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Pesticide Management and Integrated Pest Management in Southeast Asia

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Pesticide Management and Integrated Pest Management in Southeast Asia

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CONTENTS

FOREWORD vii
PREFACE ix

KEYNOTE PAPER

Future needs for pesticide management in Southeast Asia 1
I. N. Oka

IPM INFRASTRUCTURE

Overview of IPM infrastructure and implementation on food crops in Indonesia 13
Kasmo

Overview of IPM infrastructure and implementation on estate crops in Indonesia 21
S. Wirjosuhardjo

Overview of IPM infrastructure and implementation on food crops in Malaysia 27
A. H. Nik

Overview of IPM infrastructure and implementation on estate crops in Malaysia 31
B. J. Wood

IPM RESEARCH

Role of insect-resistant varieties in rice IPM systems 43
E. A. Heinrichs

The surveillance and forecasting of insect populations in rice pest management 55
K. L. Heong

The role of insecticides in rice IPM systems 67
D. Soekarna

Feasibility of using locally produced *Bacillus thuringiensis* to control tropical insect pests 73
E. H. Tryon and J. A. Litsinger

Role of cultural techniques in rice IPM systems 83
I. N. Oka

Development of action control thresholds for major rice pests 95
J. P. Bandong and J. A. Litsinger

Economics of integrated pest control in rice in Southeast Asia 103
H. Waibel and P. Meenakanit

Development of simple sampling methods for pest surveillance in rice 113
B. Heuel-Rolf and P. Vungsilabutr

Status of biological control in non-rice crops in Southeast Asia 123
B. Napompeth

Biological control of corn stalk borer in the Philippines 131
L. C. Tran-Gruber

IPM DEVELOPMENT

Crop protection and IPM in rainfed cropping systems in Northeast Thailand 135
W. Amaritsut, W. Prasartsri, and I. A. Craig
IPM of *Plutella xylostella* (L.) on vegetables in Southeast Asia: rationale, need, and prospects 145
G. S. Lim
An approach to integrated pest management: activities of the Philippine-German Cotton Project 157
V. Hasse, A. Drews, R. Corales and A. Querubin
Economic justification of IPM: the bilateral agency's view 169
T. Engelhardt
IPM activities in sugarcane in Thailand 175
O. Prachuabmoh, A. Kusulwong, K. Suwanarak, and P. Raksarast
IPM activities in coconut in Southeast Asia 181
R. Kaske
Pest management on oil palm in Malaysia 187
S. S. Liau
Pest management on cocoa in Malaysia 193
C. T. Ho
Crop protection and pest management of oil palm in Indonesia 205
A. Djamin
IPM in rice – an extension role for the agrochemical industry 213
W. T. Vorley

IPM IMPLEMENTATION

Communicating integrated pest control to rice farmers at the village level 221
M. M. Escalada and P. E. Kenmore
Factors affecting the success of extension-communication strategies used in a rice pest surveillance program in Thailand 229
J. Hamelink and S. Kaewjantuk
The organization of the Thai-German Plant Protection Program: a bilateral technical cooperation project 235
J. Schaefer
The organization and implementation of the surveillance and early warning systems in Thailand 241
S. Sri-Arunotai
Radio-based communication campaigns: a strategy for training farmers in IPM in the Philippines 251
E. H. Pfuhl

PESTICIDE RESISTANCE

Overview of pesticide resistance problems in Southeast Asia 257
T. Saito
Pesticide resistance problems in Malaysia 269
K. H. Tan
Pesticide resistance problems in Thailand 279
N. Sinchaisri

Pesticide resistance in the Philippines – an enigma waiting for solution 285
E. D. Magallona
The status of pest resistance to insecticides in Indonesia 291
D. Soekarna and D. Kilin
Pesticide resistance: the realities 297
D. M. Evans

PESTICIDE POISONING DATA COLLECTION

Health hazards due to the use of pesticides in Indonesia: data collection and surveys 301
M. Mustamin
Pesticide poisoning data collection in the Philippines 311
C. P. Castañeda
Pesticide poisoning studies and data collection in Malaysia 315
N. M. T. Aros
Pesticide poisoning studies and data collection in Thailand 321
S. Kritalugsana
Pesticide poisoning: improving and evaluating pesticide data collection in Southeast Asia 325
J. Jeyaratnam
Estimating the impact of poisoning: changing patterns of mortality in Central Luzon, Philippines, in relation to pesticide use 331
M. E. Loevinsohn

ENVIRONMENTAL CONCERNS

Pesticide residues in Thailand 343
N. Tayaputch
Pesticide residue studies in Malaysia 349
B. L. Hashim and H. F. Yeoh
Pesticide residues in the Philippines 355
V. E. Ramos-Ocampo, E. D. Magallona, and A. W. Tejada
Pesticide residue trials in rice in Indonesia 369
D. Soekarna
Pesticide residue control and monitoring in Indonesia 373
M. Soekardi
Pesticide residues in food and the environment: what do the levels really mean? 379
G. A. Willis
What do pesticide residue levels in the environment really mean in Southeast Asia: an NGO perspective 391
S. Rengam

LEGISLATION, APPLICATOR EXPOSURE AND PESTICIDE DISPOSAL

Manual on the use of pesticides under bank-financed projects 399
C. P. Rees

A comparative study on the occupational exposure of spray workers using knapsack and spinning disc sprayers 407
S. H. Tan, S. Ramasamy, C. H. Yeoh, and K. Ahmad
A preliminary study on exposure of rice farmers to pesticides 417
O. M. Alba
Destruction of pesticides and chemical wastes by means of a cement kiln 423
W. A. Schimpf
Looking for Thailand's "Love Canal" 433
J. K. Jensen and G. Zweig
Pesticide problems and Indonesian non-governmental organization activities in solving these problems 437
E. S. Widjanarka
A study of occupational pesticide exposure among Filipino farmers in San Leonardo, Nueva Ecija 441
C. P. Castañeda

PESTICIDE SAFE USE TRAINING PROGRAMS

Pesticide safe use training program in Malaysia 445
Y. M. Esa and S. Ramasamy
Pesticide safe use training programs in Indonesia 451
H. Siswomihardjo
Training the trainer by industry 457
E. F. Djohan
Train-the-trainer programs in Thailand 459
U. Dechmani
Pesticide safety training programs in the Philippines 463
A. V. Ordas
Pesticide safety campaign in the Philippines 469
S. A. Cuyson

FOREWORD

The Southeast Asian Pesticide Management and Integrated Pest Management Workshop held in Pattaya, Thailand, February 23–27, 1987, was organized by the Consortium for International Crop Protection (CICP) and the Ministry of Agriculture and Cooperatives, Thailand. The workshop was organized under the auspices of the "Pest and Pesticide Management" Project of CICP, which is funded by the Bureau for Science and Technology, U.S. Agency for International Development (USAID) in Washington D.C. Additional sponsors of this workshop were the Food and Agriculture Organization of the United Nations, the German Agency for Technical Cooperation (Deutsche Gesellschaft für Technische Zusammenarbeit or GTZ), the USAID Mission in Thailand, and the USAID Bureau for Asia and Near East.

Two hundred delegates from eighteen countries attended the workshop, and CICP is pleased to have been a catalyst in bringing together all these delegates, who collectively represented both public and private sector interests in this important topic. The program of the workshop consisted of formal presentations and a series of mini-workshops addressing specific issues. These mini-workshops in turn developed recommendations for future action on key issues. The formal presentations are documented in this book, while a booklet containing the executive summary of the workshop and recommendations of the twelve mini-workshops has been published with assistance from the regional office of the United Nations Environmental Program in Bangkok, Thailand. We in CICP are confident that the recommendations developed by the working groups will serve as an important platform to accelerate the implementation of IPM in the region, which will in turn help to reduce environmental pollution and pesticide-related hazards to human health, and lead to safer and more cost-efficient plant protection practices.

CICP is dedicated to environmentally-sound plant protection, and we look forward to working with scientists in this region towards that goal in the near future. The workshop delegates, in their wisdom, approved the creation of an *Action Committee* to ensure that the recommendations of the workshop will not languish files. The members of this committee will be drawn from representative national programs and international agencies, and CICP will take the lead in developing the role of this committee.

The workshop would not have been successful but for the tireless efforts of Dr. Harvey Riessig, Cornell University, U.S.A., and Ms. Janice Jensen, Pesticide Consultant in Bangkok. CICP expresses its appreciation to them, to our USAID project monitor, Dr. Carrol Collier, and to all the members of the Thai organizing committee. Thanks are also due to Ms. Joan Sarasin for arranging convention logistics, and to Dr. Terry Schmidt for helping facilitate deliberations in the mini-workshops.

A. L. Steinhauer
Executive Director, CICP

PREFACE

The Southeast Asian region is one of exciting changes in agricultural and industrial development. Associated with these changes, however, is the dilemma of higher crop productivity versus less environmental pollution and fewer health hazards. Pesticide use is increasing in Southeast Asia; so too is the awareness of potential hazards from their indiscriminate use, especially their effects on the environment, on man, and on the overall ecosystem. Throughout the region, estimates of crop losses due to all pests range from 10% to 30% per year, depending on crop and environment; at the same time, reports of pesticide poisoning of humans and livestock are frequent. Furthermore, the symptoms of irrational pesticide use – pest resurgences, development of resistance to select pesticides – are increasingly felt in many countries. To balance the twin needs of more food for growing populations and a cleaner, safer environment requires sound policy supported by credible science. Towards this end, the management of pesticides and the management of pests, which are often treated separately, need to be considered together as a single activity. The theme of this book, which reflects the theme of the workshop, is therefore pesticide management in the context of Integrated Pest Management (IPM).

IPM has been the conceptual basis for most of modern plant protection since the 1960s. The concept developed as a response to evidence of pesticide failures due to resistance development; but since then, IPM has become a focal point for interdisciplinary problem-solving in plant protection. In practice, IPM implies a "need-based" application of pesticides, and judicious use of pesticides in the context of a "best-mix" of control methods, such that there is no sole reliance on any one method for a prolonged period. The decision to use pesticides is made after appropriate determination of the magnitude of a pest problem, using sound methodology for pest intensity assessment and sampling, with a knowledge of the yield losses caused by the pest, and whether these losses exceed certain thresholds for action. IPM decisions on the level of a single field may often be influenced by the larger environment, since pests do not commonly recognize artificial boundaries. Surveillance systems have been implemented in several Southeast Asian countries to provide early warning of pest spread, so that a safety period is availed for making corrective actions. To practice IPM also requires that some basic infrastructure be present for plant protection, but this does not appear to be a constraint in the region. IPM technology has reached different levels of development and implementation for different pest-crop systems in Southeast Asia, and this will be shown by the papers in this book. We have organized the chapters so that readers will first be given an overview of the organizational aspects of IPM in national programs, followed by specific research highlights, and then aspects of IPM development and implementation.

The buildup of pest populations resistant to specific pesticides is a matter of concern to farmers, to IPM practitioners, and to the agrochemical industry. The status of this phenomenon is presented through a regional overview and specific country reports.

Problems associated with pesticide poisoning and pesticide residues are covered by twelve papers in the book. These chapters highlight methodology

weaknesses in assessing the impact of pesticides on human health, especially in the measurement of residue levels at different trophic levels of the food chain. It was therefore not surprising that the workshop recommended further investment of concurrent effort in the development of methodology, and of the facilities to use methodology for the above. Remaining papers in the book are concerned with pesticide legislation, applicator exposure, pesticide disposal, and training programs to ensure safe use of pesticides. Although many of the above topics concern regulatory agencies, they should nevertheless be of interest to researchers, who are primarily responsible for improving the many aspects of each topic.

Pesticide management should be viewed as an integral part of IPM, which in turn provides the *modus operandi* for modern plant protection. It is unfortunate that because many aspects of pesticide management are not "on-farm," while IPM is very much an on-farm activity, an integrated approach to both has not evolved. We sincerely hope that the Southeast Asian Workshop, and this book, will play at least a small part in bringing together the elements needed for an integrated approach to pesticide and pest management, at levels ranging from farmers to policy-makers.

The speakers at the workshop, and therefore the authors of these proceedings, come from different ethnic backgrounds. In the course of editing these proceedings, we have attempted as much as possible to preserve the linguistic flavor of the many cultural groups represented. Furthermore, we have only ensured that all citations in the papers are listed, but have relied on authors to check the accuracy of their literature citations.

Lastly, we would like to thank Ms. Siew-Fing Wong for her painstaking efforts in getting the manuscript into camera-ready form, and the International Rice Research Institute for allowing us time to edit these proceedings.

P. S. Teng
K. L. Heong

September 1988

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FUTURE NEEDS FOR PESTICIDE MANAGEMENT IN SOUTHEAST ASIA

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One of the major objectives of agricultural development programs in Southeast Asia is to increase food production so that the countries concerned can feed themselves and earn foreign exchange. Towards the year 2000 and beyond, these countries will have to face a continuing challenge to increase their food output because of the high population growth rate of 2% per year (World Bank 1982), and because of increasing demands for more and better quality food.

Food production in the region, particularly of rice, has been increased mainly by intensifying the productivity per unit land area through the use of modern high yielding varieties, improved irrigation systems, higher cropping intensity, increased inputs of chemical fertilizers, and last but not least, pesticides. An average increase of food output from 2.8% during 1960–1970 to 3.8% during 1970–1980 has been achieved. The per capita food output for those two periods also increased by 0.3% and 1.4%, respectively (World Bank 1982). Pesticides have become an integral part of modern rice technology in the region, not only for increasing and maintaining high crop productivity, but also for saving human lives. Pesticides are reported to significantly reduce yield losses from pest attack. Experiments with various insecticides, carried out by the International Rice Research Institute (IRRI), and in Malaysia and other countries to control a combination of rice insects, have given yield increases ranging from 1.29 t/ha to 1.35 t/ha (Lim & Heong 1984).

Pesticide use in Southeast Asia has been increasing since the early 1960s. Fragmentary data from Thailand revealed that in the early 1960s, rice areas treated with insecticides fluctuated between 125,000 ha and 268,000 ha, which corresponded to 1.9% and 4.5%, respectively, of the total rice area (Ishikura 1984). Recently, the annual demand for agricultural pesticides in Thailand was around 20,000 t and is forecasted to expand by 20% each year. Imports of insecticides in 1980/81 were 6,625 t; of fungicides, 2,864 t; and of herbicides, 7,000 t; while 1981/82 imports were 10,045; 3,025; and 9,441 t respectively (Anon. 1984b). There are 10 formulators in the country, and their number continues to increase (Anon. 1984a). In the Philippines about 54% of insecticides sold were used in rice insect pest control; 35% of the rice area was treated with granular insecticides, and 25% with liquids (Ishikura 1984). The Philippines has 27 formulation plants in operation. Prior to 1981 there was a steady 15% growth in demand per year for pesticides, and in the same year, total demand was 34,000 t (Anon. 1984a).

In Vietnam, the use of pesticides has also increased. Import of pesticides in 1982 was 11,680 t while in 1983 it was 23,970 t, an increase of more than 200% (Bateman & Watt 1985). In Malaysia, estimates of apparent consumption of pesticides have been made on the basis of actual production and net imports. Between 1976 and 1980, the apparent consumption of liquid pesticides fluctuated between 9,709 L and 11,200 L, but non-liquid pesticides increased from 12,950.4 t to 16,444.2 t. About 75% of the pesticides used in Malaysia are herbicides extensively applied in rubber, oil palm, and cacao plantations (Anon. 1985).

In Indonesia, about 16% of the total 1970/1971 wet season rice crop received pesticides, i.e., 1.3 million ha. From 1974 to 1982 pesticide use for rice increased dramatically by 644% (Bimas 1982). The government food production project (BIMAS, INMAS) makes up about 75% of the pesticide demand; the remaining 25% is consumed by estate crops, horticulture, health and household uses (Anon. 1984a). Indonesia is striving to gradually become more independent of the importation of pesticides. In addition to the 11 domestic pesticide formulators already in operation, the government decided to operate the first government-owned manufacturing plant for producing active ingredients of diazinon (2,000 t/year), BPMC (900 t/year), and MIPC (400 t/year). Another seven companies have so far been given licences to build manufacturing plants of active ingredients (Anon. 1984a).

The use of pesticides is expected to increase in the near future, and this is based on the fact that they have demonstrated their potential for increasing crop yields in Indonesia, and to the belief of many people that other control alternatives, such as host plant resistance and biological control, are slow and limited (Ishikura 1984).

Pesticide use is a mixed blessing. While its benefits for preventing crop losses and saving human lives are well recognized, it very often results in unwanted side effects. The issue is therefore careful judgement and evaluation of the benefits and risks of pesticide use so that the efficacy and efficiency are maximized and, concurrently, unwanted side effects are minimized to tolerable levels.

The trend of increasing demand for pesticides in Southeast Asia is causing great concern to those who are aware of the environmental risks of pesticide use.

ENVIRONMENTAL RISKS OF PESTICIDES

There are major safety issues associated with the manufacture, transportation, and use of pesticides. Data on pesticide poisonings and fatality cases in developing countries are fragmentary. For example, reported cases of pesticide poisoning in the Philippines are limited to patients admitted to government hospitals. More than half were suicidal, more than 20% accidental, and fewer than 15% were work related (Castaneda & Maramba 1984). Between 1981 and 1984 as many as 1,400 cases of poisoning due to pesticides were reported in the Philippines, of which 137 proved to be fatal. In Malaysia, during the brown planthopper (BPH) outbreak in 1977, 17 farmers succumbed to

poisoning from the highly toxic dust of carbofuran granules (Anon. 1985). In Indonesia, from April 1985 to March 1986, cases of death and poisoning due to pesticides were 62 and 324 persons respectively (Directorate of Food Crops Protection 1986). Pesticide poisoning may occur during the manufacture and formulation of pesticides, while loading sprayers or, most frequently, during the actual application of pesticides on crops. Farmers are exposed through dermal contact and inhalation of fine particles or vapor, particularly in developing countries where most farmers are unaware of the toxic nature of pesticides. Protective clothing has been designed, such as a completely closed mask that circulates air through a filter and which can be equipped with a refrigeration system for use in warm climates (Yates et al. 1981). However, most Southeast Asian farmers may not be able to afford such a device. Other cases of accidental poisoning are exposure to pesticides during storage and transportation, and contamination of foodstuffs. Accidents may also arise from spillage of pesticides in storage and transportation and from the use of unlabeled pesticides by mistake for food and drink (Oka 1983). In villages, people bathe or wash their clothing in irrigation drainage canals or rivers that may be contaminated with pesticides originating from nearby rice fields. We suspect that there may be cases of chronic toxicity, cancers, spontaneous abortion or abnormal offsprings, but unfortunately no documented reports are available.

The development of pest resistance to pesticides has been demonstrated in 16 orders of arthropods totalling 428 species (Georghiou & Hellon 1983). A pest may become resistant to one formulation of pesticides, to chemically related pesticides (cross resistance), or to a variety of insecticides with differing modes of action-detoxification pathways (multiple resistance). All the above seriously limit the choice of available pesticides (Litsinger & Sanchez 1984). Most of the work on the resistance of a number of rice insects to pesticides has been done in Japan (Nagata & Mochida 1985). Data on insect resistance to pesticides in Southeast Asia are rare. Brown planthoppers in the Philippines have been reported resistant to BPMC, acephate and chlorpyrifos-BPMC (Mochida & Basilio 1983); and to carbaryl, carbofuran, diazinon, and malathion (IRRI 1984). The GLH in Indonesia was reported to be resistant to fenitrothion, diazinon, and carbaryl (Merthakota & Sutrisno 1982). The diamondback moth *Plutella xylostella* has most likely developed multiple resistance to insecticides in Indonesia since various pesticide formulations have become ineffective.

Extensive studies have been carried out on the resurgence of BPH in the Philippines (Chelliah & Heinrichs 1980) and in Indonesia (Oka 1978, Soekarna 1979, 1981). Destruction of the natural enemies of the insect due to intensive application of broad spectrum insecticides, the phytotonic effect of certain pesticides (Chelliah & Heinrichs 1984), and increased feeding rates, and stimulation of BPH reproduction due to some pesticides (Chelliah 1979, Chelliah & Heinrichs 1980) are some of the factors causing BPH resurgence. Also, pesticide application at sublethal dosages (Chelliah 1979), differential insecticide rates (Chelliah & Heinrichs 1984) and timing, and the number and methods of application can induce BPH resurgence (Heinrichs et al. 1982). To date, all classes of insecticides studied have been identified to induce resurgence

(Castaneda & Maramba 1984, Reissig et al. 1982). Two examples illustrate the effect of pesticides on non-target species and as a cause of secondary pest outbreaks: the first was the destruction of inland and coastal fish populations in East Java following aerial application of endosulfan on rice fields in 1968, and the second was the outbreak of rice gall midges in West Java subsequent to the aerial spraying of phosphamidon to control rice stemborers in 1969 (Oka 1983a, b).

Pesticide residues in foodstuffs, particularly in vegetables, are also of much concern. Although farmers are commonly told that the last pesticidal spray on vegetables should be carried out at least two weeks before harvest, they nevertheless keep spraying. This is partly due to the changing attitudes of consumers, who prefer unblemished vegetables. Cases have also been reported of DDT contamination of export commodities like tea and tobacco.

Adulteration of pesticides, cross-labelling, rebottling, and repackaging, frequently occur. In view of the projected demands for pesticides in Southeast Asia in the near future, the problems of toxicity, pest resistance, resurgence, and other unwanted side effects certainly will become more serious. Therefore, proper pesticide management throughout the region is a must, and existing management practices should be improved. Good pesticide management will strengthen the implementation of IPM programs in Southeast Asia.

THE CONCEPT OF PESTICIDE MANAGEMENT

Selectivity

To increase the "harmony" of integrating pesticides with non-chemical control tactics, the pesticide to be used should be selective, i.e., it should only destroy pests with little or no side effects on non-target animals or plants. However, such ideal conventional pesticides with intrinsic selectivity are rare (Way 1977). Moreover, intrinsic selectivity, if present, is limited to only a group of non-target species. For example, permethrin and fenthion are selective in favoring mammals (Norway rats), but not very selective in favoring fish (trout) (Reissig et al. 1982). Consideration of pesticide selectivity in favoring fish is very important in rice-fish cultures. Of special relevance is selectivity of pesticides to favor natural enemies of pests and beneficial insects. In rice pest control, pyridafenthion and tetrachlorvinphos are highly selective, favoring the wolf spider *Lycosa pseudoannulata*, but toxic against its prey, the green leafhopper. Lindane and fenthion, on the other hand, selectively favor the pest. Malathion, diazinon, and carbaryl have selective values of 2.7, 1.5 and 2.3 respectively, and may be less toxic to *Lycosa* than to the pests (Shepard & Brown 1984). Insectistatic chemicals (molting inhibitor) like buprofezin have been reported to be highly effective against BPH and to be safe for its natural enemies (Sogawa, pers. comm.).

Operational Factors

Operational factors such as time of application, formulation, methods of application, dosage, and biodegradability are very important to increase pesticide selectivity.

The most proper time for applying insecticides in rice pest control is early in the morning or late in the afternoon when the wind is calm. This prevents drift or percolation of the pesticides, thus enabling most of the pesticides to reach the target pests.

Proper application methods of insecticides are related to their formulations. The possibility of farmers getting poisoned with granular insecticides like carbofuran is less compared with spray formulations, provided they properly protect their hands with gloves or plastic bags when broadcasting the granules. With spray or dust formulations, certain amounts of the solution or fine particles may contaminate clothing and skin, and some of the pesticide particles in the air may also be inhaled. The advantages of emulsifiable concentrate (EC) formulations are that they are easy to transport, not bulky, and can be applied at any growth stage of the plant. Seed treatments, particularly with systemic pesticides, provide minimum dosage and high ecological selectivity (Metcalf 1984). Effective control against downy mildew *Sclerospora maydis* on corn is by seed treatment with a systemic fungicide, ridomil. Only 5 g of the fungicide formulation is needed for every kg of corn seed. Spot treatments will use much smaller amounts of pesticides, and therefore are less damaging to biological control agents and other non-target species. This method of application is most appropriate on pests occurring in foci like BPH and WBPH during the early stage of an outbreak. Rat control may be effectively carried out by the ecologically sound method of baiting the animals with 8 cm^3 wax cubes containing rice bran mixed with the anticoagulant rodenticide, Klerat RM.

Reduced rate of application of pesticides is also pertinent to good pesticide management. It relates to economic thresholds of the target pests and the duration of the effective residues. For example, the insectistatic buprofezin needs to be applied only once at 40 DAT to effectively control the BPH while BPMC needs to be applied twice to obtain the same level of control as buprofezin (Panoedjoe 1980).

The use of pesticide mixtures should be avoided because the mixtures generally result in the simultaneous development of resistance (Metcalf 1984). Slow release of pesticides should also be discouraged to avoid development of resistance of the pest to the insecticides (Litsinger & Sanchez 1984) due to a continuous selection pressure. Moreover, it is a wasteful practice since the pest may not occur at all growth stages of the plant. To prevent development of cross resistance and multiple resistance in pests, a choice of suitable alternative insecticides should be made based on the genetics underlying the resistance (Brown 1977 as cited by Metcalf 1984).

It is important that there be continuous monitoring of the development of resistance in field populations of the pest, using standardized methods.

Economic Threshold Levels

The determination of realistic economic threshold levels that relate crop damage to pest population densities is basic to IPM. Economic thresholds should be used only when non-chemical control methods are ineffective to suppress pests. Economic threshold levels for most important rice pests have been determined. When BPH numbers on susceptible rice varieties are 10, 25, and 50 per hill at 14–18 days, 35–63 days, and booting and ripening stages respectively, pesticide treatment is necessary. On resistant rice varieties, the threshold is twice that of the susceptible varieties (Soekarna 1981). The threshold level for the yellow rice stemborer *Scirpophaga incertulas* is 10% plant damage at maximum tillering stage, or one egg cluster per 16 hills (1 m^2) (Soejitno 1976). The most proper time to control gall midge *Orseolia oryzae* is when there are 5% "silvershoot" before maximum tillering (Soekarna 1981). The economic threshold for *Leptocorisa oratorius* lies between 2 and 5 insects per m^2 of paddy field (Oka et al. 1983). A preliminary threshold of 0.5 GLH/sweep in the early vegetative stage of rice (transplanting to 30 DAT) is recommended when RTV is endemic in the area (IRRI 1979). This will avoid unnecessary pesticide applications and fixed calendar schedules, and therefore markedly reduce the frequency of treatment.

PESTICIDE REGULATIONS

Pesticide regulations deal with various aspects of pesticide management, usually starting with registration, permits, safe handling and use, storage, transport, disposal, and sanctions to violators. A number of Southeast Asian countries have established their own pesticide regulations dealing with aspects of production, registration and use of pesticides. Basically, these legislation are in conformity with the FAO guidelines (FAO 1985). Table 1 presents data on four countries in Southeast Asia, their respective legislation and rules, and the administering authorities.

In Indonesia, Government Decree no. 7 is enforced by the Pesticide Commission. The Chairman of the Commission is the Director of Food Crops Protection under the Ministry of Agriculture, and the members of the Commission are experts from research institutes, and the Departments of Health, Labor, Trade, and Environment.

Vietnam recently established a pesticide quality control laboratory within the Ministry of Agriculture (Bateman & Watt 1985), as a first step towards better pesticide management.

One weak point in existing pesticide regulations in Southeast Asia is, perhaps, not so much the content of the regulations, but their enforcement. This is due to various factors such as lack of well-trained personnel to enforce the provisions of the regulations; inadequate physical facilities (pesticide residue laboratories, quality control); lack of or inadequate public awareness of the dangers of pesticides to human beings and the environment; ignorance of most

Table 1. Pesticide legislation, rules and administering authorities in some Southeast Asian countries.

Country	Legislation and rules	Administering authority
Indonesia	Government decree No. 7(17 March, 1973); some controls instituted in 1969 before the enactment of legislation, but actual implementation through: (a) Decree No. 280, June 1973 on pesticide registration procedures; (b) Decree No. 429, September 1973 on labelling and packaging; (c) Decree No. 944, November 1984 on limitation of pesticides registered.	Directorate of Food Crop Protection, Ministry of Agriculture
Malaysia	Pesticides Act 1974 (a) Pesticides Rules, 1976 on registration procedures; (b) Pesticides Rules, 1981 on Importation for Research Purposes	Pesticides Board, Department of Agriculture
Philippines	P.D. 1144, 30 May 1977 EPA Rules and Regulations No. 1, Series of 1977	Fertilizer and Pesticide Authority, Ministry of Agriculture and Food
Thailand	Poisonous Articles Act 1967 (Amended 1973) (a) Ministerial Regulation BE 2512	Agricultural Regulatory Division, Department of Agriculture

farmers on the proper use and handling of pesticides; and the lack of responsibility of most pesticide distributors, who sell expired pesticides at low prices. The above practices were reportedly common in Thailand (Pothisiri 1985), together with inadequate education and extension programs on various aspects of pesticides. In Indonesia, heavily subsidized pesticides tend to encourage farmers to use more pesticides indiscriminately, while there is a relatively poor monitoring and reporting system on import/export, usage and other aspects of pesticides, including human poisoning and fatality cases.

The first priority of FAO activities in the field of plant protection should be to assist in developing national pesticide regulatory programs. This has been partly done, as reflected in the establishment of four FAO Panels of Experts, one

of which is the "Panel of Experts on Pesticide Specification, Registration Requirements and Application Standards". The Panel published two booklets entitled "Guidelines for Legislation concerning the Registration for Sale and Marketing of Pesticides" and "A Model for the Establishment of National Organizations for the Official Control of Pesticides". These booklets provide broad policy guidelines on various aspects of pesticide management (FAO 1985). Countries in Southeast Asia in the process of establishing pesticide regulations will find these booklets very valuable.

With regards to residue problems in food, the FAO "Panel of Experts on Pesticide Residues in Food and Environment" has established the "Acceptable Daily Intake" for humans, of more than 180 compounds.

The responsibility for safe and effective pesticide management does not only rest with the Government but also with all public sector groups, i.e., scientists, pesticide industry personnel, traders, farmers, consumers, environmentalists, health workers, laborers, formal and informal leaders, etc. The public sector groups should share in these responsibilities and participate in the successful implementation of regulations. Because of the dynamic nature of modern plant protection technologies, the existing Pesticide Regulations should also be amenable for improvement to meet changing needs. The governments of Southeast Asian countries who have already made several adjustments to their respective regulations as needed, should continue to do so.

Public sector groups should actively interact with the government in providing information on the socioeconomic as well as technical problems that arise from pesticide use. In this regard, the International Code of Conduct recently developed by FAO (1985) is particularly of value to those countries that do not yet have control procedures for development, distribution and use of pesticides, or those countries with inadequate pesticide regulations.

One important point to consider is harmonization of pesticide registration requirements. There has been good progress made in this respect through the activities undertaken by the Regional Network on Pesticides for Asia and the Pacific (RENPAF) (Gaston 1986). We suggest that RENPAF continue to hold periodic consultations to encourage harmonization in other aspects of pesticide management. The agrochemical industry has reacted positively to the Code and has actively participated in its formulation. Industry has already adhered to many of the Code's provisions, for example, the safe application of pesticides, and training for safe-handling guidelines of various aspects of pesticide safety (Aebi 1986).

CONCLUDING REMARKS

Training in various aspects of pesticide and pest management for officials engaged in law enforcement is essential to increase the effectiveness of their operations. Some training should also be given to plant protection field workers, pesticide distributors, retailers, and last but not least, to farmers who directly work with pesticides. Vigorous action should be taken to better cope with pesticide residues in food and environment, problems that have become

significant in Southeast Asia. In this respect, more trained manpower and laboratories to facilitate analysis and monitoring of pesticide residues are urgently needed. Countries within the Region should closely cooperate in this important issue. The proposal of a group of developing countries, which met in Thailand in 1984 for establishing a Regional Pesticide Training Center and Service Laboratory, should be fully exploited.

Public awareness of the benefits and risks of pesticides to health and environment should be increased through various activities. Television, radio, mass media, and periodic gatherings are effective means for this purpose. Close collaboration among government officials and various public sector groups is essential in this respect.

In the future, selective pesticides such as botanicals and insectistatics, are likely to be in higher demand than broad-spectrum pesticides, although it is understood that the manufacture of selective pesticides is getting more and more difficult, and therefore very costly.

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OVERVIEW OF IPM INFRASTRUCTURE AND IMPLEMENTATION ON FOOD CROPS IN INDONESIA

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In her effort to increase production of food crops and to cope with the ever-increasing food demand due to rapid population growth, Indonesia implemented four main agricultural programs emphasizing intensification, extension, diversification, and rehabilitation, respectively. The implementation of the intensification program focused on rice production by means of five principal efforts (the so-called 'Panca usaha') that consists of (1) utilization of improved varieties, (2) good soil management, (3) good water management, (4) better fertilization, and (5) adequate crop protection. The 'Panca usaha' has been considered successful in the sense that it led Indonesia to self-sufficiency in rice in 1985 (Table 1). The challenge now is to maintain this level of production bearing in mind that the annual rate of population growth is still considerably high.

Next to rice, the production of maize soybean, and peanuts is to be increased through diversification and intensification programs. However, the

Table 1. Rice (milled) production in million tons for 1970–1985.

Year	Production
1970	13.1
1971	13.7
1972	13.2
1973	14.6
1974	15.3
1975	15.2
1976	15.8
1977	15.9
1978	17.5
1979	17.9
1980	20.2
1981	22.3
1982	22.8
1983	24.0
1984	25.8
1985	26.6

Table 2. Order of importance of rice pests in Indonesia based on cumulative weights of infestation for 1979–1985.

Rice pest	Cumulative weight[a] of infestation intensity	Order of importance
Brown planthopper (BPH)	29,750,729	1
Rat	21,268,828	2
Rice stemborer	11,302,015	3
Leaf folder/leaf roller	6,770,431.4	4
Rice bug	5,116,307.6	5
Army worm	4,142,039.2	6
Rice gall midge	1,427,661.2	7
Stink bug	1,017,403.2	8
Green stink bug	353,530.1	9
Wild pig	347,869.2	10

[a]Cumulative weight of infestation intensity $= \frac{\text{area infested x intensity}}{\text{area infested}}$

targets for these commodities so far have not been met, one reason being that as the programs are being implemented, pest problems have increased, particularly in rice (Table 2).

To cope with pest problems, Indonesia used to rely on the "single control technique" approach, which employs either resistant varieties or intensive chemical sprays. This approach seemed to be disadvantageous as it brought about the occurrence of biotypes, pest resistance, and resurgence.

The Integrated Pest Management (IPM) or Integrated Pest Control (IPC) approach was then introduced and developed in the 1970s. Nevertheless, implementation of this approach in operational terms could not be smoothly done. There were constraints, which were more institutional and perceptional than technical in nature, until a breakthrough was made with the issuance of the Presidential Instruction known as Inpres no. 3 1986. This instruction made IPM a national policy and strategy for crop protection. It stipulated the utilization of natural enemies, cropping patterns, and resistant varieties as the major components of control. Pesticides could only be applied on a need basis to avoid undesirable impact on natural enemies, or on resistance, resurgence, and environmental pollution.

IPM INFRASTRUCTURE

The government has organized a number of institutes to implement its crop protection programs, and these are:

1. At the Central level: the Directorate of Food Crop Protection, which is responsible for the formulation of national policy, strategy and program, and for supervising and providing guidance during implementation.

2. At the Regional level: Crop Protection Centers, responsible for giving technical support to the Provincial Agriculture Agency in providing farmers with (1) timely information of pest occurrence, (2) appropriate control methods and (3) judicious pesticide use recommendations. The functions of the technical staff include (1) carrying out adaptive trials on farmers' fields to obtain appropriate recommendations for control methods, (2) pest surveillance to enable them to give timely and proper information, and (3) inspection of the storage, distribution, and the use of pesticides. At the Provincial level, the Crop Protection Division of the Agriculture Agency is concerned with the motivation of farmers, dealing with their awareness, equipment support, guidance, and mobilizing crop protection brigades for emergency or outbreak cases.
3. At Agriculture Development Area level: At this level a field laboratory is developed which represents a Crop Protection Center's working unit with the following functions:
   a. to analyze data delivered by pest observers.
   b. to carry out pest surveillance.
   c. to carry out studies on pest occurrence, biology, ecology and its population dynamics, and
   d. to inspect and coordinate pest observers' activities.
4. At Rural Extension Center Working Area level: At this level, which covers about 6,000–10,000 ha, pest observers are responsible for pest observation and monitoring the results which are used as information to determine what precautionary measures are needed.

Through technical cooperation with the Japanese government, the infrastructure will be considerably strengthened both in terms of hardware and software.

IPM PROGRAM IMPLEMENTATION

To make the IPM approach more acceptable to farmers and to convince them of its soundness so that they will be motivated to practice it, some IPM pilot projects were started from 1979 on in cooperation with FAO (Table 3). The projects generally lasted 3–5 years and had different activities (Table 4).

Meetings

Meetings were held every season when planting time was about to begin and involved subject matter specialists, senior extension workers, pest observers, agricultural extension workers, seed growers and farmer leaders. Work plans were formulated in these meetings and solutions to potential problems were discussed. Additionally, during the crop season biweekly meetings were held in which senior extension workers and key farmers discussed solutions to their problems.

Training of Technical Staff

These were carried out in order to improve the working abilities of pest observers, and senior and field extension workers. The training dealt with ways of organizing, coaching and guiding farmers to make them better acquainted with IPM concepts and application in the field.

Courses for Key Farmers

Courses were given to teach key farmers to be motivators of their followers and to be multipliers in the technology transfer process.

Pest Scouting

Scouting activities were carried out by pest observers with the assistance of key farmers and field extension workers, and were coordinated by the pest-observer coordinator.

The projects have been evaluated by the Bogor Agriculture Institute (IPB) and considered a success based on the following data:

i. farmer institutions have been growing and becoming more active,
ii. there are more control equipment possessed by farmers,
iii. better response of farmers trained as pest observers in the project areas,
iv. there are more farmers trained as pest observers in the project areas,
v. government officers are better equipped with knowledge of pests and IPM concepts,
vi. there are more IPM components incorporated in the control techniques, and
vii. farmers reap bigger harvests.

Table 3. IPM pilot project implementation.

Year	Rural extension center working area	Regency	Province
1979	Jatisari	Karawang	West Java
1979	Sereang II	Sidenreng Rappang	South Sulawesi
1979	Muara Mulia	Simalungun	North Sumatera
1979	Sewon	Bantul	Yogyakarta
1980	Paduraksa	Pemalang	Central Java
1982	Tanggul	Jember	East Java
1984	Kepala Hilalang	Padang Pariaman	West Java
1984	Mengwi	Badung	Bali
1984	Gambut	Banjarbaru	South Kalimantan
1984	Sumber Suko	OKU	South Sumatera

Table 4. IPM project activities in 10 locations, 1985.

Location	Coordination meeting	Staff training	Farmers courses	IPM demonstration	Complementary study
North Sumatera	1 x (Jul)	1 x (Jul)	1 x (Jul)	1 x (Oct)	1 x (Oct)
West Sumatera	2 x (Jul, Oct)	2 x (Jul, Oct)	2 x (Jul, Oct)	1 x (Oct)	1 x (Oct)
South Sumatera	1 x (Sep)	1 x (Oct)	1 x (Oct)	1 x (Oct)	1 x (Oct)
West Java	1 x (Sep)	1 x (Oct)	1 x (Oct)	1 x (Oct)	1 x (Oct)
Central Java	1 x (Aug)	1 x (Aug)	1 x (Oct)	1 x (Nov)	1 x (Nov)
Yogyakarta	1 x (Aug)	1 x (Sep)	1 x (Oct)	1 x (Oct)	1 x (Oct)
East Java	1 x (May)	1 x (May)	1 x (May)	1 x (May)	1 x (Oct)
Bali	2 x (Jun, Jun)	2 x (Jul, Nov)	2 x (Aug, Nov)	2 x (Apr, Nov)	1 x (Oct)
South Kalimantan	2 x (May, Oct)	2 x (Jul, Nov)	2 x (May, Nov)	1 x (Jul)	1 x (Oct)
South Sulawesi	2 x (May, Oct)	2 x (May, Nov)	1 x (Jul)	2 x (Apr, Oct)	1 x (Oct)

MEASURES AGAINST THE BPH THREAT

The Indonesian government is very confident that IPM measures can solve the BPH problem. Although IPM has been implemented since the early stages of the rice intensification program, poor pest control practices are still encountered at the farm level, some of which have resulted in the emergence of resistance and resurgence. Because of this, an intensive campaign is now being launched by means of the following activities in line with the Presidential Instruction No.3 1986 (Kasmo 1986):

1. Setting up of operational units down to the lowest level of administrative unit (the village) to organize BPH management.
2. Recruiting more pest observers. (There are now about 3,000 persons.)
3. Conducting BPH surveillance throughout the threatened areas.
4. Conducting IPM training and courses for officers and farmers supported by the FAO Regional Program for Southeast Asia (Table 5).
5. Conducting on-farm IPM demonstrations in collaboration with the FAO Regional IPC Program for Southeast Asia (Table 6).
6. Mobilizing crop protection brigades together with the needed equipment and supplies.
7. Implementing a regular reporting system.
8. Utilizing all kinds of available mass media such as television, radio, periodicals,and newspapers to familiarize farmers with the BPH problem and how they should cope with it using the IPM concept, viz.,
   - natural enemy buildup and conservation,
   - improved resistant varieties,
   - cropping patterns (rotation, synchronized planting), and
   - wise need-based insecticide use.

Table 5. Number of participants in IPM officers training (FAO-DFCP), 1985.[a]

Province	PO	SEW	FEW	KLAA	Total
North Sumatera	10	5	15	-	30
West Sumatera	6	2	22	-	30
South Sumatera	8	2	20	-	30
West Java	8	4	18	-	30
Central Java	8	7	21	-	36
D.I. Yogyakarta	7	2	18	4	31
East Java	8	2	20	-	30
Bali	6	3	21	-	30
South Kalimantan	8	2	20	-	30
South Sulawesi	7	2	21	-	30
Total	76	31	196	4	307

[a]PO = Pest Observer, SEW = Senior Extension Worker, FEW = Field Extension Worker, KLAA = Kecamatan Level Agriculture Administration.

Table 6. Distribution and number of IPM demonstration plots (1985).

Province	No. of plots
North Sumatera	160
West Sumatera	160
South Sumatera	160
West Java	160
Central Java	160
D.I. Yogyakarta	160
East Java	160
Bali	160
South Kalimantan	160
South Sulawesi	160
Total	1600

9. Selecting the kind of insecticides which can be applied on rice pests to allow for natural enemy buildup.

It is planned that all these activities will be carried out before each rice-planting season starts in order to avoid BPH infestations that will otherwise be economically injurious. It is hoped that the success of the campaign will enable Indonesia to control the BPH problem.

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OVERVIEW OF IPM INFRASTRUCTURE AND IMPLEMENTATION ON ESTATE CROPS IN INDONESIA

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Estate crops have been given top priority in the national development plan of Indonesia. It is felt that further improvement in the production of estate crops should bring about a corresponding increase in national income as well as the income of individual farmers, and at the same time create more job opportunities and reduce dependence on imports such as cane sugar and cotton.

There are approximately 9.4 million ha of estate crops, of which 8.1 million (87%) belong to smallholders, 0.8 million (8%) are government-owned estates, and 0.5 million (5%) are private estates. The crops include annual crops such as sugarcane and tobacco, and perennial crops like coconut, rubber, oil palm, cocoa, and coffee. More than 20 crop species are grown as estate crops.

Considering the large number of crop species and management patterns, the development of estate crops is done through various projects. However, primary attention is given to the development of smallholders and to crops like rubber, sugarcane, coconut, oil palm, and cotton. Estate crop development is divided into three programs, namely:

1. The Nucleus Estate and Smallholder (NES) project, which includes a government estate as the nucleus to provide the necessary services and facilities to smallholders in a specific new area,
2. The Project Management Unit (PMU), providing similar services and facilities for smallholders in existing areas, and
3. The partial project, in which the smallholder is given only partial assistance.

As of 1986, the NES project area was 401,950 ha, the Project Management unit area was 673,440 ha, and the remaining were partial assistance project areas. Assistance to smallholders consists of providing seeds, fertilizers, pesticides, and services related to crop protection, extension, harvesting, yield processing, and marketing.

Adequate crop protection is necessary to further guarantee the success of these programs. Therefore, crop protection has been an essential component in all institutions and agencies dealing with estate crops. To keep up with pest problems of increasing complexity, estate crop protection services must be continuously improved and oriented towards the implementation of integrated pest management (IPM), since the concept of IPM has been adopted as a national policy in Indonesia.

THE PEST SITUATION IN ESTATE CROPS

In the past, pests have always created serious problems on estate crops, often resulting in huge losses and drastically affecting the welfare of the people involved. One example is the Sexava problem on coconut in North Sulawesi, which forced people to migrate from the Talaud islands to other parts of Indonesia and even to the Philippines in 1938. The copra yield in Talaud dropped to 1.6 kg per tree compared to 7.3 kg in the neighboring islands where there were less Sexava infestations. Another example is the rust disease which forced the government to have all Arabica coffee destroyed in the 1920s.

At present, pests remain a significant limiting factor in the intensification of estate crop production. As a consequence of the development of estate crops, minor pests have become major ones because of the sudden abundance of food, especially in new areas which were previously forests. Table 1 shows the total area affected by various pests from 1980 to 1984.

In 1980 alone, the Directorate of Estate Crop Protection estimated the level of infestation and annual value of crop losses on selected estate crops as follows: insects at infestation levels from 5% to 70% (mean 25%) causing estimated losses of Rp20 billion (US$32 million) mainly on coconut and coffee; diseases with infection levels ranging from 15% to 62% (mean 27%) causing a loss of Rp11 billion (US$18 million) mainly on cloves and rubber; and weed infestation causing losses valued at Rp100 billion (US$166 million) mainly on rubber, coconut and coffee.

Insects are the most important group of pests on estate crops. They can cause damage ranging from light to very severe, sometimes resulting in the death of the crop. Some of the major insect pests of important estate crops are listed in Table 2. Besides insects, vertebrate pests may also cause serious damage to estate crops. These include rodents, wild pigs, and elephants. The intensity of damage is usually more severe near fallow lands, uncultivated areas, and secondary forests.

Although plant disease epidemics are not as widespread as insect infestations, they cannot be ignored in the development of estate crops. A number of diseases, previously of minor importance, have become major ones causing damage over large areas. Examples are the Phyllosticta leaf disease on cloves, Xylem Limited Bacteria (XLB) also on cloves, and the Vascular Streak Dieback (VSD) on cocoa. Besides these pathogens, others which have been

Table 1. Total area (in hectares) of estate crops damaged by pests during 1980–1984.

Year	Insects	Pathogens	Weeds[a]	Total
1980	350,000	38,000	884,000	1,272,000
1982	898,000	259,000	134,000	1,291,000
1983	714,000	259,000	NR	1,003,000
1984	120,000	45,000	NR	165,000

[a]NR = no report.

Table 2. List of some of the major estate crop insect pests.

Estate crops	Pest species	Distribution
Coconut	*Oryctes rhinoceros*, *Brontispa longissima*, *Tirathaba* spp., *Batrachedra arenosella*.	All over Indonesia
	Artona catoxantha, *Hidari irava*, *Sexava* spp. *Aleurodicus destructor*	At most coconut areas in Indonesia
Cocoa	*Conopomorpha cramerella*	At several cocoa plantations in Indonesia
Coffee	*Hypothenemus hampei*	At most coffee plantations in Indonesia
Cotton	*Heliothis armigera*, *Spodoptera* sp., *Earias* spp.	All cotton plantations
	Empoasca sp., *Pectinophora* spp.	At several cotton plantations
Tobacco	*Heliothis* sp., *Spodoptera* sp.	At most tobacco plantations

Table 3. List of some of the major estate crop diseases.

Estate crops	Major diseases	Distribution
Cloves	Leaf disease, *Phyllosticta* sp.	At most clove plantations
	Xylem Limited Bacteria	At several clove plantations
Pepper	Foot rot disease, *Phytophthora* sp.	At most pepper plantations
Cocoa	VSD, *Oncobasidium theobromae*	Most of cocoa main producing areas
Coffee	Leaf rust, *Hemileia vastatrix*	Several coffee plantations

known for a long time are still potentially capable of causing serious damage if neglected. Table 3 shows a list of some of the major diseases on estate crops.

In the case of weeds, damage to crops are not usually apparent as in insects or pathogens where one can see the characteristic injuries or symptoms on the plant. Weeds, therefore, are usually ignored. However, both direct and indirect damage due to weeds have caused tremendous losses. The major weeds include alang-alang (*Imperata cylindrica* [L.] Beauv.), *Cyperus* spp., and other broad leaf species.

PRESENT STATUS OF PEST MANAGEMENT IN ESTATE CROPS

In Indonesia, the estate crop grower is responsible for the pest management of his crop. The Government only provides advice, training, and extension to the grower for effective, safe, and economic pest management methods. In certain situations the government may provide pesticides at subsidized prices or give free pesticides in extreme circumstances such as insect pest outbreaks or disease epidemics.

As a result of government assistance through training and extension, and together with their personal experiences, farmers have implemented some methods of pest management by themselves. These methods range from traditional, such as mechanical and cultural methods, to biological and chemical controls. Previously, these crop protection measures were satisfactory, but with the expanded development of estate crops, more complex pest problems arose, resulting in more extensive use of chemical pesticides, usually replacing traditional methods and biological control.

At present no evidence exists for the development of resistance by estate crop pests to chemicals. However, considering the experience in other countries and also for efficient and economical operation of estate crop production, pest management in estate crops is now being directed towards implementation of IPM. Presently some components of IPM are available in Indonesia, and can be utilized for initiating IPM pilot projects and, eventually, for general recommendations in the management of a number of pests on several estate crops. These components include biological control, which has been practiced in Indonesia for about four decades, cultural and mechanical controls, and regulatory measures.

In the case of coconut, chemical pesticides are not recommended for the control of *Oryctes rhinoceros* L. and *Brontispa longissima*. Instead, a combination of biological, cultural, and mechanical control practices are used. Chemicals, however, could be utilized either alone or in combination with biological, cultural, and mechanical controls for the control of *Sexava* spp. depending upon its population density. In the latter case continuous pest surveillance and monitoring are conducted.

Chemicals are primarily employed for cotton pest management because of insufficient information about other methods. However, we do have limited application of other methods such as hand-picking of *Spodoptera* eggs, early planting to prevent *Hypomeces* infestation, delaying first pesticide application to allow biological control agents to operate, and shortening the planting periods of cotton to prevent the continuous supply of food in the field for the pests.

