evaluations. Nor is there any formal process to establish an objective benefit-cost and risk-benefit estimates. The evaluators usually present their respective performance evaluations of a chemical, but no integrative analysis is done with the data.

The appropriate time period for renewing pesticide registration should be studied. Currently once registered, a pesticide is in use forever or until restricted because of proven hazards.

In the long term, a proactive model should be built for regulatory purposes. The model should be able to predict scenarios on productivity effects and levels of externalities corresponding, for example, to different policy instruments (banning, pricing, farmer training). Some international research institutions are trying to build these models.

8.3.2 Pricing policies

Pesticide retail prices are significantly affected by taxation, tariffs, import levies, and other instruments including exchange rates. An effective pricing policy might apply a selective tax/tariff system, taxing less hazardous pesticides at lower rates than more hazardous ones. However, a direct ban is preferred to selective taxation, as discussed in Chapter 7. Because retail prices are lower for older, more hazardous insecticides, farmers have been using more of them. Newer or less hazardous pesticides such as pyrethroids cost more because they are still under proprietary rights. Such commonly used chemicals are very dangerous, but cheaper (Pingali et al 1991, Rola et al 1990).

8.3.3 Public sector investments

Public sector investments are needed in training programs for agrochemical dealers, rural medical workers, agricultural workers, and farmers and for information campaigns at different levels. Government should also sponsor research into application technologies that mitigate risks and maximize gain from pesticide use.

Training programs. Agrochemical dealers, as potential sources of information on pesticide use, must be kept up-to-date with information about the nature and consequences of the pesticides they handle. They must be trained along the lines of a pharmacist so that they can dispense pesticide that matches the symptom described by the farmer. The impact of training agrochemical dealers on productivity and safety should also be evaluated.

All rural *medical workers* should be trained to recognize symptoms of pesticide poisoning. The Department of Health should be responsible for training these workers. However, this has yet to be institutionalized at the local level.

Agricultural technicians who work closely with farmers should be trained in current technologies regarding safe and judicious use of pesticides. Their training would cover appropriate pesticides for certain crops and pests, correct dosages and application timing, appropriate application technologies, and early warning systems and corresponding treatments. Over the past four years, pest pressure on rice farms was so insignificant that some of the returns on insecticide use were negative (Adalla et al 1992). If agricultural technicians could be trained on pest surveillance techniques, they could advise farmers when to apply pesticides. DA programs currently train agricultural technicians on pest management only for rice. Pest management programs in vegetables and other crops should be developed.

Farmers are the critical link in the pesticide chain as pesticide consumers and producers of foods. In the Philippines, they also face the pesticide externalities such as illness and sometimes death. The most urgent efforts should go into persuading farmers to handle and use pesticides correctly and to recognize symptoms of pesticide poisoning. Filipino farmers lack the knowhow about handling and storing pesticides properly and disposing of their containers (Pingali et al 1991. Rola et al 1992). They are careless about storing pesticides safely, throw pesticide containers into open pits or anywhere on the farm, and wash sprayers and containers in irrigation canals. These practices increase the farming community's risk of direct pesticide exposure.

Information campaigns. The mass media should be enlisted to explain safety practices in pesticide use. General information about protective clothing, safe storage and disposal of pesticides, appropriate application technologies, and the like, can be made available through popular newspapers, radio, and television. For technical information, where individual training is needed, farmer organizations could be an effective medium. Their leaders could be trained to relay information to members.

Training on pest management and proper pesticide handling may be subsumed in other training packages such as production technologies.

In places where pesticides are used intensively, pest clinics could be set up. There, farmers could consult experts about identifying old and evolving pests and using alternative methods of controlling them. State colleges and universities should be able to perform this service, spreading new research knowledge to the farming community.