Most of the present pest control practices on estate crops employ the unilateral approach. This is usually chemical control, which is applied based on different criteria, such as high pest population densities with *Hidari irava* on coconut, the degree of pest damage with cocoa mirid *Helopeltis* spp., or through a calendar system as employed on the pepper lace bug *Diconocoris hewitti*, and the large pepper berry bug *Dasynus piperis*.

Other examples of the use of a single component other than chemicals are the use of natural enemies *Trichogramma* spp. and *Diatraeophaga striatalis* on sugarcane borers, and plastic sleeves as pod-covering against cocoa pod borers *Conopomorpha cramerella*. The latter is now practiced in the primary cocoa-growing regions of the country. The "rampasan" method for cocoa pod borer or coffee berry control is still recommended, usually as the only method of control.

Control of plant diseases and weeds on estate crop also generally follows only one approach. This is usually either chemical control or mechanical control like cutting and burning infected plants.

Surveillance and monitoring of pests, and establishment of economic thresholds, which are among the essential elements of IPM, have been used only to a limited extent, as was done for Sexava control on coconut. Besides budgetary constraints, there is still a lack of technical information on the ecology of pests and on appropriate methodologies for successful implementation of these IPM activities.

In support of the implementation of estate crop protection, the Directorate of Estate Crop Protection (DECP) was established in 1980 at the Directorate General of Estates (DGE), under the Ministry of Agriculture. The DECP consists of five sub-directorates, namely, 1) Monitoring and Forecasting, 2) Crop Protection Means, 3) Pest Control, 4) Disease Control, and 5) Weed Control. Estate crop protection divisions are also established at the provincial level, under the regional estate crop service.

To execute the activities of the Directorate we plan to have about 500 personnel with different levels of educational achievement, from high school graduates to post-graduates, at the Central office in Jakarta, and at all provincial offices. Since its establishment, the DECP has completed a number of activities such as: 1) publication of manuals, leaflets and brochures on estate crop protection, a total of 60 titles, 2) training field workers on estate crop protection, 3) adaptive research and evaluation trials, 4) providing guidance to provincial personnel on estate crop protection, and 5) establishment of biological laboratories. All of these activities are directed towards the development of IPM for the various major pests of estate crops.

DEVELOPMENT OF IPM ON ESTATE CROPS

"IPM programs have come about as the result of gradual evolution in which new technology has been introduced in a step-by-step process rather than through the introduction of a complete fully formed system," (Smith and Huffaker 1973). A similar situation exists with IPM on estate crops in Indonesia. IPM started without waiting for all elements of the system to be available. Components needed were gradually developed. Beginning in 1985, however, a 15-year master plan for IPM on estate crops in Indonesia was implemented. Within this master plan, buildings needed for speeding up the implementation of IPM will be constructed. These include biological control laboratories, field laboratories, pesticide analysis laboratories, vertebrate pest laboratories, crop protection brigade buildings, and pest observatory units. These will be constructed in different regions and provinces.

Furthermore, as part of the plan, a number of people will be trained in cooperation with selected faculties of agriculture of local universities. The training will include a one-year diploma program for high school graduates, who will serve as pest observers, scouts in crop protection brigades or assistants in special laboratories. Personnel selected to head the various laboratories will have at least a Bachelor's degree and will undertake graduate studies before occupying those positions.

Technologies generated for the implementation of IPM are the result of researches conducted by research institutes under the Agency for Agricultural Research Development (AARD) and by agricultural faculties of local universities. In order to synchronize the plans of DECP with research activities, constant consultations are made between DECP officers and researchers from the different research institutes and universities. Furthermore, AARD facilities are also used for short-term training of DGE technicians and field workers.

In addition to research by AARD and universities, DECP also conducts adaptive research and makes field observations to determine components of IPM that could be suitably combined. Such research activities are usually conducted in cooperation with university personnel. An example is the development of IPM on cotton which involves cooperation between DECP, Hasanuddin University, and Gajah Mada University. The following aspects were covered: 1) economic thresholds of cotton pests, 2) the effect of intercropping on the development of pests, 3) the spatial distribution of major pests, and 4) the development of a sequential sampling plan for *Heliothis* sp. The results of these will be used in an IPM pilot project on cotton. Similar cooperative activities were employed in the development of IPM on coconut and clove.

Considering that chemical pesticides are still a major component of IPM, and that pesticide companies have the financial and technological potential, cooperative research activities have also been conducted with these private firms. Such cooperation, started a few years ago, include large-scale trials on the efficacy of some pesticides and the effectiveness of pesticide application equipment. In addition, field technicians of chemical companies are mandated to assist in the training and supervision of local DGE technicians and farmers in pest management.

CONCLUDING REMARKS

The implementation of IPM on estate crops is still in its initial stages with limited supporting components. However, it is our view that IPM will continue to be implemented and improved in the estate crop sector of the Indonesian economy.

ACKNOWLEDGEMENTS

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OVERVIEW OF IPM INFRASTRUCTURE AND IMPLEMENTATION ON FOOD CROPS IN MALAYSIA

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The Food and Agricultural Organization/United Nations Development Program (FAO/UNDP) initiated global programs for the development and application of integrated pest management (IPM) in agriculture in 1975. These programs aimed to assist member countries improve their overall pest control and food production capabilities in basic food crops. Activities are focussed on the setting up of inter-country IPM programs on specific crops, namely cotton, rice, sorghum/millet, and associated crops. For rice, the seven participating countries are Malaysia, Bangladesh, Sri Lanka, Philippines, Indonesia, India, and Thailand. A meeting was held in March 1978 in Bangkok, where it was agreed to establish an IPM program on rice in Peninsular Malaysia.

In Malaysia, the IPM program was established and implemented in mid-1980 to cover all the major rice-growing states; namely, Perlis, Kedah, Penang, Perak, Kelantan, Terengganu, and Selangor. The long-term objective of this program was to establish IPM as one of the desirable operational strategies for rice production in Malaysia (Majid et al. 1985). The program provided for a mechanism to increase the capabilities in participating countries for research and application of IPM in rice. Seven activities were emphasized; namely, training, pest forecasting and surveillance, pesticide management, biological control, stable plant resistance, IPM impact, and cultural management (integrated weed management).

IMPLEMENTATION OF IPM ACTIVITIES

Infrastructure

In the implementation of the IPM program, the existing infrastructure of the Department of Agriculture (DOA), the Malaysian Agricultural Research and Development Institute (MARDI), and other agricultural agencies are utilized. A committee administers the IPM program in Malaysia. This committee is headed by a National Program Leader (NPL), who is the Director of the Crop Protection Branch of the Department of Agriculture. The NPL is assisted by a Technical Advisor, two Joint Program Leaders (JPL) and seven technical working groups. The two JPLs are nominated by their respective organizations – the DOA and MARDI. The main objective of this committee is to ensure better communication between research and extension activities on IPM in rice. The

seven program areas listed above are then implemented using the Training and Visit (T & V) system. As a result of this organizational arrangement, officers from various agricultural agencies work very closely with each other in the implementation of the various activities planned by the national committee.

The Department of Agriculture has an extension network supported by technical units dealing with crop protection, soil management, commodity development, and agricultural mechanization. These technical units provide the necessary supplementary and complementary support at all levels. Each technical unit is equipped with the necessary basic laboratory facilities and manpower. In addition to these facilities, nine surveillance and forecasting centers have been established in the main granary areas to enhance the surveillance activities of the IPM program.

Apart from the above, there are also Regional Extension Training and Development Centers for the training of extension and technical personnel. To facilitate the adoption and implementation of IPM, communication support materials such as posters, extension pamphlets, leaflets, charts, audiovisual aids, etc., are constantly produced and upgraded. At the farm level, the transfer of IPM technology to farmers is effected through the existing T & V system utilizing facilities at the extension service centers and sub-centers. In addition, IPM clinics are being established by the farmers themselves to provide necessary support and services to ensure active participation and commitment of fellow farmers.

MARDI also has research stations in each of the major rice-growing states to carry out problem-oriented research at the farm level (Chang 1980). The mechanism for regular feedback on extension and research requirements, especially IPM, is carried out through the State Pest Control Action Committee, which meets regularly at least once in two months or at monthly intervals. It is through this committee that the IPM problems and needs of farmers are tackled and solved.

Implementation

In 1981, IPM was implemented utilizing the T & V system mainly through demonstration plots at selected pilot areas. The main focus was on technical aspects of crop protection such as recognition of major rice pests, the role of natural enemies and the judicious and efficient use of pesticides. Socioeconomic factors on the needs of farmers were not given due consideration. Moreover, only a small number of farmers was actively involved. As a result, the adoption and practice of IPM was limited and slow among rice farmers (Anonymous 1986).

To speed up and institutionalize the implementation, a workshop on the implementation of IPM at the national level was held in March 1984 at Kangar, Perlis. The workshop recommended the use of the T & V system as the platform for implementing IPM in the country. The *modus operandi* for implementing IPM was also formulated (Figure 1).

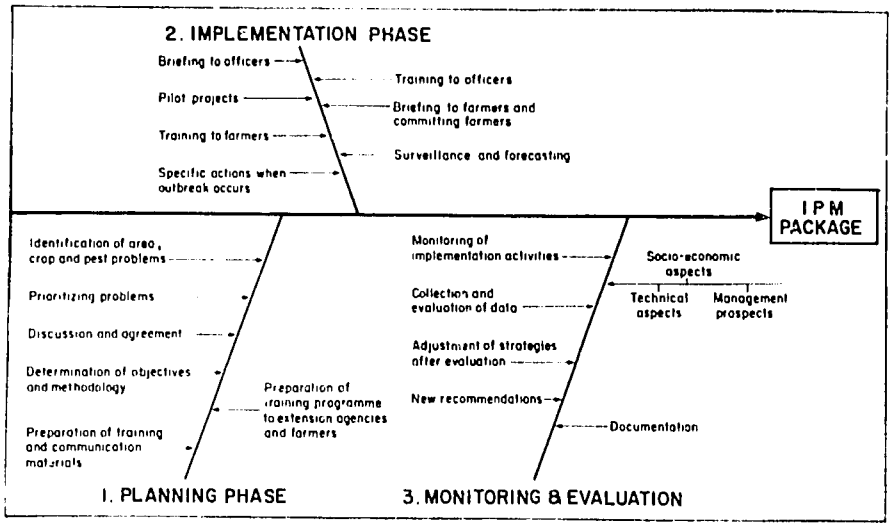

Figure 1. Schematic diagram to show *modus operandi* of IPM program on rice in Malaysia.

In line with the National Agriculture Policy (NAP) the basic implementation framework was modified to incorporate the 'group farming' approach. As a result, IPM packages were developed based on the needs and capabilities of the farmers in a defined area. IPM packages in each locality were developed by the various relevant technical working groups in close cooperation with the farmers and the extension workers of the respective areas. These packages are implemented and managed by the farmers, who are trained by the area extension workers. Subsequent impact studies have shown that this approach has accelerated the adoption and practice of IPM at the farm level.

In the context of IPM implementation in Malaysia, support and participation by agencies other than the DOA are vital to ensure success at all levels. MARDI's role in this program is to provide the necessary backup research on IPM. DOA is responsible for the overall implementation such as training, demonstration, and extension of IPM packages. The other agricultural agencies such as the Muda Agricultural Development Authority (MADA), the Kemubu Agricultural Development Authority (KADA), the North-West Selangor Project, and the Krian/Sg. Manik Project, are also directly involved in implementing IPM projects at the farm level.

The coordination of all IPM programes is done through the National Committee on IPM in Rice. This National Committee meets periodically to monitor and evaluate overall IPM activities in the country. It further serves as an effective operational link between research and extension activities. A similar set-up also operates at the state and district levels.

FAO is involved through the "FAO Inter-country Program for IPC in Rice in South and Southeast Asia", which provides specialized technical support, liaison, and coordination among the participating countries.

CONCLUDING REMARKS: POTENTIAL EXPANSION AND SCOPE OF IPM

Since IPM is a dynamic crop protection system that aims to reduce losses due to pests, maximize returns on investment in pest control, and minimize environmental disruption (Bottrell 1979), it is inevitable that the IPM approach will be intensified to become part and parcel of the overall rice production system in Malaysia. Furthermore, IPM programs will be developed for other major crops such as vegetables and cocoa as identified under the Fifth Malaysian Plan, 1986–1990 (Anonymous 1985). As for rice, the implementation of IPM will be expanded to include traditional rainfed areas which are found in the non-granary states; namely, Pahang, Johor, Melaka, and Negeri Sembilan.

The present IPM program will be continuously refined and further improved as new technology becomes available. The knowledge and skill of relevant personnel and farmers will be constantly upgraded through more specialized training.

The management of human and natural resources will be emphasized in the development and intensification of IPM programs for rice and other crops in the future. In line with agricultural development in the country, the group farming approach will be intensified to implement IPM programs at the farm level. In addition, active participation in IPM activities by family members will be encouraged, e.g. in surveillance scouting, pest control, etc. To inculcate IPM values into the present and future farming communities, an attempt has been made to incorporate the IPM concept as part of the Malaysian school curriculum.

It is envisaged that eventually, all farmers will adopt and consciously practice IPM in their farms to maximize farm productivity and to optimize the use of farm resources and inputs. They should, for instance, be able to conduct surveillance of pests in their own farms and to make rational pest control decisions on their own.

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OVERVIEW OF IPM INFRASTRUCTURE AND IMPLEMENTATION ON ESTATE CROPS IN MALAYSIA

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The principles of integrated pest management (IPM) in tropical perennial crops are by now reasonably well established, disseminated, and generally accepted by both agricultural scientists and plantation operators in Malaysia (Wood 1971, 1984). Some aspects were drawn forcibly to the attention of scientists by the massive outbreaks of pests that were set off by broad spectrum, long residual contact insecticides (BSLRCs) in the 1950s and 1960s (Wood 1973), details of which may be found in the literature cited. In this paper, I will summarize the main points to show how IPM can presently be implemented, and to consider requirements for improvement.

Oil palm, rubber, and cocoa occupy extensive land areas and the Malaysian economy strongly depends on them. Examples of IPM strategies are taken largely from those crops. Coconuts, tea, coffee, fruit and nut trees, sugarcane, etc., are less valuable or occupy smaller areas, but the general principles are the same, and remain recognized as such in pest control procedures.

THE BASICS OF IPM

A Listing of Principles

The principles of IPM most relevant to plantation crops are contained in the statements enumerated below. Where one point follows from others, those from which it chiefly derives are shown in brackets.

1. Only a few insect species are regular pests under existing agricultural conditions at various growing stages. These are called *key* pests. Several others have sporadic outbreaks (i.e. irregularly and locally) and are called *occasional* pests. Some only occur as a result of a particular action (usually, application of an insecticide) and are the *potential* or *induced* pests (Smith & Reynolds 1966).
2. The latter two categories include many phytophagous insects that can find all the food and shelter necessary to complete their life cycle on the crop plant. They often have a high fecundity.
3. An important limitation to insects realizing their increase-potential is their natural enemies, in a dynamic balance (density dependent mortality). The key pests are those in which this limitation is generally inadequate.
4. The physical and crop plant environment favors the activities both of the pests and their enemies, most of the time.

5. Both of these remain rare at the balanced levels (3, 4).
6. If the natural enemy limit is removed temporarily, occasional and induced pests can build up rapidly (2, 4).
7. Reproduction of most phytophagous insects is continuous through the year, and so is that of their enemies. There tends to be a full overlap of generations (multiphase or continuous generation mode – CGM). There is no biological need for life cycles of pests and their enemies to be synchronized.
8. Where outbreaks of occasional or induced pests do occur, the vast majority of individuals are at about a similar stage in their life history (single phase or discrete generation mode – DGM).
9. After an outbreak starts, it may be some time before natural enemies can build up to restore control, even though the disruptive condition may have been brief (5, 7, 8).
10. Even after natural control appears to have been restored, there may be resurgence some generations later (6, 7, 8, 9).
11. Sporadic outbreaks may occur due to chance local conditions adversely affecting the balance temporarily (4, 5, 6, 9).
12. Phytophagous insects tend to be relatively static on the plant (crop) whilst the natural enemies range more widely in search of hosts.
13. Insecticides can disrupt the natural balance and cause outbreaks by relatively favoring the pests – even where they appear to kill the pests. BSLRCs are most inclined to do this, and poor coverage can make the effect worse (3, 8, 12).
14. Insect diseases often spread rapidly to restore low numbers once the host population crosses a threshold density. Sometimes outbreaks recur later (10).
15. Artificial control measures (continuous adjustment of cultural conditions or specific interventions) are necessary against key pests and outbreaks, actual or incipient, of other categories. The wrong measures can worsen the outbreak eventually and recurrent application becomes necessary (13).
16. Properly used, chemicals may favor the enemies of pests. The characteristics predisposing to this tend to be opposite of those of BSLRC – i.e., narrow spectrum, fast fading residues, and stomach poisons (including systemics) (13). Topical or very low dosage application may limit the effect on natural enemies.
17. Chemicals can thus help to restore natural balance, but a good kill still can be important in achieving this (5, 10).

Evaluation

Some of the statements – 1, 2, 4, 5, 7, 10, 12, 14 and 15 – are observations or proven fact. Some of the derivative points are reasonably well proven, whilst others are still dependent on circumstantial evidence. However, the pattern of events fits in with the overall interpretation, and actions taken have consequences that are predictable on that basis. As proofs accrue, they tend to confirm what circumstantial evidence has previously suggested.

Statements 3, 6, and 13 are crucial. Circumstantial evidence is overwhelming and there is an accumulation of more objective proof. Whenever a spontaneous decline of an outbreak, whether completely unaided or after an intervention, is monitored closely, the build-up of natural enemies can be seen. One proof using the insecticidal check technique was carried out. In this, an insecticide is applied so as to deliberately cause a pest upsurgence (DeBach 1958). The technique has been mostly used for quite static pests (e.g. scale insects), otherwise there is a spread effect. In the present case, it effectively demonstrated an induced buildup of a bagworm (*Metisa plana*) on oil palms (Figure 1).

Statements 8, 9 and 10 are related to observable phenomena, but the underlying causes and implications may be less apparent. Frequently, the pest in outbreaks is seen to be in DGM and parasites build up at times, but then may decline again because they cannot find enough suitable hosts (which itself helps to maintain DGM). A well-studied example is that of the hispid leaf miner (*Coelaenomenodera elaeidis*) and its parasites, in particular an egg parasite, on oil palms in West Africa (Marian 1976).

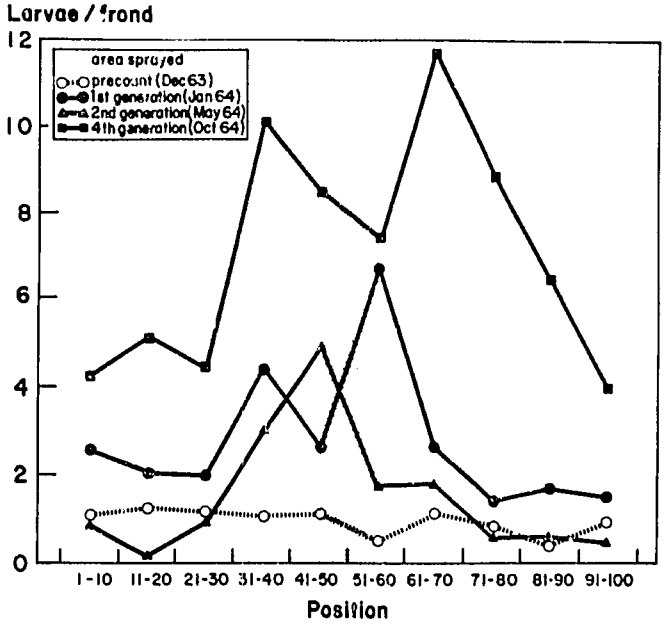

Figure 1. Insecticidal check technique, as applied in oil palms starting with a low level population of the bagworm *Metisa plana*. The horizontal axis represents the total count at corresponding points on three count lines of length *c.* 900 m, which pass through *c.* 1 ha plot subject to dieldrin application (represented by the stippled band). There is a build-up in the sprayed area, but due to the pest moving, it gradually spreads from the upset area (after Wood 1971).

Statement 11 presents the fact of sporadic outbreaks and assumes disruption to natural enemy control on the basis of all the other factors. This particularly draws attention to the probabilistic nature of many of the consequential events. An outbreak might, for example, be attributed to a weather influence, but similar weather prevails over a wide area which is not affected, or which has several separate outbreaks (of the same or different pests). The effect must occur at a particular stage in the dynamic balance between the pests and the enemies. Similarly, BSLRCs may often cause a resurgence but they will not necessarily do so at every application. On the other hand, an insecticide with selective characteristics might occasionally lead to an outbreak, suggesting that it has just tipped a delicate balance in favor of the pest.

There are many events illustrating statements 16 and 17. The long-term effect of a well-timed aerial spray of a selective chemical in indefinitely eliminating an outbreak, but with a tendency for further reverberations where kill is incomplete, is shown in Figure 2.

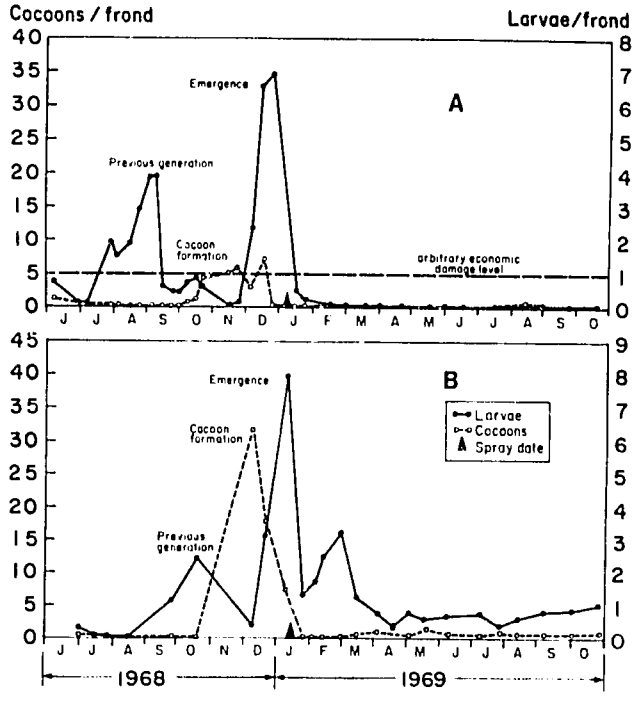

Figure 2. Aerial spraying of trichlorfon (at *c.* 1.5 kg/ha) against the bagworm *Mahasena corbetti* on oil palms. In A, the timing was correct and there was no repercussion. In B, timing was slightly early, before all eggs hatched. In B, there was some further resurgences and limited ground spraying, but the attack came under natural control eventually (after Wood 1971).

IMPLEMENTATION

Cost Objectives

IPM should be the cheapest way of controlling pests. However, this implies cost in the long rather than short term, and includes acceptable losses as well as direct expenses of control measures. A chosen control measure may not be the cheapest for the immediate job, but should have minimum risk of side effects whilst giving the required results. A cultural policy may not be the cheapest for an agronomic benefit, but if it reduces losses to pests or expenditure on other control methods, it can add up to the lowest cost strategy overall. For example, very frequent and complete harvesting of cocoa may give a raised cost per ton harvested, especially at time of trough crop, but with its value in control of cocoa pod borer (CPB) (Mumford 1986), it can be the most profitable procedure.

Census Monitoring and Economic Damage Levels

It is important to know the relationship between pest numbers and crop loss. This requires two stages – the relationship of an amount of damage to crop loss, and of numbers of pests to an amount of damage. Crop loss studies can either directly compare yields at given numbers of pests, or use simulated damage related indirectly to pest numbers. This approach is exemplified in oil palms by Wood (1977). Detailed studies show that there is no limit to losses due to pests. 50% or more reduction in a crop may be sustained regularly or sporadically if there is no control, or if it is misdirected. The cost of interventions can be related to the losses that would otherwise occur, but some degree of prediction is needed about how an incipient buildup is likely to progress.

Census Monitoring and Control Measures

Proven census systems exist for most common pests in plantation crops in Southeast Asia. For occasional pests they usually are done in stages with first, a generalized alert system, followed by a detailed count on a grid, where incipient infestation is noted. The latter is carried out until the outbreak declines (naturally, or after intervention), and is then continued long enough to cover the period of likely re-outbreak (see statement 10).

Where key pests are concerned, such systems may be used to ensure that chemical applications are kept to a minimum, by response only to spots where outbreaks are beginning (e.g. *Helopeltis* spp. on cocoa – Youdeowei & Toxopeus 1983). In such cases, the optimum point for intervention needs to be determined – in some cases a certain level can be tolerated before treating larger areas. In others, less total amount of treatment is needed if there is response at first sign of the pest at individual grid points.

Census is generally used to determine the optimum time of intervention in

relation to the life cycle of the pest, e.g. young larval stage of leaf eating caterpillars (see Figure 2).

Cultural Measures

Sometimes a simple cultural measure can reduce pest risk, e.g. the palm rhinoceros beetle is restricted both from its breeding sites and from attacking palms by dense vegetation. Young replantings tend to be vulnerable because the beetle breeds in the tissues of the previous stand. By felling the stems of old palms and establishing and encouraging ground vegetation, attack generally remains below economically serious levels. The effect of harvesting frequency and technique on the incidence of cocoa pod borer was mentioned above. Bagging of individual fruit is practiced against fruit flies (Vijaysegaran 1983) and is often useful for CPB (Wardojo and Moersamdono 1984).

Resistance

Plant resistance is less often considered against insects than diseases. Rapid selection in perennial crops is difficult because of their long generation time and large size. However, many are planted as clones, and more (in particular oil palms and cocoa) are moving towards this. Thus the possibilities of finding resistant types and multiplying them with sufficient speed will increase. There are few commercial scale examples at present, but thickness of the sclerotic layer in the pod husk is being considered as part of the approach to CPB control (Day 1985).

Biological Control By Natural Enemies

INCREASING ENVIRONMENTAL SUITABILITY Syed and Shah (1977) suggest that blanket removal of weeds, by destroying the food sources of adult parasites, was a factor that precipitated caterpillar outbreaks in oil palms in Sabah. Generally, plantations allow some weeds to remain. An ant *Dolichoderus bituberculatus* can exclude *Helopeltis* spp. key pests on cocoa (Isa 1985, Khoo & Muhamed 1986). Measures to ensure the establishment and prominence of this species would constitute a good IPM approach. Numerous other examples exist.

MASS REARING AND INUNDATION This method is more often used in seasonal situations, where a pest increases at a favorable time and the natural enemies do not build up fast enough to prevent economic damage. Inundation with laboratory reared enemies at this period gets over the period of imbalance. It is less widely used in tropical perennial crops due to the need for constant releases, but interesting results have been obtained with egg parasites against lepidopterous borers in sugarcane (Lim 1972) and against CPB in cocoa (Lim et al. 1982).

IMPORTATION The establishment of exotic natural enemies has been rather neglected in perennial crops in Southeast Asia in general, but there are a few

dramatic examples with key pests reduced to usually well-controlled potential pests, e.g. a leaf mining hispid in coconuts (Dharmadhikari et al. 1977), or the tea tortrix on tea in Ceylon (Danthanarayana 1967). In Malaysia a major effort is being made to find effective exotic natural enemies for CPB (Ooi 1987). Sometimes the future of a crop may depend on it – e.g. *Leucaena leucocephala*, a legume tree, has lately been attacked by a newly introduced Psyllid. The crop as yet has insufficient economic value to justify regular control measures and the only hope is for an effective enemy (Ooi 1986).

Chemicals

Chemical application remains an important way of dealing with key pests and with incipiently severe outbreaks of others. Several aspects are mentioned above, including the characteristics predisposing to their suitability for IPM (Statement 16), and the regulation of use by census (census monitoring and control measures). Difficulties can be posed by choice of chemicals which requires constant review, especially to incorporate newer ones, and by application method.

CHOICE Several newer chemicals are more subtle in their action than the earlier generation of toxic materials, and generally more selective. Insect growth regulators give promise, e.g. the chitin inhibitor difluobenzuron against bagworms (Ho & Sidhu 1986). Poisons solely of stomach action, e.g. those derived from *Bacillus thuringiensis*, and relatively fast-fading pyrethroids, are also finding an increasing role. The use of behavior modifiers (semiochemicals) is not widely developed in these crops, but pheromones to attract males are showing promise against CPB in Sabah state (Beevor et al. 1986).

Where insect disease becomes noticeable in a pest still below the threshold number for its rapid contagion (see statement 14) there are cases of successful spread simply by grinding the bodies of succumbed individuals and spraying a suspension (e.g. the nettle caterpillar *Darna trima* by a virus – Tiong & Munroe 1977). Biological insecticides (that is, preparations of entomopathogens), formulated for ease of application and adequate shelf life offer increasing promise. They may be prepared with diseases that are virulent but not common in the field, because host numbers rarely or never increase to the level of easy transmission.

APPLICATION METHODS However effective and selective the chemical, it must reach the target. Two dangers of poor coverage are relatively disfavoring natural enemies (statement 13) and failure to bring the pest to a low level at which natural control is restored (statement 17).

Various types of hand-operated or shoulder-carried mechanized sprayers are used, but each can cover only small areas, and reach only low canopies. Tractor drawn power sprayers (air blast or supplying hand lances) can continue to be effective for trees a good deal denser and higher, but eventually their limits are reached in tall tree crops. Their passage may be restricted under low canopies such as cocoa. The terrain on which plantation crops are grown is often too

uneven for the continual traverse that is often necessary for this type of equipment. They represent a large capital investment for equipment that is only occasionally used. Aerial spraying is technically excellent for many purposes (see Figure 2), but it is very expensive for small areas, due to a high fixed cost.

In trunk injection, certain systemic insecticides are put into holes bored in the stem of palms, in which it spreads to all parts of the crown (Wood et al. 1974, Ooi et al. 1975). It can cover large areas quickly with electric drills driven from a tractor mounted generator (Singh 1986). In 1985, three separate infestations of the bagworm *M. plana*, spreading over *c.* 1,000–2,000 ha each, of oil palms, were treated at about 10–15 ha/day/team of two drills. This allowed good timing of the injection and there were no resurgences in any case, though counts had been as high as 2,000 hatchlings/fronds, prior to treatment.

IPM – NEED AND DEVELOPMENT

It has been said that plantation crops in the humid tropics are particularly suited for IPM, whilst any other approach, particularly involving only direct confrontation of individual pests with BSLRCs is bound to be problematic (Wood 1979). A further risk is resistance to pesticides. Application may control the immediate outbreak, and although it sets the scene for resurgence, regular use might be effective if done properly (albeit expensive). However, if the pests become resistant to the chemical, this control, too, breaks down. The choice between IPM and chaos is illustrated in Figure 3.

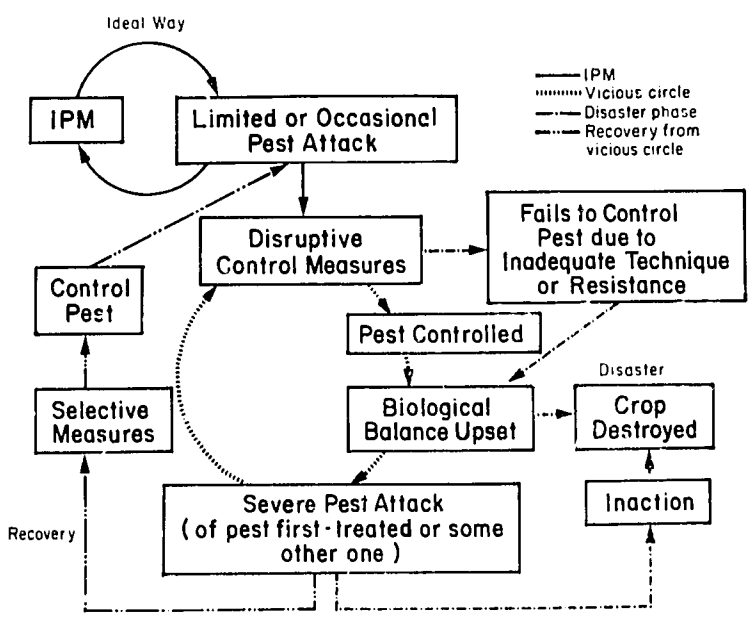

Figure 3. Patterns in pest control (after Wood 1979)

IPM requires a good knowledge of ecological principles. As the general points covered in the statements above become more closely related to a particular crop agroecosystem, so adaptation and implementation becomes easier – e.g. in the "new" crop cocoa, from the mid-1970s. Full detailed knowledge of the biology and ecology of any one pest is not necessary for reasonable success, although procedures tend to become simpler and cheaper as details build up. Some pests occur so sporadically that specific details about their biology are very difficult to obtain.

General experience helps, both because of the probabilistic nature of events (The Basics of IPM – evaluation), and because in making decisions on interventions, it is helpful to know not only what the situation is, but also how it might develop.

There are several centers where ecological studies and screening for selective chemicals are done, particularly relating to the more commercial plantation crops. Trials can be frustrated by near-complete elimination in untreated check plots also due to natural control (e.g. spread of entomopathogens). The need of several large scale applications monitored for signs of resurgence is the only way to completely confirm suitability in IPM programs. For most key and sporadic pests suitably tested measures are available. The biggest causes of failures for chemical interventions are from incorrect timing of application and inadequate coverage.

Further problems can arise from regulation. Pesticide bodies must primarily pay attention to toxicology. They may well appreciate the technical value of carefully restricted application, but they are constrained by the possibility that any permitted chemical could be abused in blanket application, too near to harvest, over catchment areas, and so on. Valuable aids to IPM thus can become unavailable, and flexibility is taken out of the hands of the grower. This is unfortunate because above all else, IPM requires a flexible approach. Cultural approaches, both to directly affect pest numbers and to establish the right environment for natural control; efforts to reduce the status of pests by plant resistance or establishment of more effective exotic enemies; and techniques such as spread of insect disease or use of pheromones; all have been given prominence in plantation crop research, and many are incorporated into local or general practice.

Education of intending crop protection scientists, plantation operators, and administrators involved is paramount. But it should not stop at that level. The people who do the field jobs, including census takers and spray teams, will do better if they know what they are aiming at, and why. Generally, in the Malaysian plantation sector, the situation in these respects is satisfactory although there always remains room for improvement in the technology available and in the understanding and application of the principles involved.

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ROLE OF INSECT-RESISTANT VARIETIES IN RICE IPM SYSTEMS

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It is extremely difficult to estimate rice yield losses caused by pests, even though figures have been published (Cramer 1967). Because of the myriad of interactions between the plant and its abiotic and biotic environment in space and time, and the lack of intensive research on the subject, only estimated guesses can be made. In spite of this, it is obvious to those involved in field-oriented rice research that insects, diseases, weeds, and vertebrate pests are major constraints to rice production in Southeast Asia. Chronic pests such as stem borers regularly reduce yield but seldom reach outbreak levels. Acute pests such as the brown planthopper *Nilaparvata lugens* (Stal) infrequently occur in outbreak proportions, but when they do, cause severe economic damage.

Outbreaks of insect pests have challenged rice farmers ever since rice was first cultivated. In response, farmers have developed numerous traditional control methods. Because of the need to feed a rapidly growing population, rice production, especially in the last few decades, has been intensified and this intensification has brought about significant changes in rice production technology. Many of these changes appear to have been favorable for the development of certain insect pests, and outbreaks of these pests appear to have become more frequent.

THE CAUSES OF INSECT OUTBREAKS

Changes in rice production technology have, in most cases, accompanied the Green Revolution which resulted from the widespread release of modern rice varieties in the 1960s. These changes have brought about an increase in the carrying capacity of the ecosystem for certain insects.

Expansion of irrigation systems has increased the area planted to rice. The short duration of the photoperiod, insensitive varieties, and the availability of irrigation water has made possible the planting of rice throughout the year -- often without a fallow period – where previously the dry season depressed insect numbers. Irrigation has also favored aquatic pests such as the caseworm *Nymphula depunctalis* (Guenee) because of a stable supply of water in the paddies.

Because of the responsiveness of modern rice varieties, fertilizer usage has greatly increased in rice. Insects such as the leaffolder *Cnaphalocrocis medinalis* (Guenee) and the brown planthopper (BPH) are most severe in fields with high

levels of N fertilizer. Populations of the BPH have been shown to triple with an increase in N fertilizer in greenhouse studies (Heinrichs & Medrano 1985).

The increased yield potential of the modern varieties has also resulted in greater returns from pesticide applications and has thus made it more economical to apply pest control measures than was the case for the lower yielding, traditional varieties. Thus, national production programs have encouraged the use of insecticides, and have in some cases heavily subsidized their use. The misuse of insecticides has resulted in the development of resistance, destroyed natural enemies, and stimulated the reproductive activity of the BPH, resulting in outbreaks due to resurgence (Heinrichs and Mochida 1984).

The pest problems brought about by the modern technology are certainly not unique to rice. The phases that certain cotton insect protection programs have gone through have been classified by R. F. Smith and cited by Luckmann and Metcalf (1975):

(1) Subsistence phase – a traditional system where there is no organized crop protection program.
(2) Exploitation phase – crop protection programs consist primarily of pesticides to protect new varieties.
(3) Crisis phase – after several years of heavy insecticide use, insects become resistant, and secondary pests become serious pests as their populations resurge.
(4) Disaster phase – insecticide use increases to a point where the crop can no longer be grown profitably, and the pest control program collapses.
(5) Integrated control phase – an integrated pest management (IPM) system is implemented to bring the production system back to profitability.

Most rice insect control programs fit into the exploitation phase, and in some regions they have reached the crisis phase. Some regions have gone to the integrated control phase without passing through the disaster phase and sometimes even bypassing the crisis phase. This is commendable. IPM systems need to be implemented early to avoid the problems described above for cotton, and in this paper, I will discuss the role that resistant varieties play in such systems of pest control.

RICE IPM SYSTEMS IN SOUTHEAST ASIA

In this paper, IPM is considered a system of crop protection where pests are maintained at populations below the economic injury level through the use of two or more control methods. It is a strategy that utilizes various control tactics – cultural, host plant resistance, biological, and chemical – in a harmonious way and which is ecologically, sociologically, and economically acceptable.

Monitoring

IRRI and national rice research programs throughout Southeast Asia have been instrumental in developing monitoring techniques for rice pests which are suited to local conditions. For some insects, sequential sampling plans are

available. FAO, in concert with national programs, has been instrumental in extending monitoring technology to the farmer.

Economic Injury Levels (EILs)

Rice research programs in Southeast Asia have identified the population levels at which economic loss occurs. For some species, the levels are still crude and in need of further refinement but can be utilized in IPM systems. The EILs have mostly been developed on susceptible rice varieties. More data is needed for the development of EILs for moderately resistant varieties. Also, EILs are based on a single insect species and should be developed to include a combination of different insect species and multipest complexes (insects and plant pathogens).

Cultural Control

The use of agronomic practices to control insect pests is considered cultural control. As previously mentioned in this paper, changes in agronomic practices over the last three decades have contributed to greater insect problems through an increase in the carrying capacity of the rice ecosystem. However, agronomic practices such as synchronous planting, crop rotation, early maturity varieties, avoiding excess N fertilizer, flooding fields, and stubble destruction are some examples which are effective in rice IPM systems. In general, cultural control is a farmer-based technology with little dependence on outside resources.

Biological Control

All rice insect species are attacked by biological agents – parasites, predators, and pathogens – which limit their populations. There is an abundance of natural enemies (in species and in total numbers) in rice ecosystems in Southeast Asia. It is generally believed that pest outbreaks occur when some environmental stress decimates the biocontrol organisms and releases the reproductive capacity of pests. Thus, conservation of biocontrol agents is a cornerstone of any effective rice IPM system.

Chemical Control

Because of the economic benefits, some rice production programs have subsidized the sale of pesticides. As a result, insecticide applications have often been more numerous than required. Insecticide evaluation programs have been productive (Heinrichs et al. 1981) and every country has a wide assortment of different insecticides upon which to draw. Certain insecticides, unfortunately, have been responsible for BPH outbreaks (Heinrichs and Mochida 1984). Destruction of natural enemies by insecticides appears to be a major component in resurgence. Commercial insecticides differ greatly in their safety to natural enemies (Fabellar and Heinrichs 1984), and insecticides which are less toxic to natural enemies should be used in IPM systems. New insecticides which have a

novel mode of action, e.g., buprofezin (Applaud), a BPH insecticide which is a growth regulator and is extremely safe to natural enemies and the environment (Heinrichs et al. 1984a), will likely play an increasing role in the management of rice insects.

Host Plant Resistance

Resistant varieties are sought as the major tactic in the integrated control of rice insect pests because they (1) are free to the farmer, (2) require no special skills to use, (3) are safe to the environment, and (4) are compatible with the other control tactics – cultural, biological, and chemical (Heinrichs 1986).

Screening methods have been developed for 32 rice insects throughout the world and resistance sources of varying levels to most have been found (Heinrichs et al. 1985). These sources have been used as donors in national hybridization programs throughout Southeast Asia and numerous resistant varieties have been released including 29 from IRRI (Table 1). Varieties such as IR36 are resistant to a complex of insects and pathogens, have tolerance to adverse soils, and have other desirable qualities (Table 2). Insect resistant varieties occupy large areas in Southeast Asia. Hybrid rices in China occupy more than 6 million hectares, and more than half of the area grows BPH resistant rices.

Host plant resistance is highly compatible with other control tactics and is a key tactic in the integrated control of rice insects. The following discussion describes some of the ways in which host plant resistance can be integrated with other control tactics in rice IPM systems in Southeast Asia.

HOST PLANT RESISTANCE IN INTEGRATED CONTROL SYSTEMS

Host Plant Resistance and Cultural Control

There are examples of rice varieties that have high levels of resistance to certain pests and in these cases the plant resistance can provide complete control. However, such varieties exert extreme biotype selection pressure on the pest. Such high levels of resistance are not necessary when resistance is integrated with other control tactics.

Moderately resistant varieties, which can be manipulated to evade insect attack, are useful in cultural control systems designed to maintain insects at subeconomic levels (Adkinsson and Dyck 1980). Agronomic practices used in rice to evade insect populations include synchronous planting and early crop maturity. Synchronous planting of rice within an area, when related to the effective dispersal period of the BPH, decreases pest load on the crop (Loevinsohn 1984). Where farmers planted synchronously in Indonesia, BPH populations were 25% of that where staggered planting was practiced (Oka 1979).

Early maturing rice lines evade BPH damage by maturing and becoming unsuitable before the insect reaches the damaging third generation (Heinrichs et

Table 1. Resistance of IR varieties to insect pests.[a] IRRI, 1986.

Variety	Maturity (DAS)	*N. lugens* biotype 1	2	3	*Nephotettix virescens*	*Sogatella furcifera*	*Scirpophaga incertulas*	*Chilo suppressalis*	*Hydrellia philippina*	*Stenchaetothrips biformis*
IR5	130	S	S	S	MR	S	S	S	S	S
IR8	125	S	S	S	MR	S	S	S	S	S
IR20	121	S	S	S	MR[d]	S	MR	R	S	S
IR22	119	S	S	S	S	S	S	S	S	S
IR24	118	S	S	S	MR	S	S	S	S	S
IR26	121	R	S	R	MR	S	S	MR	S	S
IR28	104	R	S	R	R	S	S	S	S	S
IR29	112	R	S	R	R	S	S	S	S	S
IR30	105	R	S	R	R	S	S	MR	S	S
IR32	130	R	R	MR[c]	MR	S	S	MR	S	S
IR34	122	R	S	R	R	S	S	MR	S	S
IR36	110	R	R	MR[c]	MR	S	MR	R	S	S
IR38	123	R	R	MR[c]	MR	S	S	MR	S	S
IR40	130	R	MR	S	MR	S	MR	R	MR	S
IR42	132	R	R	S	MR	S	S	MR	S	S
IR43	120	S	S	S	MR	S	S	MR	S	S
IR44	123	R	R	MR[c]	MR	S	S	R	S	S
IR45	120	R	S	R	MR	S	S	S	S	S
IR46	112	R	S[b]	R	MR[d]	S	S	S	S	S
IR48	127	R	R	S	MR	MR	S	S	S	S
IR50	107	R	MR	R[c]	R	S	MR	R	S	S
IR52	117	R	R	MR[c]	R	MR	S	MR	S	S
IR54	120	R	R	S	R	S	MR	MR	S	S
IR56	106	R	R	R	R	S	S	MR	S	S

Continued on next page

Table 1 *continued*

Variety	Maturity (DAS)	*N. lugens* biotype 1	2	3	*Nephotettix virescens*	*Sogatella furcifera*	*Scirpophaga incertulas*	*Chilo suppressalis*	*Hydrellia philippina*	*Stenchaetothrips biformis*
R58	108	R	R	R	R	S	S	MR	S	MR
IR60	110	R	R	R	R	MR	S	MR	S	MR
IR63	110	R	R	R	R	MR	S	MR	S	R
IR64	115	R	MR	R	R	S	S	[e]	S	[e]
IR65	115	R	R	R	R	MR	MR	[e]	S	[e]

[a]Based on replicated experiments. Hopper resistance based on greenhouse evaluation of seedlings; yellow and striped stem borer resistance based on a screenhouse evaluation of 40–70-day old plants; leaffolder and caseworm resistance based on the reaction of 30- and 11-day old plants in the greenhouse; whorl maggot resistance based on field observations at 30 days after transplanting. Varieties with ratings as based on the standard evaluation system of 1–3 are considered resistant (R), 5–7 moderately resistant (MR) and 9 susceptible (S). [b]IR46 has field resistance to biotype 2. [c]Reaction to biotype varies, occasionally being susceptible and often resistant. [d]Occasional susceptible reactions. Least resistant of the IR varieties except for IR22, which is highly susceptible. [e]Tests still to be conducted.

Table 2. Qualities that have made IR36 the most widely grown rice variety in the world.

Maturity	Climate	Grain quality	Insect resistance	Disease resistance	Adverse soil tolerance
110 days	wetlands	long, slender	brown planthopper	blast	alkalinity
	irrigated	good cooking	biotype 1, biotype 2	bacterial blight	aluminum toxicity
	rainfed	high milling		grassy stunt virus	boron toxicity
	rainfed drylands		green leafhopper		iron deficiency
	drought tolerant		gall midge		iron toxicity
			stemborer		salinity
					zinc deficiency

al. 1986a). Short duration varieties provide effective BPH control and complement host plant resistance and other cultural, biological, and chemical controls.

In Indonesia, a gene rotation approach is being used to slow the rate of green leafhopper *Nephotettix virescens* (Distant) biotype selection in resistant varieties. This involves a wet-dry season alternation of rice genotypes so that varieties with one gene for resistance are planted in the wet season and varieties with a different gene in the dry season.

Although high levels of N fertilizer increase rice yields of modern varieties, they are also conducive to causing high BPH and leaffolder populations. However, BPH increase is dependent on the level of plant resistance to the insect in a variety (Heinrichs and Medrano 1985). Populations on a susceptible variety increased threefold; on a moderately resistant variety twofold; and on a highly resistant variety the population remained low. Thus, the N responsiveness of the modern varieties can be taken advantage of without causing damaging levels of insect populations, if the variety has resistance to the insect.

Host Plant Resistance and Biological Control

Although insect resistant rice varieties have an indirect effect on predators because of a lower prey density, they are considered to be compatible with biological control agents. Resistant varieties decrease the insecticide load and thus conserve natural enemy populations.

The combination of varietal resistance and predation has a cumulative effect on green leafhopper control. In greenhouse studies, leafhopper mortality on resistant variety IR29 was 66% due to host plant resistance alone but increased to 92% with the addition of the mirid predator *Cyrtorhinus lividipennis* Reuter. On susceptible TN1, mortality was only 41% with the predator (Table 3) (Myint et al. 1986).

Resistant varieties enhance the activity of natural enemies on some species of insects. Because of a low feeding rate on resistant varieties, BPH populations are stressed and are thus more susceptible to pathogen attack. Resistance increases the predation rate of spiders on the BPH (Kartohardjono & Heinrichs 1984). The restlessness of the BPH on the resistant variety apparently causes it to be more easily detected by the spider. Prey-predator ratios in field tests have been shown to be most favorable for biocontrol on the BPH-resistant variety.

Host Plant Resistance and Chemical Control

Resistant rice varieties increase the effectiveness of insecticides. BPHs and whitebacked planthoppers *Sogatella furcifera* (Horvarth), reared on resistant or moderately resistant varieties, are killed with lower rates of insecticides than those feeding on susceptible varieties (Heinrichs et al. 1984b). The LD_{50} of the whitebacked planthopper treated with ethylan was 9.4 on susceptible TN1 but only 2.8 when reared on moderately resistant N22 (Table 4).

Table 3. Effect of levels of varietal resistance and *C. lividipennis* predation on *N. virescens* nymphs (Myint et al. 1986).

Variety[a]	Mortality (%) of *N. virescens* nymphs[b] With predator	Without predator	Difference[c]	Variety means of % mortality with and without predator
IR29 (R)	92 a	66 a	26 a	79 a
IR56 (R)	87 a	64 a	23 a	76 a
IR36 (MR)	48 b	28 b	20 a	38 b
IR42 (MR)	45 b	27 b	18 a	36 b
IR22 (S)	40 b	7 c	33 a	24 c
TNI (S)	41 b	5 c	36 a	23 c

[a]Thirty-day-old plants, R = Resistant, MR = Moderately resistant, S = Susceptible. [b]Means of four replications with 25 first-instar *N. virescens* nymphs and five *C. lividipennis* for 7 days. In a column, means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test. Analysis is based on values transformed to $\sqrt{x}$. [c]The difference in mortality (with-without predator) was significant at the 1% level for all varieties.

Table 4. LD_{50} of insecticides applied topically to the whitebacked planthopper *S. furcifera* reared on susceptible TNI and moderately resistant N22 rice varieties (Heinrichs et al. 1984).

Insecticide	TNI LD_{50} (µg/g)	TNI 95% Limits	N22 LD_{50} (µg/g)	N22 95% Limits
Carbofuran	0.46	0.36–0.55	0.24	0.18–0.29
Acephate	1.15	0.26–3.62	0.44	0.25–0.68
Ethylan	9.42	4.75–31.41	2.77	1.63–4.98

There is a cumulative effect of host plant resistance and insecticides in the control of green leafhoppers (Heinrichs et al. 1986b). Field studies have shown that insecticide-treated varieties that are highly resistant to the green leafhopper vector have a low incidence of tungro virus and susceptible varieties have an extremely high incidence. In contrast to the vector susceptible varieties, the moderately resistant variety (IR36) shows a response to the insecticide where treated plants have decreased tungro virus and untreated plants have a high incidence (Fig. 1).

Insecticide applications have been responsible for BPH outbreaks, a phenomenon referred to as "resurgence". Host plant resistance can mitigate the degree of BPH resurgence. In field tests in the Philippines, the BPH resistant

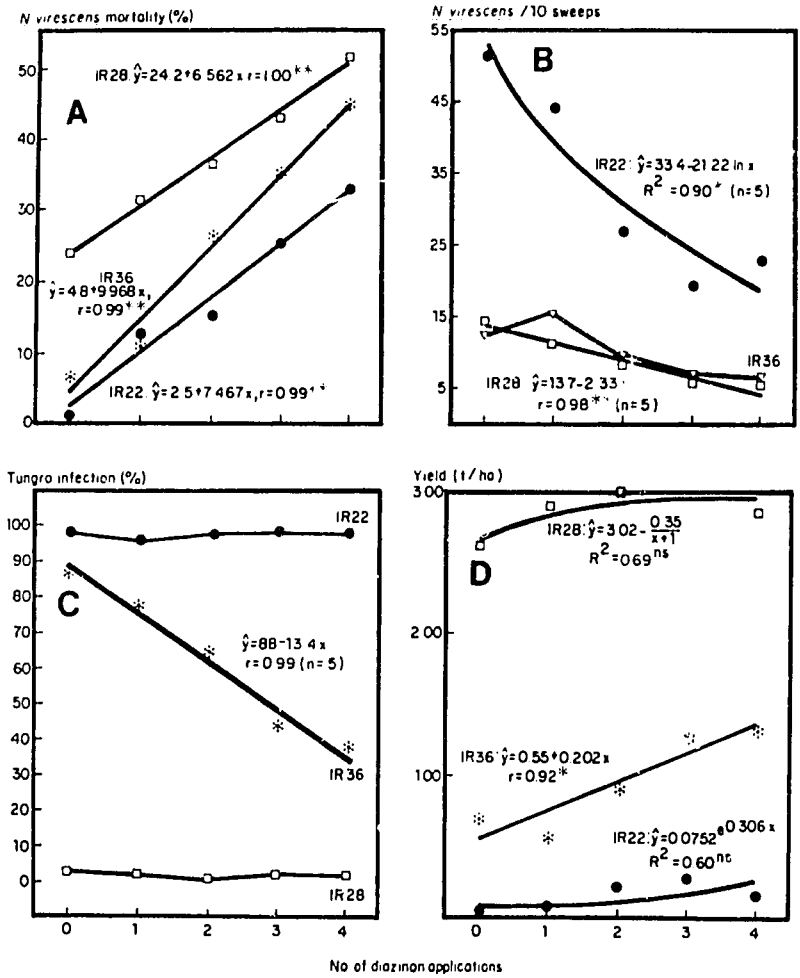

Fig. 1. *N. virescens* mortality and field populations, RTV infection, and grain yields as affected by number of diazinon applications at 1.5 kg a.i./ha on rice cultivars 'IR22', 'IR28', and 'IR36' having different levels of *N. virescens* resistance, IRRI, 1983 wet season. (A) mortality of caged *N. virescens*, (B) *N. virescens* populations per 10 sweeps at 35 DT, (C) Percent RTV infection, (D) Grain yield. (Heinrichs et al. 1986b).

variety had only 10 BPHs per hill whereas susceptible varieties had 1100 per hill (Aquino and Heinrichs 1979). In cases where the BPH resurges after the application of insecticide to control the leaffolder, resurgence can be minimized, providing BPH-resistant varieties are cultivated.

The decreased insecticide requirement of insect resistant varieties conserves natural enemies, preserves environmental quality, slows rate of selection for insecticide resistant insect strains, and increases the profitability of crop production (Adkinsson and Dyck 1980). The incorporation of a resistant variety

into an integrated control system is more effective and economically profitable than complete reliance on insecticide control on susceptible varieties.

Integration of Host Plant Resistance for Insects and Control of Other Pests

There are many interactions among the various pests attacking the rice plant. The different pests (insects, diseases, nematodes, rodents, and weeds), abiotic environmental factors and the rice plant are interdependent and linked together. Because of the linkages, control measures directed against a target pest may cause population decreases, increases, or not affect another pest (Reissig et al. 1985).

Insect resistance has an adverse effect on weeds and plant diseases in rice fields. Insects attacking the seedling and vegetative growth stages slow plant growth and reduce foliage area of susceptible varieties. As a result, the canopy closes late and the reduced competition for light and nutrients allows greater weed growth. Feeding by insects predisposes plants to attack of fungal and bacterial diseases which invade the plant tissue. Some insects are virus vectors. Decrease of insect feeding through resistant varieties thus may also decrease attack by fungal, bacterial, and viral diseases.

CONCLUDING REMARKS

In a relatively short period of a few decades, remarkable progress has been made in the development of insect resistant rice varieties and the development of integrated control systems in which these varieties are a key tactic. Rice is without equal in the extent to which insect resistance has been incorporated into high yielding varieties and in the extent to which these varieties are being commercially grown by farmers over millions of hectares in Southeast Asia. However, much remains to be done and the potential for improvements in the IPM system for rice is great.

There is a great need to develop rice varieties having not only resistance to several insect pests but also multipest resistance – resistance to several insect and pathogen species. Breeding programs must increase the stability of resistance. Biotype selection is a constant threat to resistant varieties and integrated control systems that minimize selection pressure are needed. The genetic diversity concept to slow biotype selection is being evaluated in Vietnam and in Indonesia, and we anxiously await the results of these novel approaches. Future studies must consider the effect of the various biotic and abiotic stresses on the level of host plant resistance to specific insects.

In crops other than rice, it has been shown that plants respond to the feeding damage caused by one insect by becoming more resistant to the following insects which attack the plant. Inter-plant pheromonal communication between a damaged and undamaged plant has been suggested to render the undamaged plant more resistant to insect attack (Baldwin and Schultz 1983). These mechanical stresses plus plant mediated effects of adverse soils, light, temperature, moisture, other insects, plant pathogens, and weeds on the levels of insect resistance must be included in the development of more accurate insect economic injury levels.

A great deal of IPM technology is already available, but much of this has not yet reached the rice farmers of Southeast Asia. However, there has been an increase in emphasis on rice pest management in international and national rice production programs. IRRI has cooperated with national programs in the training of national scientists in the principles and practices of rice IPM. The FAO Integrated Pest Control Program for Rice is extending IPM to the farm level. The close working relationships of the international and national programs are effectively delivering the technology to farmers.

I believe that it is not being overly optimistic to predict that the breakdown of crop protection practices as described for cotton will not occur in rice, and that rice farmers will move from the exploitation phase to the integrated control phase without passing through the disaster phase.

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THE SURVEILLANCE AND FORECASTING OF INSECT POPULATIONS IN RICE PEST MANAGEMENT

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Pest management decisions require information on the current status of the crop, on the pest and weather, on past trends, and on the potential losses that might occur. Based on these and other experiences, future damage is estimated and a decision on whether to take any control action is made. Norton (1982) has classified pest management information needs into four main types:

1. Fundamental Information, which is concerned with the biological and ecological processes, damage relationships, control measures, their effectiveness and consequences.
2. Historical Information, which is derived from past levels of attack and damage. This serves to indicate trends in pest development and to assess the probabilities of forthcoming attacks and losses.
3. Real-time Information, which is collected through on-farm monitoring and regional surveillance. This concerns the current status of the crop and pest, and includes both direct and indirect assessments of attack and damage.
4. Forecast Information, which estimates future levels of attack and damage and is often obtained by combining the three types of information above through the use of models.

Fundamental information is often obtained from research and the literature, while the other three types are generally provided by pest surveillance systems. In addition, pest surveillance systems are also concerned with information processing, delivery, and reception.

SURVEILLANCE SYSTEMS IN RICE

The majority of rice growing countries in Asia have pest surveillance programs. These activities began as early as the 1940s in Japan (Yoshimeki 1967) and programs there are still playing an active role in pest management (Hirao 1979). In India, pest surveillance started in 1969 following a widespread epidemic of tungro. in the Philippines and Thailand, surveillance and early warning systems (SEWS) are being implemented through the German aid program. Pest surveillance started in Indonesia in 1975 and there are now 1,160 pest observation units, each supervised by a pest observer.

Computer-Aided Pest Surveillance in Malaysia

In Malaysia, the national pest surveillance system was implemented in 1979 following outbreaks of the brown planthopper (Ooi 1982), and is now being conducted in all the rice-growing areas in Peninsular Malaysia by a team of 11 officers, 5 assistant officers, 36 technicians, 7 drivers, and 131 pest scouts. Data collected from the field are summarized and recorded on several copies. One copy is sent to the headquarters where they are entered into a microcomputer and subsequently stored on magnetic tapes (Heong 1986b). Another copy is used by the local pest surveillance officer for real-time decisions in the various localities under his charge. The officer scans the data for all the localities and if abnormally high pest levels are observed, he calls a meeting of the local pest control committee. The committee, comprising officers from research, technical, and extension units, then decides on the control action to be taken.

At the headquarters, the data retrieved by the microcomputer are used to generate various reports for policy makers. For better visual displays, density maps are also generated by the microcomputer. The data sets are later analyzed to produce historical information such as population trends and probabilities of attacks.

The main constraint of the system is the time delay between data collection and information reception at the regional agricultural offices. Information delivery to individual farmers is also inefficient. To partly overcome this, a relatively inexpensive system involving the use of 8-bit microcomputers, data storage on diskettes and data communications via the RS 232 interface was proposed (Heong 1986b). This system allows the regional surveillance officer to retrieve information every afternoon about the pest, crop, and environment, from data collected and keyed-in each morning, thus enabling him to make real-time decisions more effectively. The computer in the headquarters then serves as the main data bank from which further analysis of the data to develop historical and forecast information can be carried out. It can also provide executive summaries to policy makers for planning purposes. With the recent advances in microcomputer technology, the management of pest databases using this approach is now more efficient and economical.

Pest Surveillance Methods

A variety of absolute and relative insect population estimation methods for rice are now available (Benigno 1978, Dyck 1978, Gomez 1972, Heong 1981, Kiritani 1972, Ministry of Agriculture and Forestry, Japan 1967, Nishida & Torii 1970). Other ecological methods that can be adapted for rice have also been described (Heong 1986a, Southwood 1978). Different methods are used depending on the objectives of sampling and the expected reliability. Most of the absolute methods are laborious, like direct counting of egg masses, insect adults and nymphs using an aspirator and suction machines. The "sticky board" used by pest surveillance in Malaysia (Heong 1981), on the other hand, has proved to be reliable and easy to manage. This method involves tapping insects on rice plants onto a board holding a piece of white paper spread with a sticky

material such as "Fujitangle" or "Tanglefoot". The paper is then covered with a piece of clear polythene and brought back to the laboratory for counting.

The relative methods include light traps, yellow pan traps, sticky traps, sweep nets and aerial nets. In many rice pest surveillance programs, light traps are commonly used. Despite controversy over its reliability, it is by far the most convenient method available.

In the case of insects that cause visible symptoms, such as stem borers, gall midge, leaf folders and whorl maggots, direct counts of the hills with the symptoms are often the most convenient. Visual scores of insect damage ranging from 0 (no damage) to 9 (severely damaged) can be easily adopted by farmers. Though used successfully in disease assessments (Teng 1984), the difficulty lies in standardizing these scores, which can differ from observer to observer.

PEST INFORMATION AS AN AID TO DECISION MAKING

Historical Information

Information synthesized from historical data can serve to enhance both tactical and planning decisions. Mean populations over a number of years are being used as guides to decide whether action is needed (Hirao 1979). The probability distribution of attacks obtained using cross classification analysis can provide decision makers with some idea on whether action would be needed (Norton 1976). This can also form the basis for the application of decision theory to aid in decision making (Carlson 1970, Heong 1983, Valentine et al. 1976). In Canada, infestation probabilities and economic consequences of grasshoppers were derived using pest, weather, and crop data over a 32-year period (Gage & Mukerji 1978). Migration patterns of the rice brown planthopper in Japan (Kisimoto 1976), China (Cheng et al. 1979) and Southeast Asia (Rosenberg & Magor 1986) have been established from historical records.

Real-Time Information

Real-time information is required for making short-term tactical decisions. This is usually collected through field monitoring. In order to be effective, data processing needs to be fast and efficient. The microcomputer-based pest surveillance system discussed earlier, each with an independent database management system (DBMS) will serve this purpose effectively. Several systems in the United States are based on mainframe computers such as SCAMP in New York (Sarette et al. 1979), PMEX in Michigan (Tummala & Haynes 1977) and MINPEST in Minnesota (Teng 1984). The development of these and other computer-based IPM delivery systems were reviewed by Welch (1984) and Tummala and Gage (1985).

Monitoring data can also be converted into real-time information by several other means, such as using a set of decision rules, a sequential sampling plan (Ho & Heong 1984, Shepard et al. 1986), a graph (Conway et al. 1975, Heong

1986c) and a nomogram (Heong 1986c, Sutherst et al. 1979). Such decision aids can be modified for use by technicians and farmers in the field.

Forecast Information

FORECAST MODELS When using real-time information to make pest management decisions, a forecast of what is likely to occur in the future is of paramount importance. Forecast information is derived by combining fundamental and historical information through the use of modelling techniques. Based on historical data, time series models were developed to forecast rice stem borers (Torii 1967) and blast (Ono 1965) in Japan. Such models, developed either by multiple regression or time series analysis, have limited abilities. They may be adequate in describing past trends, but may not forecast future events.

Models developed from research may be less dependent on past trends. In Japan, an epidemiology model of rice dwarf virus (RDV) was developed to forecast RDV infestations (Nakasuji et al. 1975). Thus by monitoring the green leafhopper (GLH) densities in late May each year, RDV infestations can be predicted. In Europe, the EPIPRE system uses both yield loss and disease development models. Data on the crop, pest and weather are sent to a computer which predicts the expected epidemics and yield losses (Zadoks 1983). Based on these predictions, a control recommendation is sent back to the farmer. Out in the field, models in portable computers are required. In Minnesota, RUSTMAN was developed using a hand-held computer for the control of common rust on maize (Teng & Montgomery 1982). Field data is entered into the computer as prompted, and the model responds with an estimated yield reduction and the expected profit if control is made. There are now fully integrated electronic systems with built-in automated units placed in the field that record the weather variables to help in the timing of fungicide sprays (Teng & Rouse 1984). Such pest forecasting gadgets are being produced at a commercial scale in Michigan (Gage 1986, pers. comm.).

CROP LOSS MODELS Apart from forecasting pest and disease development in the field, it is essential that potential losses are also predicted as it provides a means for evaluating the benefits of implementing management decisions (Teng 1985). Most insect loss models in rice are developed empirically using field experimental data and multiple regression techniques (Sogawa & Cheng 1979). Since yield responses to insect damages are usually more complex (Southwood & Norton 1973), accurate predictions will need the coupling of pest development and crop growth models.

COMPUTER MAPPING Computer maps can be used to display the spatial dimension of insect populations. In England, mapping techniques are used to analyze aerial suction trap data of aphids and to indicate areas in which crops are at risk to damages (Woiwood & Taylor 1984). A computer program, SURFACE II, capable of performing difference mapping has been used for these purposes. Recently, a microcomputer-based mapping program that can run on

the Apple computer was developed in Korea (Song et al. 1982). In Malaysia, this program has been modified to print density maps of pests in the major rice-growing areas.

FUTURE DEVELOPMENTS IN RICE PEST SURVEILLANCE

With the aid of computers, data processing in pest surveillance is now faster and more efficient. However, pest information systems are still restricted because both the transmission of the data to the computers and the information delivery system are slow and inefficient. With modern advances in microprocessor technology, however, more effective systems can now be designed. This paper will only discuss the potentials of a few, since more details may be found elsewhere (Heong 1985, Rouse & Teng 1984, Teng & Rouse 1984, Tummala & Gage 1985).

Data Capture and Transmission

With the availability of electronic notebooks, the tedious tasks of recording field data and transferring them onto standard forms to be keyed into the computer may now be reduced to just one step. These devices can be used for direct field entry of data; the data collected is stored in memory and then "uploaded" to a computer for tape or disk storage. Some of the devices are equipped with modems that will allow direct transmission of the data via telephone lines to a distant computer. The recording of data such as RH, temperature, precipitation, soil moisture, leaf wetness, solar radiation, wind speed and other physical variables can now be done using data loggers. These devices not only allow data to be uploaded from memory tapes, but also permit the researcher to "dial-in" for the data.

Pest Information Delivery Systems

COMPUTERIZED PEST MANAGEMENT DELIVERY SYSTEMS The development of computerized pest management systems began in the early 1970s in the United States. In 1975 the Pest Management Extension (PMEX) system was implemented (Croft et al. 1976). Based on these ideas, SCAMP (System for Computer-Aided Management of Pests) was set up in New York (Sarette et al. 1979) and in New Hampshire (Welch 1984).

Another mainframe-based system is EPIPRE, implemented in Europe (Zadoks 1983). First started in the Netherlands in 1978, it is now being used in Belgium, Switzerland, Sweden, and the United Kingdom (Rijsdijik 1982). In 1981, 54% of the wheat fields in the Netherlands were treated following EPIPRE recommendations.

These systems are mainframe-based and the high hardware and communications costs have limited their availability. Aside from the cost, the potential of these systems for regional extension delivery is extremely promising. With the availability of the electronic mail systems, users such as the data suppliers, policy makers, extension specialists, scientists, and farmers

can communicate directly with one another over vast distances. Unlike the telephone, electronic mail does not require the simultaneous presence of the sender and recipient and is thus excellent for conveying messages. In addition, it can also store large numbers of text databases, like pest profiles and pesticide information (Welch 1984). With hardware costs dropping rapidly, such a system may become more acceptable in the Southeast Asian region.

VIDEOTEX The videotex system enables users to obtain frames of information through the ordinary telephone. These frames may be viewed through the ordinary television, recorded onto cassette tapes using a normal tape recorder or printed out using a thermal or dot matrix printer. In Britain, the PRESTEL system carries more than 4,000 frames of agricultural information, principally pest and disease intelligence reports (Houseman 1982). In addition, there are frames of agricultural advisory information, such as pest control measures.

In Malaysia, videotex systems are available for corporate and public use. More research is necessary to fully utilize such systems for extension purposes.

EXPERT SYSTEMS A potentially useful means of delivering pest management information is the use of expert systems (Heong 1985, Heong & Kenmore 1986). These are computer programs that offer solutions by mimicking human reasoning processes (heuristics), employing a knowledge base of applications extracted from human experts (Waterman 1986). Examples of these applications in pest management are in the areas of diagnostics, simulation delivery and decision support. Examples of diagnostic systems are SYSTEX (Systematics Expert System) in Texas which identifies insect species (Stone et al. 1986) and PLANT/ds in Illinois, which diagnoses soybean diseases (Michalski et al. 1983). As a simulation delivery system, the expert system acts as the delivery shell for models, accessing the models when appropriate to analyze problems. An example is an expert system for making recommendations for the control of the velvetbean caterpillar (VBC) of soybean in Florida (Jones et al. 1985). For decision support, the model is run outside the expert system and the output is transferred back as updates. FLEX (Farm Level Expert System) for cotton production in Texas is one such system (Stone et al. 1986). The expert system can also be made available to the extension worker and farmers through videotex as in the WHEAT COUNSELLOR in England, which diagnoses and advises on wheat disease control (Jones & Crates 1986).

With the development of microcomputer-based expert system shell programs, it is becoming easier for pest management experts to build expert systems. Such programs are portable and can form part of the regional DBMS in the surveillance system. Expert system research is now being actively pursued in Texas A&M, the University of Florida, and the Silwood Center for Pest Management in England. For rice, the potential of employing expert systems for extension is high and should be further investigated.

Regional Pest Surveillance Network

There is increasing evidence to show that several important rice pests are constantly displaced by wind. Downwind flights of the BPH of up to 1,000 km

have been documented in Japan, China and Korea (Cheng et al. 1979, Kisimoto 1976, Lee & Park 1972). In the Southeast Asian region, although direct evidence is still lacking, wind trajectory analysis has shown that similar movements of the BPH are likely to occur (Rosenberg & Magor 1986). It is thus important to establish regional large-area surveillance. In Europe, for instance, EURAPHID, which involves 12 countries was established in 1981 to coordinate aphid sampling and forecast aphid infestations (Taylor 1981). The Cooperative National Plant Pest Survey and Detection Program (CNPPSDP) was started in the United States, with 13 states participating, to detect new exotic pests and monitor pest epidemics (Teng 1984).

For the ASEAN countries, a regional pest surveillance network for rice pest and disease management should be established. This network should, among other things, standardize sampling methods of pests and diseases, establish a common data format or structure, identify mechanisms to exchange pest data and related information, establish areas of cooperative research, and provide regional pest forecasts. An expected result of this network is improved pest management decision making for all the countries concerned in this region.

CONCLUDING REMARKS

Many strategic and tactical decisions in agriculture rely on information. In pest management, surveillance systems are expected to generate these information. Since modern computers are extremely powerful tools in information technology, greater effort should be directed at applying them more effectively. On the other hand, computers are only machines and their usefulness depends largely on the quality of the input data. It is thus equally important that data are collected using accurate sampling techniques. Automating data capture will undoubtedly solve some of these problems. Even though data processing may be efficient, delivery systems often limit information flow. In the West, where there are efficient telecommunication networks, information delivery systems can utilize electronic means. While it may be possible for some countries in Southeast Asia to adopt this, in places where telecommunication is poor, another means of delivery is needed. Besides the traditional extension methods like mass media, billboards, and pamphlets, etc., we can look forward to expert systems which can be implemented on microcomputers.

In the Southeast Asian region where many of the countries are geographically quite close, an international large-area surveillance program should be considered. This will link not only surveillance efforts in different countries, but research as well. Such a program will enhance pest management decision-making in the region.

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THE ROLE OF INSECTICIDES IN RICE IPM SYSTEMS

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Insect pests are particularly abundant on rice grown in Asia. There are about 30 major species, of which the stemborer, brown planthopper (BPH), green leafhopper, seedbugs, gall midge, and army worms are the most common. These pests often cause big reductions in agriculture production.

Scientists are increasingly realizing that the control of these pests cannot be done by use of a single tactic. The introduction of rice cultivars resistant to BPH led to the development of biotypes after a cultivar had been cropped successively for four or more seasons. It appears that in almost every instance a new cultivar is introduced, a new biotype of BPH emerges. Several biotypes are postulated to occur in Indonesia, namely, biotypes 1, 2, 3; these are found throughout the rice-growing areas of North Sumatra. There is still much controversy about biotypes of BPH in Indonesia. In a panel discussion recently attended by entomologists from the Bogor Institute of Agriculture (IPB), the Directorate for Crop Protection and the Central Research Institute for Food Crops, it was agreed that the term "population" would be used rather than "biotype", to denote groups of BPH found to overcome the resistance of certain cultivars (Anonymous 1986).

Reliance on insecticides is not a good tactic for pest management as injudicious use can create unwanted effects such as pest resurgence, development of pesticide resistance, disturbance of ecosystem balance due to deaths of natural enemies of insects, and deaths of other non-target animals. The net response to these effects is the introduction of Integrated Pest Management (IPM) philosophy to Indonesia, a philosophy that still needs a lot of improvement before it can be practiced on a large scale. Insecticides can be a component of an IPM system, provided they are used judiciously.

INTEGRATION OF INSECTICIDES INTO IPM SYSTEMS

Insecticides should be applied only when they are needed to minimize the risk of creating negative side-effects from insecticide misuse, and to obtain maximum benefit. The word "needed" implies that there must be knowledge of several factors, among which are the economic threshold, population density, ecological data on larval or nymphal instars, and toxicity to natural enemies. Applying insecticides without consideration of the above will lead to potentially problematic situations. In the following sections, I will describe how insecticides may be used in a judicious manner, in relation to specific biological data.

POPULATION DENSITY AND INSECTICIDE APPLICATION

The introduction of a high yielding cultivar, 'Pelita', with good cooking quality resulted in the development of a new BPH biotype which caused serious losses and disrupted the national program for self-sufficiency in rice. Field observations indicated that 'Pelita' was very susceptible to BPH.

A field experiment was done to study the control of BPH with various insecticides. In the experiment, application of insecticides was done based on the population density of BPH of 10 hoppers per hill at 14–28 days after transplanting, 25 hoppers per hill at 36–65 days, 50 hoppers per hill at booting stage and 75 hoppers per hill at earing stage. BPH populations were counted weekly to measure trends in hopper population.

The combination of fenitrothion and BPMC was the most effective, resulting in the lowest BPH populations and differing significantly from the

Table 1. Brown planthopper population at various insecticide applications. Klaten, planting season, 1978.

Insecticides	Dosage a.i./kg ha	Number of hoppers per hill[a] days after planting 56	63	70	77	84	92	No. of applications	Hopperburn (%) DAT 91	98	105
DDVP 50 EC	1.00	24.75	25.55	36.30	4.05	140.90	311.57	4	25	40	55
Methomyl 20 EC	0.54	25.80	25.50	53.80	8.30	489.60	419.47	5	30	95	100
Phentoate 50 L	1.20	27.25	36.30	72.60	8.95	585.65	311.17	5	84	100	100
Cyanophenfos 25 EC	0.75	23.55	44.15	92.75	14.55	845.30	421.83	5	97	100	100
Fenitrothion 50 EC	1.20	22.80	42.00	58.45	11.55	403.95	398.48	5	57	98	100
Deltametrin 2.5 EC	0.01	26.55	36.90	80.25	11.50	561.00	379.50	5	80	100	100
Phentoate 60 EC	1.20	23.80	34.35	83.83	10.25	584.50	757.90	5	62	89	100
Pyridaphenthion M 50	1.00	33.25	15.80	23.80	2.85	181.65	345.68	3	16	23	53
Fenitrothion + BPMC 75 EC	1.12	23.40	7.00	12.10	1.90	80.95	27.22	2	3	5	10
Diazinon + BPMC 750 EC	0.75	21.15	7.20	13.83	1.65	110.75	327.45	3	2	10	25
Fenitrothion +BPMC	0.75	17.05	9.15	11.10	2.40	104.10	40.28	2	2	14	33
Control	-	16.55	41.85	56.70	14.00	308.05	520.27	-	67	83	100

[a]Underlined numbers indicate insecticide was applied the following day.

untreated plot; the same treatment needed only two applications and had the lowest hopperburn (Table 1). The next most effective treatment was the combination of diazinon and BPMC, in which three applications were needed and hopperburn was much lower than the control.

The other insecticides tested – cyanophenfos, phentoate, deltametrin, fenitrothion, DDVP and methomyl – showed higher BPH populations than the untreated plot. This was the first reported case of BPH resurgence in Indonesia and suggested that more research needed to be done to identify the cause.

The predator populations in plots treated with insecticides that showed resurgence were almost similar to those in the control plots, indicating that the resurgence was not due to the death of natural enemies (Table 2). We also found

Table 2. Populations of predators before and after insecticide applications. Klaten, planting season, 1978.

Insecticides	Dosage (a.i./kg) ha	Population[a] Spider a	Spider b	Coccinella a	Coccinella b	Cyrtorhinus a	Cyrtorhinus b	Paederus a	Paederus b	Casnodea a	Casnodea b	No. of applications
DDVP 50 EC	1.00	9	8	1	5	1	0	0	2	0	1	4
Methomyl 20 EC	0.54	11	7	2	4	1	0	0	1	1	1	5
Phentoate 50 L	1.20	12	8	0	5	0	0	1	1	1	1	5
Cyanophenfos 25 EC	0.75	10	8	1	5	1	0	1	1	1	1	5
Fenitrothion 50 EC	1.20	12	11	2	6	0	0	1	2	1	1	5
Daltametrin 2.5 EC	0.01	11	8	1	6	1	0	1	2	0	2	5
Phentoate 60 EC	1.20	14	9	1	6	0	0	1	2	2	2	5
Pyridaphenthion M 50	1.00	11	9	1	5	1	0	0	2	2	1	3
Fenitrothion + BPMC 75 EC	1.12	13	8	1	3	0	0	1	2	0	2	2
Diazinon + BPMC 750 EC	0.75	12	10	1	6	1	0	1	2	0	2	3
Fenitrothion + BPMC	0.75	11	8	1	5	1	0	1	3	1	2	2
Control	-		9	1	3	1	0	0	1	1	2	-

[a]a = before insecticide application, b = after insecticide application.

that 'Pelita' could be protected from economic loss by only two applications of insecticide at various population densities, depending on the growth stage of the crop. The control threshold on moderate and resistant cultivars will be reached later in the growing season so that the application of insecticides will be required only later or not at all. Therefore, by introducing moderately resistant and resistant cultivars, the use of insecticides is reduced and only applied when the control threshold has been reached.

LARVAL INSTARS AND INSECTICIDE APPLICATION

Laboratory experiments with army worms *Spodoptera litura* , showed clearly that the effectiveness of insecticides depends on the age of the larval instars. The older the larvae, the less susceptible they are as shown in Table 3.

Fenitrothion, methamidophos and deltamethrin were effective up to the third instar larvae causing 100% mortality. The same insecticides at the same dosage gave lower mortalities to the fourth and fifth instar larvae. This indicated that the proper time of insecticide application was when most of the larvae were in the first to third instar stages. Regular scouting should therefore be made to determine the correct time of insecticide application.

NATURAL ENEMIES AND INSECTICIDE APPLICATION

Important natural enemies of BPH found in rice-growing areas are *Cyrthorinus lividipennis*, *Lycosa seudoannulata*, *Tetragnatha*, *Casnodea interstitialis*, *Paederus tamulus*, *Microvelia sp.*, *Coccinella arcuata*, and *C. repanda* (Otake 1977).

Feeding tests to study the potency of the predators showed that *P. tamulus* and *Casnodea interstitialis* were the most effective predators, consuming an average of eight prey a day (Soekarna 1984). *Cyrthorinus* and *Lycosa* consumed 3–5 BPH per day.

Table 3. Response of insecticides to various instars of army worms, *Spodoptera litura*. Lab. 1984.

Treatment	Dosage a.i./ha	Mortality of instar (%) I	II	III	IV	V
Control	-	0	0	0	0	0
Fenitrothion 50 EC	1.00	100	100	100	63	43
Methamidophos 200 LC	0.40	100	77	100	57	23
Diazinon 60 EC	0.90	100	83	17	27	13
Phentoate 60 EC	0.90	100	97	87	47	33
Deltamethrin 2.5 EC	0.02	100	100	100	60	50
Carbaril 85 SP	1.27	100	47	23	23	23
BPMC 500 EC	1.00	100	47	3	7	0

The potency of these predators is significant and therefore should be taken into account during pest surveillance. When the control threshold is reached due to the fast population buildup of the BPH, and the inability of the predator to reduce the population density, any insecticide application should be effective on the BPH population, but be relatively non-toxic to the predators. For this purpose, extensive studies should be undertaken to identify the proper insecticide.

ECOLOGICAL DATA AND INSECTICIDE APPLICATION

A major insect pest, often causing serious damage to upland and dry seeded rice, is the seedling maggot, *Atherigona exigua*. In several places, infestations on young plants were between 20% and 40%. The most favorable stage for infestation is between 4 and 10 days after planting. Older plants suffer less damage than younger plants. The recommended control was previously to dust daily with 5% BHC dust up to one week after the seedling had emerged.

Recent studies (Soekarna 1981) indicated seed treatment of rice seed just before planting with carbofuran, carbosulfan, and thiodicarb reduced seedling maggot damage by 20–80% (Tables 4, 5). This tactic can be recommended selectively in places where seedling maggot is a major pest, since no resistant rice varieties are available yet. Seed treatment is more practical and economical than spraying and dusting.

Table 4. Efficacy of carbofuran 30 ST as seed treatment to control seedfly, *Atherigona exigua*[a]. Field experiment, 1980/1981.

Treatment	Dosage a.i./kg/seed %	Seed emergence 8 dap[b] %	Seedfly infestation %		Yield kg/ha
			10 dap	20 dap	
Carbofuran 30 ST	0.5	99 a	0.42 a	3.65 b	1,976 ab
Carbofuran 30 ST	1.0	98 a	0.30 a	1.20 a	2,168 ab
Carbofuran 30 ST	1.5	95 a	0.68 a	2.20 ab	2,379 a
Carbofuran 30 ST	2.0	97 a	0.25 a	0.73 a	2,382 ab
Carbofuran 30 ST	2.5	98 a	0.04 a	1.11 a	2,382 ab
Carbofuran 30 ST	3.0	97 a	0.14 a	0.83 a	1,774 ab
Carbofuran 30 ST	3.5	97 a	0.20 a	0.50 a	2,632 ab
Check	-	80 b	27.54 b	85.98 c	702 c

[a] from 3 replicates. [b]dap = day after planting. In a column, means followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test.

Table 5. Efficacy of carbosulfan 25 ST and carbofuran 3G to seedlingfly. Wet season, 1981/1982.

Insecticides	Dosage concen-tration	Average tillers/hill[b]			seedlingfly infestation[b] %		
		10 dap	20 dap	30 dap	10 dap	20 dap	30 dap
Carbosulfan 25 ST	0.25%	2.79 a	4.66 a	11.72 a	1.31 bc	3.04 c	4.32 c
Carbosulfan 25 ST	0.50%	2.66 a	4.98 a	13.32 a	0.61 c	0.82 d	0.80 d
Carbosulfan 25 ST	1.00%	2.80 a	4.93 a	13.35 a	0.11 d	0.11 d	0.41 d
Carbofuran 3G	0.50[a]	2.60 a	3.93 a	10.97 a	3.27 b	12.58 b	9.82 b
Carbofuran 3G	1.00[a]	2.52 a	3.91 a	11.06 a	1.04 bc	8.09 bc	5.29 bc
Carbofuran 3G	2.00[a]	2.47 a	4.44 a	15.13 a	0.14 c	1.11 d	1.36 d
Control	-	2.07 a	2.47 b	6.61 b	8.87 a	23.77 a	15.94 a

[a] = kg a.i/ha. [b]dap = days after planting. In a column, means followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test.

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FEASIBILITY OF USING LOCALLY PRODUCED *BACILLUS THURINGIENSIS* TO CONTROL TROPICAL INSECT PESTS

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Bacillus thuringiensis or "*Bt*," a spore-forming, entomopathogenic bacterium naturally found in soils, can selectively kill the larvae of some insect pests when ingested by them. The potential of *Bt* as a microbial insecticide for use in Southeast Asian field crops, vegetables, and rice is considerable. *Bt* has been a commercially successful insecticide for more than two decades and its use is increasing in quantity, quality (increased toxicity/kg), and range of target pests. Although *Bt* primarily kills lepidopteran insect pests, commercial companies have recently introduced specific strains that kill dipteran (mosquito) and coleopteran (beetle) pests. This microbial insecticide has an outstanding safety record with *no* reported toxicity to non-target organisms, including man, even in maximum challenge and mutagenicity screening tests (de Barjac 1980, Dulmage 1982).

Bt has been commercially available in Asia since 1972. In 1985 Thailand imported 46 metric tons valued at nearly US$500,000. Most of this commercial *Bt* product is sold to vegetable (crucifer) farmers in Central Thailand for control of a serious pest, the diamondback moth *Plutella xylostella*. *Plutella* has developed resistance to all other insecticides including the recently introduced insect growth regulators. So far, no resistance to *Bt* has occurred even though it has been heavily used (Rushtapakornchai & Vattanatangum 1985). *Bt* has not been successfully exploited in other tropical crops including rice because 1) the available commercial *Bt* formulations are expensive and must be imported, and 2) for this microbial insecticide to be effective, it must be used within the framework of a cropping systems IPM program employing economic threshold levels for control decisions. It is important to note that although *Bt* is a true microbial insecticide, it is applied as any other chemical pesticide (mortality dependent on a.i./ha) and not as all other microbials that are dependent on environmental factors (humidity, etc.) restricting biomagnification and therefore their effectiveness.

There is a documented need for *Bt* in Thailand, both the Northeast and Central Regions, and in the Philippines (Katanyukul et al. 1984, Reissig 1986, Tryon 1986). To lower *Bt* cost, research is being initiated by BIOTECH and the Entomology Department of the International Rice Research Institute (IRRI), both in the Philippines, and several research centers in Thailand to 1) identify local *Bt* strains, 2) to utilize existing expensive fermentation facilities to develop local mass production expertise, and 3) to cooperate in the design of key pest threshold-based IPM programs. *Bt* has been easily and inexpensively mass-

produced from local agricultural by-products in the Philippines and Thailand, with relatively simple technology (Dharmsthiti et al. 1985, Dulmage 1982, Padua et al. 1986).

Recent tests at IRRI and BIOTECH to screen 312 Philippine strains of *Bt* have shown that several strains are more toxic to rice, vegetable, and corn insect pests than the commercial *Bt* products. Padua et al. (1986) have demonstrated that several Philippine *Bt* strains in their collection are significantly more toxic to diamondback moth larvae than the commercial formulations used for its control in Thailand. Tryon (1986) has shown that many of the Philippine strains of *Bt* in the BIOTECH collection are more toxic to eight important rice pests, with several of these strains being 10 times more toxic to the rice leaffolder *Cnaphalocrocis medinalis* than the commercial strain. As a result, BIOTECH (Philippines) and Mahidol University (Thailand), with funds from the WHO, have been developing the technology to locally produce *Bt* insecticide in commercial quantities. In this paper, we will discuss the need for *Bt* in Southeast Asia and report some initial results of research done in the Philippines.

NEED FOR *Bt* IN SOUTHEAST ASIA

Philippines

RICE The use of high-yielding modern rice varieties (MV) and broad-spectrum, petroleum-based insecticides has not provided acceptable insect pest control for rice farmers in the Philippines. Both technologies, long considered important insect pest control weapons, have combined to aggravate the situation. The "genetic treadmill" and the continuous need for the next improved insect resistant MV is analogous to the "insecticidal treadmill" and both have proven to be endemic and expensive, placing the Philippine rice farmer in an economic "no-win" situation. The Green Revolution in the Philippines, which started with the development, release, and farmer acceptance of MVs, has increased the average rice yield from 2.2 t/ha in 1966 to 4.5 t/ha in 1985 in Central Luzon, but has also led to drastic changes in agronomic practices that have unintentionally increased insect pest problems (Bull 1982, Cordova et al. 1981, Herdt 1978, Norton & Conway 1977).

The agronomic practices that have increased insect pest problems on MVs include planting large areas to a single variety, an increase in the number of rice crops per farm per year, and increased use of fertilizer. It is common practice in the Philippines to plant large areas of irrigated lowland to a single MV, thus providing ideal conditions for insects to develop biotypes to break down plant resistance. Planting a large area to one MV puts extremely high pressure on selection for and the subsequent evolution of a new, more virulent insect biotype within a few generations (Odhiambo 1982). The well-documented evolution of prolific brown planthopper (*Nilaparvata lugens*) biotypes in response to mass release of a series of highly resistant MVs over the last 15 years demonstrates the evolution of biotypes as a real threat to the stability of any insect-resistant MV with vertical resistance.

Loevinsohn (1985) has documented the increase in number of rice crops per year in Central Luzon from 1 in 1966 to 2–3 in 1985, made possible by the photoinsensitive and short maturation (90–115 days) MVs. The result is a year-round environment favorable for rice insect pest survival.

A third agronomic practice that is increasing insect pest problems is the use of large quantities of fertilizer to maximize the yield potential of the highly fertilizer-responsive MV. Fertilizer, particularly nitrogen, not only dramatically increases yield but also makes the MVs more susceptible to pests like *C. medinalis*, the rice leaffolder (RLF). The RLF is now one of the most important rice insect pests in the Philippines (Dhaliwal et al. 1979).

The result is an increased dependence on expensive broad-spectrum petroleum-based insecticides with the number of insecticide applications per crop increasing from 0.4 in 1966 to 3.0 in 1980, and to 4.7 in 1985. The total cost of all chemical inputs needed to maximize the yield of MVs, including fertilizer herbicide, and insecticides has increased from ₱60 in 1966 to ₱663 in 1980, and to ₱1,326 in 1985. About 20% of the inputs in 1985 were attributed to insecticides (Bandong & Litsinger 1986, Cordova et al. 1981).

The insecticidal treadmill is triggered by insect pest resurgence from the destruction of natural enemies (Sawicki 1979) and the development of insecticide resistance forcing the farmer to increase 1) dosage (a.i./ha), 2) frequency of application, and/or 3) the need for new and more toxic insecticides (Saxena 1983).

Thailand

VEGETABLES In 1985, Thailand imported 46 metric tons valued at nearly $500,000. Most of this commercial *Bt* is sold to vegetable (crucifer) farmers in Central Thailand for control of populations of the diamondback moth (*P. xylostella*) that have developed resistance to all other insecticides. Farmers normally apply 3 kg/ha of formulated *Bt* every 3 days and usually in a 'cocktail' with several petroleum-based chemicals. The cocktail is the farmers' method of controlling an insect pest complex in one application. The *Bt* brand of choice is Bactospeine®. The liquid formulation (EC) is believed to be more effective than the powder (WP). Three brands of *Bt* (Bactospeine®, Dipel® repackaged as Argone®, and Thuricide®) are available in 500- and 1-kg (and 1-liter) packs at $15/kg. Each application of 3 kg/ha costs the farmer $45. Although this is expensive, farmers have no other choice if they want to protect their crops from the diamondback moth larvae. High volumes of watering on a daily basis washes the foliage and removes pesticide to prevent any lasting residual activity.

RICE There is a documented need for a *Bt*-IPM research program in Northeast Thailand. Although water problems and non-fertile soil have been justifiably the concentration of most research efforts in the region, pests are presently a serious problem in Thailand (Tryon 1986, Reissig 1986, Katanyukul et al. 1984). As crop quality, particularly for rice, improves through the introduction of improved rice varieties, insect problems will increase from the increased soil fertility resulting from use of inexpensive second-crop green manure such as sesbania,

and improved irrigation and drainage systems. Insect problems will also become more complex as farmers in the Northeast shift from a rice monoculture to new cropping patterns. Serious yield losses from insect damage have been reported on sesame, peanuts, corn, mung bean, and kenaf. Present insecticide alternatives are unacceptable to the Northeast farmer because they are expensive and toxic to fish.

INITIAL RESEARCH

Laboratory Screening

Efforts have been underway (Table 1) for over a year to screen 295 Philippine *Bt* strains against the nine major rice pests including *Cnaphalocrocis medinalis* (leaffolder), *Marasmia patnalis* (leaffolder), *Chilo suppressalis* (stem borer), *Mythimna separata* (armyworm), *Rivula atimeta* (green hairy caterpillar), *Naranga aenescens* (green semilooper), *Nymphula depunctalis* (caseworm), and *Hydrellia philippina* (whorl maggot). Many of these *Bt* strains (25% average) are toxic to these insect pests with several significantly more toxic than the commercial *Bt* formulations. The most toxic formulation will ultimately be the least expensive to mass-produce. Eventually all *Bt* strains will need to be cataloged by toxicity (LC_{50}) to specific insect pests and stored for future reference and/or use.

On-Farm Trials

WET SEASON 1986 Data obtained from five on-farm trials demonstrated that plots receiving weekly applications of *Bt* insecticide had significantly ($P < 0.01$) larger yields ranging from a low of ±32% to a high of ±192% with an average increase of ±65% and an average yield of 5.94 t/ha relative to the insecticide-free or untreated plots with an average yield of 3.55 t/ha. The rice yield from the plots receiving weekly applications of *Bt* were also significantly ($P < 0.01$) larger by 29% than the yield from a plot with a similar weekly application of *Bt* and two additional applications of monocrotophos at 5 and 12

Table 1. Screening of indigenous isolates of *Bacillus thuringiensis* for toxicity to lepidopterous pests of rice. IRRI, 1986.

Insect pests	Isolates	
	Screened (no.)	Toxic (%)
Green semi-looper	287	34
Green hairy caterpillar	285	53
Leaffolder	276	26
Caseworm	265	27
Striped stem borer	181	3
Yellow stem borer	55	13

DAT to control a severe whorl maggot infestation. The yields from the *Bt* +monocrotophos plots from Farms 6, 4, 1, and 5 were 3.61 t/ha, to 3.73 t/ha, 5.51 t/ha, and 5.62 t/ha, respectively, with an overall average yield of 4.62 t/ha.

Yield of rice from both *Bt* treatments, applied singly and in combination with monocrotophos were significantly ($P < 0.01$) increased relative to both the IRRI-IPM Working Group (IPMWG) treatments with an average yield of 4.07 t/ha for the IPMWG and 4.26 t/ha for the monitored Farmer's Practice (Litsinger and Shepard 1986, unpubl.). The IPM plots failed to give higher yields because one or two applications of azinphos-ethyl failed to control leaffolder.

The whorl maggot and leaffolder were the only two rice pests to reach threshold levels of 1 whorl maggot egg/ha and 2 leaffolder larvae/hill, respectively in our trials. Of the two insects, only leaffolders resulted in significant yield loss (>40%); fortunately, the larva is highly susceptible to commercial *Bt*. IR64, a MV, had sufficient time with ample standing water and fertilizer (75 kg N/ha) to recover from the early whorl maggot damage.

The leaffolder was able to significantly reduce the rice yield because the adult population reached levels of 2–3 moths/m^2 by 40 days after transplanting (DT) and remained near this level until 80 DT (Fig. 1). The yield data support the claim that the control of the leaffolder population was a direct result of the toxic effects of *Bt* and not beneficial organisms. Tryon (1986, unpubl.) found three WP commercial formulation of *Bt* HD-1 (Dipel®, Bactospeine® and Thuricide®) 100% effective in the laboratory, killing 3rd-instar leaffolder larvae within 96 h at rates of less than 0.1 kg/ha. A rate of 1.0 kg/ha of *Bt* is the recommended application rate.

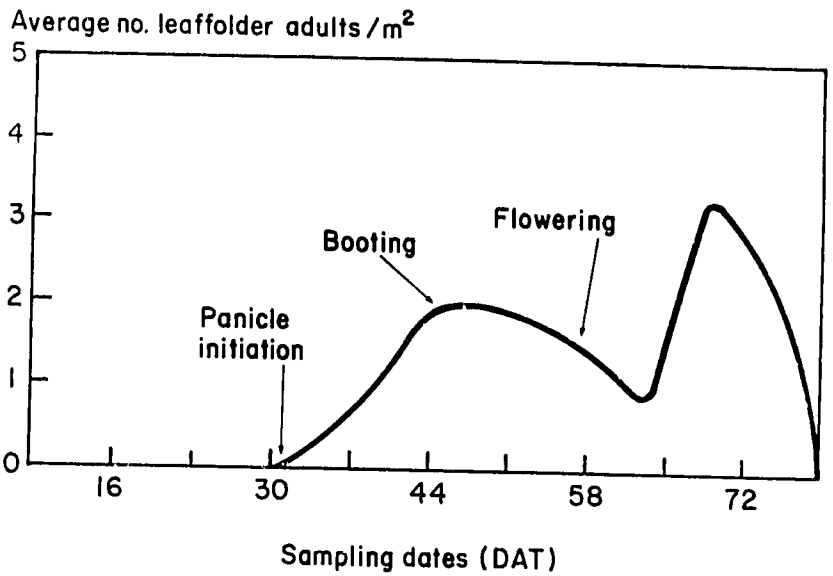

Figure 1. Number of leaffolder *Cnaphalocrocis medinalis* per m^2 from 5 rice farms treated with *Bacillus thuringiensis*, Central Luzon, Philippines, wet season, 1986.

The impact of the large numbers of beneficial organisms, although minimal in controlling the leaffolder infestation, was critical in suppressing the potentially dangerous hopper population (Fig. 2). The hopper population was made up of the brown planthopper, whitebacked planthopper *Sogatella furcifera*, and the green leafhopper *Nephotettix virescens*. The primary beneficial organisms observed and counted weekly were *Lycosa* sp. (spider), *Cyrtorhinus* sp. (mirid), *Metioche vittaticolis* (sword-tailed), and *Microspis crocea* (coccinellid), and there was no difference in the numbers of these beneficials in the *Bt* and untreated plots. As demonstrated in Fig. 2, the planthopper population has never reached the insecticide treatment level (threshold) of 1 hopper/tiller despite an early infestation (20–30 DT). There are numerous reports of the importance of these beneficial spiders and insects in controlling these hoppers (Chiu 1987, Heinrichs et al. 1978, Vorley 1985). Severe hopper outbreaks and resurgence resulting in hopperburn and complete yield loss are a direct result of the indiscriminate use of broad-spectrum insecticides that are extremely toxic to these predatory insects and spiders.

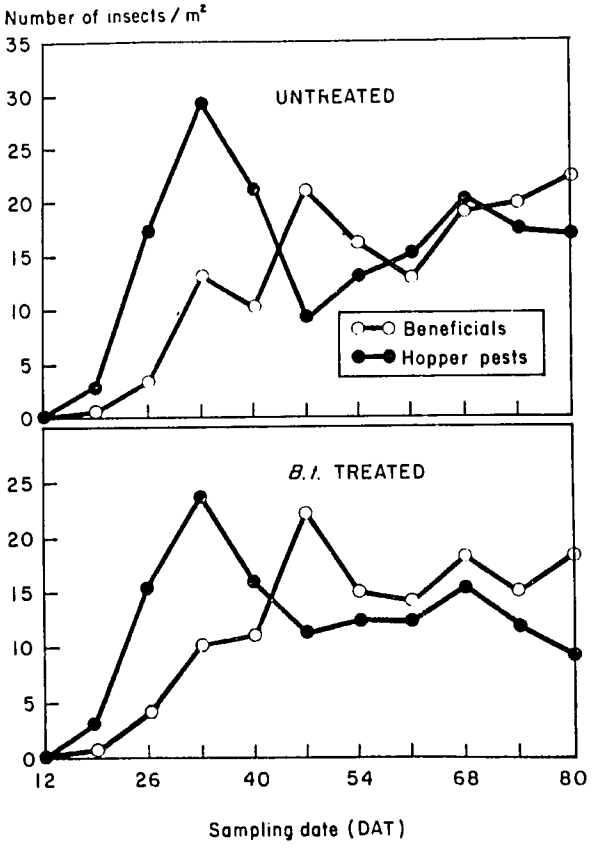

Figure 2. Number of beneficial insects, spiders and hoppers from counts made weekly from rice fields in Central Luzon, Philippines, wet season, 1986.

Bt RESEARCH GOALS

We believe that the following are needed in Southeast Asia, and urge scientists in the region to seriously consider activities that will,

1. Develop region specific IPM programs,
2. Identify and characterize key insect pests,
3. Collect and identify local *Bt* strains and develop an Asian *Bt* germplasm bank,
4. Screen commercial and local *Bt* strains against key pests,
5. Develop local *Bt* mass production capabilities, and
6. Set up an international network between *Bt*-IPM research programs.