Application technologies. The backpack sprayer is the most popular way of applying pesticides to rice, vegetables, and fruit trees in the Philippines. Backpack sprayers are inefficient when plants are taller than farmers. Fruit trees like mangoes need a boom sprayer, but most farmers improvise an application technology that consists of a drum, a hose, and a pump. Furthermore, backpack sprayers are low in quality and sometimes have inefficient nozzles that cause unnecessary drift. Given this state of the art, the farmer's probability of dermal exposure is high. Investments thus are needed to develop appropriate application technologies.

8.3.4 Research and development

In the long term, government and private resources could be channeled into developing alternative pest control measures to complement or substitute for pesticides. These would include pest-resistant varieties, biological control, cultural management, improved cropping patterns, and the like. A more effective research-extension delivery system should likewise be set up to disseminate technology to farmers. Farmer participatory research is one way of doing this.

With regard to research on farmers' safety, protective covering for pesticide applicators should urgently be developed. Some pesticide companies have developed protective clothing, but fear that the psychological effect of persuading farmers to use it will hurt pesticide sales (by alarming farmers about dealing with hazardous substances).

8.3.5 Structural reform of the regulatory agency

Rola (1986) recommended creating a Pesticide Regulatory Agency (PRA) as a separate agency within DA or assigning pesticide regulatory functions to the Environmental Management Bureau (EMB) of the DENR. The PRA should be responsible for registering and regulating pesticides. Pesticide marketing should be left to the private sector. PRA operational components should include:

- a *Policy Direction Committee* to set PRA policy and report directly to the Secretary of Agriculture. Members should include representatives from DA, EMB, universities, the Department of Health, and the farming community.
- a *Legal Committee* to assemble cases from enforcement data, and to prosecute violators of regulations.
- a *Public Liaison Committee to* report standards and regulations, and violations of these standards, to the public, creating an arena for the discussion of the views of various sectors, including farmers, consumers, and industry.
- a *Training and Information Committee to* advise government and nongovernment agencies on the latest information on pesticides and to support and evaluate the

technical accuracy of training for pesticide dealers, extension workers, community organizers, and farmers.

Good policy guidelines for regulating pesticides exist. However, the FPA full-time staff is too small to enforce and monitor the thousands of pesticide distribution outlets and supply networks around the country. While collection of pesticide samples from the shelves or residue from crops is not always a full-time job, the only way to cover the country is to draw upon a larger pool of trained personnel. Using the specially trained crop protection staff of the national Surveillance and Early Warning System (SEWS) is the most logical solution to the manpower shortage. Doing so would immediately add over 300 people to the corps of field experts who monitor pesticide use in the Philippines.

The PRA must have exclusive use of enough laboratories to handle the expected volume of analyses for regulatory monitoring. If the PRA cannot plan on having this capacity, it cannot effectively monitor pesticides either in the fields or in the distribution networks.

A basic aspect of scientific practice is independent confirmation of laboratory results. The PRA should regularly have independent analysts check the results of its own analyses. This serves as a check against problems in the chemical and administrative procedures of the PRA.

A network of field trials should be coordinated by the PRA, involving the RCPCs, the UP Medical School, and agricultural universities including the NCPC at UPLB. These research trials should allow the PRA to set standards and develop and test safe handling guidelines including those for protective clothing during application and for the minimum preharvest interval after final application.

To summarize:

- PRA must conduct quality control of chemicals on dealers' shelves. It must spot check these inventories to verify that labels accurately reflect the contents' quality and conformity to standards.
- To protect the Philippines from becoming a dumping ground for pesticides that are restricted elsewhere, the PRA must set and enforce standards on specific chemicals that can be used for each crop system. PRA should develop tropical environmental classifications instead of' simply adopting temperate-zone standards.
- The PRA must be given legal wherewithal to prosecute offenders in court.
- The PRA must be protected from interference from vested interests in the industry.

These recommendations are not mutually exclusive. With enough resources, they could all be followed simultaneously for the best possible social outcome. Given limited resources, however, the cheaper way to go is strengthening regulatory policies and adopting pricing policies that reflect social costs as well as resource costs of pesticide use.

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