CONCLUDING REMARKS

Interest in *Bt* is not only due to its insecticidal qualities, but also to its ability to selectively kill targeted lepidopterous insect pests without harming other organisms. It is also a politically and socially attractive alternative to chemical insecticides and can be safely applied by relatively untrained, often illiterate farmers, without the need for elaborate protective equipment. The research program discussed in this paper hopes to make *Bt* locally produced, inexpensive, highly toxic to key insect pests, safe, and an IPM-compatible insecticide. Several large agricultural donor agencies, including the International Development Research Center in Canada (local *Bt* production in Nicaragua), World Health Organization (local production of *Bt* strain H-14 in several countries including Thailand and Philippines), and Asian Development Bank are taking the initiative in supporting this research.

Despite the economic potential and safety benefits from the documented insecticidal success of *Bt*, relatively little progress has been made in developing countries to take advantage of this simple technology. Whether *Bt* will succeed in Southeast Asia will depend more on reducing the cost through local production and on the existence of effective IPM programs than on the failure of petroleum-based insecticides. It is absolutely necessary that key pests be identified, thresholds for these pests be established, and simple sampling methods be developed. The thresholds are needed for effective and judicious use of any insecticide and this is particularly critical for this microbial insecticide.

Environmental and human safety hazards from the use of petroleum-based insecticides are difficult to document but are an important "secondary cost" to the Asian farmer. The majority of the farmers are extremely poor and it is unlikely that they would go to a health clinic for any medical problem (Bull 1982). The pesticide poisoning problem is magnified when one realizes that many pesticides restricted in most developed countries are readily available to these farmers who are largely unaware of the hazards. For example, aldicarb and DDT are sold by distributors in Northeast Thailand. Many insecticides are repacked locally and mislabeled. Rice farmers in Northeast and Central Thailand have refused to use any recommended insecticides because of potential fish poisoning. The extensive use of insecticides has resulted in almost a complete elimination of rice-fish culture in the Philippines. There are efforts being made both by the

Philippine Government and international donors to reduce farmer dependency on these chemicals and increase the hectarage in rice-fish culture to improve the farmers' diet and income. With the increasing cost of conventional insecticides and the safety problems, locally produced *Bt* may provide an effective, inexpensive and safe approach to protect the Asian farmer from crop losses resulting from insect damage.

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ROLE OF CULTURAL TECHNIQUES IN RICE IPM SYSTEMS

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Experience indicates that the use of resistance alone in rice varieties may not be an adequate control tactic, particularly in coping with highly mutable pests such as the brown planthopper (BPH), the green leafhopper (GLH), the whitebacked planthopper (WBPH), rice tungro virus (RTV) and rice blast. The pest populations quickly undergo selection and develop new biotypes/races capable of breaking down the resistance in existing varieties. For example, IR26 and other varieties with the same gene for resistance to BPH were infested and hopperburned in two widely separated small areas in the Philippines (Anon 1975a). In the Solomon Islands all resistant selections including IR26 became susceptible (Stapley 1975). The same happened in Indonesia when IR26 and other varieties with the same BPH-resistant genes became susceptible in North Sumatra, East Java, and Bali due to the development of biotype 2 (Oka 1977). New varieties with biotype 2 resistance lasted only for 5–8 crop seasons, e.g., IR42 in North Sumatra and Central Sulawesi (Oka & Bahagiawati 1985, Shagir Sama et al. 1983). A number of local modern varieties, Cisadane, Kruengaceh, and IR42 possessing biotype 1 and 2 resistance genes have also recently become susceptible in parts of Central Java.

With the breakdown in resistance, natural control agents of key pests may then not be able to catch up with the population buildup of the pest and large-scale severe outbreaks would become unavoidable. Frequent sprays with pesticides have proved to be futile because the pest quickly develops resistance to the pesticide(s), resulting in the well-known "pest resurgence" phenomenon.

Cultural methods such as synchronized planting and crop rotation, sanitation, and water and fertilizer management play an important role in helping to suppress pest populations. Therefore, in rice IPM systems, the first line of defence against certain rice pests should be a combination of nonchemical methods – cultural methods, varietal resistance, and natural control (e.g., using parasites, predators, and insect pathogens). These will serve to maintain pest populations well below damaging levels. Cultural methods should also be the basis of natural control and the use of resistant varieties. Cultural methods, if carried out properly, prolong the life span of resistant varieties. Moreover, it is entirely compatible with the proper functioning of the natural control agents. Cultural methods may not give immediate and spectacular results when compared to pesticidal control, but they are cheap, highly dependable, non-polluting, ecologically sound and easily understood by farmers.

Cultural methods are as old as agriculture itself. A cultural method may be defined as the modification of certain farm operations to make the environment less favorable for the development and multiplication of pests, but favorable for crop production.

Certain cultural methods may be aimed at destroying the pest population, such as flooding the field after harvest, plowing under the stubbles, or burning the stubbles and straw after harvest. For example, the larvae and pupae of the white stemborer *Scirpophaga innotata* (Walker) (Goot 1925), and all stages of BPH, GLH, and WBPH and the three rice viruses SGV, RSV, RTV will be destroyed. Other methods like synchronized planting and crop rotation, plant spacing, and fertilizer management are aimed at preventing further buildup of the pest population. Planting synchrony and crop rotation carried out over wide areas are highly dependable for preventing continuous buildup of BPH, GLH, and WBPH (Oka 1983). The practices prevent development of overlapping generations of pests.

Types of cultural methods to be carried out should be based on thorough knowledge of pest eco-biology and rice agronomy. For example, a sanitation program against BPH may only require that infested rice plants be eliminated since rice is the only real alternate host of the insect.

SYNCHRONIZED PLANTING AND CROP ROTATION

In well irrigated areas in Indonesia, traditional rice farming systems used old, long-duration local varieties (5–6 months) planted once or twice a year. Wet season rice was planted during December–May/June and dry season rice during July–November. In areas of limited water supply the farmers planted rice only once a year during the wet season. Thereafter non-rice crops (soybean, peanut, sweet potato, vegetables, etc.) were raised. There was some degree of simultaneous rice cropping and rotation with non-rice crops covering relatively extensive acreages. Relatively mild attacks of endemic rice pests occurred, such as by the white stemborer *S. innotata*. No serious outbreaks of BPH, GLH, WBPH, and rice viruses were recorded.

However, since the massive introduction of the rice intensification program in 1968/69, when short duration modern rice varieties were introduced, there was room for planting rice three times a year or even five times in two years. Due to socioeconomic factors (labor shortages, market prices), staggered rice planting became unavoidable. This situation was ideal for continuous development of pests. Staggered planting with short idle intervals appeared to stimulate the buildup of BPH populations and resulted in serious outbreaks (Chatterji 1975, IRRI 1972, Mochida 1976, Oka 1975, Otake & Hokyo 1976). Outbreaks of the rice dwarf virus in Japan were also attributed to mixed rice cropping, which increased the abundance and varied patterns of the virus vector, the green leafhopper *N.virescens* (Nakasuji 1974). In Indonesia, from 1974 until recently, large-scale outbreaks of BPH, RTV (transmitted by GLH), and WBPH occurred in fields with staggered planting patterns such as in the Western part of West Java, Yogyakarta, Southern parts of Central Java, Eastern parts of East Java, coastal areas of North Sumatra, South Bali, Central Lombok, Central Sulawesi,

parts of South Sulawesi, and the eastern coastal parts of Aceh province. Rice gall midge and the rice stink bug also became more serious there. In staggered rice patterns, the generations of the pests are overlapping. This causes difficulties in gathering reliable quantitative data, which in turn makes right timing of pesticide treatment impossible, and thus less effective. Development of BPH biotypes also occurred for the first time in those areas (biotype 2 in coastal North Sumatra, eastern tip of East Java and South Bali in 1976/77 crop season; it is thought that biotype 3 may have occurred in the same areas of North Sumatra and Central Sulawesi in 1983 and Yogyakarta and Klaten (Central Java) in 1986). In these areas the varieties, IR42, Cisadane, and others became susceptible.

Synchronized planting and crop rotation have been initiated since 1976/1977 and gradually implemented on a large scale throughout the main rice centers in well-irrigated fields in Indonesia (Oka 1976, Sunardi 1976). In general the yearly cropping patterns are as follows:

Rice — rice — non-rice
Rice — non-rice — rice
Rice — non-rice — non-rice
Rice — rice fallow.

Cropping systems of well-irrigated areas in parts of West Java, Central Java, and East Java are shown in Figures 1 to 4. The acreages of synchrony covered irrigated fields bounded by at least one tertiary canal, i.e., between 300 and 500 ha. Rice in the wet season may be immediately followed by rice in the dry season (Fig. 1), or rice in the dry season may be immediately followed by rice in the wet season (Fig. 2). However, because of staggered planting, there is no clear-cut fallow period (i.e., for soil preparation) between the two rice seasons. In this situation any rice pest will build up continuously. On the other hand, in the synchronized patterns, there is a fallow period between the two rice seasons for about one month, e.g., April (Fig. 3) or November (Fig. 4). This is the time for simultaneous soil preparation (irrigating field, deep plowing under the stubbles (ratoons), and sanitation). Most rice pests will then be destroyed. During the growing of short maturity non-rice crops, there is no chance for rice pests : develop and they are gradually brought under control in areas where synchrony and crop rotation are strictly followed. The famous national, modern variety Cisadane, resistant to biotype 1 and moderately resistant to biotype 2 of BPH, is still holding up in these areas even after more than eight croppings.

SANITATION

In any sanitation program it is important to know the real alternative host of an insect pest. Sanitation aims to remove all breeding or hibernating sites and sources of food of the insect. In Okayama, Japan, epidemics of the rice dwarf virus transmitted by the green leafhopper were almost completely subdued within two years by winter plowing to control weeds such as *Alopecurus aequalis*, alternate host of the green leafhopper (Nakasuji & Kiritani 1976).

The overwintering stages of the rice stemborer, BPH, and GLH, which may survive in the ratoons, are all destroyed by plowing under or burning stubble,

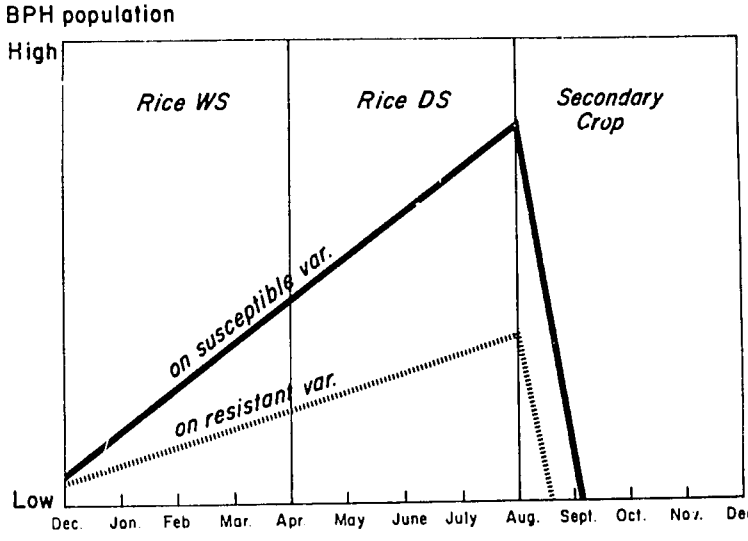

Figure 1. Cropping system type 1 in well irrigated areas (in reality staggered planting).

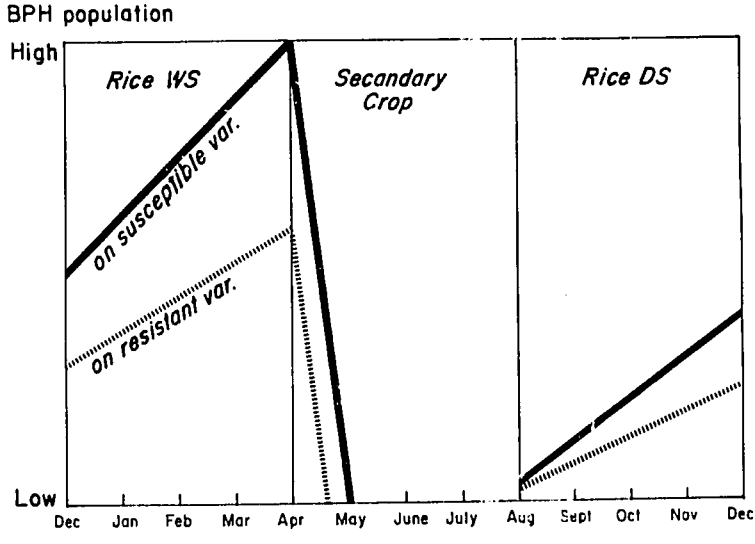

Figure 2. Cropping system type 2 in well irrigated areas (in reality staggered planting).

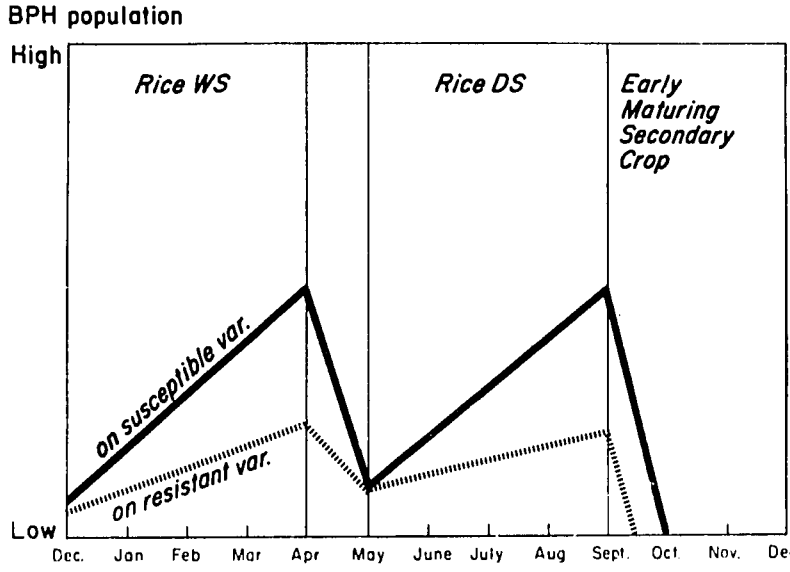

Figure 3. Suggested cropping systems to reduce the build-up of the brown planthopper population when wet season rice is followed by dry season rice.

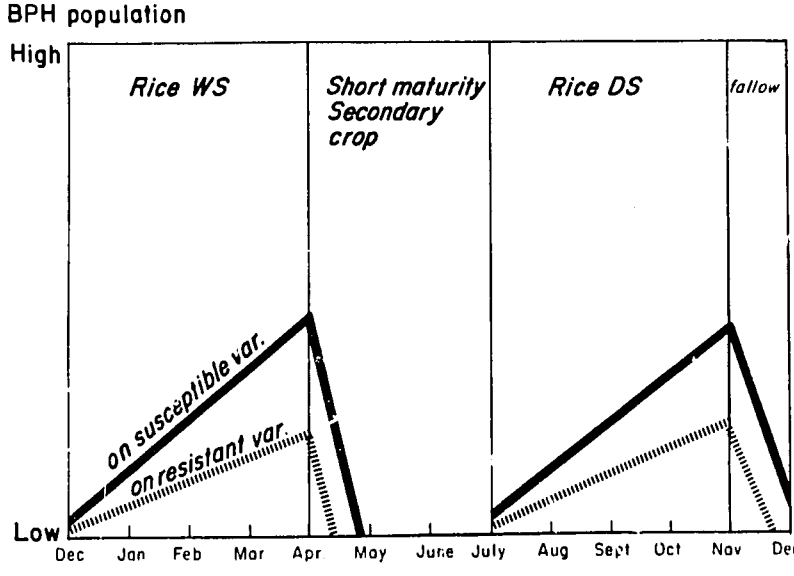

Figure 4. Suggested cropping system to reduce the build-up of the brown planthopper when dry season rice is followed by wet season rice.

ratoons, and straw. Grasses on the dykes and surrounding areas may also be removed or cut short to disrupt the life cycles of stink bugs and the green leafhopper. In rice, intensive cultivation and wet weather do not permit drying and burning of the straw. Straw burning is not always advisable because it destroys most of the arthropod populations that play an important role in decomposing plant remains. It also eliminates the available nitrogen in the plant remains. Nutrient loss by leaching is also much higher after burning (IRRI 1973). When the rice plant is somewhat older, weed sanitation in the field is, of course, needed. Weedy fields may make the microclimate more favorable for insect pests than clean fields However, interactions between the rice plant, weeds, and natural enemies are not well understood. Clean weeding may not be always advantageous for certain species of natural enemies because there may not be any shelter left for them. With respect to BPH, the sanitation program may be limited to only destroying the rice stubbles and ratoons because other grasses are not real host plants for the insect (Mochida & Okada 1971, Oka 1979).

FERTILIZER AND WATER MANAGEMENT

Some insect species become less abundant with increased nitrogen fertilization of crops. On the other hand, the population of many others such as certain aphid species and spider mites, are significantly more abundant with increased nitrogen levels (Pimentel et al. 1968). The rice stemborer *Chilo suppressalis* Walker (Ishii 1964), and the gall midge *Orseolia oryzae* (Wood-Mason) (Narayanan et al. 1973), were significantly more abundant in fields treated with high rates of nitrogen. Evidence from various countries suggest that high rates of nitrogenous fertilizers have caused increased infestations of BPH (Chatterji 1975, Dyck & Hsieh 1972, Fernando 1975, Wirjosuhardjo 1976). However, the exact relationship between increased abundance of BPH and high rates of nitrogen fertilizers is not known. It has been suggested that high nitrogen causes the rice plant canopy to become very thick and thus favor BPH (Nishida 1975). Field observations have further shown that rice fields receiving nitrogen fertilizers higher then the recommended dosages (90 kg N/ha) are more severely attacked by the sheath blight fungus *Rhizoctonia*, and bacterial blight *Xanthomonas campestris* n.sp. *oryzae*. High rates of nitrogenous fertilizers may result in more protein and amino acid synthesis in the rice plant. Both substances are among the essential requirements for growth and development of immature insects but are also needed by insect adults for the reproductive process (Bursell 1970, House 1965).

Although high nitrogen generally favors pests, it is not advisable to use fertilizers at lower than the recommended dosage, i.e., to sacrifice high yield for expected pest control. BPH-resistant varieties have commonly been selected in high fertilizer environments, and integrating such varieties with synchrony, rotation and other control tactics should achieve both high yield and BPH control.

Water may influence the abundance of some pest species. Stapley (1975) reported that BPH problems increased in the Solomon Islands when irrigated rice cultivation replaced dry rice cultivation. In Japan, insects are abundant in the

humid lowlands (Suenaga 1983), and rice fields with standing water have been found to encourage the multiplication of BPH (Pathak & Dyck 1973). In Indonesia, BPH prefers irrigated rice to upland rice. The problems are more serious in plots continuously flooded or with standing water. The green leafhopper *Nephotettix virescens* also seems to favor fields with stagnant water, and specially those with intermittent rain as well.

Good water management should therefore be able to help control certain rice pests. Draining the fields for about two days suppressed BPH outbreaks in Malaysia (Miller & Pagden 1930). In the Philippines, farmers withhold irrigation in BPH infested fields when the rice crop is almost mature, and plants are spread apart every few rows to help dry out the fields (Dyck 1974). To effectively control the rice water weevil, fields are drained at the proper time and irrigation is stopped for a predetermined period (Pimentel et al. 1968). Draining the water level in rice fields destroys the eggs of BPH laid in the leaf sheaths. Deep irrigation in the morning followed by the addition of a certain amount of kerosene (preferably mixed with pyrethrum) to water gives good control of BPH in Taiwan (Grist 1968, Iso 1954). In Indonesia, it was a common practice to raise the irrigation water level to control BPH. Sand or sawdust containing 0.25 L kerosene for every 100 m^2 was then broadcast on the raised water level and the plants were shaken (Tjao 1952).

TIME OF PLANTING

When synchrony and crop rotation are practiced, the planting time of the wet and dry season rice are December and May or July respectively (Figs. 3 and 4). In this situation there is no room for manipulating a planting time (early or late) for controlling certain pest species. In areas where synchrony is difficult to achieve due to water shortages and labor problems, manipulation of planting time (early or late) can provide effective control of some rice pests. Late planting of rice minimizes infestation by the white stemborer *Scirpophaga innotata* (Walker) (Goot 19[illegible] At Cuttack, India, crops planted at the end of July suffered little from leafhoppers and planthoppers, but crops planted later were severely damaged (Israel 1969). Gall midge incidence becomes more severe if rice is planted later than December in West Java.

SPACING

The spacing of rice plants in a field is believed to influence the abundance of certain rice pests. Close spacing may rapidly increase the BPH population (Kalode 1974, Kisimoto 1976). Data from IRRI show that a 10 x 10 cm plant spacing of both tall and short 'Peta' at time of peak insect populations had significantly more BPH per tiller than a 50 x 50 cm spacing (Dyck 1973, IRRI 1972).

Close spacing results in a more shaded, cooler, and more humid microenvironment, which makes it less favorable for the development of the natural enemies of BPH (Nishida 1975). The thick rice canopy also prevents foliar insecticidal sprays from reaching the basal portions of the rice plants where

the BPH congregates, resulting in ineffective control of the pest. Furthermore, the pesticides will kill some species of the natural enemies inhabiting the foliage (Nishida 1975). Both GLH and WBPH may also increase in closely spaced rice plants. In direct seeded rice, where spacing is much closer than transplanted rice, these pests may become more severe. Close spacing would also be expected to intensify the severity of rice diseases.

Spacing should be such that it allows some sunshine to penetrate into the basal portions of the rice plants. Solar and ultraviolet radiation restrain BPH increase (Suenaga 1983). More air flow also makes the microenvironment less humid and may also help the natural enemies develop. The distance between rice plants depends on the variety. Modern rice varieties with high tillering capacity may be planted further apart than those with less or moderate tillering capacity. In Indonesia the usual spacing between rice plants is 20 x 20 cm or 25 x 20 cm. The complex relationship of plant spacing – disease/insect – environment should receive more attention by researchers.

CONSTRAINTS AND SUGGESTIONS FOR THEIR REMOVAL

Various socioeconomic and technical constraints are evident when cultural control methods are implemented, particularly with respect to synchronized planting and crop rotation, as follows:

1. Water is available in abundance, which tempts the farmer to plant at any time of the year.
2. Synchronized planting, which should be followed by simultaneous harvesting and drying of the field, results in labor shortages despite the active participation of all members of the farmer's family.
3. As a result of synchronized planting and harvesting, there is a sudden over-supply of rice in the market, resulting in significantly reduced rice prices. To avoid this, farmers prefer not to plant rice simultaneously.
4. There are problems of post-harvest technology, e.g., drying, transport, threshing and storage.
5. Not all farmers understand the advantages of synchronized planting and crop rotation.
6. In some places, the existing farmers' organization is still very weak. Most of the members do not comply with group decisions, particularly with respect to synchronized planting and crop rotation.
7. Cheap input energy policy, i.e., highly subsidized pesticides, tends to encourage the farmers to only rely on pesticidal controls rather than cultural controls.
8. Promotions of the legally used pesticides are carried out very intensively through field demonstrations and billboards.
9. Limited numbers of qualified extension workers hamper the continuous "training and visit" programs for farmers.

The provincial government has introduced a detailed guide for synchronized planting and crop rotation at the village level, in an effort to overcome the above constraints. Along with this, there is a program to group farmers into small units of farmers' associations, each consisting of about 50–150 farmers called

"Kelompok tani" (farmers' group). Each group chooses its own leader and the group will collectively decide on any agricultural activity including programs of synchronized planting and rotation for the group based on the guidance of the extension service. At the same time, regulations on use of irrigation water are being improved to suit the program. There are traditional, farmer water use organizations in many parts of the country, for example, the well-known "subak system" in Bali, the "Dharma tirta" in East and Central Java, the "Mitra Cai" in West Java and the "Panriahan Pamokkahan" in parts of North Sumatra. Recently the Government encouraged the setting up of farmer water users' organizations (P3A). These organizations at the farmers' level make the program of synchronized planting and crop rotation easier to implement.

There is a comprehensive extension program including the "training and visit" system by extension, to continuously strengthen the farmers' organizations and to provide them with new technology.

Labor shortages in some of these areas are being overcome by introducing mechanization with units such as small tractors, threshers and hullers. The existing floor price for rice is being periodically reviewed and adjusted. The national logistic agency guarantees the purchase of excess rice grain when the free market is saturated. Subsidies for pesticides are also gradually being decreased, while the infrastructure and transport facilities down to the village level are gradually being improved.

All the above are only possible through massive involvement of the government in giving guidance to farmers and providing them with new technologies and other facilities. The political will of the government to protect the farmers and improve their living standards is widely appreciated and fully exploited. Researchers, in collaboration with extension personnel, are bringing the IPM into rice farming systems.

Research in various institutes and universities are given priority to strengthen the IPM concept. Implementing rice IPM at the farmer's level gives the scientist in plant protection and the practitioner an opportunity to prove that IPM is a sound concept for achieving a sustained high crop yield and a healthy environment, and last but not least, for helping millions of farmers to elevate their standard of living.

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DEVELOPMENT OF ACTION CONTROL THRESHOLDS FOR MAJOR RICE PESTS

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Economic thresholds (ET) are determined by (i) damage functions relating insect pest abundance to yield loss and (ii) control functions relating the degree of control from insecticides (Smith & Litsinger 1985). These are evaluated economically based on prevailing costs. However, the use of ET values derived from controlled single insect pest studies have proven unreliable as there can be a large site interaction as well as the influence of other pests. In addition, since scouting is commonly done weekly there needs to be an allowance for time delays in applying ETs. Therefore, in practice, action control thresholds (ACTs) are derived empirically from trial and error verification on farmers' fields and used in place of ETs.

DEVELOPING THE KNOWLEDGE BASE

Sites

Verification trials were conducted in farmers' fields in four irrigated rice locations representing distinct sites. Guimba in Nueva Ecija was supplied by deep well pumps while Zaragoza in Nueva Ecija, Laguna, and South Cotabato sites were irrigated by river systems (Bandong & Litsinger 1986, Litsinger et al. 1980, IRRI 1984, 1985a, b). We aimed to develop ACTs for sites or recommendation domains which are usually irrigation systems.

Yield Losses by Crop Growth Stage

Development of ACTs involved determining yield loss, preferably partitioned by growth stage, and relating various ACT values to those economic losses. Variability in yield loss was evident across sites from 5% (0.19 t/ha) in Laguna to 37% (0.80 t/ha) in Guimba (Table 1). ACTs therefore will be higher in Laguna and lower in Guimba. Higher yield losses occurred in the vegetative (38%) and reproductive stages (38%) than ripening (24%) (Table 1). If an ACT triggered an insecticide decision during a growth stage without economically significant yield loss, then the ACT was too low and was raised.

Major Pests

Insect pests attacking the vegetative stage comprised mainly the whorl maggot *Hydrellia philippina* Ferino, the rice green semi-looper *Naranga*

Table 1. Yield loss partitioned by crop growth stage in four irrigated transplanted rice sites. Philippines, 1978–86.

Site	Yield		Loss		Proportion of yield loss (%)		
	Protected	Unprotected	t/ha	%	Vegetative	Reproductive	Ripening
Laguna	4.56	4.33	0.19	5	38	42	21
Zaragoza	4.91	4.26	0.65	11	44	28	28
South Cotabato	4.75	4.16	0.59	12	32	39	29
Guimba	2.69	1.89	0.80	37	39	42	19
					$\overline{X}$ = 38	38	24

aenescens Moore, the rice hairy caterpillar *Rivula atimeta* (Swinhoe), and the rice caseworm *Nymphula depunctalis* (Guenee). The rice monoculture and the stable water supply favors their development. Farmers taught us to first scout for their presence in the most flooded fields.

Pests present during the reproductive stage are leaffolders *Cnaphalocrocis medinalis* (Guenee) and *Marasmia patnalis* (Bradley), the yellow rice borer *Scirpophaga incertulas* (Walker), and the whitebacked planthopper *Sogatella furcifera* (Horvath).

Rice bug *Leptocorisa oratorius* (Fabricius), a pest of the ripening stage, is more common in areas of thick vegetation like Cotabato.

Thresholds

Greater variability of yield loss was recorded between farms than sites, indicating the need to adjust to prevailing insect abundance from field to field. An ACT is composed of a character which has a life stage of the pest or a symptom of damage. It has a unit value and is derived through sampling, commonly sequential sampling, which is a time-saving method. Sampling is followed by the use of an insecticide at a minimal dosage applied in a particular way. All of the components of each ACT must work if it is to produce the highest profit.

Farmers' Thresholds

Farmers monitor their fields for the occurrence of pests. Only a minority of farmers apply insecticide by prophylactic scheduling. They carry out monitoring concurrently with other farm operations like weeding, checking the water level and clearing dikes. Farmers' ACTs are based on experience and are highly qualitative. Farmers' ACTs are derived quickly, often from only what they see while walking around their fields. They tap plants for hoppers and defoliators, flush moths while walking along dikes, and observe changes in the size of patches of damage over time. Farmers' ACTs, however, are as complex as those developed by researchers.

ACTION CONTROL THRESHOLDS

Whorl Maggot

Adult flies are attracted to an open water surface to oviposit. They lay eggs on newly transplanted seedlings 2–14 days after transplanting. Eggs hatch in 3–5 days and the young maggots tunnel into the whorl of the rice plant. Damaged unopened shoots are not completely severed so leaves emerge tattered in a diagnostic way.

"Damaged leaves" were first used as the ACT character for this pest. Experience showed this character to occur too late — 2 weeks after transplanting — for effective control. Very low percentage of control (26%) was obtained from trials using "damaged leaves" (Table 2).

Table 2. Development and performance of action control thresholds (ACTs) for irrigated rice insect pests tested in farmers' fields in four sites. Philippines, 1982–86.

Pests	ACT	n	Chemical (kg a.i./ha)	Control (%)
Whorl maggot + green semi-looper & hairy caterpillar	10% damaged leaves	10	Monocrotophos EC (0.4) 1–2x	26
		18	Diazinon G (0.75) 1x	28
	10% damaged leaves (use of earlier planted fields as indicator)	7	SI Carbofuran G (0.5) 1x	49
		15	Monocrotophos EC (0.4) 2x	43
		14	Deltamethrin (0.01–0.02) 1–2x	24
Whorl maggot	0.5–1 egg/hill (use of earlier planted fields, trap crop as indicator	18	Carbosulfan EC or isofenphos SD (0.3) 1x seedling root soak	40
		6	Monocrotophos EC (0.4) 1–2x	34
Defoliators (green semi-looper & hairy caterpillar)	10–15% damaged leaves with live larvae	13	Monocrotophos EC (0.4) 1–2x	16
	0.5–1 larva/hill	2	Monocrotophos EC (0.4) 1–2x	16
Leaffolders	10% damaged leaves	2	Monocrotophos EC (0.4) 1x	56
	5–10% damaged leaves (use of indicator fields 2 moths/20 meter row)	15	Monocrotophos EC (0.4) 1x	11
		18	Monocrotophos EC (0.4) 1–2x	44
		5	Azinphos-ethyl EC (0.4) 1–2x	18
	0.5–1 live larvae/hill	9	Monocrotohpos EC (0.4) 1x	42
Stemborers	3–8% deadhearts	11	Chlorpyrifos 20 + BPMC 11EC (0.4) 1–2x	14
	0.5–1 eggmasses/m^2	10	Chlorpyrifos 20 + BPMC 11EC (0.4) 1–2x	32
Planthoppers	15 hoppers/hill	7	BPMC EC (0.4) 1x	34
	0.5 hopper/tiller (nymphs)	8	BPMC EC (0.4) 1x	46

Use of indicator fields planted a week earlier is a strategy utilizing earlier chemical treatment. Diazinon granules were recommended as they performed satisfactorily at experimental stations. Again the treatment failed to give adequate control (28%). Diazinon granules broadcast into paddy work well with assured water supply. This situation does not exist in most fields as they tend to drain intermittently. Carbofuran, a systemic granule, was tried and the degree of control improved, but was too expensive for small-scale farmers. Monocrotophos sprays (5 and 15 DT) work well only when there is no rain.

A new strategy was developed in which whorl maggot eggs were used as the character. An early planted field nearby or a trap crop planted a week earlier, was monitored for eggs. The field itself is monitored twice a week and the ACT ranges from 0.5 to 1.0 egg/hill depending on the site. If this value is reached, the roots of seedlings are soaked overnight in insecticide solution. This technology provides reasonable control (40%) (Table 2) and is effective even during rainy periods. The degree of control will improve with better insecticide technology.

Defoliators

For simplicity, we included defoliating caterpillars with whorl maggot damage. However, as defoliators could be controlled by less expensive insecticides and they do not always occur with whorl maggot, we separated them.

Damaged leaves plus the presence of live larva were first used as a character. The resulting control using this character was very low (16%). The "damaged leaf" character proved too late, and often when we sprayed, the population had pupated. We therefore changed to using "larvae per hill", but again the control was not satisfactory (16%). The action of parasites lowered the larval populations resulting in a lower number of damaged leaves compared to the threshold. We will now incorporate the presence of parasite- and pathogen-affected larvae into the ACT.

Leaffolder

Using percentage damaged leaves as a character was acceptable (56%, Table 2) except that sometimes, when the larval population had already pupated, then spraying gave no benefit. The "damaged leaf" symptom does not become undamaged after spraying.

Farmers readily noticed moths when walking in the field and used them as the basis of their treatment. We tried to set a threshold using the moth as a character and this provided reasonable control (44%). However, the action of effective egg predators – sword-tailed crickets and ladybeetles – occasionally meant that little damage occurred even with high moth numbers.

We currently record the number of larva per hill by opening damaged leaves, setting a threshold of 0.5–1 larva/hill. The control (42%) using one spray can be improved with experience. We will look further into the possibility of reducing the dosage from 0.4 to 0.2 kg ai/ha.

Table 3. Comparison of the marginal net benefits and benefit-cost ratios from four insect control practices for four sites and two seasons.[a] Philippines, 1985.

Site	Treatment	Dry season			Wet season		
		Insecticide application (no.)	Marginal Net benefit (₱/ha/crop)	Marginal BC ratio	Insecticide application (no.)	Marginal Net benefit (₱/ha/crop)	Marginal BC ratio
Zaragoza, Nueva Ecija	Prophylactic	1.0	7907	0.0	3.0	6830	0.1
	Farmers' practice	2.0	8614	1.2	2.6	7589	- 0.1
	ACT	0.2	8862	3.3	1.6	7378	- 0.2
	Untreated		8512			8540	
Koronadal, So. Cotabato	Prophylactic	1.2	7764	1.7	2.0	8700	0.7
	Farmers' practice	3.0	7451	0.92	2.5	10438	3.1
	ACT	1.2	7929	1.9	1.1	9438	1.4
	Untreated		7504			9240	
Calauan, Laguna	Prophylactic	1.0	7710	- 1.1	4.0	9613	0.15
	Farmers' practice	2.8	7131	0.1	2.2	9738	- 0.9
	ACT	0.8	7154	- 1.0	0.8	10034	- 0.6
	Untreated		7840			10920	
Guimba, Nueva Ecija	Prophylactic	3.0	1012	0.2	3.0	5108	0.2
	Farmers' practice	0	2576	untreated	1.3	5512	- 0.4
	ACT	2.0	1844	0.2	1.0	5926	0.3
	Untreated		2436			6216	

[a] Calculations based on seasonal prices. Yield discounted from experimental bias (15%), harvesters' share (16%), labor for monitoring costs 30 hours/ha/crop, respectively. Interest charge was 60%.

Stemborer

ACTs have historically been based on percentage deadhearts. However, this character has proven unreliable as the damage is done before an action can be taken. Very low control in our trials (14%) supported this observation.

We tried yellow rice borer egg masses as a character (0.5–1 egg masses/m^2) with a sample size of 200 hills. When egg masses were present, we held them for parasite emergence before taking action. Spraying is only done when less than 50% parasitization occurs and therefore is timed with larval emergence. We were faced with problems of having whiteheads without egg masses. To overcome the problem we set up a light trap to give us warning when to sample for egg mass. We obtained very low control (32%), and feel that pheromone traps are needed to improve the ACT.

Planthoppers

Our previous ACT for planthoppers was 15 insects (adults and nymphs) per hill. Because of resurgence due to spraying at the time adults or young nymphs were present, we improved the ACT by measuring only older nymphs (0.5/tiller). With this approach, natural enemies were given time to exert their effect. Sequential sampling, when used together with the ACT, saves valuable time and is quite effective.

EVALUATION

Threshold technology over sites and seasons for crop year 1985, dry and wet seasons, were analyzed for economic benefits (Table 3). The untreated resulted in the highest net benefit (₱7638/ha), followed by farmers' practice (₱7381/ha), ACT (₱7320/ha), and prophylactic (₱6831/ha). The benefit-cost ratios from the farmers' practice and ACT treatments were almost identical. The ACT treatments resulted in fewer insecticide applications than the farmers' practice, but farmers used lower dosages and therefore spent less money. ACTs performed poorest in sites with highest or lowest yield losses and worked best in sites with intermediate losses. The ACTs thus need to be adjusted more to site conditions to bring higher net returns.

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ECONOMICS OF INTEGRATED PEST CONTROL IN RICE IN SOUTHEAST ASIA

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Integrated Pest Management (IPM) has been defined as the farmers' "best mix" of control tactics for any pest problem (Kenmore et al. 1985). Since pest populations vary over time and space, the "best mix" eventually needs to be changed from season to season and from location to location. To put this definition into practice, and at the same time give an answer to the question of "how to mix", one cannot ignore economic considerations. However, it is still not feasible to derive an optional mixing procedure due to insufficient data even for irrigated rice.

In this paper, we will give an economic assessment of the status of IPM based on conditions in Asian countries, with special emphasis on Thailand. To approach this topic, we divided pest control measures into two kinds, firstly, the direct chemical control measures, which, in the context of IPM, means economic thresholds or need-based pest control, and secondly, the economic consequences of IPM-based indirect control measures, also referred to as cultural or agronomic practices.

ECONOMIC THRESHOLDS

To our knowledge, there is no scientific evidence so far that farmers have adopted any of the economic threshold levels being recommended by extension services in Southeast Asian countries. Our experience with training shows that it is difficult to make farmers follow exactly those recommended economic thresholds. Rather, pesticides are commonly applied at a pest level which is only 30% of the recommended threshold level, on average (TG-PPP 1986). When discussing the adoption of modern technology, the first and possibly most important aspect is the technology's relative advantage in economic terms.

Results from field trials comparing farmers' practices or prophylactic treatments with economic thresholds (ETs) from various sources are presented in Table 1. The relative advantage of ETs is assessed by using the criteria of percent increase in net return and percent of successful cases. The net return of the ET-technology generally was found to be higher than that of the farmer's or prophylactic treatments (successful cases). In Thailand, for example, based on a total of 40 trials in farmers' fields carried out under the surveillance program, the ET-strategy increased the net return of rice production by 4.2% with 80% successful cases (Meenakanit 1985). Similar trials had been carried out in the

Philippines with varying results. Trials in collaboration with the regional Crop Protection Centers in the Philippines showed a 3.3% increase in net return with 61% successful cases (Waibel 1986a). Litsinger (1984) reviewed results from trials comparing prophylactic treatments with ETs during the period 1976 to 1983, and found that overall, 52% of the cases were successful, when data for all pests were averaged, with a range from 29% (rice whorl maggot) to 71% (caseworm).

Rola and Kenmore (1986), in a study in Laguna, found a considerable increase in net return with a high proportion of successful cases (Table 1).

In addition to the criteria used in Table 1, technology such as economic thresholds has also to be viewed from the perspective of risk. Risk is often measured in terms of the standard deviation of net returns, with the assumption that net returns are normally distributed. In Figure 1, it becomes obvious that the ET technology increases average net returns along with an increase in standard deviation. This means that farmers have to 'pay' for the benefits obtained by following economic thresholds in terms of a higher risk. For example, in the Philippines (P. Kenmore, unpublished), for a $25 increase in net return farmers would have to 'pay' merely $2 in standard deviation, while in Thailand the ratio is almost 1:1. The practical implications are as follows: in a given location a number of farmers are doing perfectly well with thresholds, while others are not. It might be quite realistic to assume that farmers will look at a number of early adopters before they decide to practice ETs by themselves.

It has been hypothesized, however, that farmers in developing countries are only moderately risk averse, and would be willing to 'pay' two units of standard deviation for one unit in increased net returns (Ryan 1979). If we apply this rule, the ET technology would seem to be acceptable under risk considerations.

On the other hand, we find that while economic thresholds increase farmers' profits, they do not significantly increase yields (Rola and Kenmore 1986). Litsinger (1984) concluded that Philippine rice production could be maintained at

Table 1. Economic assessment of economic thresholds in rice in two Southeast Asian countries.

Country/(Source)	Average increase of farmers' net return (%)	Percent of successful cases
Thailand[a]	4.2	80
Philippines		
(Waibel 1986a)[b]	3.3	61
(Litsinger 1984)[c]	-	52
(Rola & Kenmore 1986)[d]	7.6	82

[a]Results of 40 farmers' fields 1985 dry season. [b]Results of 58 farmers' fields 1980-1981 dry and wet seasons. [c]Compared with prophylactic treatments. [d]Results of 22 farmers fields 1986 wet season.

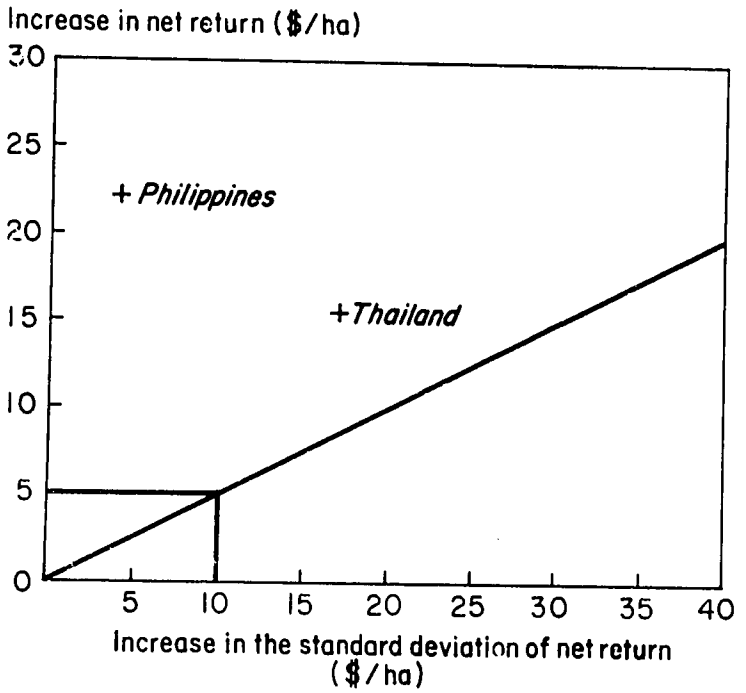

Figure 1. Assessment of need-based control under risk aspects.

Table 2. Fertilizer and pesticide costs as a percentage of total cash costs of rice production in selected Asian countries.

	Thailand[a]	Philippines[b]	Sri Lanka[c]	Taiwan
Fertilizer	27.1	18.2	9.9	54.5
Insecticides	2.4	6.1	3.1	26.4
Fungicides	2.2	0	0	0
Herbicides	0.4	1.8	3.1	5.8

[a]Based on selected farms in Central Thailand. [b]Own surveys during 1981. [c]Source: Barker et al. 1985.

current levels with potentially half the insecticides being used now. Other studies have shown that 95% of the increase in profits is due to a reduction in the cost of control (Waibel 1986b). This indicates the limits in the potential benefits of need-based pest control, since the most that can be saved is the amount which is currently being spent. The amount of money farmers spend on insecticides – which, at the present level of technology, are the main target of economic thresholds – varies with the production intensity in the different countries. As shown in Table 2, insecticides usually accounted for less than 10% of the cash costs, with the exception of an extremely capital intensive rice production system found in Taiwan. This raises the question of whether farmers

would be willing to take the trouble of sampling for pests following the often time-consuming and complicated methods suggested by crop protection researchers for the sake of saving a few bahts, pesos, or rupies. To make matters worse, the farmers' perception of missing one insecticide application per season is quite different from that of the researcher's "objective" loss assessment. While the magnitude of yield losses due to insects are in the order of 10%, farmers, on average, attribute a loss of more than 40% to one missed spraying (Waibel 1986b) or even expect total loss (Brunold 1981). This, in the eyes of farmers, makes spraying a highly profitable undertaking and makes *not* spraying a rather risky affair.

INDIRECT CONTROL MEASURES IN THE CONTEXT OF IPM

Agronomic or cultural practices (we include varietal selection) with regard to pest control are measures which aim at reducing the probability of pest attack by creating unfavorable conditions for pest development (Heitefuss 1975). Since agronomic practices affect both the pest and beneficial complex, as well as crop yield, their adoption always requires a judicious compromise between plant protection and plant production (Heinrichs et al. 1979).

In Table 3, we have tried to investigate possible negative effects of IPM-based agronomic practices on the economics of rice production. Only those practices that are supposed to have an influence on the pest and beneficial complex, referred to as 'potential loss', were selected. Following Table 3, the more interactions between agronomic practices and economic factors, the more conflicting the adoption of practices would be.

The only IPM practice with supposedly no negative impact on economic factors is the use of economic thresholds (not an agronomic practice), making it the easiest to adopt. Practices most conflicting are variety, planting date and planting method. In varieties, pest resistance is a trait which mostly goes with high yield, although there are cases where these do not match. For example, in Thailand, RD1, a highly susceptible variety, has a potential yield of almost 750 kg/rai, while the later-developed varieties which were more resistant could not reach this yield level (Anonymous 1985). Furthermore, highly resistant varieties do not always command a price as high as susceptible varieties. Also, if new certified seeds need to be purchased from seed producers, additional cash is required in comparison to the regular practice of using owner exchanged seeds.

Another example of conflicting agronomic practices is the change of the planting method due to pest reasons. In the intensive rice areas in Thailand, direct seeding is widely practiced. To change back to the transplanting method would severely affect labor and, consequently, cash resources as more transplanters would have to be hired.

An important question to address is what quantitative basis exists for the IPM recommendations currently being made. Undoubtedly, research has achieved a lot in the past in identifying the influence of cultural practices on the pest and beneficial complex. On the other hand, how valid such results are beyond a given area and a given year is yet to be determined. In the surveillance system in

Table 3. Possible negative impact of IPM on the economic factors of irrigated rice production.

	IPM Practices								
Economic factors	Variety	Planting date	Planting method	Plant spacing	Seed quantity	Land Preparation	Fertilizer Input	Water Management	Pesticide Application
Potential yield	*	*	*	*	*	*	*	*	
Price of crop	*	*							
Cash resources	*		*		*	*			
Labor resources			*	*		*		*	
Cropping intensity	*	*	*						
Irrigation resources		*						*	
Potential loss	*	*	*	*	*	*	*	*	*

Table 4. Agronomic factors where pest populations is significantly higher.[a]

Pest[b,c]	Provinces		
	Chachoengsao	Suphan Buri	Chai Nat
ACW	Farmers using insecticides Farmers planting early	-	Dry season crop (early infestation)
BPH	-	Dry season crop Farmers using RD7 variety Farmers using insecticides	Dry season crop Farmers not using insecticides
GLH	Farmers using more than the recommended level of nitrogen	Farmers not using insecticides	Wet season crop Farmers using direct seeding
RLF	Wet season crop	Farmers using insecticides Farmers planting early	Dry season crop Farmers using direct seeding Farmers using insecticides
STB	Farmers using more than the recommended level of nitrogen	Farmers using direct seeding Farmers using more than the recommended level of nitrogen	Dry season crop Farmers using ttransplanting
THR	Farmers using less than the recommended level of nitrogen	-	Farmers not using insecticides Farmers using direct seeding
BLA	Dry season crop Farmers planting early	Farmers using seed treatment	-
DPA	Wet season crop Farmers using fungicides	-	Farmers using transplanting Wet season crop
TWI	Wet season crop	-	Dry season crop Farmers using direct seeding Farmers not practicing hand weeding

[a]Using t-test for independent samples. [b]Using the seasonal maximum of each field. [c]ACW = Army/Cutworm, BPH = Brown planthopper, GLH = Green leafhopper, RLF = Rice leaffolder, STB = Rice stemborer, THR = Thrips, BLA = Rice blast, DPA = Dirty panicle disease complex, TWI = Total weed infestation.

Thailand, we collected data on agronomic practices and pests as well as beneficial populations. We grouped these practices (Table 4) for all significant differences in pest levels. For example, in the province of Chachoengsao, we found that farmers who apply more than the recommended level of nitrogen have significantly higher population levels of green leafhopper *Nephotettix spp.* and rice leaffolder *Cnaphalocrocis medinalis*. Should we recommend the farmers concerned to reduce their fertilizer level? In the province of Chai Nat as another example, we found that farmers who followed the transplanting method experienced a significantly higher stemborer infestation. Should they shift to direct seeded rice? We are well aware that results as shown in Table 4 must be treated with extreme care, more so because data are collected from farmers' fields and not under controlled conditions. Also they represent only a short period of time. We need to have more of such information in quantitative terms and to use this information for resource allocation and goal achievement.

We cannot refrain from asking another equally important question. How do farmers assess the possible effects of changing agronomic practices?

In the Thai-German Plant Protection Program (TG-PPP), we are at present conducting a study on the decision making process of farmers. In Table 5, a farmer's expectations from changing his variety is presented (Tuettinghoff 1987, pers. comm.). The two varieties under consideration were assessed by the farmer as being equally susceptible to some insect pests while the resistance in the second variety was believed to be effective against rice blast *Pyricularia oryzae*. The farmer expected the resistant variety to command a lower price which, however, he expected to be compensated for by its higher yield due to the non-occurrence of rice blast. He also expected the effect of applying fertilizer to be higher than in the non-resistant variety. On the other hand, he expected a higher yield loss from not spraying insecticides in the non-resistant variety and equal loss from not applying herbicides. It is remarkable that he placed herbicides

Table 5. A farmer's expectation from changing from a non-resistant to a resistant variety.

	Non-resistant variety	Resistant variety
Expected price (Baht/tang)	21.5	20.5
Expected yield (tang/rai)	72	82
Yield increase from fertilizer application (tang/rai)[a]	21.4	24.6
Yield increase from insecticide application (tang/rai)[a]	31.6	26.9
Yield increase from herbicide application (tang/rai)[a]	32.6	32.4

[a]Measured in terms of yield reduction in case input would not be applied.

before insecticides and the latter before fertilizer, in terms of their expected contributions to yield increase.

This selected example shows that in implementing IPM programs, we need to identify the farmers' perceptions. These have to be compared to location specific, research findings and eventually need to be corrected by training and communication approaches.

CONCLUDING REMARKS

IPM, if it is to be adopted by a large number of farmers, has to offer more economic advantages based on more concrete recommendations than it does at present. If the IPM definition adopted by us is going to be realized, there is a strong need, in our view, to add other aspects to it.

Firstly, when we talk about reducing costs of pest control by applying the ET concept, we should not only consider the amount which can be saved by less spraying, but also the output of an alternative use of this amount. For example, when pest sampling shows that no insecticide application is required before flowering, the money originally being reserved for insecticides could be used for applying more fertilizer.

In another study based on a simple decision model using time series pest data, the marginal net return in relative terms of the ET-strategy may be increased from 0.67% to almost 8% as compared to a farmer's strategy (Waibel 1986a).

Secondly, location specific agronomic practices, which combine the requirements of plant production and plant protection in an economically optimal way, need to be defined. Only then would one be able to substitute the 'green revolution' package of technology with an 'IPM package'. There would be a marked difference between both packages. Whereas the old package was offered as a fixed product, e.g., the 16 steps of rice production (Masagana program in the Philippines), the IPM package would consist of a set of decision rules, e.g. if you find less than a specified level of pest until this date, then apply more fertilizer. The new package would be more likely to achieve an optimal allocation of scarce farm resources as inputs would have to be applied according to states of nature, thus increasing the overall productivity of the farm.

There are also demands to be made on the organizations and institutions involved in the implementation of IPM. IPM clearly is a multidisciplinary problem-solving technology and as such it needs to be treated at least within extension organizations. To date, IPM has been too much of the entomologist's business but it should – much more than is the case now – include other disciplines, especially agronomy.

Surveillance programs can serve as a good point for launching and gradually implementing IPM. However, these programs often combine two things which cannot go together: to prevent large-scale pest outbreaks and to collect data for developing IPM-based recommendations. We believe that surveillance has to concentrate on the second aspect while the prevention of pest outbreaks can only effectively be achieved by the farmers themselves with the support of local

extension workers. Therefore, the role of plant protection services needs to be changed from being the 'fire brigade' to the 'information office', and plant protection staff need to involve themselves in on-farm research as well as training. In the end, successful implementation of IPM in rice requires a plant protection information system established on a local (at least regional) level with emphasis at the farm level rather than experiment station research.

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DEVELOPMENT OF SIMPLE SAMPLING METHODS FOR PEST SURVEILLANCE IN RICE

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Pest surveillance may serve two purposes, tactical decision-making and/or strategy development (Heong 1983). This paper deals only with the first aspect of surveillance, the gathering of information as a sound basis for pest control decisions.

Under conditions prevailing in rice production in Thailand, this kind of surveillance information cannot be provided for all rice farmers by governmental services (Heuel-Rolf & Waibel 1985). The available personnel and budget limit such activities to selected farmers only. Instead of monitoring the pest situation in a limited number of fields, the scarce resources of the surveillance service can be used more effectively for farmer-training on pest surveillance methods.

One basic requirement for such a training program is adequate sampling methods. Sampling methods must be sufficiently reliable for decision-making and be cost effective, i.e., require low time expenditure per field, and also be very simple for farmers to use. For example, no complicated calculations should be involved in the assessment of the infestation level. In cases where many pests are involved, identification of damage symptoms is easier than searching for certain pest stages.

Predetermined levels of accuracy combined with low sampling time requirements and simple pest assessment can be achieved with the sequential sampling method. Detailed treatises on the underlying concepts and mathematical formulas may be found in the papers by Waters (1955) and Onsager (1975). While sequential sampling plans have been developed for a variety of crops (Pieters 1978), few are published for rice insect pests (Nishida & Torii 1970, Shepard et al. 1986).

The highest savings in sampling time in connection with sequential sampling are achievable when the plan is based on the binomial distribution. Instead of counting insects or damaged plant parts, only the presence or absence of pest or damage symptom is to be recorded. With this approach, considerable savings in sampling time have been accomplished in cotton (Pieters & Sterling 1975, Sterling 1975).

Some results of the on-going research program on sequential sampling for major insect pests of rice in Thailand are presented in this paper.

SAMPLING FOR STEMBORER

Four stemborer species occur on rice in Thailand, of which the most important are *Scirpophaga incertulas* and *Chilo suppressalis*. They are sampled

as a group without differentiating between species. The number of deadhearts per sample unit (= 1 hill) is commonly recorded (Anon 1985).

As the basis for a binomial sequential sampling plan, a model was derived using data from field trials and surveys; data which would allow a prediction of the average number of deadhearts per sample unit from the proportion of infested sample units. Similar models were described by Sterling (1975) and Ingram and Green (1972) for cotton pests. The stemborer model is shown in Figure 1.

As shown by the coefficient of determination and confirmed by an analysis of the residuals, the model provides a sufficiently reliable prediction. It is valid for up to 3.5 deadhearts per hill and thus includes the currently recommended economic threshold of 1.5 deadhearts per hill in transplanted rice (Anon 1985).

According to the model, the economic threshold corresponded to a proportion of 0.68 infested hills. For calculating the sequential decision lines, the lower limit, i.e., highest infestation level that can be tolerated without control measures, was set at 0.50 or 50% infested hills. This seemed to be a practical compromise between accuracy (i.e. probability of wrong decisions) and feasibility (i.e. average number of samples to be taken). Based on the same considerations, the acceptable risk levels were set at $\alpha = 0.20$ for spraying when actual pest density is still below the economic threshold, and $\beta = 0.10$ for not-spraying when the economic threshold has already been surpassed. The resulting decision lines are shown graphically and in sampling table form in Figure 2.

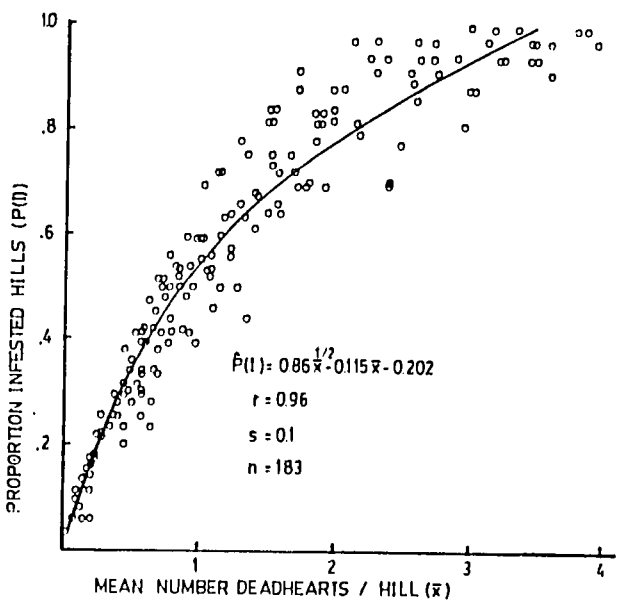


Figure 1. The relationship between the proportion of hills infested by stemborer and the mean number of deadhearts per hill in transplanted rice.

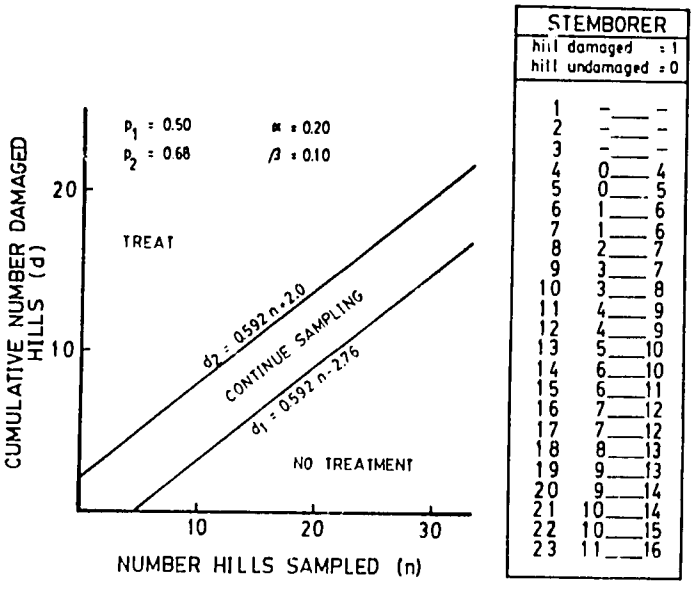


Figure 2. Binomial sequential sampling plan for stemborer in transplanted rice.

Using the formulas given by Onsager (1975), the theoretical maximum number of sample units to be taken was estimated to be approximately 23. Thus, at certain infestation levels, the sequential sampling method requires a higher number of hills to be examined for stemborer damage than the currently used sampling method of the surveillance service of the Department of Agricultural Extension (Anon 1985). In the surveillance guidelines, a sample size of 10 hills is fixed and it is recommended that an additional 10 hills be examined if a mean close to the economic threshold resulted from the sampling of the first 10 hills. Therefore, the sequential sampling method can only be accepted if the reduced time for examination of one hill, as well as the reduced sample size for low and high infestation levels, result on average in a reduced sampling time per field.

The sampling plan described above was developed for transplanted rice and cannot be applied in direct seeded rice because, besides other factors, the sample unit and therefore also the economic threshold, are different. Preliminary results on developing a model indicate a linear relationship between mean number of deadhearts per sample unit, a cluster of 10 tillers, and the proportion of infested sample units.

SAMPLING FOR GALL MIDGE

The same approach, as for stemborer, was followed in the development of a sequential sampling plan for rice gall midge (*Orseolia oryzae*). First, a model for

the prediction of the average number of galls per hill from the proportion of infested hills was derived from sampling data of various field trials and surveys (Figure 3). The currently recommended economic threshold of 0.8 galls/hill (Anon 1985) corresponds to a proportion of $p_2 = 0.5$ infested hills. The lower limit was set at $p_1 = 0.35$. The same acceptable risk levels were chosen as for stemborer, namely $\alpha = 0.2$ and $\beta = 0.1$. The resulting sampling plan is shown in Figure 4.

The theoretical maximum sample number was estimated to be approximately 33. However, we limited the table to 30 samples. At this point the alternative to be selected should be close to the running total.

FIELD TESTING OF THE SAMPLING PLANS

In order to obtain information on the efficiency of decision-making regarding control measures, the sequential sampling plans were tested against two systematic sampling methods with different sample size, namely, 10 and 20 hills, respectively. In the first case, the economic threshold was calculated as the average number of damaged tillers per sample unit and in the second as percentage damaged tiller. The test was carried out in farmers' fields, with the standard size of the surveillance fields (Anon 1985) of approximately 1 rai (= 0.16 ha). The results are shown in Table 1.

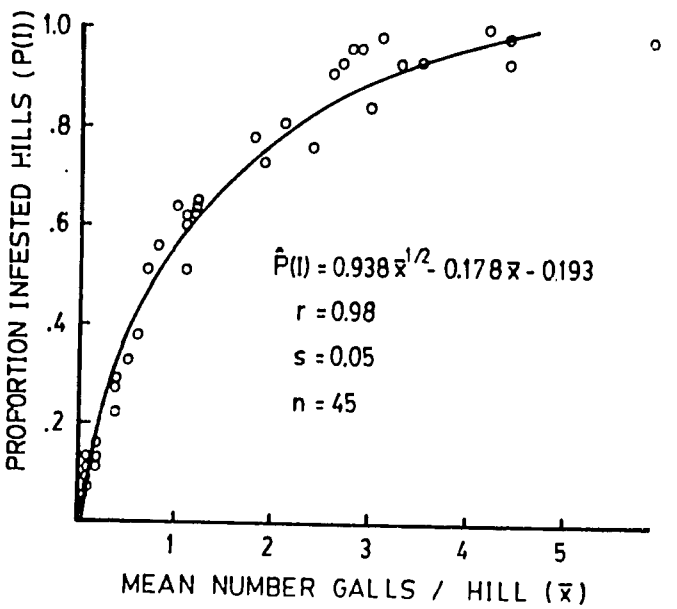
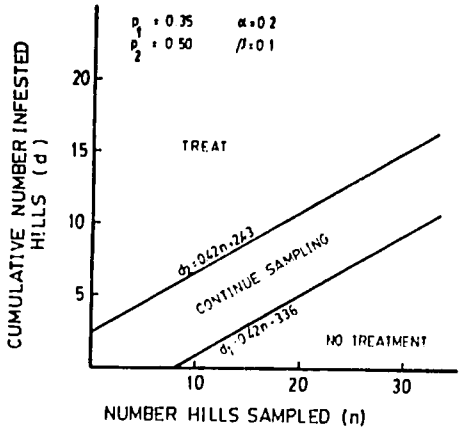


Figure 3. The relationship between the proportion of hills infested by gall midge and the mean number of galls per hill.



GALL MIDGE	hill with galls = 1	hill without = 0
1	–	–
2	–	–
3	–	–
4	–	4
5	–	5
6	–	5
7	0	5
8	0	6
9	1	6
10	1	7
11	1	7
12	2	8
13	2	8
14	3	8
15	3	9
16	3	9
17	4	10
18	4	10
19	5	11
20	5	11
21	6	11
22	6	12
23	6	12
24	7	13
25	7	13
26	8	14
27	8	14
28	9	14
29	9	15
30	9	15

Figure 4. Binomial sequential sampling plan for gall midge in transplanted rice.

Table 1. Field testing of the stemborer and gall midge sequential sampling plans.

(a) Agreement in control decision

		20 sample units[a]		10 sample units	
		Treat	No trmt	Treat	No trmt
Sequential sampling	*Treat*	36 (52%)	2 (3%)	31 (45%)	7 (10%)
	No trmt	3 (4%)	28 (41%)	2 (3%)	29 (42%)

(b) Average sampling time per field (minutes)

20 sampling units	10 sampling units	Sequential
10 +[b]	5 +	3.1

[a] 1 sample unit = 1 hill; [b] + = time needed for calculation not included.

A relatively good agreement between sequential sampling and the systematic sampling method, with 20 units, was obtained; and in 13% of the cases, the sequential method led to a control decision different from the fixed sample size of 10 hills. The latter failed to indicate the need for chemical control in several fields. Thus, the data in Table 1 illustrate the benefits of sequential sampling in

comparison to the presently used surveillance method (Anon 1985). The accuracy of control decisions is improved while the time expenditure for sampling is reduced.

SAMPLING FOR BROWN PLANTHOPPER

At present, brown planthopper (*Nilaparvata lugens*) population densities have to be assessed by direct counting (Anon 1985). Depending on the infestation level, this can be a very laborious and time-consuming undertaking. Therefore, a sampling method based on the frequency of infestation, i.e., presence or absence of hoppers in the sample unit, would mean a significant improvement of the surveillance system.

However, our field data indicated that the present sample unit of 10 tillers seems to be unsuited for such a method. As is evident from Figure 5, the frequency of infestation increases very rapidly with increasing hopper density. Thus, at population densities below the economic threshold, all sample units were already infested, with at least one hopper found on all of them.

There are two feasible solutions in order to realize a presence-absence sampling method. First, a smaller sample unit could be introduced. However, the 10-tiller sample unit is already well-established through the surveillance service and one should try as much as possible to retain a standard sample unit for all insect pests as well as diseases.

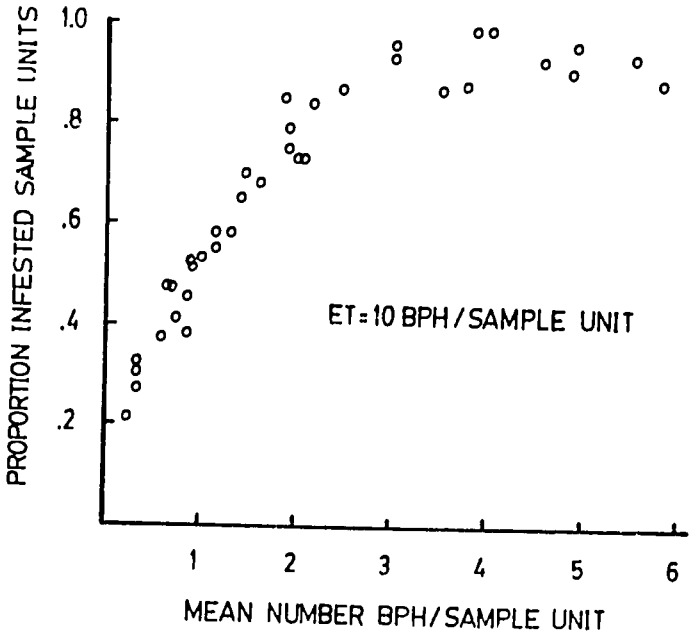


Figure 5. The relationship between the proportion of infested sample units and the mean number of brown planthopper per sample unit (= 10 tillers).

Table 2. Regression models to predict the mean brown planthopper (BPH) density from the proportion of sample units with at least n hoppers.

Dependent variable[a]	Regression model	Predicted proportion corresponding to ET[b]
Proportion of sample units with at least 1 BPH	$y = 0.603\sqrt{\bar{x}} - 0.079\,\bar{x} + 0.012$ $r = 0.96$ $N = 44$	(>1)
Proportion of sample units with at least 2 BPH	$y = 0.649\sqrt{\bar{x}} - 0.077\,\bar{x} - 0.265$ $r = 0.98$ $N = 44$	(>1)
Proportion of sample units with at least 3 BPH	$y = 0.548\sqrt{\bar{x}} - 0.055\,\bar{x} - 0.314$ $r = 0.98$ $N = 44$	0.87
Proportion of sample units with at least 4 BPH	$y = 0.427\sqrt{\bar{x}} - 0.033\,\bar{x} - 0.290$ $r = 0.97$ $N = 44$	0.73

[a]Independent variable always: mean number brown planthopper/sample unit; [b]ET = economic threshold = 10 BPH/sample unit.

The second option consists of an alternative definition of "proportion infested units". Instead of relating the mean number of hoppers per sample unit to the proportion of units with at least one insect, it might as well be related to the proportion of units with at least 2, 3, or 4 insects. In this way, the enumerative sampling cannot be substituted completely but the expenditure for counting may at least be minimized.

Table 2 shows the regression models for the relationship between the mean number of hoppers per unit and the proportion of units with at least 1, 2, 3, or 4 hoppers, respectively. The last column of Table 2 gives the criterion for evaluating the practicability of the models with regard to binomial sequential sampling. Hence, sampling plans based on either model (3) or (4) will be tested.

SAMPLING FOR LEAFFOLDER

All attempts to work out a presence-absence sampling method for leaffolder (*Cnaphalocrocis medinalis*) have so far failed. The available information indicates that probably only fundamental changes in the present surveillance system could make such a method possible, namely, either by reducing the 10 tiller sample unit to one tiller or sampling larvae instead of damaged leaves. Both alternatives would make the surveillance system more complicated, rather than simpler. Therefore, a sequential sampling plan which requires counting of damaged leaves was determined.

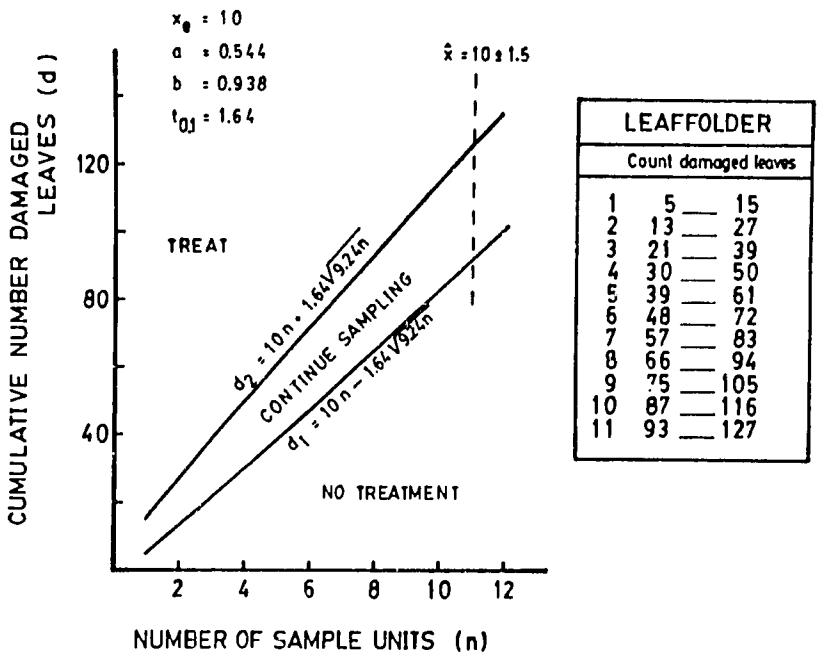


Figure 6. Sequential sampling plan for rice leaffolder in direct seeded rice: x_e = economic threshold; a, b = intercept, slope of patchiness regression; t = value of normal deviate for 0.90 confidence probability; n_{max} = 11, for allowable confidence interval at $\hat{x} = x_e$ of 10 ± 1.5.

Data collected over several seasons on leaffolder damage fitted either Poisson, negative binomial or normal distributions, although none in a consistent manner. Therefore, the sequential sampling approach described by Iwao (1975) was utilized. The method is based on Iwao's patchiness regression (1968), which relates the mean-crowding index (Lloyd 1967) to mean density. Coggin and Dively (1982) applied this method for sequential sampling plans in wheat and barley and Bechinski et al. (1983) in soybean. The decision lines are calculated as the upper and lower limits of the confidence interval of a critical density (i.e. economic threshold) with a predetermined confidence probability. Figure 6 shows the obtained sequential sampling plan for leaffolder.

By setting a tolerable width of the confidence interval for the case that the true infestation level is equal to the economic threshold, it is possible to determine a maximum number of sample units to be taken (Iwao 1975). The chosen confidence interval of 10 ± 1.5 damaged leaves resulted in a maximum of 11 sample units to be examined in case the infestation level is close to the economic threshold (see Figure 6). The sample size is, of course, lower for light or more severe infestations so that on average, considerable savings in sampling time can be anticipated. Respective field tests are being carried out at present to

compare time expenditure and agreement in control decisions, with other sampling methods.

The sampling plans presented here are all based on the current recommended economic thresholds in Thailand. However, loss assessment studies and on-farm trials to test these thresholds are still ongoing. If these activities should lead to readjustments, it will only be a matter of recalculation to adapt the sequential sampling plans. For the time being, it seems most essential to prove, in collaboration with the extensive service, the feasibility of these sampling methods for farmers.

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STATUS OF BIOLOGICAL CONTROL IN NON-RICE CROPS IN SOUTHEAST ASIA

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The Southeast Asian region geographically includes the countries of Brunei, Burma, Indonesia, Kampuchea, Laos, Malaysia, Philippines, Singapore, Thailand, and Vietnam. Among these are members of the Association of Southeast Asian Nations (ASEAN) – Brunei, Indonesia, Malaysia, Philippines, Singapore, and Thailand. All forms of biological control, viz., natural, classical, and augmentative, have been investigated and carried out within the region for insect pests of agricultural crops, insect pests and insect vectors of medical and public health importance, other vertebrate and invertebrate pests, and both aquatic and terrestrial weeds of economic importance. Geographically and ecologically, the region is relatively conducive for biological control attempts, and substantial cases of achievement ranging from partial to complete and spectacular successes are known. However, literature and information regarding such attempts are not readily available, making it rather difficult to prepare a highly needed compendium on biological control in the various countries of Southeast Asia.

The objective of this paper is firstly, to provide an overview of the status of biological control in non-rice crops in Southeast Asia from available literature and information, and secondly, to provide an insight into the potential of biological control as a major component in IPM systems being adopted in the region.

BIOLOGICAL CONTROL IN VARIOUS SOUTHEAST ASIAN COUNTRIES

Biological control of insects and other pests in Southeast Asia and the Pacific Region has been reviewed by Rao et al. (1971), who dealt with the introduction of natural enemies and the regional transfer of natural enemies for biological control of various pests of agricultural and public health importance, as well as those of weeds. The same review covered those biological control agents which have been introduced for exploitation outside the region. Reviews of biological control on a country by country basis in Southeast Asia are those of Ooi et al. (1979) for Malaysia; Baltazar (1963, 1980) for the Philippines; Napompeth (1982) for Thailand; and Napompeth (1983, 1986) for Vietnam. No such reviews were found for Brunei, Burma, Indonesia, Kampuchea, Laos, and Singapore.

At the first meeting of the International Organization for Biological Control, South and East Asia Regional Section (IOBC/SEARS) held in Kuala Lumpur in 1982, member countries were requested and urged to prepare a comprehensive review on biological control in their respective countries, but until today the information has not been forthcoming.

Other references to biological control in terms of the occurrence and record of natural enemies of crop pests in Southeast Asia are those of Ghosh (1940) and Napompeth (1980) for Burma; van de Laan (1981) for Indonesia; Nickel (1979) for Kampuchea; Ooi et al. (1979) and Yunus & Subramaniam (1975) for Malaysia; Baltazar (1963,1980) for the Philippines; Napompeth (1965,1966,1982) for Thailand; and Ho Khac Tin (1982) and Napompeth (1983,1984,1986) for Vietnam. No substantial literature and information are available for Brunei, Laos, and Singapore.

SOUTHEAST ASIA AS A SOURCE OF BIOLOGICAL CONTROL AGENTS

An extensive review of the Southeast Asian region as a source of biological control agents was made by Rao et al. (1971) covering Indonesia and the Philippines. Similar reviews covering Malaysia and Thailand were those of Ooi et al. (1979) and Napompeth (1982), respectively. Literature on other Southeast Asian countries as sources of biological control agents are not adequately available.

A eulophid *Pediobius parvalus* (Ferriere) introduced from Indonesia resulted in a complete control of the coconut leaf miner *Promecotheca coeruleipennis* Blanchard in Fiji and New Hebrides. An encyrtid *Anagyrus aegyptiacus* Moursi, introduced from Indonesia to Egypt for the control of *Pseudococcus filamentosus* (Cockerell), and *Maconellicoccus hirsutus* (Green) gave satisfactory control together with the introduction of *Anagyrus kamali* Moursi, *Leptomastix phenacocci* Compere, *Achrysophagus* sp., and *Scymnus conformis* Jordan. *Telenomus beneficiens* Zehnt., introduced from Indonesia to Taiwan, became the most important parasite of the sugarcane top borer *Scirpophaga nivella* (F.) (Rao et al. 1971).

A tachinid *Betta remota* Aldrich, introduced from Malaysia, has successfully controlled the small coconut leaf moth *Levuna iridescens* Bethune & Baker in Fiji. A eulophid, *Eretmocerus serius* Silvestri, was also introduced to Cuba, and gave successful control of the citrus black fly *Aleurocanthus woglumi* Ashby in Cuba and other Caribbean Islands. Other natural enemies introduced from Malaysia which resulted in successful biological control were *Scelio pembertoni* Timberlake, for the control of the grasshopper *Oxya japonica* (Thunberg) in Hawaii; and *Tetrastichus brontispae* (Ferriere) for the control of the coconut hispid *Brontispa mariana* Spaeth in Saipan and Rota Islands (Ooi et al. 1979).

The import and export of biological control agents in the Philippines during 1850–1960 have been reviewed by Baltazar (1963, 1980). *Puilus* sp. and *Scymnus binotulatus* Boheman were introduced to Hawaii for the control of the sugarcane mealybug *Saccharicoccus sacchari* (Cockerell), and gave very beneficial results while *Anagyrus saccharicola* Timberlake gave substantial control. The

coccinellid *Menochilus sexmaculatus* (F.), introduced to Hawaii for the control of aphids in 1958, has become fully established. This coccinellid is native to Southeast Asia and is now playing a major role as the most important predator of the newly introduced pest in Southeast Asia, the leuceana psyllid *Heteropsylla cubana* Crawford. The psyllid is now widespread in the Pacific islands, Australia, and Southeast Asia, where regional effort in biological control is a priority and chemicals are not recommended for field control.

The braconid *Apanteles erionotae* Wilkinson, introduced from Thailand to Hawaii for the control of the banana skipper *Pelopidas thrax* (L.), has resulted in a spectacular success, causing the extinction of *P. thrax* in Hawaii (Mau et al. 1980, Napompeth 1982). The braconid was also introduced to Guam where satisfactory control was achieved (Muniappan 1980). The predatory pentatomid *Eocanthecona furcellata* (Wolff) introduced from Thailand to Florida has also given satisfactory control of avocado caterpillars (Sailer 1980). Several parasites of the Oriental fruit fly *Dacus dorsalis* Hendel, and the melon fly *Dacus cucurbitae* (Coquillet), were also introduced from the Southeast Asian region and fully established with some degrees of control in Hawaii. The more important ones are *Biosteres arisanus* (Sonan), *Biosteres longicaudatus* (Ashmead), *Biosteres persulcatus* (Silvestri) and *Biosteres vandenboschi* (Fullaway) for *D. dorsalis*, and *Biosteres fletcheri* (Silvestri), and *Biosteres skinneri* (Fullaway) for *D. cucurbitae* (Baltazar 1980, Clausen et al. 1965, Napompeth 1982, Ooi et al. 1979, Rao et al. 1971).

CLASSICAL BIOLOGICAL CONTROL IN SOUTHEAST ASIA

Attempts on classical biological control of crop pests in Southeast Asia have not been extensive, mainly because most insect pests of the region are endemic species. The few attempts have not met with much success.

For the diamondback moth *Plutella xylostella* (L.), *Diadegma cerophagus* Grav. was introduced from the Netherlands in 1928 to Indonesia but failed to establish. Another introduction made from New Zealand in 1950 gave 72–82% parasitization and fully established in Java and Sumatra (Rao et al. 1971). In Malaysia, the parasites introduced for *P. xylostella* were *Tetrastichus sokolowskii* Kurdjunoo, *Macromalon orientale* Kerr. from India; *Thyraella (Diadromus) collaris* Gravenhorst from India, New Zealand and Australia, and *D. cerophagus* from Indonesia and New Zealand during 1975–1977, but to date only *T. collaris* and *D. cerophagus* are established in the Cameron Highlands (Ooi et al. 1979). *Cotesia plutellae* Kurdjunoo, *T. collaris*, *M. orientale*, *T. sokolowskii*, and *Brachymeria* sp., introduced from India to Thailand in 1965 by the Commonwealth Institute of Biological Control (CIBC), failed to survive in the laboratory (Napompeth 1982, Rao et al. 1971) and no releases were made.

For the control of the coconut rhinoceros beetle *Oryctes rhinoceros* (L.), *Scolia ruficornis* F., introduced from Zanzibar in 1960, established in Malaysia (Ooi et al. 1979). In Thailand, *S. ruficornis* was introduced from the West Caroline Islands in 1963, but its present status is not known (Napompeth 1982). Other natural enemies which were also introduced for biological control of *O. rhinoceros* in Malaysia but failed to become established were *Platymeris*

laevicollis Distant, *Hololepta quadridentata* (F.), and *Pyrophorus* sp. (Ooi et al. 1979).

In-country, classical biological control has also been tried in the region, especially in Indonesia, where an encyrtid egg parasite, *Leefmansia bicolor* Waterson, was introduced from Amboina for the control of the coconut grasshopper *Sexuva nubila* (Stal) in the Talaud Islands (Rao et al. 1971, van de Laan 1981). Other parasites introduced for the same purpose were *Doiramia leefmansi* Waterson, *Prosapegus atrellus* Dodd from New Guinea, and *Eupelmus* sp. from Java. *Tetrastichus brontispae* (Ferriere) was also introduced from West Java to South Sulawesi to give complete control of the coconut hispid *Brontispa longissima* (Gestro) (Rao et al. 1971, van de Laan 1981).

Attempts to carry out classical biological control of crop pests in Southeast Asia, although numerous (Baltazar 1963, Napompeth 1982, Ooi et al. 1979, Rao et al. 1971), have met mainly with failures and few successes. The predaceous snails *Gonaxis quadrilaterlis* (Preston), native to Africa, and *Euglandina rosea* Ferrussac, native to Florida, introduced to Malaysia, Philippines, and Thailand via Hawaii and elsewhere, seem to have uncertain status and it is not definitely known if they have become fully established as biological control agents for the giant African snail *Achatina fulica* Bowdich in the region. All the coccinellids introduced to Thailand during the 1970s and early 1980s, *Azya orbigera* Mulsant, *Coelophora pupillata*, *Cryptolaemus montrozeiri* Mulsant, and *Orchus chalybeus* (Boisduval) from Hawaii, and *Coelophora lunata* from Kenya, could not be recovered (Napompeth 1982). Most coccinellids introduced for various crop pests in Indonesia and the Philippines also faced a similar fate (Baltazar 1980, Rao et al. 1971), including the introduction of *Coelophora biplagiata* Swartz from Vietnam via Taiwan for the control of the sugarcane wooly aphid *Ceratovacuna lanigera* Zehnt. in Indonesia, although these coccinellids are very effective predators in their native habitats.

Such failures were due in part to the overuse and improper use of pesticides among Southeast Asian farmers and growers, which in turn resulted from the promotion of agrochemicals as "technology packages" sponsored by government agencies and foreign agrochemical investment within the region. As far as biological control workers in the region are concerned, such failures were also due to the lack of sufficient interest, support, and expertise in biological control research and development.

PROGRESS AND DEVELOPMENT OF BIOLOGICAL CONTROL

Unlike the use of pesticides, where control is short-lived, biological control, when achieved, is long-term, permanent, and leads to invisible end results. A number of successes in biological control have been witnessed in several Southeast Asian countries but all of the achievements have been overlooked, and in some cases, totally ignored. Natural enemies introduced to other countries from this region are nevertheless exerting a controlling effect and contributing to the naturally occurring biological control of the pest species concerned in their

native range. It is only recently that some of these endemic natural enemies have been evaluated and utilized for augmentative biological control independent from the IPM programs, or as a component of the pesticide-dominated IPM programs of various agricultural pests.

Biological control is beginning to receive more attention among economic entomologists because of the relatively rich natural sources of natural enemies within the region. The fauna of endemic natural enemies associated with key insect pests are being intensively explored and evaluated for further utilization. Campaigns have also been made to optimize and minimize the use of pesticides so that these valuable natural resources could be conserved and properly augmented for use on the control of insect pests. Augmentative biological control is also gaining in popularity and attempts are being made to include biological control as a key and important component of existing pesticide-based IPM programs.

It is also encouraging to note that economic entomologists in the region are now putting their efforts more in the area of non-pesticidal pest control, employing cultural methods such as using resistant crop varieties, semiochemicals, and other biologically-based control strategies ironically termed "parabiological control" by Sailer (1981).

BIOLOGICAL CONTROL AND IPM SYSTEMS

An overview of the status of biological control and integrated pest control in the tropics with emphasis on Southeast Asia was given by Napompeth (1987) at the International Meeting on "Towards a Second Green Revolution: From Chemical to New Biological Technologies in Agriculture in the Tropics" organized by Accademia Nazionale delle Scienze detta dei XL in Rome in 1986. Among all the countries in the tropics, those in the Southeast Asian region have so far progressed the most in adopting new and more appropriate technology in pest control, and this achievement has been possible in spite of the presence of aggressive competition from agrochemical industries and dealers within the region.

IPM in its strictest sense is based on sound ecological, economic and sociological aspects of pest control practices. The available natural biological control factors must therefore be fully utilized, and chemicals should be considered as a last resort in such approaches. However, IPM being practiced in most Southeast Asian countries emphasizes and concentrates on the use of pesticides with a disregard for the existence of natural enemies. Some IPM programs are merely modified pesticide spray programs. IPM has been used as a new term to replace the words "pest control", "plant protection", or "crop protection". Such misconception and malpractice must be lessened and removed so that biological control will have its proper place as the main component of IPM systems.

Biological control in Southeast Asia still has a long way to go before it can play a prominent role in IPM programs. However, judging from the nature of biological control itself, it still has ample room as a single-component control pest management strategy, such that when operated alone, it can lead to

successful and permanent control. In other cases, however, it must be realized that more effort must be taken to exploit biological control agents in the overall IPM program. Initial attempts such as exploration to find natural enemies of key pests like *Heliothis* spp. (Napompeth 1985) and others must be undertaken so that biological control will be substantially used in existing IPM programs.

Finally, it should also be realized that biological control research and development will be of no value unless there is a parallel attempt to minimize the misuse and improper use of pesticides in the region. It is only then that the "better", if not "ideal", IPM program in Southeast Asian countries will become a practical reality.

CONCLUDING REMARKS

Biological control research and development in Southeast Asia has been quite satisfactory, with successes being seen for a few insect pests. However, this research and development needs further effort, especially when biological control is to be considered a major component of IPM systems. With the highly pesticide-addicted IPM practice being adopted in Southeast Asian countries, there is also a need to concentrate on the safe and effective use of pesticides and on other pesticide management practices so that the antagonistic nature of biological and chemical controls can be minimized.

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BIOLOGICAL CONTROL OF CORN STALK BORER IN THE PHILIPPINES

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One of the factors limiting corn production in Southeast Asia is the Asian Corn Stalk Borer *Ostrinia furnacalis* Guenee. The promising effect of *Trichogramma evanescens* Westw. on corn stalk borer in the Philippines in 1983–1984, with 40–76.9% parasitism having been obtained at six locations (Tran & Hassan 1984) led to further studies on biological control of corn stalk borer, in particular the performance of *T. evanescens* against *O. furnacalis*.

MATERIALS AND METHODS

T. evanescens was mass-reared mainly on eggs of *Sitotroga cerealella* and partly on *Corcyra cephalonica*. The parasitized host eggs were glued on cardboards (1 x 6 cm) with 1,500–2,000 eggs per card. *Trichogramma* was inundatively released at 200,000 parasitoids per release when the first corn stalk borer eggmasses were found in the field. The distance between two release points was 7–10 m and between plots was 50–100 m. The number of releases varied between two and five per cropping season.

Monitoring of parasitism was conducted before the first release and at 7–10 day intervals after the release. The control plot was also monitored for possible natural parasitism. The dissection of 100 plants per treatment, taken at random from the two plots for larvae, pupae, and entrance holes of corn stalk borers was made one week prior to harvest to verify the effect of *Trichogramma*.

Concurrently, a survey of *Trichogramma* parasitism was conducted in the areas where *Trichogramma* had been released in previous years to determine the extent of *Trichogramma* occurrence in the field(s).

RESULTS AND DISCUSSIONS

In 1983, the lowest parasitism recorded was 40% in the released field (Tran & Hassan 1984). There was no single parasitized eggmass observed prior to the introduction of *T. evanescens*. Table 1 (Tran et al. 1986) shows the average parasitism obtained at different locations in the Philippines. The trend of parasitism was to increase over the years from 1983–1985, and to decrease in 1986. The low parasitism especially in Tacurong (32.2%) could be related to low corn borer population, which was only 0.6 eggmasses per plant at 51 days after planting (DAP), and possibly to the poor quality of *Trichogramma* released (in terms of sex ratio, % parasitism and % emergence).

Bustamante (1986) reported a strong reduction of exit holes and the larvae or pupae of corn stalk borer, in corn fields treated with *T. evanescens*. This in turn resulted in a remarkable increase in the yield and quality of the marketable corn ears (sweet corn) against the untreated control plot (Table 2).

Between 1985 and 1986, surveys (Leyza et al. 1986, Tran et al. 1986) revealed that *T. evanescens* had established in the areas where the parasitoid had been released. Leyza (1986) observed in an economic threshold level-corn stalk borer trial that there were 3.7 parasitized eggmasses per corn plant at 50 DAP (July 1985). In his survey in Sultan Kudarat, he further found significant increases in parasitism at later growth stages of the plant, especially at high corn borer incidence: e.g., at Tuka, Bagumbayan, 33% parasitism occurred on Pioneer White Hybrid 3224 at growth stage 6, with a total of 3–15 corn borer eggmasses per plant, but 10 days later at growth stage 7–8, 94.07% parasitism was recorded. There was a record of 42 parasitized eggmasses and two with *Trichogramma* in action on one plant.

Table 1. Percent of parasitism of corn borer eggmasses by *Trichogramma* released at different locations and years.

	Average % parasitism			
Location	1983	1984	1985	1986
Region II				
Isabela	73.8	44.56	65.5	-
Region IV				
Calauan, Laguna	41.8	74.6	-	-
Cavite	-	76.0	78.2	76.8
Region V				
Pili, Camarines Sur	46.5	53.2	-	-
Region IX				
Molave	-	72.4	-	60.0
Region X				
Malaybalay, Bukidnon	-	65.7	77.2	-
Region XI				
Bansalan, Davao	44.7	62.1	-	-
Region XII				
Koronadal	54.2	-	-	-
Tacurong	51.3	60.1	78.9	32.2

Sources of data: Regional Crop Protection Centers and Biolab, Crop Protection Division, Bureau of Plant Industry, Manila, Philippines. - = No data available.

Table 2. Number of stemborer (larvae and pupae) exit holes and weight of ears harvested per 100 stalk on *Trichogramma* treated and control plots (on sweet corn). Wet seasons, 1984-1985. (Tran et al. 1986)

Location	Trichogramma				Control			
	Larvae	Pupae	Exit holes	Ear wt. kg./ 100 plants	Larvae	Pupae	Exit holes	Ear wt kg./ 100 plants
Calauan	48	24	73	21.2	47	43	188	14.3
Cavite	9	12	55	23.9	60	14	144	10.2

In Isabela, Region II (C. Rodriguez, personal communication), a 100% parasitism of corn borer eggmasses in December 1986 was recorded, whilst *Trichogramma* occurrence was very low during the wet season (June–September) of 1986.

Besides *Trichogramma*, predators such as green lacewings (*Chrysopa* sp.), coccinellid beetles (*Menochilus sexmaculatus* F.), Anthacorid bugs (*Orius* spp.), ants, and spiders were observed from whorl to silking stages, and earwigs in the stages from tasseling to maturity. These natural enemies were more prevalent in fields where chemicals were scarcely applied.

Trichogramma has thus proven to be effective in minimizing the damage caused by corn stalk borer. Corn borer persists through alternate hosts (Tran et al. 1986) and, therefore, *Trichogramma* is believed to persist as well. Its population buildup, however, is slower than that of the corn stalk borer, especially when corn borer incidence is low, which means its natural effects on early generations of corn stalk borer is limited. The following measures are recommended as a means of maximizing the positive effect of *Trichogramma* on corn borer:

1. To apply inoculative-release of *Trichogramma* on vegetation surrounding the corn field at least at the start of the cropping season.
2. To apply inundative-releases of good quality *Trichogramma* with high sex ratio, high percentage of parasitism and emergence when the very first corn borer eggmass is found. However, in cases of high corn borer incidence, release of *Trichogramma* can be stopped if 30% of corn borer eggmasses are parasitized (Leyza et al. 1986).

Aiming at an effective use of parasitoid, not only against corn stalk borer but also against other lepidopterous pests of other crops, necessitates studies on factors influencing the parasitism and multiplication of the parasitoid *in vivo* as well as *in vitro* (mass production).

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CROP PROTECTION AND IPM IN RAINFED CROPPING SYSTEMS IN NORTHEAST THAILAND

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The Northeast region of Thailand contains about one-third of the nation's population and land with a total area of 17 million ha, of which 8.3 million ha are cultivated and less than 5% are irrigated. The region faces several constraints to crop production including highly variable rainfall resulting in crop losses from both flooding and drought. The soils are sandy with low organic matter and clay (predominantly kaolinitic) contents and have low cation-exchange and water-holding capacities. Over 50% of the cultivated area are planted to rice, while cassava, kenaf, and maize are the major field crops. The area with sugarcane, cotton, and peanut has fluctuated widely in recent years (Craig & Pisone 1985). Agricultural productivity and farm incomes in the region are very low.

Agronomic inputs and pesticide usage are generally low in the region due to the severe environmental conditions limiting crop production. Although some crops are not usually attacked by pests at economic levels, others are always severely damaged and pest control is economically justified. Pests and diseases are important production constraints of the crops grown in the region and weeds are severe in rice in low rainfall years. The potential benefits from pesticide application, however, should be carefully examined, particularly for low-yielding crops that can survive under these stressed conditions as extensive, low-return systems. Monocropped wet season rice is the dominant cropping system of the region and is a good example of the low-input, low-return cropping strategies commonly practised by Northeastern farmers. Furthermore, many pests such as paddy crabs, rats, birds, and even insects are important sources of food for farm families, and any proposed control measures should take careful consideration of this fact both from safety and subsistence standpoints.

The RTG/USAID-funded Northeast Rainfed Agricultural Development (NERAD) Project was initiated in 1981 to address the afore-mentioned problems of the region. It follows a problem-oriented, interdisciplinary approach working through eight departments in the Thai Ministry of Agriculture and Cooperatives (MOAC), with the purpose of strengthening departmental capability and stimulating research and extension activities more appropriate to the development of rainfed farming systems within the region.

FARMERS' PEST CONTROL PRACTICES

Northeastern farmers' knowledge of pests is generally very poor with the exception of some common rice insects such as the stem borer (*Scirpophaga incertulas* Walker) and army worm (*Spodoptera mauritia* Boisduval), with which most farmers are familiar. Pest-damage identification by farmers is commonly incorrect and many farmers attempt to control beneficials. Farmers rarely use more than two and often only one type of insecticide for all pests of all crops and the compound used is commonly one with which they have experienced satisfactory control of a pest in the past. Pesticides are also often used at rates much higher or much lower than those recommended by the manufacturer. Almost without exception, farmers in the region are very poor and use simple, cheap sprayers such as the two-handed piston type, resulting in poor coverage and inadequate applicator safety. Carbofuran is the most commonly used insecticide on rice, where it is mainly applied only to the nursery beds. It is often used at less than a quarter of the recommended rate. In the case of upland crops and vegetables, there has been a long history of using methyl parathion, methamidophos, monocrotophos, and methomyl, and resistance is suspected in some pest species. Serious pesticide misuse is also evident and includes such practices as spraying without adequate protective clothing, infringement of harvest intervals, and addition of pesticides to livestock rations for parasite control.

IPM WORKING GROUP

Prior to the establishment of the working group for pest management in Cropping Systems, NERAD was severely lacking in expertise on pest control. No formal channels were available for assistance with problems as they arose, and responsibility for pest control generally fell on site supervisors, agronomists, or field assistants who had no specialist expertise in pest control. In 1984, a pest management working group was established within NERAD to overcome these problems and to more effectively address the pest problems of the region. This group consists of regional and Bangkok representatives from the Department of Agriculture (DOA), Department of Extension (DOAE), Khon Kaen University (KKU), NERAD, and the Northeast Regional Office of Agriculture (NEROA). Its purpose is to review currently available crop protection technologies and research results in Thailand and elsewhere in Southeast Asia, and to develop an appropriate IPM program for the Project's cropping systems component. The working group has responsibility for:

a) Formulating plans for research and extension activities in pest control,
b) Assisting in the implementation and monitoring of the project's pest control programs,
c) Conducting training programs for project staff in pest control methods and monitoring techniques, and
d) Assisting in the analysis of data generated by the project's pest control research and in the dissemination of the results to government agencies and farmers.

Before NERAD's pest management working group was established, there was very little information available for identifying major pests of the region. As a consequence, yield loss assessment trials had not been systematically conducted for key pests, making it impossible to set economic thresholds and make control recommendations. The working group therefore had the task of integrating the following IPM components into the pest management program for each important crop within the cropping systems research and extension trials:

(a) Chemical control of the entire pest complex, including insects, diseases, weeds, birds, and rodents,
(b) Selection of appropriate varieties, cultural and agronomic practices, and biological agents for reducing economic pest losses,
(c) Identification, ranking, and conservation methods for important pest parasites and predators,
(d) Development of appropriate techniques for data collection and analysis to set economic treatment levels for key pests, and
(e) Publication of handbooks, bulletins, and other training aids for farmers on pest control recommendations, pesticide application, safety, and pesticide resistance.

These activities are implemented on a pilot basis within NERAD (Figure 1), in order to test and further develop them for future adoption in the MOAC's regular programs in the region.

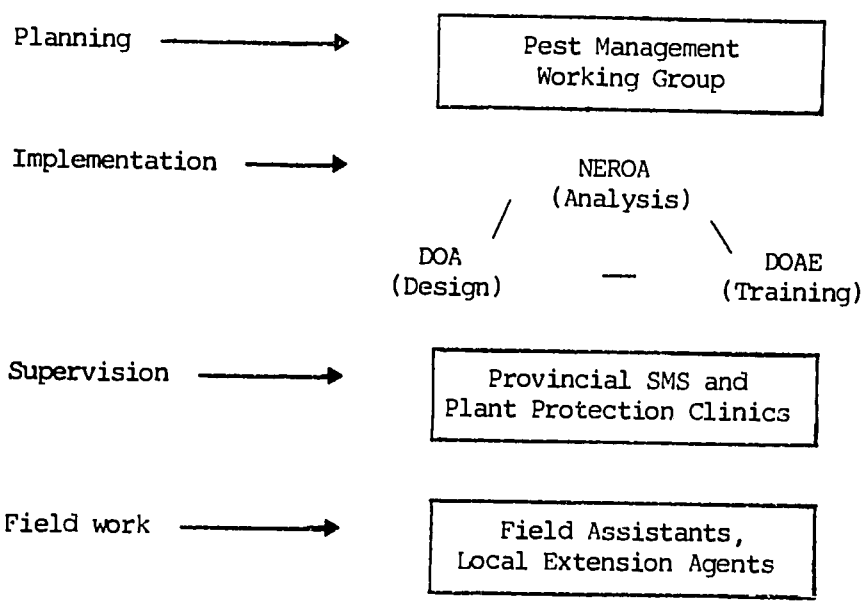

Figure 1. Organizational structure and inter-agency responsibilities of the NERAD Pest Management Working Group.

The IPM working group also attempts to communicate regional pest control problems to agencies with the appropriate expertise necessary for their solution. These efforts include forging links not only with the relevant technical departments in Thailand's Ministry of Agriculture, but also with international agencies such as Cornell University in the United States on the study of papaya ringspot virus control (Gonsalves 1986a), and with the International Rice Research Institute in the Philippines with a feasibility study on microbial insecticide use in Northeast Thailand (Tryon 1986).

IDENTIFICATION OF MAJOR PEST PROBLEMS

In order to identify the major pest problems facing farmers and to select sites for a pilot IPM program for the project, the IPM working group conducted an informal rapid rural appraisal study of all project sites in April, 1984 (Katanyukul et al. 1984). They observed pest problems well over economic threshold levels at every site visited and farmer interviews revealed a history of economic insect pest damage on rice and upland crops. The Working Group concluded that pest problems are already one of the most serious constraints to cropping systems development in the region and they recommended that yield loss assessment trials be implemented within NERAD as the basis for pest control recommendations in the future.

TRAINING PROGRAMS

During the development of a practical pest control program for use in the cropping systems component of the project, the IPM working group conducted a training program for the project site supervisors, field assistants, plant protection clinic staff, and technical extension assistants working in villages in the project area. This dealt with identification of key pests and beneficials, pest monitoring techniques, and control measures. It soon became obvious that for IPM trials to be successfully implemented in the field by staff with no formal pest control background, further regular visits of the pest management working group were necessary to give follow-up, hands-on training in the field.

The working group also designed a simplified training course for participating and other interested farmers in the cropping systems trial sites, aimed at overcoming the problems caused by farmers' lack of knowledge on pest control as identified by the working group.

YIELD LOSS ASSESSMENT TRIALS

These trials were implemented using the 'superimposed trials' technique whereby four treatments (complete control, recommended practices, zero control, and farmer-practices) are superimposed on the regular cropping system trials so that pest populations and damage levels can be assessed. The trials were conducted in 4 project sites chosen to be representative of the region. Each trial was replicated over 6 farms and sub-plot size was 20m x 20m. Participating farmers received training in IPM principles and some farmers were subsequently

capable of sampling their own fields. The project technicians and local extension agents, under the supervision of the provincial subject matter specialists and staff of the plant protection clinics, worked directly with the farmers in the trial plots to ensure that they were frequently and correctly monitored to determine pest incidence and damage levels. During the trials, farmers were advised of the environmental hazards of pesticide use and taught proper safety precautions. In later stages of the project farmers will be encouraged to manage and monitor their fields without assistance from project personnel.

Initial IPM trials on rice indicated that insect pest and disease levels were relatively low; gall midge (*Orseolia oryzae* Wood-Mason), stem borer (*Scirpophaga incertulas* Walker), and brown planthopper (*Nilaparvata lugens* Stal) were observed in trial plots and nearby fields. Complete control and IPM recommendations increased yields but did not significantly increase farmers' profits. Carbofuran applications gave an apparent stimulation of rice yields (Reissig 1986), but recommendations for this input need to be adjusted in order to maximize profits (Table 1).

The results of the kenaf and peanut yield loss assessment trials were similar to those of rice. There were no consistent trends in pest populations among different treatments, but yields were substantially higher in the complete control and recommended practices than those in the farmer-practices and control treatments. Assuming that pest control treatments did affect production, yields in the complete control and recommended practices plots are quite similar. However, the obvious conclusion is that using lower pesticide inputs should be considered in an attempt to maximize profits.

PAPAYA RINGSPOT VIRUS CONTROL

In their first report (Katanyukul et al. 1984), NERAD's IPM Working Group identified papaya ringspot virus (PRV) as severely limiting the production of this important subsistence crop in the Northeast. The virus infects cucurbits and papaya and is transmitted non-persistently by a number of aphid species.

Table 1. Economics of IPM Trials on rice (Average from 3 sites).

Treatment	Yield (kg/rai)	Crop value (B/rai)[a]	Pest control cost (B/rai)	Net returns (B/rai)
Complete control	535	1,400	287	1,113
Reemd. practices	461	1,203	60	1,143
Farmer-practices	436	1,131	0	1,131
No control/check	447	1,164	0	1,164

[a] Selling Price = 2.60 Baht/kg

PRV eradication programs in the region gave only limited success in the control of this virus (Prasartsri et al. 1985) and integration with other control measures was therefore considered necessary.

Mild-strain, nitrous-acid-induced mutants of a severe PRV strain were isolated in 1982 (Yeh & Gonsalves 1984) and showed promise as potential cross-protection strains (cross-protection is a method of protecting plants against damage from severe strains of a virus by infecting them with a mild strain of the same virus). These isolates were brought to Thailand under the sponsorship of NERAD's IPM Working Group for evaluation in June 1986, and experiments to test the effectiveness of cross-protection in papaya at the greenhouse, nursery, and limited village level were initiated.

Results to date have demonstrated that papaya can be satisfactorily infected with the mild PRV strains in Northeast Thailand, although high temperatures at certain times of the year can produce poor infection rates. Mild-strain-infected plants grew as well as uninfected plants, but the growth of plants experimentally-infected by the severe Thai strain was drastically reduced. Trial results have so far shown that the effectiveness of cross-protection against mechanical-challenge-inoculation by the severe strain is dependent on inoculum pressure (Table 2).

Nursery trials to assess the effectiveness of cross-protection against natural aphid challenge are giving promising results (Table 3) but the true potential of the technology will only be clear once the results of village level tests under severe, moderate, and no disease pressure are available later this year.

Cross-protection is not expected to solve the papaya ringspot virus problem in the Northeast on its own just as eradication, although showing early promise,

Table 2. Reaction of mild-strain-protected papaya challenge-inoculated with severe strain at varying disease pressure (Gonsalves 1986b).

Treatment	Days after challenge	Plants without severe symptoms at various leaf position challenges:			
		3	3+4	3+4+5	All
HA 5-1 mild-strain	0	5	5	5	5
	10	5	5	5	3
	21	4	3	0	2
	30	4	2	0	0
HA 6-1 mild-strain	0	5	5	5	5
	10	5	3	1	4
	21	5	2	0	0
	30	4	1	0	0
Unprotected	0	5	5	5	5
	10	0	0	0	0
	21	0	0	0	0
	30	0	0	0	0

Table 3. Reaction of mild-strain-protected papaya under natural aphid-challenge conditions (Gonsalves 1986b).

Treatment	Number of plants	Plants with severe strain symptoms (Days after transplanting)			
		0	12	46	86
Protected	13	13	13	12	12
Unprotected	20	20	20	9	7

Table 4. Rice yields in paddies with and without fish from on-farm and research station trials.

Treatment	Number of replicates	Rice yield (Kg/Rai)	Net returns (Baht/Rai)
Farmer Fields:			
With fish	6	576	1092
Without fish	6	506	925
Research Station:			
With fish	4	367	729
Without fish	4	291	539

was unable to give satisfactory control. It is anticipated, however, that cross-protection integrated with eradication and, possibly, also combined with a breeding program for resistance may give satisfactory levels of control at an acceptable cost to subsistence farmers.

Research on cross-protection against papaya ringspot virus is no longer funded under the NERAD IPM program. The working group's objective of identifying a significant regional pest problem, stimulating research and integrating the efforts of the relevant agencies, in this case the Northeast Regional Office of Agriculture, Department of Agriculture, Department of Extension and Khon Kaen University, has been achieved.

IPM IN FARMING SYSTEMS RESEARCH

One of the most promising farming systems technologies developed by NERAD is a method of raising fish in rice paddies under rainfed conditions. Not only is farmer income supplemented by the sale of fish but rice yields are also considerably increased (Table 4) and farmers are already adopting this technology on a significant scale.

Joint research between the Department of Fisheries (DOF) and DOA was initiated this year to determine what was causing the increases in rice yields.

Beneficial fish-pest interactions were hypothesized as likely to contribute to rice improvement and therefore insect, disease, and weed populations were monitored in the trials by the IPM working group. Unfortunately, results of the pest population analyses are not yet available, but plot observations would suggest that weed populations were considerably reduced by fish due to inclusion of herbivorous carp in the released fish population. It is anticipated that results of this IPM activity will assist DOF in determining the relative proportions of the various fish species that they should recommend to optimize pest control in this rice system.

EXTENSION ACTIVITIES

The IPM working group follows the NERAD approach of integrating the efforts of various government agencies to better respond to farmers' pest control problems. NERAD's extension activities are based on the IPM program's research and problem identification components and include the following:

IPM Demonstration Plots

Thirty rice farmers in each site were selected and trained in pest surveillance procedures. The total surveillance area in each site is 80 ha and is divided into 5 plots. Pest populations and damage levels are monitored on about 1.5 ha every 15 days. These data are then used to decide pest control measures using the previously established economic threshold levels. In most cases, 1986 pest populations were below thresholds (Figure 2) and control measures were unnecessary.

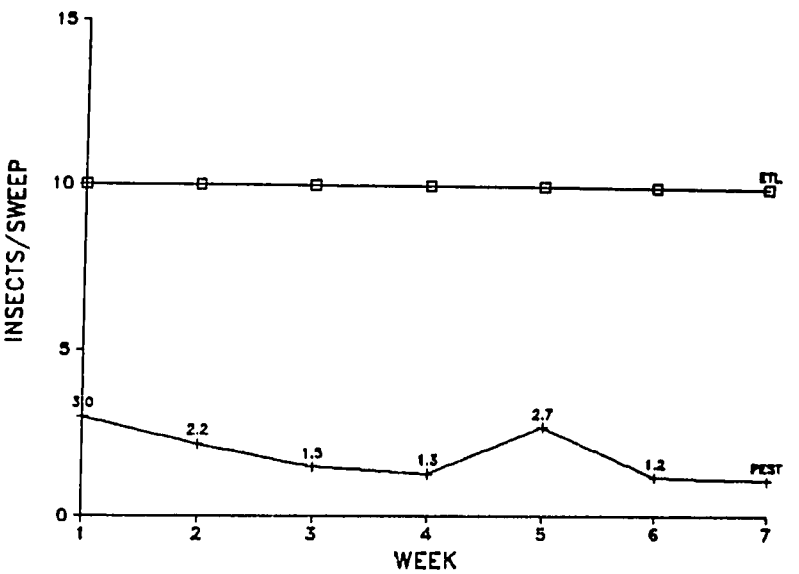

Figure 2. Green leafhopper infestation, IPM trials, Srisaket, 1986.

Plant Protection Information Centers

Information on plant protection, including pesticide recommendations, application procedures, pesticide safety precautions, and other technical aids including pest and disease specimens are provided at the NERAD Site Offices. Pest forecasting bulletins are distributed every 15 days to participating and other farmers.

Training and Visit System

In order to monitor the IPM program, the local Plant Protection Clinics hold farmer training sessions and follow-up visits every month.

CONCLUSIONS

Crop protection programs for rainfed agricultural systems in the Northeast region need careful consideration particularly as agronomic inputs and pesticide usage are generally low because of the severe environmental constraints to crop production. Cooperation among the government agencies involved is essential for the successful implementation of any IPM program and NERAD's efforts in this respect have resulted in DOA and DOAE fully cooperating right from the initial planning to the implementation stages in the project's IPM program.

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IPM OF *PLUTELLA XYLOSTELLA* (L.) ON VEGETABLES IN SOUTHEAST ASIA: RATIONALE, NEED, AND PROSPECTS

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There are many accounts of the importance of the Diamondback Moth (DBM), *Plutella xylostella* (L.) (Lep: Yponomeutidae) (AVRDC 1986), with at least 128 countries listing it as a pest of concern (CIE 1967, Salinas 1972). Prominent among these are the Southeast Asian countries. In this region in particular, the DBM poses a serious limiting factor in the production of crucifers. For example, Quebral and Caramancion (1972) reported that farmers in the Philippines experienced extensive yield losses, sometimes up to 100% if no insecticidal control was instituted. Similar situations have also been encountered elsewhere in Indonesia (Sudarwohadi 1975), Malaysia (Ho 1965), Singapore (Chuo 1973), and Thailand (Rushtapakornchai & Vattanatangum 1986).

Among the cruciferous vegetables in cultivation, cabbage ranks highest both in quantity and area (Lim 1982, Magallona 1986, Rushtapakornchai & Vattanatangum 1986). A recent mail survey revealed that the extent ranges from between 1,000 and 10,000 ha in countries like Thailand and Malaysia to more than 30,000 ha in Indonesia. For the Philippines, the estimated annual production in 1972 was more than 49,500 tons with a value of $5.4 million (Magallona 1986). In Malaysia the crop value for 1964–74 averaged $6.1 million (Lim 1972). Cabbage cultivation, therefore, contributes a sizeable source of income towards the livelihood of many vegetable farming households.

Since DBM can be so destructive, its control during the production of cabbage (and other crucifers) has commanded top priority among the farmers concerned. In nearly every situation a unilateral approach, which relies solely on chemical insecticides that are used indiscriminately, has been the practice. How this has come about shall be examined in this paper, as well as the associated problems and their implications. A critical appraisal will also be attempted with the aim of determining necessary direction for future action.

FARMERS' PERCEPTIONS OF DBM AND THEIR CONTROL PRACTICES

In all the Southeast Asian countries where crucifers are cultivated, DBM has been perceived by farmers to be a very serious, if not the most important, insect pest. An attitude of desperation exists in most situations, leading farmers to resort to rampant insecticide use. To the farmers, cultivation of crucifers (especially cabbage) is not possible without extensive use of insecticides. Not

only is a high input of insecticides perceived as necessary but also that insecticidal mixtures are generally considered desirable. For example, in a farmer survey conducted in Malaysia in 1977, 44% felt that using a single insecticide was not sufficiently effective all the time, but two chemicals together would make the spray more potent (Ooi & Sudderuddin 1978). About 65% of the farmers were found to commonly mix two, and sometimes more, insecticides ("cocktails") for spraying their cabbage crops. Besides, "cocktails" were also employed to save time on spraying for other pests. A similar tendency exists elsewhere, as in the Philippines where about 50% of the farmers interviewed in 1982 were reported to use mixtures (Magallona et al. 1982). The use of "cocktails" is also widespread in Indonesia (Iman et al. 1986) and Thailand (Rushtapakornchai & Vattanatangum 1986).

Another characteristic prevalent among cabbage farmers in Southeast Asia is frequent spraying on a calendar basis, irrespective of the level of DBM infestation. In Malaysia, at least 50% of farmers would spray two to three times per week (Ooi & Sudderuddin 1978).

The unilateral approach of farmers in trying to overcome the DBM problem with chemical insecticides has itself generated other undesirable effects. Farmers are known to pay high prices to secure the most powerful chemical, regardless of its safety qualities. This applies also to new products that are still not adequately evaluated. Moreover, using highly toxic and prohibited materials clandestinely is well-known, though this is often not readily admitted in official circles.

A close look into the perceptions and practices of vegetable farmers clearly reveals that most of the farmers are suffering from the "pesticide syndrome" (Doutt & Smith 1971). They continually perpetuate the massive and regular use of a variety of insecticides without any possibility of relenting. Often, chemicals are applied right up to harvest (Oei-Dharma 1969, Ooi & Sudderuddin 1978, Magallona 1986), largely to preserve the cosmetic value of the crop. This obsession to produce totally unblemished vegetables is, in essence, the crux of the DBM issue. And arising from this are many associated problems.

THE ASSOCIATED PROBLEMS

The problems associated with the indiscriminate and unilateral use of insecticides for the control of DBM are, in general, not unlike many other serious pests in similar situations. These problems may be broadly categorized into five major aspects.

Development of Insecticide Resistance in the Pest

Nearly all the insecticides introduced into each Southeast Asian country have been tried against the DBM. In all the countries, the trend has been essentially the same – there was a shift from the early botanicals to the organochlorines, then to the organophosphorus, carbamates, pyrethroids, and now to the insect growth regulators (IGR) (Table 1). This shift was due largely to the development of resistance by DBM to insecticides. Such development is well

illustrated by the number of compounds which were effective against DBM when first introduced, only to become ineffective or marginally effective later. Barroga (1980) has extensively reviewed the insecticide resistance situation in the Philippines, while similar studies have been done for Thailand (Rushtapakornchai & Vattanatangum 1986) and for Indonesia (Oei-Dharma 1969). The continual search for newer insecticides to replace ineffective ones is well illustrated in Table 2, using the case for Malaysia (Lim 1974, 1982, Ooi 1986, Ooi & Sudderuddin 1978, Sudderuddin & Kok 1978, Teh et al. 1982). This situation is particularly serious as the resistance can sometimes be very high, as in the case of malathion where the resistant factor reached 2,096-fold (Sudderuddin & Kok 1978).

Presence of Insecticidal Residues on Marketed Produce

This has been shown in several instances, when fresh leafy brassicas purchased from grocers were fed to DBM larvae and shown to produce a high mortality in the DBM larvae (Balasubramaniam 1974). Studies with cabbage in the Philippines showed that insecticide residues were mainly concentrated in the leaves. However, a considerable amount of the residues can be removed by washing and the removal of the wrapper leaves (Magallona et al. 1977, 1981) (Table 3).

To a large extent, the presence of residues is mainly due to the failure of farmers to observe a delay before harvesting. The problem may therefore be minimized if farmers can be persuaded to follow proper pre-harvest intervals.

Table 1. Changing trend in the use of major groups of insecticides for the control of diamondback moth in Southeast Asia (Oei-Dharma 1969, Barroga 1980, Lim 1982, Magallona 1986, Ooi 1986, Rushtapakornchae & Vattanatangum 1986).

Insecticide grouping	Country			
	Indonesia	Malaysia	Philippines	Thailand
Inorganic	1923-33	?	?	?
Botanical	1933	before 1950	**	?
Organochlorine	1945	after 1950	**	**
Organophophorus	1958	1956	1959	1965
Carbamate	?	1973	**	1974
Pyrethroid	1977	1974	late 1970	1975
Insect growth regulator	?	1986	?	1982

** = Trend indicated, but no year given; ? = Probably have been used, but no published record seen.

Table 2. History of insecticide usage for control of DBM in Malaysia (Lim 1974, 1982, Ooi & Sudderuddin 1978, Sudderuddin & Kok 1978, Teh et al. 1982, Ooi 1986).

Insecticides	Year introduced	Status
Nicotine & rotenone	Before 1950	Replaced by synthetic organic insecticides
DDT	1950	Resistance suspected by 1956, resistance factor (rf) = 529.6
Gamma BHC	1950	Resistance suspected by 1956, rf = 64.4
Dieldrin	1950	Not used on cabbages after 1956.
Malathion	1956	Used in combination with other insecticides, rf = 2096.
Dimethoate	1956	Used mainly for leafminer control.
Diazinon	1956	Used in combination with others.
Trichlorfon	1964	Poor control by 1966.
Isobenzan	1964	Usage stopped by 1966.
Dichlorvos	1966	Used in small amounts, rf = 40.
Methomyl	1967	Use reduced by mid-1970s, rf = 12.3
Aminocarb	1969	Resistance suspected by 1970.
Quinalphos	1969	Poor control by 1970.
Leptophos	1970	Poor control by 1971.
Methamidophos	1970	Used at high dosage and in combination with other insecticides, rf = 6.2
Cartap	1973	Poor control by 1975, rf = 15.5
Bioresmethrin	1974	Good initial control but only for short period.
Fenvalerate	1975	Usage reduced by 1979, rf = 4.5
Prothiophos	1976	Farmers used high dosage by 1979
Decamethrin	1977	Effective initially. Dosage had to be increased substantially later on. Use gradually faded out.
Permethrin	1978	Used in combination with other insecticides rf = 754.5
Bacillus thuringiensis	1979	This was introduced and used on a limited scale in the early 70s, and for only a brief period. In 1979, the Dipel formulation was introduced and used fairly extensively. It is still being used today.
Insect growth regulators	Since 1984	These have become very popular with the farmers because of their being highly effective against the diamondback moth. More effective formulations are continually introduced and evaluated. Today, the use of insect growth regulators has expanded rapidly, in some instances, newly introduced and unregistered ones are used clandestinely.

Table 3. Effect of washing and cooking on the residue level of some organophosphorus insecticides in treated petsay (Magallona et al. 1981).[a]

	Uncooked			Cooked			
Treatment	U	W	R	U	R	W	R
Malathion	1.0	0.7	31.7	0.4	65.4	0.3	72.1
Methyl-parathion	1.8	1.1	37.3	1.1	36.2	0.3	81.4
Mevinphos	1.7	0.5	70.1	0.4	78.2	0.2	90.8
Triazophos	1.0	0.4	56.9	0.6	43.1	0.4	62.7

[a]U = Unwashed (in mg/kg), W = Washed (in mg/kg) and R = Reduction (%).

Rising Incidence of Pesticide Poisoning of Farmers

A recent mail survey conducted in the region, with personnel involved with DBM, revealed that insecticidal poisoning is fairly common among vegetable farmers. However, no accidental death has been reported to date. In Malaysia, there was an increase in accidental poisoning in the Cameron Highlands from five in 1968 to ten in 1970 (Singh 1971), due mainly to the rampant and unscrupulous use of insecticides (Singh 1971, Lim 1972, Ooi & Sudderuddin 1978). Besides, in most of Southeast Asia, protective gears are rarely worn by farmers during spraying operations.

Hazards in the Environment

Although complete evidence is as yet not available on the deleterious effects to other organisms by the insecticides used against DBM, such effects are nevertheless suggested by the relatively much-reduced fauna of treated crops. Not unexpectedly, any beneficial species (parasitoids and predators) that may have existed are also likely to be decimated. This could be critical as the pest infestation and its stability could well be very dependent on the abundance of these species.

Among the vertebrates, birds have been found common victims of pesticide misuse in Malaysia during 1964-66. During this period, when Telodrin 15 was used extensively against DBM, numerous wild birds were noted to have died after feeding on contaminated worms (Lim 1974).

Spiralling Costs in Crop Production

The spiralling costs of vegetable production are, to a large extent, due to the "pesticide syndrome" of farmers. In general, many types of pesticides have been used, often in large quantities. Unlike many other crops, production inputs are unusually high with cabbages; insecticides alone contribute about 30% of the

costs (Lim 1972). This is necessitated essentially by resistance development, although pesticide adulteration is also believed to have played a role.

The high production cost has been accentuated in recent years by the spiralling cost of insecticides brought about by fewer new compounds being introduced into the market. Furthermore, in some countries the supply problem is compounded by foreign exchange restrictions (Magallona 1986). Due to the high cost, as well as the unreliability of DBM control, some farmers have begun to abandon cabbage planting (Sivapragasam et al. 1984). Thus, unless other means are found to effectively and economically manage the DBM problem, cabbage cultivation will gradually diminish in many Southeast Asian countries.

NEED AND PROSPECTS FOR IPM

Although heavy application of insecticides seems to be presently justifiable because vegetable production is still profitable, many of the associated problems have become increasingly aggravated. DBM control is largely dependent on quick response to emergency situations as well as on calendar spraying. Farmers are resigned to using chemicals and determined to look for newer insecticides to replace less effective ones, often resorting to high concentrations of "cocktails". The problems encountered in DBM control today seem to be approaching a "crisis phase" (Smith 1969), resembling that of the situation with cotton production in the Canete Valley in Peru (Barducci 1969).

It appears essential that, as a state of crisis in the control of DBM is approached, there is action to abandon the dogma of continually searching for more potent chemicals and total dependence on them. Although insecticides will continue to remain a powerful and essential tool, it is important that their use is minimized. Moreover, under existing conditions there seems little choice except to pursue an integrated pest management (IPM) strategy, which incorporates economic, social, and ecological considerations. Such an approach not only would reduce the many associated problems but also ensure a more productive and stable crop output in an environment that is both cleaner and less hazardous. Should the IPM approach be not practiced and the current trend of unilateral use of chemicals allowed to persist, then a "disaster phase" may be inevitable.

That the IPM approach can provide benefits is well demonstrated by numerous successful programs in developed countries. For example in the U.S., research and extension efforts in developing and implementing IPM on major crops have paid extremely good dividends in terms of crop and environmental protection (Adkisson 1986). Overall insecticidal use on cotton, grain sorghum, and peanuts has decreased by 77%, 56%, and 83%, respectively. The amount of active ingredient applied has also declined; that on cotton decreased by 4.42 lb/ac, for sorghum by 0.09 lb/ac and peanuts by 3.23 lb/ac. The area being treated with pesticides has also declined dramatically between 1971 and 1982. IPM is therefore considered a developed technology, and is used on a large scale by many farmers because it optimizes profits by protecting yields and lowering costs of production. Successes in the developed countries should convince us that the IPM approach cannot be ignored as a future strategy to control the DBM.

The IPM approach has been attempted on an experimental basis in Malaysia (Sivapragasam et al. 1984). Results show that IPM can reduce the number of sprays and yet secure marketable cabbage heads. In Hawaii an integrated system to control DBM, together with other insect pests, has been evaluated commercially and found to be cost effective, with chemical control costs reduced by 89% and production raised by 93% (Nakahara et al. 1986). These limited attempts show that IPM of DBM is feasible, even though more work is needed to refine it. Nevertheless, efforts similar to these should receive increased emphasis in order to ensure more rapid progress, particularly in Southeast Asia where the DBM problem is especially critical.

CURRENT CONSTRAINTS TO ADOPTING IPM

Many problems result from the unilateral approach to control DBM. Some of these are particularly acute, such as resistance development. The most plausible alternative seems to be the IPM approach which has also been established to be feasible. Yet, in spite of this, IPM is not widely adopted and requires much more knowledge to support it. What then are the major constraints on IPM implementation?

Firstly, most pest management practitioners dealing with DBM have never needed or been encouraged to think in terms other than chemical. Such a "single-track" mind, according to Way (1985), has come about primarily from the burgeoning of cheap, simply-applied, and highly effective chemicals that fit readily into complex crop production systems. The mounting adverse side-effects have gradually forced pest control personnel to awaken to the need for sensible restraints on over-dependence on chemicals and to turn to IPM. All this has, however, come about only recently, with many still having little awareness of the need for IPM. Greater awareness undoubtedly will grow with time, but until the level attained is adequate, IPM adoption can only expand slowly.

Another major constraint is that research into DBM is largely on component aspects rather than from a holistic approach. Even so, there is over-concentration on the chemical component. On the other hand, ecological understanding which provides the key to rational management has been neglected. Of even greater importance, however, is the lack of progress in a true integration of research in developing IPM. Furthermore, the research oftentimes has been conducted in isolation from farmers resulting in scientists not truly appreciating the practical problems of farmers. A big gap therefore exists between the minds of the innovators and the clientele. Because of this, farmers' perceptions of DBM and its management probably differ from that of scientists. Communication of IPM technology to farmers therefore has met with little success. Programs need to be simplified based on knowledge of farmers' behavior and attitudes. All the above factors partly explain why the practical impact of IPM has so far been limited and why IPM has not lived up to expectations.

NEEDED COURSE OF ACTION

Having identified the main factors obstructing the development and adoption of IPM for DBM, it now becomes clearer what actions are needed to help overcome the problem. The steps to be taken are variable depending on existing conditions in the different Southeast Asian countries. Nevertheless, the following course of action can be generally applied.

Research Consideration

Self-regulating processes to maintain stability must be present for an IPM program to have maximum and long-lasting impact. As with most other insect pests, DBM has its share of effective biocontrol agents that can well satisfy this role (Ooi 1979, Lim 1986). In many countries outside the Southeast Asian region and in at least one country (Indonesia) in Southeast Asia, the parasitoid of DBM *Diadegma eucerophaga* Horstm. (Hym: Ichneumonidae), has demonstrated its ability to suppress DBM populations to non-pest levels. Several other species have also shown promising potential – *Cotesia plutellae* Kurdj.(Hym: Braconidae), *Thyraeella collaris* (Grav.), and the ichneumonids *Diadegma fenestralis* Holmgren and *Diadegma insularis* (Cresson).

Presently, not all these species occur throughout the Southeast Asian region. Their absence, to a large extent, is the major reason for the lack of natural control of DBM and hence the development of a strong dependence on insecticidal control. Introduction of these species into areas where they are absent should, therefore, be an important first step to developing an IPM program. By broadening the ecological base, not only will inherent stability of the ecosystem be enhanced, but also the potential for developing integrated techniques.

Research on the DBM needs to be pursued with a holistic perspective, and, to ensure practical impact it must also involve close collaboration with farmers. While specialist IPM research needs to be continued and strongly supported, adequate effort must be directed to involve growers in order to establish those elements of IPM that are likely to be useful in practice.

Although many social and marketing factors influence pest control decisions and actions of farmers, very little is known of this aspect. DBM management research has to date been centered only on biological aspects. However, since IPM technology adoption extends well beyond this, studies must now be initiated to cover the areas pertaining to better understanding of the farmer, such as his knowledge, perception, attitude, and practice relating to DBM. Arising from these will then be a truer understanding of the farmers' aspirations and constraining factors, leading to a likely improvement in communicative processes for translating IPM for adoption.

It is only recently that IPM has been established to be feasible for the DBM, albeit on a limited scale. More widespread efforts are needed, with feasibility studies carried out over more locations within different countries. More successful trials confirming that IPM can be feasible for DBM would greatly assure research and extension personnel of the validity of such an approach.

3) la oportunidad de la obtención de datos para los informes (por ejemplo, la matriculación inicial es frecuentemente inferior a la de mitad de año);

4) técnicas dispares de obtención de datos, que causan variaciones adicionales en las series de datos;

5) aplicación inadecuada de la información (por ejemplo, la utilización de los puestos del personal docente como indicación del número de personas que trabajan como maestros).

6) comprensión poco clara de los principales indicadores de planificación, especialmente en materia de educación básica.

Además, la precisión exacta de los datos necesarios para la adopción de decisiones gerenciales difiere frecuentemente de la precisión necesaria para una auditoría financiera. Los gerentes y administradores necesitan principalmente comprender las tendencias y disponer de antemano de advertencias sobre situaciones extremas frente a las que deben reaccionar de inmediato. Los contadores necesitan valores absolutos vinculados a servicios claramente definidos, seguidos por una clara "pista de auditoría".

En el caso del Ministerio, con frecuencia los gerentes y administradores esperan un nivel de precisión de auditoría (superior al que la mayoría de los administradores necesitan en la práctica), sin tener conciencia de la sustancial variabilidad que típicamente presentan los informes estadísticos en materia educacional. Sólo como ejemplo, puede mencionarse que las escuelas típicamente no proporcionan suficiente información sobre los estudiantes que repiten, porque una alta tasa de repetición tiende a dar una imagen desfavorable de la idoneidad de la enseñanza en la escuela. En contraste, con frecuencia se considera que la escuela no puede modificar una alta tasa de deserción, y que por lo tanto la misma no es responsabilidad de los maestros. La escasa comprensión de las diversas repercusiones de política y de administración que tiene dicha información contribuye a incrementar los desacuerdos administrativos.

Estas diversas distinciones deben ser comprendidas en todo el Ministerio, tanto por los proveedores de la información (en la actualidad principalmente en la DIIE) como por los usuarios de la información (en todo el Ministerio). Además, es preciso formalizar en mayor medida

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AN APPROACH TO INTEGRATED PEST MANAGEMENT: ACTIVITIES OF THE PHILIPPINE-GERMAN COTTON PROJECT

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Cotton-growing in the Philippines has historically been constrained by serious pest problems. Early attempts to introduce threshold levels (Disu 1980) were abandoned by the Philippine Cotton Corporation in favor of scheduled pesticide application. However, the resultant high pest control costs were coupled with only moderate yields and it became obvious that a more economic approach to pest management was needed (Daxl 1980).

The pest complex of cotton in the Philippines consists of 30 described arthropod pests of cotton, of which 12 occur regularly (Schmutterer 1978) and 3 may be described as key pests . When the Philippine-German Cotton Project started in 1981, it was apparent that to be successful, any integrated pest management system needed a holistic approach, simplified enough to enable small farmers to understand and adopt the approach.

Research concentrated on cultural control programs to which farmers could relate, coupled with redesigned biocontrol methods appropriate to village technology. These were supported by IPM-based rapid, accurate sampling methods which were initially used by field technicians and subsequently adapted for farmers' use as a guide in spraying decisions.

Since many pest outbreaks in cotton have been attributed to secondary pests or resurgent minor pests (Huffaker 1980), research focussed mainly on integrated control of the three key pests *Amrasca biguttula* (Shir.), the cotton leafhopper; *Amorphoidea lata* Motsch., the cotton flower weevil; and *Heliothis armigera* (Hb.), the cotton bollworm.

MANAGEMENT OF COTTON LEAFHOPPER

Deltapine 16 gave the best yields of the introduced American cotton varieties, but it was highly susceptible to *Amrasca biguttula*, a pest which does not occur in North America. *A. biguttula* thrives on glabrous (hairless) cotton leaves, feeding on the underside of the leaves between the veins. It is usually most severe early in the season. Symptoms of "hopperburn", a discoloration and curling of the leaves caused by the leafhopper's toxic saliva, frequently leads to yield losses or total destruction of the crop.

Cultural Control Strategies

Hairy-leafed cotton varieties are considerably less prone to attacks from this pest (Schmutterer 1978). Indeed, African cotton varieties with more than 100 hairs per sq. cm of at least 0.6 mm length are resistant against *A. biguitula* (Kerkhoven, pers. comm.).

A variety comparable to Deltapine 16 in lint and yield characteristics but with hairy leaves was introduced by Institut de Recherche du Coton Tropical (IRTC) in 1977. Its multiplication started in 1981. This variety originated from Paraguay as Reba P279 and was registered in the Philippines under the name UPL-C2 (Pauly 1986). In Table 1, the 'hairiness' of this variety is described. Presumably, the relative shortness of the hairs between the veins results in only moderate leafhopper resistance.

If moisture supply to the cotton plant is adequate, *A. biguttula* is satisfactorily suppressed especially at early stages. The curves in Figure 1 show this with regard to a critical infestation level. Both varieties were planted under irrigated conditions.

Table 1. Hairiness of UPL-C2 leaves.

Leaf position from top down	Hairs per cm^2[a]	S.D.[b]	Hair location	Length of hair[c](mm)	S.D.
2nd	251.8	(31.6)	midrib/vein	0.99	(0.21)
4th	176.5	(41.0)	intercostal	0.55	(0.22)
6th	169.2	(35.0)			

[a]6 replicates, [b]Standard deviation, [c]10 replicates.

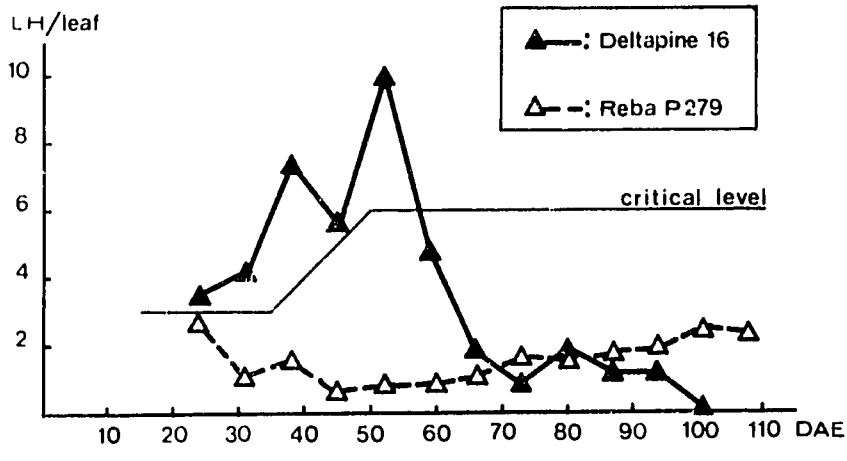

Figure 1. Leafhopper incidence (LH/leaf) on a susceptible Deltapine and a semi-resistant Reba variety at different days after emergence (DAE).

† The diminished leafhopper susceptibility of the new variety reduced the need for early insecticide sprays against this pest, thus creating conditions for the increase in entomophagous arthropod populations.

Chemical Control Strategies

Granular systemic pesticides are recommended for the control of leafhoppers in susceptible varieties. These are safe for natural enemies of cotton pests, but unfortunately are extremely toxic to man and livestock.

A simple survey system helps to determine the need for spray application against leafhoppers on susceptible as well as tolerant varieties. Research has shown that leaf production of cotton far exceeds actual needs. During the vegetative stage, where susceptibility to leafhopper is highest, cotton can tolerate up to 50% defoliation without effect on final yield (Metcalf and Luckmann 1975). In the Philippines, a conservative threshold of 50% of sample leaves infested and also slightly damaged provided satisfactory protection. Table 2 shows an example of the use of this threshold in farmers' fields.

As shown in Table 2, not all farmers were convinced to spray at the recommended level, perhaps because visible damage was slight. Nevertheless, the infestations were sufficiently suppressed as shown by the relatively high yield. The sprays were the only ones applied during that season and no other pests required control.

MANAGEMENT OF COTTON FLOWER WEEVIL

The cotton flower weevil is a major threat to cotton farmers, especially in the Ilocos region of the Philippines. The problem is so severe that farmers resort to so-called 'flower to flower' treatments in which they attempt to spray the weevils inside the open flowers.

Table 2. Chemical leafhopper control based on an action threshold of 50% infested and slightly damaged leaves.

	Days after planting						
	56	63	70	77	84	91	98
% leaves infested and damaged[a]	28.0	50.0	68.5	31.5	18.0	17.0	20.0
S.D.[b]	9.9	25.3	25.6	26.1	11.1	3.9	8.2
% fields with spray decision	–	57.1	85.7	14.3	–	–	–
% fields actually treated[c]	–	14.3	57.1	28.6	–	–	–

Final average yield: 1470 kg/ha (S.D. 203.2).

[a]average of 7 fields totalling 24.5 ha Maguindanao crop year 85/86, [b]Standard deviation, [c]treated with Metasystox R.

The key to a reasonable flower weevil control was found when it was understood that the flower weevil attacked only open flowers and never the squares or bolls. This limits the susceptibility period of any given cotton field to the time between the first open flower and the last flower which could produce a harvestable boll. In the Philippines, this is from 55 to 90 days after planting and corresponds to two and a half flower weevil generations, as one weevil generation has been reported to average two weeks (Marges 1981).

Cultural Control Strategies

CLOSE SEASON PLANTING The most efficient approach to limit flower weevil damage is to plant all fields of a cotton cluster within the shortest possible time. In an infested area, the weevils need five generations to build up to a damaging level of population. Figure 2 demonstrates the effect of a close season planting of four weeks.

The susceptible period of such a cluster covers about 9 weeks or four full flower weevil generations. During this period *A. lata* should not reach damaging levels provided that no strong and continuous migration occurs from nearby older cotton fields.

INCREASED PLANTING DENSITY There are no significant differences between the yields of fields with 60,000 and fields with 180,000 plants per ha (Adkisson et al. 1964). It is important to note that early flowers contribute most to the final yield (Metcalf and Luckmann 1975). A yield of 1.5 tons of seed cotton requires about 400,000 bolls. These can be produced in 3 weeks at 60,000 plants/ha (6.7 bolls per plant) or in 10 days at 120,000 plants/ha (3.3 bolls per plant). This principle can be utilized to shorten periods of

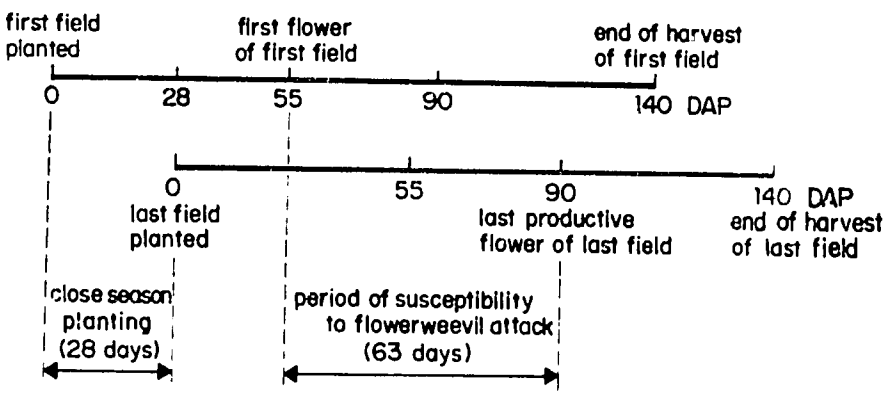

Figure 2. Close season planting with regards to flower weevil susceptibility of a cotton cluster.

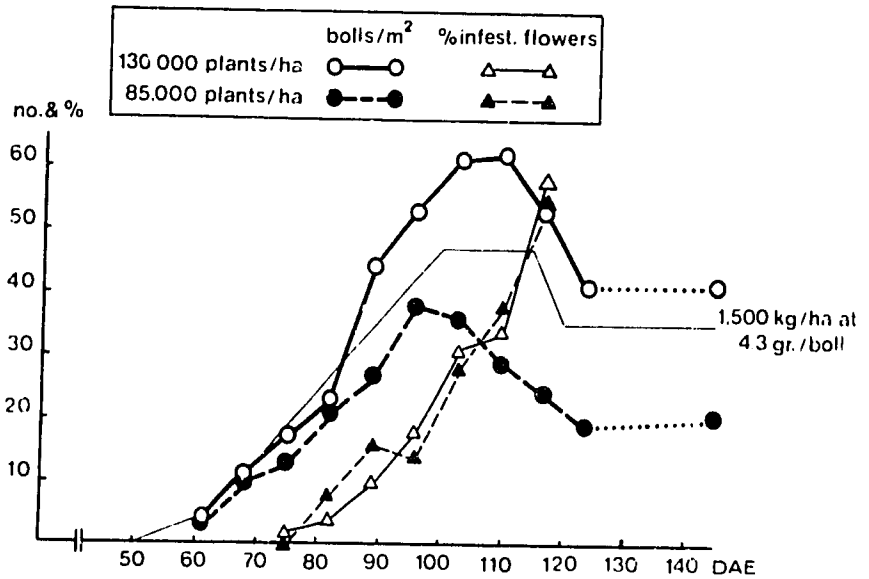

Figure 3. Yield development in relation to planting density under cotton flower weevil infestation.

susceptibility to flower weevil attack in individual fields. Figure 3 demonstrates the advantages of this technology in an area where flower weevil continuously migrated from nearby areas of heavily infested older cotton, thereby obscuring true generation cycles.

The data suggest that at about 90 days after emergence, all bolls which later contributed to the yields of 1,780 kg and 880 kg respectively had been set. Bolls developing after that date were subject to shedding due to flower weevil infestation.

WATER MANAGEMENT In areas prone to flower weevil attack, a cessation of irrigation for up to four weeks after the onset of flowering can reduce yield losses in three ways. Firstly, the reduced water supply forces the cotton plant toward maturation as flowers are initiated more rapidly, giving the "rose garden" effect. Irrigation should resume as soon as sufficient bolls are set. Secondly, dry soil surface conditions greatly decrease pupal survival, with 100% pupal mortality at moisture contents of 8–10% in clay soil. Thirdly, dry soil surfaces favor the activity of *Solenopsis geminata* L., a red fire ant which is the main predator of *A. lata* larvae and pupae in the Philippines. Table 3 shows an assessment of mortality factors affecting the flower weevil under dry season conditions in the field.

Table 3. Mortality factors affecting immature stages of flower weevil.[a]

Mortality factors	% mortality	Killing power (K-value)[b]
Pupal loss due to low soil moisture	44.5	0.568
Predation by *S. geminata*	30.8	0.392
Variation in natality	21.8	0.278
Other factors	2.9	0.037

[a]Dry season 1985, Pangasinan, Philippines, [b]K-value analysis (Varley et al. 1973).

TRAP CROPS Alternate host plants play an important role in the survival of *A. lata* during the cotton-free season. All known host plant species belong to the tribes *Gossypieae* and *Hibisceae* of the family *Malvaceae*. There are essential differences between the alternate host plants and the cultivated cotton. The comparatively thin petals of cotton remain attached, allowing the weevil larvae to subsequently bore into the young boll. In contrast, the fleshy petals of other host plants mostly shed within the same day or at least abscise, thereby preventing entry into the fruit.

Hibiscus esculentus L. (okra; "lady fingers") is occasionally cultivated near cotton fields. Weevil adults were observed to strongly prefer okra flowers over cotton flowers. However, the fruits of infested okra plants were never damaged by weevil larvae, which remained in the shed petals. Most larvae in okra petals will subsequently die through dessication. Table 4 demonstrates the effect of *H. esculentus* as a trap crop for *A. lata* along the borders of cotton clusters.

It is important to adjust planting dates for okra and cotton such that flowering occurs at about the same time. Thus most of the first invading

Table 4. Flower weevil infestation in *H. esculenta* (okra) vs cotton flowers.[a]

Date	% flower infestation		Mean no. of weevils/flower[b]			
	Okra	Cotton	Okra	(SE)[c]	Cotton	(SE)[c]
Feb. 22	19	0	0.57	(0.31)	0.00	
Mar. 1	24	5	0.14	(0.08)	0.03	(0.03)
Mar. 8	93	27	1.40	(0.34)	0.33	(0.16)
Mar. 12	90	86	1.30	(0.33)	0.86	(0.26)
Mar. 15	85	87	5.00	(0.63)	2.87	(0.52)

[a]okra planted as border row along cotton field, [b]means highly significant (alpha =.0001), t-test, [c]standard error.

weevils are attracted to okra and the cotton gains up to three weeks in which bolls can be set without flower weevil influence. Later on *A. lata* apparently overcomes the okra barrier and colonizes the cotton fields.

MANAGEMENT OF COTTON BOLLWORM

The previously described technologies against two key pests of cotton lead to a considerable delay in the need to apply pesticides. This contributes to a more favorable environment for arthropod predators capable of limiting cotton bollworm to low population levels. However, these predators are commonly absent or present only in low numbers, making it necessary to develop integrated control strategies for this most destructive of all the Philippine cotton pests.

Cultural Control Strategies

H. armigera is a highly polyphagous insect known as a pest to such diverse crops as maize, sorghum, tomato, tobacco, and cotton. It was observed that given a choice, *Heliothis* would prefer some host plants over others. Cotton does not seem to be its favorite crop. Tobacco and maize appeared to be considerably more attractive.

TRAP CROPS Single rows of trap crops can be intercropped at intervals of 15–20 rows of cotton. *Heliothis* females searching for suitable host plants are then diverted away from the main crop. On some trap crops, e.g., maize, bollworm larvae cannibalize each other in the major feeding site at the tip of the corn ear. On trap rows of tobacco the larvae are easily spotted through their feeding damage. They can be handpicked as the farmer inspects the few tobacco rows. Figure 4 demonstrates the high attractivity of tobacco rows within a cotton field.

In the tobacco-cotton intercrop, three times the number of eggs were deposited on tobacco terminals than on comparable sampling areas on the cotton plants. However, the total number of *Heliothis* eggs per season found in the intercrop was not significantly different from those found in cotton monoculture. It was noted that all host plants were generally more attractive to *Heliothis* females in the early reproductive stages. Some crops such as maize and sorghum lose their appeal abruptly after flowering. It is therefore vital to time the planting dates of the different crops so that they enter their respective reproductive phase simultaneously. Only then can cotton be expected to benefit through a delay in the need for pesticide application. In the example given in Figure 4, tobacco seedlings were transplanted right after planting cotton. The first pesticide application in the intercrop was delayed by two weeks as compared to the first treatment of the monoculture. On average, the tobacco-cotton system received 2.5 sprays per season versus 6.5 sprays on cotton alone.

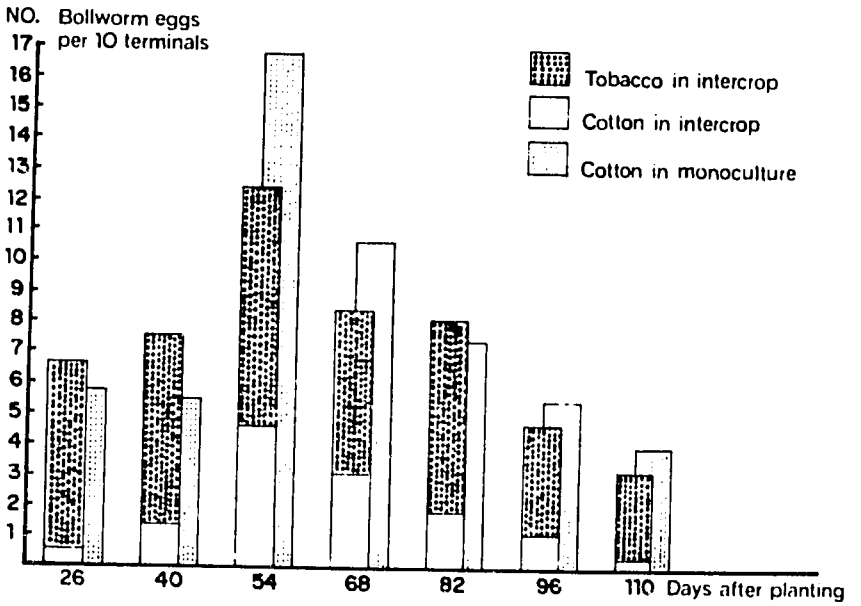

Figure 4. Heliothis egg distribution in a cotton-tobacco intercrop as compared to cotton alone.

Biological Control Strategies

Heliothis eggs in Philippine cotton areas were generally found to have a low rate of natural parasitization. However, laboratory studies confirmed the potential of *Trichogramma* spp. as biocontrol agents against *Heliothis armigera* (Torreno & Cadapan 1984). Moreover, a simple low-technology mass rearing procedure for *Trichogramma* spp. had been developed in the Philippines (Medina & Cadapan 1982). Several field trials were conducted to evaluate the use of *Trichogramma australicum* Girault against cotton bollworm as a substitute for chemical control methods (Table 5).

Table 5. *Heliothis* egg-parasitization after inundative release of *Trichogramma australicum*.[a]

	Crop year 1983/84[b]		Crop year 1984/85[b]	
	No. of eggs[c]	%	No. of eggs[d]	%
White eggs[e]	70	100.0	90	100.0
Parasitized eggs[f]	53	75.7	67	74.4
Lost eggs	11	15.7	4	4.5
Hatched eggs	6	8.6	19	21.1

[a]40,000 parasitoids per hectare in 3- and 4-day intervals, [b]no natural parasitization was detected during these years in the control fields, [c]over 20 sampling occasions, [d]over 9 sampling occasions, [e]found and marked prior to release of parasitoids, [f]black eggs recovered indicating successful parasitization.

The positive results of the field trials led to the further development of Medina and Cadapan's (1982) mass-rearing technology. Ultimately, a small home industry mass-production procedure evolved. One production unit provides full time employment for one person and can currently serve up to 20 ha of cotton, maize, eggplant, tobacco, or other crops commonly attacked by *Heliothis* and other lepidopterous pests.

It is recommended that the farmer releases the parasitoid preventively at a rate of 40,000 per ha twice a week. By comparison, the cost for a single application of a synthetic pyrethroid would be equal to six or seven weeks of continued Trichogramma release. For easier pronunciation, farmers opted to call this newly available biological pest control agent, "TRICON".

Chemical Control Strategies

For various reasons, severe infestations of cotton bollworm occasionally occur in spite of the correct implementation of all the above-mentioned pest management strategies. Synthetic pesticides then become necessary. It is important to recognize these critical infestations in time to initiate chemical control practices before much damage is inflicted. Therefore, an easy-to-use insect sampling system had to be developed.

SURVEILLANCE SYSTEM FOR TECHNICIANS Initially, a cotton surveillance system was developed, providing field technicians with a combined crop and pest management tool. The system focussed on crop development toward reasonable yield targets with pest control being seen as only one of the necessary inputs. The strategy was based on the concepts described by Hearn and Room (1979) which were extensively adapted to small-scale Philippine cotton conditions. The binomial sequential sampling system of Sterling (1976a) was redesigned and adapted to fit the local situation where a large number of small fields had to be assessed by technicians.

The new method now utilizes a fixed number of 20 sample plants. It provides general decisions on whether a pest population is above or below a critical level. Thresholds for the two major pests that can be controlled with pesticides are given in Table 6.

Attention is paid to uninfested sampling units, which are rated 1. Infested ones are considered a loss and are rated 0. For decision-making, the running total for plant number 20 is compared with the threshold. Key predators (spiders, lady beetles, ants) are similarly assessed. The running total for plant number 20 will be deducted from their threshold. A positive difference will be added to the running total of the pest counts. As a result, sometimes a treatment decision may be reversed into a no-spray decision.

PEG-BOARD FOR FARMER'S USE The surveillance system for field technicians proved infinitely too complex for farmers. However, based on the same principles, a simplified peg-board was designed, enabling the farmers themselves to assess the two most dangerous cotton pests (termed farmers' enemies). It also provides for a consideration of high arthropod predator

Table 6. Conventional critical levels for major cotton pests in the Philippines.[a]

Pest	Days after planting	Sampling unit[b]	Critical level
Bollworm larvae	28-56	terminal	less than 17 out of 20 uninfested
	56-112	terminal	less than 18 out of 20 uninfested
	56-126	2nd branch	less than 18 out of 20 uninfested
Leafhopper	28-112	3rd leaf	less than 10 out of 20 uninfested and undamaged

[a]Critical levels for minor pests are provided on the field technician's sampling cards. Sampling is optional. [b]Terminal: top 20 cm of plant main stem, 2nd branch: the second branch below the plant terminal, 3rd leaf: Third leaf below plant tip.

Table 7. Comparison of treatment decisions using peg-board and technician's sampling cards in the same cotton fields.[a]

	Decision not to spray	Decision to spray
Peg-board	13.1%	86.9%
Sampling card	19.2%	80.8%

[a]based on 99 independent samples each.

populations (termed farmers' friends) in pest management decisions. Table 7 shows how the two sampling methods compare with regards to spray decisions.

On the assumption that the sampled fields really needed treatment (more than 80% decided so in both techniques), the decisions not to spray were obviously erroneous. However, both systems were originally based on sequential sampling plans designed to tolerate an error of 20% in order to reduce the number of samples needed (Sterling 1976b). In any case, the basic critical levels have been determined conservatively, i.e. to result in a treatment decision earlier than a truly "economic" threshold level would prescribe. This means that the apparently erroneous decisions not to spray in Table 7, even if implemented, would not lead to an economic loss. Farmers and technicians alike are extremely sensitive to such errors. It was found to be considerably easier to allow a few more spray decisions to inspire confidence in the system, and then gradually acquaint the users with the principles of integrated pest management.

CONCLUSION

The integrated pest management strategies presented here have been developed using a combination of large experimental field plots and farmers' fields, as well as testing through field technicians. All components of the system, even if used individually, can result in substantial savings on chemical sprays. Initial results from on-farm research indicate that farmers appreciate the different components to varying degrees. However, all were able to understand how to implement the various technologies. An economic appraisal is currently being undertaken and will be reported elsewhere.

Nevertheless, this approach has barely left the developmental stage. Much more effort is needed to create an awareness of its advantages and uses among farmers themselves before a judgement can be made as to how well it can be implemented and how well it suits the needs of the Filipino cotton farmer.

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ECONOMIC JUSTIFICATION OF IPM: THE BILATERAL AGENCY'S VIEW

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Projects designed to promote integrated pest management (IPM) in developing countries are the Federal Republic of Germany's response to the demand that development cooperation should take account of the need for environmental protection.

Projects of this type are intended to meet several objectives – conserving natural resources, utilizing ecological balances in agricultural production, and reducing the dangers threatening man as a result of the use of farming techniques geared to the short-sighted principle of profit maximization. IPM aims to make pest management more efficient by combining biological, chemical, and arable farming methods. The intention is not to banish chemical pest control from agriculture altogether, but rather to ensure that it plays its proper role in efforts to achieve long-term stability of ecosystems. If the latter is achieved, then the existence of family farms may be safeguarded. However, even though we do not advocate a complete banishment of pesticides from agriculture, we recognize that the success of certain biological control techniques is endangered by simultaneous pesticide application in IPM.

As an element of its development cooperation services, the German Agency for Technical Cooperation (GTZ) devoted a total of US$20 million in 1986 to IPM projects in over twenty Third World countries. Such projects assist the respective partner countries to introduce IPM methods and to put practical solutions into effect. A development cooperation project always involves at least two partners: the Federal Republic of Germany as the donor country and the counterpart country concerned. Other organizations such as the World Bank or the European Community often also participate.

Projects designed to promote IPM have the following characteristics:

- The target group of such projects is the smallholder,
- Concentration on individual crops or pests is being increasingly abandoned in favor of a focus on crop rotations and cropping systems,
- A key task of all such projects is to pinpoint the real pests within the wide range of existing organisms and to develop specific strategies for combatting them,
- The criterion for the use of chemical pesticides is their comparative advantage when considered alongside all possible alternatives,
- An important feature of optimum pest management strategies is the determination of "action thresholds" for pests and diseases and their

introduction to extension,

- Control strategies are developed through on-farm experiments and tested in the farmers' fields, and
- In addition to the conventional pest management disciplines (e.g., entomology), particular attention is also devoted to breeding for resistance, cultivation techniques and chemical residue analysis.

In this paper, four typical projects, selected from the GTZ's on-going projects, will be compared and analyzed in terms of their economic efficiency.

THE ECONOMIC IMPACT

The economics of projects designed to promote IPM will be analyzed at three levels: that of the target group (represented by smallholders), that of the project executing agency, and that of the economy as a whole.

The Farmers

From the farmer's point of view, the main question is whether or not the use of IPM will boost his income. An increase in income will stem either from the reduction of crop damage or from reduced expenditure on pesticides; a combination of the two is also possible. Furthermore, field surveys (Waibel 1986) have revealed that a reduction in pesticide use can even improve the yield per unit of area in the case of rice and soybean.

Taking the average for the four projects analyzed, a 10% reduction in expenditure on pest management produces an increase of US$60–115 in the total gross margin per farm. The gross margin per ha can rise by between 3% and 30% (Table 1). Research evidence, however, shows that farmers will adopt new technologies if an increase in income of at least 30% is achieved (Zandstra et al. 1981). On-farm research in Germany has shown that IPM technology increases gross margins by 5.5% and reduces cost of pesticides by 30% (Zeddies et al. 1986).

Table 1. Impact of IPM technology on average farm household in US$ (Daxl & Schubert 1986, Doppler et al. 1986, Grosse-Ruschkamp et al. 1985, Waibel 1986).[a]

	Philippines	Thailand	Nicaragua	Cape Verde
Additional gross margin /ha	61	12	12	19 dry land 825 irrigated
Increase in %	9 - 21	3 - 30	4 - 15	30 - 50
Additional income/ farm	152	69	60	148

[a] Philippines: maize, cotton, paddy. Estimate based on farm trials; Thailand: paddy, soya. On-farm trials; Nicaragua: maize, beans, soya. 10% reduction of pesticide use. Official agricultural statistics; Cape Verde: Maize, beans, vegetables. Estimate based on field trials.

Waibel (1986) has reported that in some IPM trials a slight increase in risk was detected. Given normal risk aversion, however, this should still be acceptable to farmers.

It is, nevertheless, apparent that farmers still regard expenditure on pesticides as a form of "insurance premium" and in view of the fact that this expenditure accounts for only 5% of total production costs, there is a tendency to use more than the optimum from the economic viewpoint. It seems that farmers rate the risk of biological control techniques higher than risk of chemical control practices.

The Project Executing Agency

IPM projects generally entail only a low level of investment as their principal task is often to introduce new subject matter into the extension work of an existing plant protection service. However, IPM projects essentially need on-farm data collection and processing, means of transport, training of technicians (training centers), and extension (farmers' training centers or mass communication). Biological control always calls for a sizable research effort in IPM projects.

All in all, expenditure during the first ten years of investment is likely to be somewhere in the order of US$4–9 million. The follow-up costs directly attributable to IPM are well below US$0.5 million per year, but may rise depending on extension intensity (Table 2).

If the capital costs and running costs are apportioned over the area of land on which the new pest management strategies are used, in the long run, investment during the first ten years amounts to a total of US$1 per ha. It can rise to over US$100 per ha if a complete plant protection service has to be set up and appropriate research work becomes necessary, as in Cape Verde (Table 3).

The project executing agency cannot expect to derive any direct income from a project of this type. Indeed, it often even loses the revenue obtained from the sale of pesticides since IPM projects, of course, aim to reduce pesticide application.

Table 2. Investment cost of IPM projects over 10 years in millions of US$ (Daxl & Schubert 1986, Doppler et al. 1986, Grosse-Ruschkamp et al. 1985, Neutatz et al. 1985).

	Philippines 1987-1996	Thailand 1983-1992	Nicaragua 1981-1990	Cape Verde 1978 - 1987
Donor contribution	5.45	5.80	3.27	3.40
CP-country (estimate)	0.85	3.45	1.36	0.66
in % of total	14	37	29	16
Total	6.30	9.25	4.63	4.06

Table 3. Cost of IPM projects per ha arable land. Investment cost over 10 years, follow-up cost per annum in US$ (Daxl & Schubert 1986, Doppler et al. 1986, Grosse-Ruschkamp et al. 1985, Neutatz et al. 1985).[a]

	Philippines	Thailand	Nicaragua	Cape Verde
Area in '000 ha	8,390	9,600	151	33
Investment '000 US$	6,300	9,250	4,650	4,050
Follow up cost in '000 US$ per annum	130	465	135	140
Investment cost US$/ha	0.75	0.96	30.79	122.72
Follow up cost US$/ha	0.01	0.05	0.89	4.24

[a] Philippines: maize, paddy, cotton; Thailand: paddy; Nicaragua: maize, cotton, beans, soya; Cape Verde: maize, beans, pigeon peas, vegetables.

It is generally difficult to estimate the size of the counterpart contribution. This is due not merely to a lack of relevant documentation, but also to the fact that only those costs actually occasioned by the project should be attributed to the IPM program. Around 25% of the costs arising during the first ten years must be met by the partner country. Personnel costs are estimated to represent 30–40% of the follow-up costs (Table 4). The donor's investment budget, however, can be more easily broken down into the individual cost categories – commonly 32% is accounted for by personnel costs, while materials and running costs each take up 25%, 8% is used for counterpart training, and the remainder covers the GTZ overheads.

The Economy as a Whole

When assessing the economic cost and benefit of IPM projects, it is advisable to concentrate on the directly measurable effects. It is often perceived that the cost of IPM projects is far in excess of their directly measurable benefit, and efforts are therefore made to quantify indirect effects such as those of an ecological nature. Such approaches, however, often suffer from lack of clarity. For the four projects analyzed in this paper, all the costs incurred by both the donors and recipients over a period of twenty years were first compiled.

Table 4. Estimated proportion of personnel and material/operational cost of follow-up cost in % (Doppler et al. 1986, Grosse-Ruschkamp et al. 1985, Neutatz et al. 1985)

	Philippines	Thailand	Nicaragua	Cape Verde
Personnel	38	25	n.a.	33
Material/operational	62	75	n.a.	67

Working on the basis of IPM implementation at a constant rate over ten years, starting five years after the beginning of the project, these costs are set against the total of all additional agricultural income derived from IPM. The sole investment criterion is then the question of how many farms would have to adopt the IPM concept to ensure an acceptable internal rate of return (IRR), e.g., 8%, on invested capital.

In order to achieve an IRR of 8% in real terms, the relevant technologies would have to be adopted by 10,400 farms in the Philippines, 33,000 farms in Thailand, 17,000 farms in Nicaragua and 20,000 farms in Cape Verde. Seen in terms of the areas of land planted with the crops covered by the projects, this yields percentages of 0.3% for the Philippines, 2.1% for Thailand, 56% for Nicaragua and 80% for Cape Verde (Table 5).

Besides these direct production-related effects, it is fairly safe to assume that the other activities, such as promotion of quarantine (particularly in Cape Verde), counterpart training, research work and the like, also yield positive effects in economic and ecological terms.

Economic analyses of the individual projects were also carried out by experts during the planning phase (Philippines), and in conjunction with the interim evaluation (Thailand, Nicaragua, Cape Verde), with the effects actually achieved being included in the calculation. The internal rate of return is 5% for Cape Verde, 6.5% for Nicaragua, 16% for Thailand and 26% for the new project due to start in the Philippines.

Although the differences in the basic data used in the analyses (prices, project cycle) mean that the rates of return comparisons are limited, the figures obtained are probably a realistic reflection of the situation.

CONCLUDING REMARKS

Projects designed to promote IPM permit public funds to be used in a manner which is highly rational from the economic viewpoint. The comparative economic analysis for four projects promoting IPM in Asia, Africa, and Latin America reported in this paper certainly demonstrate this, even though the direct effects of the projects analyzed are difficult to measure. It can also be shown that IPM projects generally may be expected to give rise to follow-up costs of reasonable magnitude and to raise the incomes of smallholders.

Table 5. Benchmark adoption of IPM technology for 8% IRR.[a]

	Philippines	Thailand	Nicaragua	Cape Verde
% area	0.3	2.1	56.0	80.0
Number of farms	10,400	33,000	17,000	20,000

[a] Philippines: maize, paddy, cotton; Thailand: paddy; Nicaragua: maize, cotton, beans, soya; Cape Verde: maize, beans, pigeon peas, irrigated vegetables.

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IPM ACTIVITIES IN SUGARCANE IN THAILAND

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Thailand is ranked fifth among the sugarcane producing countries in the world with a total area of 0.58 million ha. The average yield is only 43.75 t/ha compared to 80 t/ha in Australia. Climate, soil, insects, diseases, and weeds are the major constraints to obtaining high yield and quality of sugarcane. Sixteen out of 70 insect species found on sugarcane are considered important pests (Prachuabmoh & Pitaksa 1986). The sugarcane borer complex consisting of *Chilo infuscatellus* Snellen, *Chilo sacchariphagus* Bojer, *Sesamia inferens* Wlk., and *Scirpophaga excerptalis* Wlk., is of major importance, causing an estimated yield loss of 6–40% in Thailand (Prachuabmoh et al. 1984). Other insects such as the stem boring grub (*Dorystenes buqueti* Guerin) have become serious in three recent years in sandy loam soil, causing an estimated yield loss of 13–43% in infested areas (Prachuabmoh et al. 1986). The white leaf, smut, mosaic, and red rot diseases, as well as variety decline, have greatly reduced yield and quality of the cane.

In 1984, an integrated pest control (IPC) pilot project for sugarcane was initiated in Thailand. An IPC working group was appointed through the cooperation of the Department of Agriculture (DOA) and the Department of Agricultural Extension (DOAE).

The objectives of the project were to develop an IPC program to improve yield and quality of sugarcane by incorporating cultural, chemical and biological methods so that pest populations may be maintained at tolerable levels and crop loss may be decreased. In addition, the IPC working group aimed to train farmers in the IPC program using field trials and demonstration plots. Screening for resistant varieties and multiplication of the healthy seed pieces from the IPC nursery plots at the farmers' level are emphasized in the project (Kusalwong 1986). Weed control is directed at the major species – *Dactyloctenium aegyptium* Willd., *Eleusine indica* (L.) Gaertn., *Echinochloa colonum* (L.) Link., *Cyperus rotundus* L., *Amaranthus spinosus* L., and *Trianthema portulacastrum* L. (Suwannarak & Kongsaengdow 1987).

MATERIALS AND METHODS

Demonstration plots of sugarcane consisted of integrated pest management (IPM) plots and farmers' plots. They were set up in two provinces, Cholburi

and Suphanburi. IPM practices were implemented in IPM plots and the results were compared to the farmers' plots. In Cholburi (rainfed area), sugarcane was planted from December to February as dry season planting, while in Suphanburi (irrigated area), planting time was from April to June, the early rainy season. The cane was harvested at 10–11 months. Pest control measures in the IPM plots are as follows.

Insect control

Sugarcane shoot borers management:

1. Planting moderately resistant variety F156.
2. Scouting the field at 15-day intervals beginning when cane is 1–4 months old, using a sequential sampling method.
3. Applying insecticides only when the deadhearts reached the economic threshold level of 10% in the dry season and 15% in the rainy season. Effective insecticides are 0.04% cypermethrin + 5% monocrotophos 20%, 0.0075 cypermethrin, 0.1% monocrotophos, 0.1% endosulfan and carbofuran as granular soil systemic insecticide at 1.5 kg a.i./ha.
4. Assessing the role of natural enemies as potential biological control agents.

Stem boring grub control

The following control measures were taken when replanting and when mean numbers of grub were 1.5/m of cane row:

1. Hand removal of grubs after ploughing two times before planting.
2. In endemic areas, spraying of the furrows with chlordane or heptachlor at 4–5 kg a.i./ha.

Disease control

The following measures were taken to control the systematic diseases in seed pieces (smut, white leaf, mosaic and red rot):

1. Encouraging healthy cane nursery.
2. Planting healthy and disease-free seed pieces from qualified nursery.
3. Eliminating volunteers before planting
4. Planting varieties F140 and Q83 which are resistant to the smut disease.
5. For cane in white leaf and smut epidemic areas, soaking the seed pieces in hot water (50°C) for 2 hours, or treating them with triadimefon 500 ppm or furmecyclox 400 ppm for 30 minutes to control smut disease.
6. Regularly inspecting the cane nursery and destroying diseased plants.

Weed control

Land preparation was for cultural purposes and for weed control. The land was ploughed and harrowed 7–10 days before planting. Weed stumps were pulled out as much as possible.

At Cholburi, where cane was planted at the end of the rainy season in the sandy loam soil, post-emergence weeds were not serious. Weeds were controlled by drawing the spring tooth harrow by tractor or buffalo between the rows of plants to uproot the weeds at 1–2 months and 3–4 months after planting. The remaining weeds after harrowing were destroyed by hoeing.

At Suphanburi, where the soil is of the clay loam type and sugarcane planting was done at the early rainy season, the weed problem is very serious and difficult to control by mechanical means. Herbicides (metribuzine/2,4-D Na., 2.5–3.25 kg a.i./ha) were applied just after planting. A second application should be done at 4–5 weeks after planting. A promising pre-emergence herbicide is atrazine, applied at 2.5-3.75 kg a.i./ha, although this was not used in our trials.

Yields were determined in each IPM and farmer's plot by harvesting a 7.8m x 10m area with 10 replications, and converting the weight to t/ha. Data were also collected on (1) pesticide use, rate, and cost; and (2) expenses for land rent, land preparation, seed pieces, cutting, planting, pesticide application, fertilizer, general labor, harvesting, loading, and trucking.

RESULTS

The plots in 1984/85 were all planted with sugarcane of variety F140. Results of IPM plots and farmers' plots for both locations are given in Table 1. The average yields of IPM and farmers' plots in Suphanburi were 66.25 and 51.25 t/ha, respectively. When the cane was sold at the guaranteed price of

Table 1. Comparison of investment costs, yield, income and profit for planted cane in sugarcane IPM and farmers' plots at Suphanburi and Cholburi, 1984/85.

	Suphanburi		Cholburi	
	IPM plot	Farmer's plot	IPM plot	Farmer's plot
Costs (US$/ha)				
Insecticide	16.59	24.04	-	-
Fungicide	84.13	-	84.13	-
Herbicide	48.80	28.61	-	-
Weeding	-	-	44.71	96.15
Fertilizer	48.65	54.09	166.10	134.61
Other[a]	755.24	764.67	887.98	738.70
Total costs	953.41	871.41	1,182.92	969.46
Yield (t/ha)	66.25	51.25	71.25	54.37
Income[b] (US$)	1,006.34	778.49	1,082.29	825.88
Profit (US$)	52.93	-92.92	-100.63	-143.58

[a]Costs for land rent, land preparation, seed pieces, cutting, planting, pesticide application, general labor, harvesting, loading and trucking; [b]Value of the yield at a price of US$15.19/ton.

$15.19/t in 1985, the IPM plot received $1,006.34/ha, while the farmers' plots yielded $778.49/ha. (All $ referred to in this paper are US$). Thus, the IPM plot had US$52.93/ha profit while the farmers' plots lost US$92.92/ha. In Cholburi, the IPM plots and farmers' plots yielded 71.25 and 54.37 t/ha respectively. The IPM plot received US$1,082.29/ha, while the farmers' plots received US$825.88/ha. The IPM plot incurred a monetary loss of US$100.63/ha, compared to US$143.58 loss from farmers' plots.

In 1985/86, plots included both planted cane and first ratoon cane. Results are given in Table 2. For planted cane in Cholburi, an area of stem boring grub outbreaks, chlordane at 4 kg a.i./ha was applied in furrows in the IPM plot, but carbofuran at 1.5 kg.ai/ha was used in farmers' plots. The IPM and farmers' plots for planted cane in Suphanburi yielded 85.69 and 63.75 t/ha, respectively. When the cane was sold at a guaranteed price of US$14.23/t in 1986, the IPM plot received US$1,219.37/ha, while the farmers' plots received US$907.16/ha. Therefore, the IPM and farmers' plots had US$245.53 and US$176.39/ha profit respectively. The IPM and farmers' plots for first ratoon cane in Suphanburi yielded 66.31 and 55.12 t/ha with US$475.33 and US$425.70/ha profit respectively. The higher profit derived from first ratoon cane was due to a lower investment cost. The IPM and farmers' plots for planted cane in Cholburi yielded 61.87 and 53.81 t/ha with the monetary loss of US$366.69 and US$185/ha respectively. The higher monetary loss in the IPM plot was due to higher investment cost. Furthermore, the IPM and farmers' plots for first ratoon cane in Cholburi yielded only 41.69 and 30.90 t/ha, but due to low investment cost, there were monetary gains of US$71.86 and US$42.69/ha respectively.

DISCUSSION

The sugarcane price crisis of recent years has resulted in most sugarcane farmers suffering monetary losses. The loss suffered by Cholburi farmers was greater than Suphanburi farmers. However, the Cholburi farmers have kept on growing sugarcane in spite of the loss because they could not find any other suitable crops. They only hope that prices will improve.

The IPM plots received more pesticides than the farmers' plots, although the cost of using pesticides could be reduced by minimizing the use of costly chemicals. Total cost of pesticides should not be more than 10% of expected income. Demonstration plots should be set up in infested areas so that the farmers can see how the problem may be solved.

The natural enemies of the borer complex showed some satisfactory results. *Trichogramma chilonis* Ishii and *Telenomus beneficiens* Zehnter were promising egg parasites of *Chilo* sp. and *Scirpophaga excerptalis*, whereas *Apanteles flavipes* Cameron was the potential larval parasite of *Chilo* sp. and *Sesamia inferens*. Entomologists in China have used *Trichogramma* to control sugarcane borers with good results (Liu and Sun 1985). However, in several regions of Thailand, sugarcane is more seriously damaged by *Sesamia inferens* than *Chilo* sp., and cannot be controlled by *Trichogramma*. Therefore, more research is needed on the biological control of *Sesamia inferens* with activities like

Table 2. Comparison of investment costs, yield, income and profit for plant and first ratoon cane in sugarcane IPM and farmers' plots at Suphanburi and Cholburi, 1985/1986.

	Suphanburi				Cholburi			
	Plant cane (var. Chinat 1)		1 st. ratoon cane (var. F140)		Plant cane (var. F156)		1 st. ratoon cane (var. F140)	
	IPM plot	Farmer's plot	IPM plot	Farmer's plot	IPM plot	Farmer's plot	IPM plot	Farmer's plot
Costs (US$/ha)								
Insecticide	-	-	33.41	5.77	78.36	44.95	38.46	-
Disease control[a]	128.36	-	-	-	137.26	-	-	-
Herbicide	35.34	17.55	-	-	-	-	-	-
Weeding	29.33	33.17	7.93	4.81	57.69	57.69	84.13	84.13
Fertilizer	74.52	54.81	65.14	35.58	126.44	75.00	86.06	57.69
Other[b]	705.29	625.24	361.78	312.50	847.35	773.08	312.74	255.77
Total costs	972.84	730.77	468.26	358.66	1247.10	950.72	521.39	397.59
Yield (tons/ha)	85.69	63.75	66.31	55.12	61.87	53.81	41.69	30.94
Income[c] (US$)	1219.37	907.16	943.59	784.36	880.41	765.72	593.25	440.28
Profit (US$)	245.53	176.39	475.33	425.70	-366.69	-185.00	71.86	42.69

[a] Costs included fungidide triadimefon and hot water treatment; [b] Costs for land rent, land preparation, seed pieces, cutting, planting, pesticide application, general labor, harvesting, loading and trucking; [c] Value of the yield at a price of US$14.23/ton.

searching for promising parasite species and strains, and developing their mass-rearing and release techniques.

The success of IPM is also dependent on a good pest surveillance system. The sampling method for each key pest should be clear and practical. And the economic threshold level of each key pest should be known as it is very important for making decisions on control treatment.

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IPM ACTIVITIES IN COCONUT IN SOUTHEAST ASIA

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Coconut palms contribute considerably to the food basket of many people in tropical regions, and also to the world production of vegetable oil. The Philippines, Indonesia, India, and the Pacific Island countries are the four largest coconut producers of the world.

Statistics on coconut production are difficult to obtain. One of the reasons is that none of the international agricultural research institutions considers the coconut palm to be within its mandate. However, recent publications (PCA 1979) indicate the following figures and the importance of this crop in Southeast Asia and the Pacific:

Country	*Size of country (sq. km)*	*Area under coconuts (ha)*
Philippines	300,000	2,800,000
Indonesia	1,450,963	2,300,000
India	3,183,643	1,082,900
Sri Lanka	65,610	485,000
Thailand	514,000	439,000
Malaysia	332,633	335,897
Papua New Guinea	222,998	250,000
South Pacific Islands	67,555	327,388
Seychelles	376	7,500
	6,137,778	8,027,685

The majority of the coconut palm growers throughout Southeast Asia and the Pacific are small farmers. Intercropping is quite common and secures a stabilized income for smallholders in times of depressed prices for copra and other palm products. It is known that various insects, diseases, rodents, and weeds are causal agents of losses in coconut production.

Since the 1950s, when effective insecticides and other chemicals became available, much attention has been paid to chemical insect control. The height of the coconut palm canopy, however, is a hindrance to spraying or dusting operations. Moreover, cost factors and the standard of technical development in the coconut-growing countries and at the individual farm level greatly limit the possibility of using power-spraying and dusting equipment. Finally, we must appreciate that the regular use of chemicals may have undesirable environmental and ecological impact within highly sensitive ecosystems.

Integrated Pest Management (IPM) will, therefore, be beneficial in dealing with the major insect problems of the coconut palms. For this paper, I have chosen three examples from nearly twenty years of cooperative research in Southeast Asia and the Pacific:

- the coconut palm rhinoceros beetle *Oryctes rhinoceros*
- rodents (*Rattus rattus*, *Rattus exulans*, etc.)
- the coconut hispine beetle *Brontispa longissima*

THE RHINOCEROS BEETLE

The coconut palm rhinoceros beetle *O. rhinoceros* (L) is one of the most serious insect pests of the coconut palm. The damage is done only by the adult beetles, which fly to the central crown of the palm and bore into the growing spear leaf cluster. The larvae develop in moist, decomposing vegetative materials. Rotting coconut trunks and stumps are the preferred breeding sites. The extent of damage recorded ranges from the total loss of young palms to all degrees of yield reduction up to 100% (Peterson 1977, FAO 1978). A reduction in the leaf area of 10%, 20%, or 30% would reduce nut production by 19%, 35%, or 51%, respectively (Zelazny 1979).

The Integrated Pest Control Approach

SANITATION PROGRAMS They should be regularly performed in order to remove breeding sites within and around coconut plantations. Legislation should provide the legal basis for these activities. The agricultural extension services should supervise sanitation and provide instructions to farmers.

BACULOVIRUS OF ORYCTES This Baculovirus, causing the so-called Malaya disease, plays a central role in integrated *Oryctes* control and is persistent in beetle populations. Discovered by Huger (1966) in Malaysia in 1963, it was first artificially introduced into uninfected rhinoceros beetle populations in Western Samoa in 1967 (Huger 1969, Marschall 1970). Surprisingly, the virus, which is absolutely safe to human beings, animals and plants, spreads throughout *Oryctes* populations in the major palm areas. Introduction of the Baculovirus into other South Pacific countries also resulted in efficient control of Oryctes populations and concomitant striking reductions in palm damage.

USE OF THE FUNGUS *METARHIZIUM ANISOPLIAE* The green, muscardine fungus *Metarhizium anisopliae* (Metsch.) Sorok. was described as early as 1913 as a possible control agent against rhinoceros beetles (Friedrich 1913). However, only recent efforts have resulted in the development of quite effective control methods, especially against larval stages (Latch & Falloon 1976, Peterson 1977, Beichle 1980). Today virulent Metarhizium strains are an important part of integrated control programs against *O. rhinoceros*. The fungus can be cultivated on organic carriers, e.g., bran, brewer's grain, corn/maize, oats, rice etc. and incorporated into moist, larval habitats either naturally or artificially. The extent of effectiveness depends principally on moisture

conditions of breeding material as a result of regular rainfall and high relative humidity. Fungus preparations proved to remain infective to larvae for at least 24 months.

COVER CROPS Young coconut palms, replanted in areas where logs and stumps of former coconut cultivations cannot be removed, can be protected by planting leguminous cover crops such as *Pueraria* spp., *Centrosoma* spp., and *Calopogonium* spp. These legumes provide a dense vegetative barrier which protects young palms from attack by beetles and greatly reduces oviposition in rotting logs and stumps.

SURVEYS Regular rapid damage surveys are practical tools for assessing recent beetle attacks on palms (Peterson 1977). The incidence of virus infection in adult beetle populations should be determined semiannually.

Recent Findings

Under the GTZ project and a preceding SPC/FAO/UNDP project, the Western Samoan coconut palm area of about 59,000 hectares (Ward et al. 1980) has been under constant supervision since 1964. Results show the high incidence of virus infections persisting in the beetle populations of Western Samoa. At the same time damage remained at low levels.

The Philippine Example

In the Philippines, we find a different situation regarding the rhinoceros beetle. The beetle is considered the most important insect of the coconut palm (Anon. 1978). In particular, a countrywide rehabilitation program to substitute the overaged plantations with new hybrid varieties is severely endangered. This is underlined by the figures in Table 1. The figures in Table 1 also clearly indicate the importance of proper sanitation measures.

The Baculovirus of *Oryctes* is autochthonous within the Philippines rhinoceros beetle population. From preliminary studies by V. Fandialan (pers. communication 1979), it appears that its incidence in adults is rather low (7–12%) in the province of Quezon (Huger 1979). Apparently, virus transmission within beetle populations is impaired by special population dynamics resulting from dry conditions in this area during several months of the year.

Table 1. Difference in rhinoceros beetle incidences between various ecosystems.

	1st Year	2nd Year	3rd Year
Replanted old palm areas	15.3%	32.7%	22.9%
Partly replanted and partly newly planted areas	2.4%	7.8%	14.4%
Newly planted areas	2.2%	7.8%	8.9%

RODENTS

Several rodent species, such as the Polynesian Rat (*Rattus exulans*) and the Roof Rat (*Rattus rattus*), are considered major pests of coconut palms throughout Southeast Asia and are sometimes the most devastating pest. Yield losses due to rodents have been estimated to range between 27% and 47% (average 40%) in Tahiti (Lasalle-Sere 1955 cited from Temme 1973). In Thailand coconut yield losses range between 3.0% and 13.3% (average 7.1%) in the Southern part, and 0% and 15.0% (average 10.3%) in the Western part (Flotow 1980). Losses in the Philippines, expressed in monetary terms, are valued up to US$175 per ha/annum in experimental plots (Kurylas 1974).

Although chemical control with acute and chronic poison bait (e.g., Wax blocks) is easier than in the case of the rhinoceros beetle, IPM procedures should be implemented too. These include measures such as habitat manipulation, plantation sanitation (removal of sheltering opportunities), physical barriers like bands of iron sheets around the palm stems, and mechanical trapping. However, to be effective, collective efforts by all farm and plantation communities are needed in rodent control.

HISPINE BEETLE

This Hispine Beetle (*Brontispa longissima* Gestro) was accidentally introduced into the coconut plantations of Western Samoa in 1979. After heavy damage (loss of leaf area) was discovered, attempts to start Integrated Pest Management were initiated. The beetle was soon considered the most important pest as it outnumbered the rhinoceros beetle. Though chemicals such as permethrin and trichlorfen proved to be effective against *Brontispa*, other means of control, especially biological ones, were tested and introduced as well.

The green muscardine fungus *Metarhizium anisopliae* is reported to eliminate up to 65% of 3rd and 4th instar larvae. The parasitic wasp *Tetrastichus brontispae* was introduced into the country, mass-reared and distributed throughout infested coconut palm plantations, and reportedly parasitized pupae to an average of 30%, and sometimes up to 88%. Further surveys in 1984 (Hollingsworth et al. 1985) indicated the presence of another parasitic wasp, *Chrysonotomyia* sp. (Eulophidae), causing larval mortality up to 96%.

The impact of other natural enemies like the mite *Brontispalaelaps leveri*, the cosmopolitan earwig *Chelisoches neosio*, and one unidentified ant, have not been determined.

It is important to mention that proper weeding considerably reduces *Brontispa* damage, especially to young coconut palms.

An economic evaluation of this IPM approach indicates very favorable results. It is estimated that an average of 10% yield loss in Western Samoa coconut production is prevented, amounting to US$2.2 million annually, while the routine costs of the program (evaluation of infestation level and percentage of parasitation) is only about US$2000 per year countrywide. However, initial input for the overall IPM program was as high as US$770,000 in the first three

years. The average farmer achieves benefits of about US$50 per ha coconut plantation per year (Klingauf & Voegele 1986) without any input at the farm level.

OTHER IPM EXAMPLES

Further examples include the promising results against the coconut mite *Eriophyes guerreronis*, gained by simple sanitation methods in coconut palm plantations in Costa Rica, reducing the damage by up to 50% (Otterbein 1985). Success has also been achieved against *Oryctes monoceros* in a cooperative project in Tanzania since 1977. All examples show that IPM programs could be worked out and applied economically. Less successful projects dealt with coconut diseases like lethal disease in the Caribbean and East Africa (Nienhaus et al. 1982), Kainkope disease in West Africa (Steiner 1975) and Cadang-Cadang in the Philippines (FAO 1982).

Further attempts and additional time and funding opportunities are necessary to provide more income and food security to coconut producers in Southeast Asia and the Pacific. A regionally-oriented project based at a capable institution might help to promote such programs.

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PEST MANAGEMENT ON OIL PALM IN MALAYSIA

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The area under oil palm in Malaysia has dramatically increased in recent years, and it is estimated that at the end of 1986, there were about 1,458,100 ha. During the rapid expansion of the industry in the late 1950s and early 1960s, the oil palm was plagued with indigenous leaf-eating caterpillars. Spraying with broad-spectrum and persistent insecticides resulted in further outbreaks and resurgences of these pests. Local entomologists were prompted to advocate using principles of Integrated Pest Management (IPM) on oil palm, and since the mid-1960s, IPM has become well accepted in the Malaysian oil palm industry and has helped to reduce the seriousness of pest outbreaks.

MAIN PEST PROBLEMS

The main insect pests on the oil palm are the defoliating caterpillars, particularly the three major species of bagworm (Psychidae), and about five major species of nettle caterpillars (Limacodidae), which have caused extensive outbreaks covering large areas of 2000 ha or more. The other defoliators of lesser importance are two hairy-caterpillars (Lymantridae), three cockchafers (Melolonthidae and Rutellidae), and a grasshopper (Acrididae) species. Another insect pest which has become more important in recent years, especially in palm-to-palm replants, is the rhinoceros beetle, *Oryctes rhinoceros* (Dynastinae).

Economic losses caused by these defoliators have been estimated by Wood et al. (1972), through a damage simulation trial, to be as high as 40–50% of the crop over a period of two years after a single defoliation of 100%. At present prices, this represents a loss of US$400–$650 per ha. Defoliation in immature palms showed similar responses, but to a lesser degree, with 12–36% loss in yield (Chemara, unpublished data).

However, all these are only occasional pests. Usually, they are present in extremely low numbers, obviously being kept well under control by natural factors. Most of the caterpillar pests have a great number of attendant parasitoids and predators, which have been recorded during outbreaks (Syed et al. 1974, Tiong 1982). In most cases, it is yet uncertain how these natural enemies operate, nor is it known which species exert the most effective regulatory pressures on the pest concerned, especially in non-outbreak situations.

The only chronic pests in Malaysian oil palm plantations are rats. In the absence of effective control measures, rat populations can potentially build up to economically damaging levels, causing losses of about US$70 per ha per

annum. The species which are responsible are the Malayan wood rat, *Rattus tiomanicus*, the rice field rat, *R. argentiventer*, and the house rat, *R. rattus diardii*. They constitute more than 95% of the rat species encountered in the crop.

PLANT PROTECTION RESEARCH

The industry, quasi-government organizations and the private sector included, spends very little for research on plant protection in oil palm. Estimates on the expenditure vary. Some 15 plant protectionists are employed in the industry, excluding technical sales personnel of pesticide firms; and of these, only a small number devote most of their time to oil palm.

A fair amount of collaboration exists among research organizations, mainly under the auspices of the Malayan Oil Palm Growers' Council, which represents about 78% of the oil palm industry. There is also good liaison concerning plant protection research among three major companies, namely, Kumpulan Guthrie Sdn. Bhd., Harrison Malaysian Plantation Bhd., and Sime Darby Plantations, which together make up about 15% of the country's oil palm hectarage, with influences through their advisory services on perhaps a further 10%.

INTEGRATED PEST MANAGEMENT

In recent years, agronomic and cultural changes are redefining plant protection strategies. The increase in palm-to-palm replants, the steady switch to higher planting densities, the advent of hybrid and clonal materials, and the introduction of the pollinating weevil impose new dimensions on control methods.

The Oil Palm Pollinating Weevil

The weevil, *Elaeidobius kamerunicus*, was introduced into the country from Africa in 1981. It has been a boon to the industry, saving millions which would otherwise have been spent on hand-pollination. The susceptibility of the species to pesticides has always been a matter of concern, and until recently, care was exercised to ensure that no pesticide application should drastically affect the population of the weevil and thereby their pollinating efficiency (Basri & Halim 1985). It has since been found to be effectively pollinating despite being reduced in numbers after aerial application of methamidaphos (Chemara, unpublished), trunk injection of monocrotophos, and fogging with deltamethrin. There is no doubt that its presence has affected the ecology of the oil palm agroecosystem and this has been actively studied (Chiu et al. 1985, Liau 1984).

Selective and Minimal Pesticides

IPM has often been approached rather passively through the philosophy of least interference, emphasizing the use of selective pesticides, minimal herbicides, and non-disruptive application techniques. Often IPM has been

practiced without full quantitative information, albeit with a fair understanding and appreciation of the ecological factors involved.

Pesticides remain the most important weapon. A list and range of suitable pesticides have been reported by Wood et al. (1977). Commonly, selective organophosphates, carbamates, and the more specific products such as the *Bacillus thuringiensis* are recommended. Employment of the time-tested strategy of using these known selective pesticides have regularly proven successful.

Moving away from this tradition, some entomologists are recommending the use of potent and broad-spectrum pesticides capable of very good kill and quick knockdown of pest populations. Such pesticides have not been used often enough to fully ascertain the wisdom of the strategy, but so far, there has been no cause to think otherwise because on many occasions, when they have been extensively sprayed from the air or fogged, there has been effective control without any lingering or recurrent problem.

Blanket sprays of herbicides have been suspected of disrupting insect ecology and causing outbreaks. Workers in Sarawak showed that when herbicide input was curbed, there was a significant reduction in insecticide requirement.

RAT CONTROL Anticoagulants in wax-bound baits provide effective control of rats. With the development of resistance to these poisons in some localities, the second generation anticoagulants have been introduced.

AVAILABILITY OF PESTICIDES Consequent to the implementation of the Pesticide Act of 1974, some of the pesticides which have been tested and used by the industry have been de-registered, more on the grounds of toxicity and safety, rather than on their relative merits as effective plant protection chemicals. There has been no shortage of suitable alternatives, though not necessarily of equivalent merit. The Pesticide Board has been extremely supportive and appreciative of the needs of IPM, and has conceded, for example, the use of monocrotophos for trunk injection. There are, however, no problems with obtaining experimental chemicals, such as growth regulators (Ng 1986) and synthetic pyrethroids which are being popularly tested and shown to be potentially useful.

Cultural and Mechanical Methods

Soil cultivation (plowing and harrowing) is normally part and parcel of the planting policy of oil palm plantations. It is especially recommended in areas prone to Ganoderma. Similarly, leguminous cover crops are grown in all plantings for a range of agronomic reasons, but they have been shown to form a vegetative barrier to reduce the breeding of the rhinoceros beetle in rotting trunks and stumps (Wood 1968); therefore, they are encouraged wherever the beetle is a problem.

PALM SHREDDING In palm-to-palm replants, palm debris are the main breeding sites of the rhinoceros beetle. Previously, the palm trunks were felled and left to rot; nowadays, as it has become as cheap as conventional felling, the

palms are mechanically shredded and burnt at about US$220 per ha. Some plantations carry out repeated burning to completely clear the palm debris at a considerable additional cost of US$180 per ha, while many others are satisfied with a single burn although the charred palm remnants are still capable of supporting beetle grubs for a number of months.

HANDPICKING This technique has proved to be useful and economical mainly for the control of bagworm infestations in the young plantings, particularly of the larger species, *Mahasena corbetti*. It has reduced the input of chemicals, and thereby generally averted indiscriminate use of the wrong kind of pesticides.

RAT CONTROL The cultural and mechanical practices adopted for rat control by various estates in Malaysia include (a) periodic removal of nests from palms, (b) periodic removal of waste materials from crown, (c) destruction of burrows, (d) the building of barriers such as wire guards around the bases of young palms, (e) trapping and (f) maintaining the field free of ground cover. Overall, these have not been very effective methods.

Application Techniques

AERIAL APPLICATION Aerial application offers many advantages during extensive outbreaks, when the timing and speed of pesticide sprays become critical to the success of the operations. Currently, both fixed-wing aircraft and helicopters are available, but this fortunate situation has not always been so, nor will it necessarily remain so because many commercial operators have found it unviable to remain in business due to the infrequent and irregular demands.

TRUNK INJECTION Borrowed from the Pacific island coconut industry, this technique was adapted, tested, and developed (Wood et al. 1974), and is now widely used. It is ecologically sound in that it does not adversely affect natural enemies directly. Used mostly in tall palms, the popularity and success of this technique has been further endorsed by the manufacture and marketing of a specific drench gun by Tiram Kimia, a chemical company, and made even more economical by the innovative use of electric drills to speed up the application operation (Singh 1986).

ROOT FEEDING OF INSECTICIDE Although it was reported to be very successful in one known instance on oil palm in the Philippines, this technique has only just been tried locally. There are problems; the chemical uptake is affected by a number of uncertain factors, one of which is root damage during application.

FOGGING This has been tested against the caterpillar defoliators using various chemicals, including the broad-spectrum, quick-knockdown, non-residual synthetic pyrethroids. Though, theoretically, the technique appears to be too broad-spectrum in its kill, there has not been any report of major disruption or pest resurgence.

BIOLOGICAL CONTROL

The success of the pollinating weevil has stimulated research on the utilization of bioagents for pest control. Even biocontrol of vertebrate pests (Wood 1986), especially of rats, has been hotly discussed by planters at large. Attempts to augment natural predation in the past have not been successful, but there is a great deal of interest in the manipulation of the Barn Owl, *Tyto alba*, as a biological control agent against oil palm rat species (Wood et al. 1974). A survey conducted by the Palm Oil Research Institute of Malaysia, PORIM (Basri & Halim 1985) indicated that 17% of estates reported the presence of the owl, a relatively recent arrival to the country, and the owl appears to have spread to all Malaysian States. There is, however, considerable concern and some controversy over the use of the second generation anticoagulants (Duckett 1984, 1986), as secondary poisoning of the owls by these more potent rodenticides may present a problem.

Against insect pests of oil palm, several workers have used the naturally occurring viruses which attack some of the defoliating caterpillars (Syed et al. 1974, Tiong & Munroe 1976). There is potential for further development of this approach for IPM.

The National Biological Control Center is in the process of being set up. Therefore, any establishment of regional and international collaboration on oil palm pests at this juncture is timely and augurs well for the advancement of biocontrol in Malaysia.

SOME FUTURE NEEDS

The development of IPM has generally not been hampered by inaccessibility to modern technology, equipment and machines, even though much remains to be done.

There is a paucity of general biological and ecological information, not to mention quantitative data, which are required to support IPM, and to facilitate a more rational approach toward formulating and extending control strategies and policies. Weather, for instance, is a major determinant of agroecosystem dynamics, yet its relationship with pest ecology is not well understood because often weather data are inadequately collected.

For the future, collecting and monitoring biological and ecological data of pest and host populations could be greatly enhanced with the computer. Strangely, despite the availability of powerful and inexpensive microcomputers, computer technology has not made much inroad into plant protection in the Malaysian oil palm industry, although the surveillance of Malaysian rice pests has become computer-based to a fair extent. At most, research stations have exploited commercially available database programs for storage, retrieval, and use of data as well as for statistical analyses of experiments, but the development of computer-based decision aids for IPM and extension programs has hardly begun.

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PEST MANAGEMENT ON COCOA IN MALAYSIA

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Although cocoa was introduced into Malaysia (then Malaya) as early as 1778, the crop's cultivation never really became an industry until well after the Second World War. Various factors contributed to such a situation, inefficient plant protection being one of them (Burkhill 1966). Hectarage under cocoa in Malaysia has expanded dramatically since the 1940s, from just 600 bearing trees in 1948 to 30,252 ha in 1975 and 242,000 ha in 1984 (Anon 1986), making cocoa the third major plantation crop in the country. Improved planting materials and agronomic practices were major contributors to the increase. It is, however, also undeniable that plant protection and, as the various aspects of this discipline developed, pest management on cocoa advanced in step, minimizing setbacks to the crop's establishment, and thus adding to the success of the cocoa industry in the country. In this paper I will outline the practices of and advances in pest management, with particular reference to faunal pests.

MAJOR FAUNAL PESTS OF COCOA IN MALAYSIA

A great diversity of insects and other fauna are trophically associated with cocoa. It is thus inevitable that a significant number of them would become pests once the tree was cultivated on a large scale. Such pests are appropriately categorized into key, occasional, and potential pests following the concept of Smith and Reynolds (1966), and representatives of each category as experienced in Malaysia are listed in Table 1. MacArthur and Wilson (1967) have proposed the concept that organisms can be graded according to their population growth strategy, which has, in turn, evolved to exploit the environment. The extremes of the strategies for insects are the r and K selected organisms, with the in-between as "intermediate". Characteristics of each category are as indicated by Heong (1981). Wood (1979) had aptly related the r-K continuum with Smith and Reynolds' concept and with reference to this, it is clear that key pests of cocoa in Malaysia (Table 1) generally adhere to the definition of being K-end or intermediate pests that are damaging at the endemic level or are regularly pushed to epidemic levels by cultural techniques. Conceptually, such key insects are best controlled by regular suppression of populations to below economic levels by use of attrition methods (e.g., selective chemicals, sterile male techniques, biocontrol, cultural control, resistant strains).

Occasional pests are defined as those that are often found in small numbers under natural conditions, but with the potential of outbreaks. Such insects often belong to the intermediate to r-end of the r-K continuum. Most of the

Table 1. Key, occasional, and potential faunal pests of cocoa in Malaysia.

Species	Order	Family
Key pests		
Apogonia spp.	Coleoptera	Scarabaeidae
Adoretus spp.	Coleoptera	Scarabaeidae
Anomala pallida (F.)	Coleoptera	Scarabaeidae
Helopeltis spp.	Hemiptera	Miridae
Conopomorpha cramerella (Snellen)	Lepidoptera	Gracillariidae
Zeuzera spp.	Lepidoptera	Cossidae
Rattus spp.	Rodentia	Muridae
Callosciurus spp.	Rodentia	Sciuridae
Occasional pests*		
Platyngomiriodes apiformis Ghauri	Hemiptera	Miridae
Caetanococcus spp.	Hemiptera	Coccidae
Planococcus spp.	Hemiptera	Coccidae
Ferrisiana virgata Ckll.	Hemiptera	Coccidae
Darna trima (Mr.)	Lepidoptera	Limacodidae
Setora nitens Wlk.	Lepidoptera	Limacodidae
Ploneta diducta Sn.	Lepitoptera	Limacodidae
Thosea spp.	Lepidoptera	Limacodidae
Clania spp.	Lepidoptera	Psychidae
Pagodiella hekmeyeri Hey.	Lepidoptera	Psychidae
Metisa plana Wlk.	Lepidoptera	Psychidae
Cremastopsyche pendula Joann.	Lepidoptera	Psychidae
Mahasena corbetti Tams.	Lepidoptera	Psychidae
Euproctis spp.	Lepidoptera	Lymantriidae
Adoxophyes privatana (Wlk)	Lepidoptera	Tortricidae
Dichocrocis punctiferalis (Gn.)	Lepidoptera	Pyralidae
Endoclita hosei Tindale	Lepidoptera	Hepialidae
Indarbela disciplaga Swin.	Lepidoptera	Metarbelidae
Valanga nigricornis (Burm.)	Orthopthera	Acrididae
Cerosterna sp. nr. *pollinosa* Buquet	Coleoptera	Cerambycidae
Potential pests*		
Lawana sp.	Hemiptera	Flatidae
Colobesthes falcata Guer.	Hemiptera	Flatidae
Ceroplastodes chiton Green	Homoptera	Coccidae

* selected.

occasional pests listed in Table 1 adhere to this definition, although there are clear exceptions (e.g., *Indarbela disciplaga* and *Endoclita hosei*). Nevertheless, for all species listed, it is possible to predict the necessity of chemical intervention for control of outbreaks. Occasional pests are the dominant group

of pests on Malaysian cocoa, and because of the very intermittent nature of outbreaks of these pests, only chemicals can be used for timely intervention.

Potential pests are commonly those that occur through artificial disturbances, and in most cases are naturally regulated once the disturbance lessens. Examples in Table 1 fit well into this definition (Shah 1978, Sidhu 1983).

As key pests are those which show most chronicity, this means that at any one time, pest management on cocoa in Malaysia would be concerned with any one of such organisms listed in Table 1. Strategies and advances in pest management in the crop may thus be illustrated with the following key pests — the scarabacid defoliators, mirids, borers and rodents (especially rats).

CONTROL OF SCARABAEID DEFOLIATORS

A complex of scarabaeid defoliators attacks cocoa in Malaysia. Prominent members are *Apogonia cribicollis*, *A. expeditionis*, *Adoretus cribratus*, *A. compressus* and *Anomala pallida* (Entwistle 1972). The insects are nocturnal feeders, adults hiding in the soil between cocoa during the day. Larval stages of the insects are spent in the soil, grubs normally feeding on grass roots and vegetable detritus.

Young cocoa is particularly susceptible to attack by the cockchafers and tend to be most set back during their first one or two years after planting out. Damage can be severe; attacked plants can suffer 50% reduction of stem cross-sectional area and plantings can require 30% replacement of points (Thong et al. 1977). Although mature cocoa are often able to tolerate some cockchafer damage, yield losses due to the insect have been recorded (Ooi & Han 1980).

Mechanical and chemical methods seem to be the most practical control methods for the insect. From as early as 1953, the placing of a physical barrier, such as palm fronds, around newly planted cocoa has been shown to reduce cockchafer damage (Lever 1953). At the same time, control is augmented by soil treatment, gamma HCH being effective. Foliage can also be sprayed with lead arsenate, a contact insecticide like dieldrin being added as trees begin to bear pods so that *Helopeltis* can be simultaneously controlled. Chemical control is the more effective of the two strategies, even at the present time. Refinements have been developed for chemical application, notably the use of stem painting and granular insecticide application techniques. For the former, Tan et al. (1974) reported that stem painting of acephate on young cocoa allowed sufficient amounts of the systemic poison to be translocated to leaves for control of defoliators. For granular insecticides, aldicarb, when broadcast on soil in a 30 cm radius around the stem, was proven by Thong (1976) to be more efficient than foliar sprays. Nevertheless, due to the high mammalian toxicity, aldicarb has since been deregistered in Malaysia, thus preventing its use. In older cocoa, granular insecticides have been tried for controlling outbreaks of the insect (Ooi & Han 1980) but results have been variable. Foliar sprays will continue to be the most effective method for control of such damage, chemicals like acephate and methamidophos being appropriate. Nevertheless, the lessened occurrence of severe damage in mature cocoa, together with an improved awareness of

Malaysian cocoa growers for early detection of such occurrences (Wood 1984) has provided a high degree of selectivity in areas that need to be sprayed at any one time.

There has not been much innovation in mechanical control, and frond barriers are still being used (Azhar 1984). The use of polythene manure bags, set up in the same manner as palm fronds to enclose newly planted cocoa is however gaining popularity, especially amongst smallholders. This technique is also proving to be useful in protecting supplied cocoa.

CONTROL OF MIRIDS

Major species of mirids encountered in the cocoa plantings of Malaysia are *Helopeltis theobromae* and *H. clavifer*, the former being found in Peninsular Malaysia and the latter in Sabah. It is generally observed that *H. theobromae* causes more damage to cocoa in the Peninsula.

Damage is caused by the mirids' sucking activity on pods, cherelles, and shoots of cocoa. Both nymphal and adult stages actively do this. Symptoms of damage are described by Miller (1941). If left unattended, losses could reach 85% (Tan 1974) and under certain situations damage to shoots is intense.

Most of the technology for controlling mirids in Malaysia originated in West African experiences with *Distantiella theobromae* and *Sahlbergella singularis* (Ho 1986a), the use of chemicals being a primary technique. Nevertheless, local adaptations and advances have also been made.

Tan (1974) verified the usefulness of gamma HCH for control of mirids in Malaysia and since then, the insecticide has become the industry standard for the insects' control in the country. As resistance by *Helopeltis* to the chemical has not yet been detected (Dzolkhifli et al. 1984), and together with a continued price differential in favor of its use, gamma HCH is expected to remain the chemical of choice for *Helopeltis* control. However, attempts are being made to identify alternative chemicals, and isoprocarb and propuxur have been shown to be the more cost effective alternatives. The latter is versatile in that it can be used with high or ultra low volume applicators (Ho 1985).

With regards to application technique, West African technology has also been adopted, especially the use of knapsack sprayers, mistblowers, and thermal foggers. Of these, the former two are the more commonly utilized. Fogging is useful in situations of labor shortage, and its efficiency is further increased by mechanization (Taylor et al. 1982). Work is presently in progress to evaluate the possibility of mechanizing high to medium volume sprayers (Ho 1986a). An immediate drawback in this is inaccessibility, since planting patterns of cocoa will have to be adapted to available machinery, e.g., creating access paths into plantings, and not vice versa. An immediate question that arises through such mechanization efforts is that the desire for judicious insecticide application could be compromised. This, however, is not the case when one considers that early warning and census systems are salient features of cocoa growing in Malaysia. Thus, at any one time, with the help of such systems, only discrete blocks of cocoa (that perhaps are conveniently demarcated by access paths) and

not entire fields, are treated, thus avoiding indiscriminate application of pesticides.

A feature of mirid chemical control in Malaysia that is original to the country is the emphasis on early warning of outbreaks through census systems. Wills (1984) and Wood (1984) describe the success of two such systems in providing ecologically sound control at economic cost.

The present great dependency on chemicals to control *Helopeltis* in Malaysia reflects the general inability and lack of effective natural control agents to suppress the populations to below economic levels. The only predator that shows prospective use as a biocontrol agent is the cocoa black ant, *Dolichoderus thoracicus* (Azhar 1986) and work is being carried out to elucidate ways of effectively using the organism for such a purpose.

No effective cultural control method, whether by shade manipulation or the use of resistant planting materials has been developed (Azhar 1986).

CONTROL OF BORERS

Stem and Trunk Borers

Although a complex of such borers that belong to the genus *Zeuzera* are known to attack a variety of trees in Southeast Asia (Barlow 1982), *Z. coffeae* and *Z. roricyanea* are the most commonly encountered in cocoa of Malaysia. The insects are almost always present in established cocoa plantings. They are often underrated, however, due to the insects' relatively undramatic mode of infestation.

Zeuzera are damaging during the larval stages of its lifecycle, description of which is as in Conway (1971). If left untreated, the borers can easily reach epidemic proportions, recent experience showing the insect reaching levels of up to 6,500 larvae per ha of cocoa, causing severe dessication of foliage through hollowing out of branches and loss of crop through damage of trunks. Trees are also known to die, and survivors often rendered unproductive.

The key to avoidance of the foregoing damage is early detection and sustained control of manifestations so that borer levels are rendered inconsequential. If early detection is achieved, a combination of cultural and insecticide treatment is effective, the former being pruning of light branches with borers, inspecting branches to kill any larvae present. Parasitized larvae (e.g., by the Ichneumonid *Spinaria* sp.) are, however, undisturbed and left in the field for parasitoids to emerge. Chemical treatment, basically on trunks and infested branches that are too thick to be pruned, entail the pumping of a dieldrin or chlorpyrifos solution into bores.

With emphasis on early detection, census is once again instrumental for success. Scoring of borer activity in conjunction with earlier mentioned *Helopeltis* census rounds have been experienced to provide the required sensitivity.

Cocoa Pod Borer

The cocoa pod borer *Conopomorpha cramerella* was first confirmed to be attacking cocoa in the Tawau area in 1980 (Lim et al. 1982), and within a period of two years had spread throughout Sabah. In 1986, the moth was also found in Peninsular Malaysia (Anon. 1987).

Of the insect pests of cocoa, *C. cramerella* is considered one of the most serious, as entire cocoa industries have been known to be destroyed by it (Anon. 1980). Losses and symptoms of damage have been well covered by many authors, Day (1985) providing a particularly comprehensive account. Owing to the seriousness of the problem, research in an unprecedented intensity for any insect of cocoa in Malaysia has been undertaken on the moth since 1980. Results of such efforts have been encouraging. Mumford (1986) indicates the following avenues of control:

SELECTIVE INSECTICIDE SPRAYING This entails spraying the undersides of roughly horizontal, lower canopy branches (which are the daytime resting site of the moth) with pyrethroid or carbamate insecticides. Four to five rounds of such spraying at 10–14 days' interval, especially when done during low crop periods have been found to be effective in protecting subsequent high crop. When carried out in the prescribed manner, ecological and pollinator risks are expected to be minimum.

FREQUENT HARVESTING AND BAGGING As many caterpillars emerge from ripe pods both before and after harvest, frequent harvesting, rapid breaking, and subsequent destruction of husks by bagging, burying, drying, etc. to reduce the successful emergence of caterpillars in the field is expected to contribute to the general lowering of moth populations. This technique also has the major benefit of avoiding the use of insecticides.

SLEEVING Small polythene plastic sleeves have been used to bag pods just before they become attractive to female moths, thus protecting the pods for the rest of their development. The method once again obviates the use of chemicals but has the disadvantage of being highly labor intensive.

PHEROMONES Synthetic female pheromones have been synthesized and are now utilized for monitoring, mass trapping and mating disruption on an experimental basis. To date, mass trapping has shown promise as a control method, but cost effectiveness is still to be fully gauged.

BIOLOGICAL CONTROL The mass breeding and inundative release of the naturally occurring egg parasite *Trichogrammatoidea bactrae fumata* is the salient development in the biocontrol aspect of cocoa pod borer research. Experimental scale release have been carried out with encouraging results being attained, albeit at higher intensities of inundation. As with the use of pheromones, cost effectiveness of the technique is still to be fully gauged.

RAMPASAN This is the complete stripping of immature and mature pods for a short period during the cropping cycle in an attempt to break the life cycle of the moth. Although neat in theory, practice of rampasan, especially in plantations, is extremely difficult, with no guarantee of success for the considerable effort expended.

RESISTANT VARIETIES Several hard-shelled cocoa varieties have been observed in Sabah that show considerable resistance to the pod borer, thus indicating feasibility of the development of resistant varieties for the long-term control of the moth. However, as with most breeding programs, realization of objectives will be time consuming.

In addition to the foregoing, more recent developments have also investigated the feasibility of the introduction of exotic parasitoids for control of the moth in Sabah (Ooi 1985) and progress to date show this to be encouraging and introductions near fruition. Also, the streaking of engine sump oil with and without mixture with malathion on pods has been indicated to be effective in repelling if not controlling moths. However, further investigations showed the technique to provide variable results.

Cocoa pod borer control measures that are presently feasible for implementation are the use of selective spraying, frequent harvesting and bagging, sleeving, use of pheromones, and inundative release of the egg parasitoid. Ideally, an integration of all such techniques would almost certainly elicit good control of the moth. However, the reality of cost overrides this and from the point of view of most Malaysian cocoa growers, selective spraying and frequent harvesting and bagging of pods are the most convenient and cost effective practices. For chemical spraying, prophylactic applications are obviously undesirable and detection, meaning census, once again is an important component towards successful implementation of selective spraying. Sidhu et al. (1987) illustrates a system of grid census that serves this purpose particularly effectively.

RODENT PESTS

Traditionally, the main species of rats attacking cocoa are *Rattus tiomanicus* and *R. argentiventer* in Peninsular Malaysia (Han 1982) and *R. cremoriventer* and *R. muelleri* in Sabah (Conway 1971). Recently, *Rattus rattus diardii*, a species normally associated with human habitations, has been found in dominance in the crop (Ho 1986b).

Damage to crop by rats can be severe; 70–100% losses are common (Wood 1982). Coupling this with the general lack of effective natural control of the pest, populations must be constantly suppressed, and wax block baiting with anticoagulants have been found to be particularly effective (Han & Bose 1982, Soh 1983). Such technology is primarily adapted from that for oil palm (Wood & Nicol 1973), baits being placed at an intensity of 60–80 pieces per ha at four-

to seven-day baiting rounds (depending on whether 'saturation' or 'pulsed' baiting technique [Khoo 1980] is employed). Fresh bait uptake is used as a gauge of when to stop baiting, this being decided upon once when bait acceptance falls below 20%. However, although as in oil palm whole estate baiting is being practiced, detect-and-treat systems based on censuses are also carried out. For the latter, Ho and Heong (1984) have elucidated a decision plan based on sequential sampling for rat damage which proved to provide high accuracy in prediction plus reduction in labor requirements, thus allowing more accurate mapping of infestations for treatment.

The key pest status of rats is characterized by its chronicity. This means that in attempts to control the pest, constant rodenticide pressure is exerted, perhaps in comparison, much greater than that of insecticides on cocoa insect pests. Accordingly, it is not surprising that tolerance or resistance of rats to first generation anticoagulants have been detected in cocoa (Lam et al. 1982, Ho & Lam 1983) leading to the necessity to use second generation ones (Ho 1986b). Fortunately, present cases of resistance seem to be isolated. Nevertheless heed must be taken that rodenticide usage should be correctly carried out, i.e., follow-through baiting should be ensured, to avoid sub-lethal dosing of rat populations (Mohd. Mat Min 1985).

CONCLUSIONS

The foregoing illustrations, albeit brief, point out the salient fact that although investigations into the better management of cocoa pests in Malaysia is a continuous process, intensity of such work is often dictated by severity of the pest. Nevertheless, even with such input providing a variety of control avenues within a short while, total integration is often impossible due to cost and difficulty of implementation. The best recourse of the use of chemicals is often a primary component of the control program of a pest. However, it should also be noted that in most cases of chemical control stated, the desire to use pesticides is obvious, as evidenced by the development and use of early warning and census systems. Correct usage of pesticides is also emphasized, otherwise repercussions, e.g., resistance in rats, will have to be contended with. Open-mindedness towards alternative techniques of pest control will greatly enhance pest management on cocoa in Malaysia. Only through greater research effort into the non-chemical control aspects of pest management in the crop, with particular emphasis on the practicality of such research, can better integration of pest management be achieved.

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CROP PROTECTION AND PEST MANAGEMENT OF OIL PALM IN INDONESIA

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Indonesia is presently the second largest oil palm producer in the world. By the end of PELITA IV (Five Year Plan IV) in 1990, Indonesia plans to have ca. 1.35 million ha of oil palm in 12 provinces stretching from Aceh to Irian Jaya (Purba & Dillon 1985). The climate in Indonesia is generally hot and humid and the temperature fluctuates only slightly. In most areas where oil palm will be planted, rainfall occurs throughout the year. These conditions favor pest development, particularly if host plants are available all year around, like oil palm.

All parts of the oil palm are attacked by pests, but leaf-eating caterpillars (LECs) are always chronic and troublesome to oil palm planters. Small attacks by nettle caterpillars occurred in the 1920s (De Jong 1925, Gonggrijp 1930). Although the attacks very seldom develop into outbreaks, experience in North Sumatra in the past two decades indicates that insects can be one of the major constraints on oil palm production. Therefore, this gigantic development plan surely calls for sound crop protection and correct management of oil palm pests, using methodology which is applicable in the whole country.

This paper will review oil palm crop protection in Indonesia with emphasis on North Sumatra, the origin and center of the oil palm industry in the country. Discussion will be limited to LECs since they are now the most important group of pests on oil palm.

OIL PALM CROP PROTECTION

Leaf-Eating Caterpillars (LECs)

Oil palm leaves are attacked by several species of caterpillars, mostly limacodids (nettle caterpillars) and psychids (bagworms). These LECs are polyphagous on many host plants, e.g., coconut, tea, coffee, oil palm, nipa palm, cinchona, etc. There were many effective natural enemies recorded on many of them (Kalshoven 1950/51). De Jong (1925) and Gonggrijp (1930) reported that in the 1920s there were incidences of chronic but small attacks by nettle caterpillars on oil palm. However, before World War II there were few reports mentioning LEC attack on oil palm that developed into outbreaks, although they did cause severe outbreaks on other hosts, e.g., *Darna trima* on cocoa and *Setora nitens* on coconut (Kalshoven 1950/51). The recommended insecticide against LECs was lead arsenate. However, Kalshoven (1950/51)

reported that lead arsenate mixed with slaked lime against *Setora nitens* gave unsatisfactory results.

During World War II, practically all oil palm plantations were neglected. Many of them were transformed into food farms by the Japanese Occupation Army. Some of them were closed completely. This condition continued up to 1947, when the estates were returned to the original owners. In 1957 the government nationalized all Dutch-owned, and in 1967 other foreign-owned, companies. The government's immediate objective in the rehabilitation program was to restore the industry to its former position as the world leader of palm oil in the shortest possible time.

Massive Use of Insecticides

The use of agrochemicals seemed to be the best way to reach that objective. So began, particularly in the 1960s, the overuse of broad-spectrum organochlorine insecticides, e.g., DDT, dieldrin, and endrin, to control LECs. The results of the insecticide campaign were no different from those obtained in other places that used broad-spectrum organochlorines. Outbreaks spread to many new areas and the pests resurged more often. This disastrous result was answered with more intensive use of insecticides. So began the insecticide treadmill in oil palm crop protection!

Experience during the later part of the 1960s indicated that outbreaks did not stop despite massive use of insecticides. In fact, in one plantation, after several heavy dustings, the damage was so severe that all the remaining skeletonized leaves had to be removed and dusting stopped. By stopping dusting, it was hoped that the plant could recover when natural control worked again. Outbreaks continued to occur in other places, but not where complete pruning and cessation of dusting were done.

In 1970, when the use of organochlorines was stopped, other insecticides, like monocrotophos, trichlorfon, endosulfan, carbaryl, quinalphos, and permethrin were used. The selection of these insecticides was based only on their efficacy for LECs since a substitute for organochlorines was urgently and quickly needed. Outbreaks still occurred requiring occasional aerial spraying. The first aerial spraying in oil palm was conducted in 1974, covering an area of about 2000 ha, against *Setoria nitens* and *Darna trima*, using monocrotophos at 300 ml/ha a.i. (Djamin 1974). The last aerial spraying was done in 1978 against *Mahasena corbetti* using trichlorfon at 950 g/ha a.i. Since then, only small, chronic infestations have occurred, and occasionally they are controlled by ground spraying of insecticides.

Natural Enemies

LECs have a complex of potential natural enemies which can be utilized as components of IPM. Many of them are polyphagous insects that attack many species of LECs. Their presence in the oil palm ecosystem has long been reported (Dammerman 1929, Kalshoven 1950/51), and together with other components of natural control, they were able to put LECs under control before

the War. Based on the study that he conducted in Indonesia in 1980, Desmier de Chenon (1982) found many natural enemies of LECs. Some of them are shown in Appendix I. Many of them are the same species that were found before World War II. This means that despite destruction of many plantations during World War II and several years after that, and the excessive use of broad-spectrum insecticides, they survived, although they are now unable to control the pests. Conservation and augmentation, therefore, are the natural ways to protect these natural enemies. Mangoendihardjo (1986) reported that many natural enemies of estate crop pests were able to establish themselves and develop after conservation and augmentation.

Different species of LECs are often attacked by different natural enemies, as shown in the case of *Darna trima* and *Setora nitens*. Desmier de Chenon (1983) reported that up to 30% of *Darna trima* larvae were destroyed by *Apanteles* sp., *Darna*'s most effective parasitoid. When the caterpillars reach middle instar, they are attacked mostly by *Fornicia* sp. and by *Platyplectrus orthocraspedae*. A tachnid *Chaetexorista javana* attacks the last instar and emerges from the cocoon. Predators *Sycanus dichotomus* (Reduviidae) and *Cantheconidea furcellata* (Pentatomidae) also destroy the caterpillars. A virus disease is also reported effective against the caterpillars.

Desmier de Chenon (1983) also reported parasitization of *Setora nitens*. The eggs are parasitized by *Tricogrammatoidea nana*. An eulophid and *Platyplectrus orthocraspedae* parasitize the first instar larvae. *Fornicia* sp. together with *Rogas* and *Apanteles* sp. attack the middle instars. *Spinaria spinator* (Ichneumonidae), the most frequent parasitoid, attacks the fourth instar onward. *Chaetexorista javana* is the most effective larval-pupal parasitoid.

Development of these natural enemies is encouraged if the adults can feed on the nectar of flowers. Therefore, the presence of cover crops in oil palm plantations is important as a source of food for the adults. Some important parasitoids take refuge or rest in the natural vegetation such as some broad-leaved weeds or ferns. Syed and Shah (1976) reported that an outbreak of *Crematopsyche pendula* and a small explosion of *Thosea bisura* occurred in Sabah in 1972, and were traced to intensive use of the herbicide that killed *Euphoria geniculata* and *E. prunifolium*, weeds frequented by natural enemies of the pests. A fungus, *Cordyseps* sp., that attacks the pupae of *Setora nitens* and *Thosea asigna* in the ground will develop better when humidity in the soil is maintained.

When natural enemies are able to keep pest populations down, less intervention by man is necessary, so less insecticide is needed. There is no doubt that excessive use of insecticides is harmful to natural enemies. Therefore, insecticides should be used judiciously and efficiently, and one of the immediate objectives is to reduce insecticide consumption.

JUDICIOUS USE OF INSECTICIDES

Despite their weaknesses and the bitter experience they gave to oil palm owners, particularly in the 1960s, insecticides remain important weapons in the control of oil palm pests. The circumstances in the 1960s were such that it was

impossible to choose other alternatives. The decision makers relied on broad-spectrum insecticides and thought that pest control was just another short-term and straight forward problem. So they searched for a simple answer, i.e., total reliance on broad-spectrum and persistent insecticides.

The results obtained were similar to those throughout the world where broad-spectrum insecticides were used. Outbreaks occurred in many places. The pests resurged in shorter time. Many secondary pests appeared and caused serious losses. To make matters worse, no one bothered to ask whether complete reliance on broad-spectrum insecticides was an intelligent policy.

Indonesia stopped the use of broad-spectrum and contact organochlorines in 1970, while Malaysia did so eight years earlier (Wood 1971). Organochlorines were replaced by other insecticides, like organophosphates, carbamates and synthetic pyrethroids. Outbreaks or small population explosions still occurred, but less frequently. The breathing spell allowed time to study ways to improve the use of insecticides and to find other alternative measures.

Spraying Technique

In the past, entire infested areas were sprayed thoroughly whenever spraying was done, regardless of the extent of damage, pest distribution, or environmental condition. Naturally this kind of spraying consumes a large amount of insecticide, little of which is deposited on plants or target insects. Spot spraying is now suggested. Blanket spraying is reserved only for treatment of outbreaks, or if the infestation in an area is very high.

Early Warning and Critical Levels

As much as possible, pest attack must be detected at the inception stage. An Early Warning System is developed through improvement in the population census system. Mapping the attack is a good practice, since it is a very useful factor for deciding whether or not to make an insecticidal treatment (Djamin & Sipayung 1986).

Often, a critical level of pest population is used as the sole factor in deciding whether a chemical treatment is necessary or not. In reality, it should be viewed as just one of the factors in decision making, besides information on pest biology, presence of natural enemies and environmental factors (Djamin & Sipayung 1986). In practice, there are many problems faced by the crew during census work, e.g., entomological knowledge of the census crew, height of the trees, determination of the sample frond, etc. These problems greatly influence the accuracy of data collected.

Selectivity of Insecticides

Selectivity is one important factor to consider when using an insecticide. For example, trichlorfon is a selective insecticide in the oil palm ecosystem. It is an effective insecticide against bagworms, is safe for their natural enemies, and has been used many times with satisfactory results. Wood (1971) reported that

trichlorfon was also effective against *Setora nitens* in Malaysia. In the early years after release of the oil palm pollinating weevil, *Elaeidobius kamarunicus*, Thuricide, and some growth regulator insecticides were recommended for LEC control since they were harmless to the weevil. Selectivity is also achieved by adapting some measures like spot spraying, improved timing, new application methods, etc. Trunk injection with undiluted monocrotophos formulation against *Setora nitens* and *Thosea asigna* gave satisfactory results, particularly in small and sporadic infestations, tall trees and when accessibility to an area was low (Hutauruk & Sipayung 1978).

By adapting the above-mentioned measures, pesticide consumption in PTP-VI (one of the major oil palm companies in Indonesia) was reduced by 29% from 1978 to 1982 (Djamin 1983). Obviously, under good management, insecticide use in "traditional" oil palm areas (North Sumatra) is still profitable. However, it does not mean that the same results will be obtained in newly-developed oil palm areas.

NEWLY-DEVELOPED AREAS

Under the Government's present development plan, about 65% of new oil palm plantings will be in newly-developed areas outside North Sumatra, the "traditional" area for oil palms. As far as climate is concerned, this area is favorable for insect development.

In a recent survey conducted in four newly-developed areas, it was found that oil palm LECs occurred at about the same levels as in North Sumatra. They were not causing serious losses. However, there were more natural enemies found (Sipayung et al. 1987). As one important component in IPM, they will play a vital role in oil palm pest management in newly-developed areas. Some important natural enemies like *Cantheconidea* sp and *Spinaria spinator* are being studied for possible release in North Sumatra.

CONCLUSIONS

With the vast expansion of oil palm cultivation to other islands, there is a strong need to have a sound and widely applicable crop protection system. The abundance of potential natural enemies, which proved very important in the control of oil palm pests during the pre-World War II period, should be strongly considered when drawing up a national oil palm crop protection policy. The existing natural enemies should be conserved and augmented. Except for their presence and percentage of parasitization, not much is known about these natural enemies. More information is needed before they can be used effectively.

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APPENDIX I

Important natural enemies of some major oil palm leaf-eating caterpillars.

Host	Natural enemy		Source[a]
Darna trima	Parasitoid		
	Braconidae	: *Apanteles* sp, *Fornicia* sp	a, b
	Eulophidae	: *Platyplectrus orthocraspedae*	a, b
	Tachinidae	: *Chaetexorista javana*	a
	Predator		
	Reduviidae	: *Sycanus dichotomus*	a
	Pentatomidae	: *Cantheconides furcellata*	a
	Pathogen		
	Virus		a
Setora nitens	Parasitoid		
	Trichogrammatidae	: *Trichgrammatoidea nana*	a
	Eulophidae	: *Platyplectruc orthocraspedae*	a, b
	Braconidae	: *Fornicia* sp, *Rogas* sp, *Apanteles*sp	a, b
	Ichneumonidae	: *Spinaria spinator*	a, b
	Tachinidae	: *Chaetexorista javana*	a, b
	Predator		
	Reduviidae	: *Sycanus dichotomus*	a
	Pentatomidae	: *Cantheconidea furcellata*	a
	Pathogen		
	Fungus	: *Cordyceps nr. pruirosa*	a
Thosea asigna	Parasitoid		
	Trichogrammatidae	: *Trichogrammatoidea nana*	a
	Braconidae	: *Fornicia* sp, *Rogas* sp	a
	Ichneumonida	: *Spinaria spinator*	a
	Tachinidae	: *Chaetexorista javana*	a, b
	Predator		
	Cleridae	: *Callimerus arcufer*	a
	Reduviidae	: *Sycanus dichotomus*	a
	Pentatomidae	: *Cantheconidea furcellata*	a
	Pathogen		
	Fungus	: *Cordyceps militaris*	a
	Virus		a
Mahasena corbetti	Parasitoid		
	Tachinidae	: *Exorista quadrilimaculata*	a, b
		: *E. Psychidarum*	a, b
	Braconidae	: *Anapteles* sp	a
	Ichneumidae	: *Xanthopimpla* sp	a

Continued on next page

APPENDIX I *continued*

Host	Natural enemy		Source[a]
	Predator		
	Pentatomidae	: *Cantheconidea furcellata*	a
	Reduviidae	: *Sycanus macracanthus*	a
	Cleridae	: *Callimerus arcufer*	a
	Pathogen		
	Virus		a
Metisa plana	Parasitoid		
	Braconidae	: *Apanteles metesae*	a
	Tachinidae	: *Exorista psychidarum*	a
	Predator		
	Reduviidae	: *Sycanus dichotomus*	a
	Cleridae	: *Callimerus arcufer*	a
	Pathogen	--	–

[a]a = Desmier de Chenon 1982, b = Kalshoven 1950/1951.

IPM IN RICE – AN EXTENSION ROLE FOR THE AGROCHEMICAL INDUSTRY

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The prevailing view in the agricultural pesticide industry is that its commitment to Integrated Pest Management (IPM) extends only to the development of new selective chemicals. In the case of rice this view ignores the following realities: firstly, that IPM must first be made to work with existing chemicals, preferred by farmers because of their broad spectrum and low cost; and secondly, that new selective compounds require intensive efforts in farmer re-education, for which extension services are usually neither trained nor adequately staffed.

Industry has a responsibility to support extension services in promoting the rational use of all insecticides, to maximize farmer profits, to conserve beneficial insects, to delay the onset of insecticide resistance, and to minimize user and environmental contamination. These goals for IPM have been articulated by other workers (Kenmore et al. 1985, Matteson et al. 1984).

The results of research efforts in Indonesia to develop an IPM system for Ciba-Geigy rice insecticides are presented here. The relative merits of threshold-based systems and those using low-cost prophylaxis are discussed, plus future prospects and limitations for extension to farmers on a large scale.

OBJECTIVES OF IPM TRIALS IN INDONESIA

In the 1986/87 wet season, a large-scale field trial was conducted at the Ciba-Geigy Research and Development Station in Jatisari, West Java, with the following objectives:

- to assess the validity of economic thresholds (ETs) published for rice pests, on both resistant and susceptible rice varieties,
- to assess the compatibility of Ciba-Geigy insecticides with an IPM system (activity and selectivity), and
- to contribute information towards the development of an IPM system for Ciba-Geigy insecticides which is easy to use and more profitable to the farmer than existing practices or calendar-based systems.

PROCEDURES

On a trial site covering approximately 1 ha, six insecticide use regimes were compared on variety Pelita (Brown Planthopper-susceptible) and variety Cisadane (Brown Planthopper-resistant):

1. Maximum protection: Seed and seedbed treatment, and 15-day interval applications of furathiocarb at high rate.

2. Minimum protection: Seedbed treatment with furathiocarb, and one field application of furathiocarb at 61 days after transplanting (DAT) in variety Pelita.
3. Low economic thresholds: Application of Ciba-Geigy chemicals at low rates only when pest numbers or damage exceeded low ETs (Table 1).
4. High economic thresholds: Application of Ciba-Geigy chemicals at low rates only when pest numbers or damage exceeded high ETs (Table 1).
5. Farmers' practice: Application of 'BIMAS' insecticides from an average action of 13 local farmers questioned weekly on their control operations. The result was applications of carbofuran to the seedbed and field at eight days after sowing (DAS) and 18 DAT respectively (0.4 g a.i./m^2; 330 g a.i./ha) and one application of BPMC at 43 DAT (525 g a.i./ha).
6. Untreated.

Pest populations were sampled visually, and beneficial insects by sticky board at seven-day intervals. Economic threshold plots were treated only if at least two of the three replicate plots had populations or damage levels above the threshold. In the case of gall midge, the granular treatment was not repeated after the ET was exceeded.

RESULTS

Pests

Populations of white-backed planthopper (WBPH) and brown planthopper (BPH) were high in the untreated Pelita plots (Table 2) leading to hopperburn and yield reduction. The maximum protection regime gave excellent hopper control. Populations were above the low ET on Pelita on six sampling occasions, and twice on Cisadane. Populations were above the high ET on four sampling occasions with Pelita only. Both the minimum protection and the farmer practice regimes, which combined early prophylaxis with one hopperside application, gave surprisingly good protection.

Leaffolders exceeded the low ET on both varieties at 47 DAT but subsequently declined in all treatments.

Gall midge exceeded the low ET and high ET on both varieties at 54 and 61 DAT respectively.

Populations of black bug, stem borer, whorl maggot, and rice bug were low throughout the trial.

Beneficials

Populations of spiders were conserved most effectively in the minimum protection, high ET, and farmer practice regimes. Numbers were very similar between the two rice varieties despite the large difference in hopper populations, indicating that varietal resistance and beneficials can give additive or synergistic suppression of pests.

The predatory mirid, *Cyrtorhinus*, was most abundant in the minimum protection and high ET regimes.

Table 1. Economic thresholds used, and solutions chosen for each rice pest, wet season, 1986/87.

Pest	Low threshold	High threshold	Solution
Hoppers	5/hill	20/hill	Furathiocarb EC 300 g a.i./ha
Leaffolder	5% folded leaves	15% folded leaves	Monocrotophos SCW 400 g a.i./ha
Whorl maggot	20% damaged leaves	50% damaged leaves	Monocrotophos SCW 400 g a.i./ha
Gall midge	1% onion shoots	5% onion shoots	Isazofos G 300 g a.i./ha
Stemborer	5% dead hearts or 1 egg mass/15 hills	15% dead hearts or 1 egg mass/5 hills	Isazofos G 300 g a.i./ha
Black bug	4/hill	12/hill	Monocrotophos SCW 400 g a.i./ha
Rice bug	1/15 hills	1/5 hills	Monocrotophos SCW 400 g a.i./ha

Table 2. Effect of different insecticide use strategies on rice pests and beneficials on BPH-susceptible and resistant rice varieties. Jatisari, W. Java, wet season, 1986/87.[a]

Regime	WBPH[b] (per hill) 47 DAT	BPH[b] (per hill) 75 DAT	Whorl maggot (% damaged leaves) 26 DAT	Leaffolder (% folded leaves) 47 DAT	Gall midge (% onion shoots) 75 DAT	Spiders[c] (per 20 hills) 61 DAT	Cyrtorhinus[c] (per 20 hills) 61 DAT
Var. Pelita (BPH-susceptible)							
Untreated	73.0 b	124.0 a	3.4 b	8.9 b	10.0 b	46.7 c	137.0 bc
Maximum protection	0.03 a	5.8 a	0.65 a	2.3 a	2.8 a	8.3 a	4.0 a
Minimum protection	18.9 a	21.0 a	3.5 b	7.0 b	9.3 b	32.0 b	250.0 c
Low econ. thresholds	1.9 a	14.3 a	3.4 b	7.5 b	9.7 b	4.7 a	4.7 a
High econ. thresholds	8.4 a	71.9 a	3.7 b	5.9 b	8.3 b	32.7 b	179.0 bc
Farmer practices	8.9 a	23.5 a	3.4 b	6.5 b	5.6 ab	30.7 b	90.0 ab
Var. Cisadane (BPH-resistant)							
Untreated	10.4 c	2.4 ab	2.5 b	5.7 bc	3.1 a	32.3 c	104.0 bc
Maximum protection	0.01 a	1.9 ab	0.39 a	2.2 a	2.3 a	8.0 a	4.0 a
Minimum protection	7.1 bc	3.5 abc	1.8 b	6.8 c	4.3 a	29.7 bc	67.0 b
Low econ. thresholds	4.7 bc	7.0 c	2.2 b	8.9 d	5.2 a	7.7 a	19.0 a
High econ. thresholds	10.7 abc	5.4 bc	2.9 b	6.4 bc	4.7 a	32.3 c	115.0 c
Farmer practices	1.1 ab	1.6 a	2.6 b	4.8 b	4.2 a	26.3 b	25.0 a

[a]All figures are mean of 3 replicates; means with the same letter are not significantly different at P = 0.05 by DMRT.
[b]WBPH = Whiteback planthopper, BPH = Brown planthopper, both counted by eye (ca. 20% efficient). [c]Counted by sticky board.

Yields and Cost-Benefit Analysis

The maximum protection regime gave highest yields in both varieties (Table 3), resulting in average yield increase of 58% and 14% over the untreated plots with Pelita and Cisadane respectively. Even this high input of insecticides gave good returns at 'BIMAS' prices. In general, use of the susceptible variety shifted the optimum strategy towards prophylaxis or low ETs.

While mostly giving good returns, the IPM regimes did not give significantly higher profit or benefit/cost ratios than "farmers' practice". However, it should be noted that "farmers' practice" is an average actual farmer practice; i.e., the farmers interviewed applied between 0 and 7 treatments (costing up to US$27/ha) and only one farmer's action actually corresponded with the average regime.

When 'BIMAS' prices were replaced with 'free market' prices, all of the regimes on Cisadane gave benefit/cost ratios below two.

DISCUSSION

Insecticides and Economic Thresholds

Use of insecticide in an IPM system (i.e. as a curative rather than preventive tool) requires different properties than those usually screened for by industry, when chemicals are applied according to a calendar-based system. If the threshold is set too high, it may be very difficult to bring a population under control with normal doses, especially at later crop stages.

The failure to significantly improve on farmer practices by using ETs can be attributed, at least in part, to the unsuitability of the thresholds used.

The hopper ET of 5/hill was clearly unrealistic, requiring six applications of hoppercide on cv. Pelita and leading to suppression of spider and mirid populations. Conversely, an ET of 20/hill, while preserving beneficials, still required four applications on Pelita because of the growth potential already inherent in the population by the time of the first application at 42 DAT.

Cost-effective hopper control was achieved by the minimum protection regime, when the seedbed drench with furathiocarb gave good control of WBPH, and the single field application at 61 DAT apparently suppressed BPH sufficiently for beneficials to keep the population in check. Future trials will concentrate on combining the labor-saving and comparatively safe technique of seedbed drenching with a hopper threshold of 10 per hill.

Thresholds for gall midge and leaffolder based on damage are very unsatisfactory, because once the threshold has been reached, a large amount of damage has already been done, or it may be too late to apply granular insecticide, or the target insect may no longer be present.

A new ET is required for leaffolder, preferably based on the number of adults disturbed while walking through the crop. For gall midge, prophylactic treatment is apparently essential in problem areas, unless adult populations can be monitored by the community.

Table 3. Comparative economics of different insecticides use strategies on BPH-susceptible and resistant rice varieties. Jatisari, W. Java, wet season, 1986/87.

Regime	Number of insecticide applications	Yield[a] (kg/ha)		Gain from insecticide[b] (US$/ha) BIMAS	Free market	Benefit/Cost ratio[b] BIMAS	Free market
Var. Pelita (BPH-susceptible)							
Untreated	0	4401	b				
Maximum protection	8	6939	a	+ 184.0	+ 83.7	6.63	1.63
Minimum protection	2	5870	ab	+ 108.9	+ 56.9	7.58	1.83
Low economic threshold	8	5783	ab	+ 90.6	+ 4.5	4.31	1.04
High economic threshold	5	5187	ab	+ 48.8	- 10.6	3.67	0.86
Farmer practices	3	5351	ab	+ 72.3	+ 45.9	9.20	2.30
Var. Cisadane (BPH-resistant)							
Untreated	0	6334	a	-	-	-	-
Maximum protection	8	7212	a	+ 16.0	- 58.0	2.29	0.56
Minimum protection	1	6983	a	+ 42.1	+ 0.14	4.15	1.00
Low economic threshold	4	6614	a	+ 9.3	- 36.5	1.64	0.40
High economic threshold	1	6742	a	+ 29.3	+ 10.1	6.35	1.41
Farmer practices	3	6917	a	+ 50.0	+ 14.5	5.65	1.41

[a]Mean of 3 replicates, corrected to 14% moisture content. Means with the same letter are not significantly different at P = 0.05 by DMRT. [b]Cost based on estimates where a compound is not registered or sold in the free market.

Forthcoming studies in Indonesia will focus on improving ETs and testing the farmer acceptability of ETs. Clearly, indices such as '% damaged leaves' will have to be simplified but it remains to be seen if the resulting field monitoring system can be easily adopted and if farmers are spraying in response to correctly measured pest populations which exceed the thresholds. Yield and profits of a group of 'IPM farmers' will be compared with a parallel group using traditional practices.

Economics of IPM

From a survey of 13 farmers in the area of Jatisari, West Java, it was found that spending on insect control averaged only the equivalent of approximately 4% of their total crop cash receipts (6.4% of total cash costs). The low price of rice insecticides in Indonesia (heavily subsidized through the 'BIMAS' scheme) dictates that an IPM program is likely to be most successful if pesticide use optimization is aimed at maximizing profit through yield increase rather than cost reduction. Insecticide subsidies shift the economically optimum strategy in favor of prophylaxis or low ETs. This and other issues of pesticide use in IPM programs have been noted elsewhere (Goodell et al. 1980, Lim & Heong 1984, Norton 1985, Waibel 1986a,b).

With the farmers surveyed, a 50% reduction in insecticide use would, in most cases, lead to approximately 2–3% increase in profit. The same increase in profit could be obtained with a mere 1% increase in rice yields.

CONCLUDING REMARKS

With the growing interest in IPM in all South and Southeast Asian countries, and increasing concern over user and environmental safety, industry can no longer market rice insecticides on the basis of activity alone. Support for the principles of IPM from industry is vital for its successful adoption by the farmer.

Farmers will only adopt IPM for economic reasons, or (as in the case of cotton and deciduous fruit) where conventional control systems fail. IPM researchers must be sure that the systems they propose are significantly more profitable than existing farmers' practices, which are themselves usually 'IPM' or low-cost prophylaxis. This may be difficult to achieve in situations where pesticides are heavily subsidized.

Ciba-Geigy has recently embarked on a research program with the aim of developing simple and profitable farmer-oriented IPM systems, incorporating our insecticides for rice.

ACKNOWLEDGEMENTS

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COMMUNICATING INTEGRATED PEST CONTROL TO RICE FARMERS AT THE VILLAGE LEVEL

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Integrated Pest Control (IPC) is a management system that rice farmers use to minimize their risks of losses and to maximize their returns to investment in pest control. To use this system, farmers must learn field skills of identification, damage assessment, decision-making for chemical use, choice of varieties, and optimal application of fertilizers.

These skills must be taught in the field by trainers who have already mastered the skills. While over 4600 rice-based extension workers in the Philippines have been trained in these field skills, this technology cannot be used by farmers unless training courses are given to them. Unless farmers are aware of the potential of IPC, and their motivation to learn IPC is high enough, successful farmers' classes cannot be organized even though technicians have skills.

A strategic communication campaign on IPC is being carried out in selected rice-growing municipalities in Western Leyte, Philippines, to raise awareness among rice farmers about IPC and to motivate them to ask extension technicians for training. Beyond the initial goal of increasing local demand for IPC training, the communication campaign had two implications:

1. Because pest problems change from season to season, it is important for farmers to consult with technicians after the training course. By motivating farmers to initiate the relationship with technicians by demanding training, the campaign should increase the chances for farmers to continue initiating consultations with technicians when new pests emerge.
2. If farmers begin to demand information about IPC, they can also demand information about other management technologies covering fertilizer, water, storage or marketing. The emphasis in agricultural technology promotions has been on the "supply" side, providing information to the extension agencies who are expected to thrust technology on farmers. The intent of the campaign is on the "demand" side, assuming that if farmers ask that technology be delivered and not merely accept their status as passive acceptors, then the extension staff will respond.

In recent years, there has been a growing consciousness for the need to utilize mediated communication to support agricultural development. This recognition has been manifested in the number of successful projects which have

reinforced changes in rural societies by reaching and mobilizing individuals. Mass mobilization campaigns have been particularly successful in Tanzania and the Peoples' Republic of China (McAnany 1973, Searle 1979, Smith 1978). From these campaigns, some lessons have been learnt on how to effectively use communication media to support development projects. Among the important points are the need to ascertain the total circumstances of the farmer and the community as a first step in designing a learning system, the stress on selecting and prioritizing the content of messages, and the proper application of the communication media or channel strategy (Escalada 1985, Smith & Ray 1985). Thus, information delivery or diffusion programs are now seen as teaching-learning systems in which learning is organized around users' needs and local communication resources.

The communication campaign reported in this paper was generally intended to motivate rice farmers to attend training on IPC. Specifically, it aimed at exploring the potential role of communication media to create a demand among rice farmers for IPC training, to evolve and implement a communication campaign on IPC in selected rice-growing municipalities, and to document and evaluate the effectiveness of the communication campaign.

MARKET ANALYSIS

Two rice-growing municipalities in Western Leyte were selected as the site of the communication campaign: Albuera and Ormoc. A third municipality, Kananga, was designated the control area with which to compare the results of the campaign. Village-level investigations were conducted to determine the total circumstances of rice farmers and their communities such as their needs and problems, socio-economic background, communication habits, and knowledge, attitudes and practice on IPC.

A combination of quantitative and qualitative research approaches was utilized, particularly the use of survey, informal talks with key informants, and participant observation. The baseline survey of rice farmers' knowledge, attitudes and practice (K-A-P) on IPC yielded the results reported below.

Knowledge of IPC

The aggregate analysis revealed that respondents had low to moderate knowledge of crop protection. The items which the majority of respondents had *no* knowledge about were:

1. Resistant rice varieties need less pesticides than susceptible varieties.
2. There are insects/animals (natural enemies) that help control insect pests.
3. The effect of natural enemies, feeding on insect pests in the rice crop, is a lower pest population.
4. The best way to conserve natural enemies is to follow the economic threshold level method.
5. Insecticides also kill most of the natural enemies.
6. Only the affected portion should be sprayed when several patches of rice crop are found to be severely infested with pests.

Attitudes Toward IPC

Respondents were evaluated for their negative attitudes toward IPC by their affirmative response to the following statements:

1. A large number of natural enemies in the field means one has to spray more.
2. Calendar spraying is the best method to control pests.
3. You should spray when your neighbor sprays pesticides.
4. The presence of only a few moths in the field requires immediate spraying.
5. The more often you spray the higher will be your profit.

Practice

The following were actually practised by farmers:

1. Almost all farmers sprayed insecticides on their rice crop.
2. The majority sprayed pesticides as soon as pests were seen on the rice crop.
3. The presence of bugs and flying insects in the paddy was the factor which influenced majority of the farmers to spray insecticides.
4. Majority would spray their rice fields even when few insects were observed.

KEY ISSUE IDENTIFICATION

The market analysis described above provided a basis for selecting the key IPC issues to be addressed by the communication campaign. Two critical issues relevant to rice farmers surfaced, namely, the concept of natural enemies and need-based use of pesticides. These issues were identified based on the findings of the item analysis of rice farmers' K-A-P on IPC, as follows:

- 42% of all respondents reported knowledge about natural enemies, but only 34% knew that the effect of natural enemies feeding on insect pests is to have less pests, and only 7% knew that the best way to conserve natural enemies is to spray insecticides only when the economic threshold level has been reached.
- only 6% of all respondents knew that when several patches of the rice crop are found to be severely infested with insect pests, only the affected portion should be sprayed and 16% knew that the best time to apply pesticides in the field is when the economic threshold level has been reached.

SELECTION OF APPROACH

On the basis of the key issues identified, four basic approaches to communicating the IPC message were proposed for testing: financial incentives, curiosity, fear, and teasing.

The principal media used in the campaign were posters and audio cassette dramas. These were selected after farmers had expressed their preference for highly visual and audio communication materials to acquire technical information on pest control. Their choice was dictated by their own difficulties in reading small types due to poor vision and lack of practice in reading.

MESSAGE DESIGN AND DEVELOPMENT

Posters

Eight distinct messages were cast in posters:

1. "Don't waste money for chemicals that don't work. Be sure. Know what chemicals to use and when."
2. "Are you killing all the friendly insects and getting pests in your field? Get Integrated Pest Management training and be more sure you're using chemicals correctly."
3. "Be more sure. If you identify dangerous pests and diseases in your field... and then you control them properly and know that they are controlled ... you can sleep easier."
4. "Be more sure what friendly insects are in your field killing pests for you."
5. "Are you ignorant? You must be ignorant if you don't know how these insects can help you."
6. "Be sure. Know the identity of rice pests. Choose the right pesticides. Don't let pests and diseases surprise you."
7. "Do you know that there are other ways to control pests ... Besides using chemicals?"
8. "The insect that you are killing now may be a useful one ... Not all insects are pests."

Audio Cassette Drama

As in the posters, the audio cassette dramas focussed on this message:

"Do not waste money; spray only when it's profitable. Don't spray the wrong chemicals because you've incorrectly identified the pest. Identify first, then decide whether or not to spray, then choose chemicals. Get IPC training and be more sure you're using chemicals correctly."

To develop locally specific drama content, a list of questions that farmers in the campaign areas had raised and excerpts of their actual conversations on IPC were handed over to the scriptwriter. This enabled him to create dialogue that the intended listeners could identify with, thus enhancing the relevance and attractiveness of the audio cassette dramas.

FORMATIVE EVALUATION

While the communication materials were developed by professionals, there was still a need to pretest them to check if they would achieve the desired response from their intended audience. Prototype material was shown to representatives of the intended audiences to check if the message was conveyed and if the communication material was acceptable, attractive, and relevant.

Pretest Procedure

POSTERS Five groups of about 30 rice farmers each were asked to pretest two posters in individual sessions. At the start of the pretest, the interviewer first explained the purpose of the posters and the importance of getting user reactions. The poster was then shown to the respondent with the text covered to focus his attention on the visual. After about three minutes, the respondent was asked what the visual was trying to convey. After noting the farmer's response, the interviewer removed the cover, showed the entire poster and asked the remaining questions.

HIGHLIGHTS During the pretest, farmers had varied reactions and suggestions, e.g., one female respondent mistook the interviewers to be sales agents of a chemical company selling posters to advertise chemicals for rice pests. Most of the farmers interviewed exhibited negative reactions to the colors used in the posters. Overall there was a preference for realistic colors such as green for a rice plant, blue or brown for farmers' shirts and light blue for the sky. Other farmers suggested that the background include rice paddies and mountains to depict a typical rice farm, diseased spots of the rice plant be emphasized, and chemical bottles have labels.

AUDIO CASSETTE DRAMA Unlike the posters, the audio cassette drama involved a group test. After a brief introduction, the drama was played on an audio cassette recorder and the farmers listened to it as a group. Individual interviews with farmers were conducted immediately after the drama was played.

UTILIZATION OF PRETEST RESULTS

Results of the pretest led to the following: improvement of prototype material, selection of promising material, and elimination of difficult-to-understand material. For the posters, the following revisions were suggested:

1. Emphasize diagnosis and control.
2. Clarify messages and make colors realistic.
3. Do not use sprayers and chemical bottles to convey the message of pest control because farmers connect it with the message of chemical companies, which states: "to be sure, one needs to spray pesticides."

Consequently, the 10 prototype posters were reduced to 5. Results of the pretest of these revised posters indicated that only three out of the five performed well on the comprehensibility test. These three posters were then finalized and printed.

CAMPAIGN IMPLEMENTATION

After the final production of the two audio cassette dramas, the mediated communication campaign began in the first week of December 1986. Farmers listened to the dramas in groups of 9 to 15 at the neighborhood store, basketball

court, a farmer's yard, or the chapel. An open forum followed each listening session with the project's research assistants acting as facilitators.

Among the highlights of the open forums were comments from farmers who were surprised to learn about the existence of friendly insects which can help control insect pests. Farmers also expressed appreciation for the good points raised in the drama. In one scene where a couple was torn between saving money for their family's needs and having to buy insecticides, the farmers identified with the drama characters and remarked, "That is also our problem!"

The first and second IPC posters were displayed in strategic places in the campaign villages beginning in the last week of January 1987. These highly visible areas consisted of the walls of the neighborhood variety store, 'barangay' hall, waiting shed, houses along the main road and even on coconut trees.

Preliminary results of the on-going campaign indicated that in the campaign areas, farmers have already drafted their petitions requesting the Ministry of Agriculture and Food (MAF) to provide them training on IPC. Two villages have already sent their petition to the MAF district office.

CAMPAIGN EVALUATION

In the evaluation of the communication campaign, the bottom line is the demand among rice farmers for IPC advice. Thus, a post-campaign survey of rice farmers and technicians, and analysis of documents and log books that record farmers' visits to technicians in the campaign areas will be conducted to determine the number of rice farmers wanting to attend IPC training.

Process documentation is also being conducted concurrently with project implementation to obtain a complete account of field activities. Documentation will enable the project staff to learn from the campaign and draw implications for possible replication of the strategy in other areas.

To be able to assess the immediate impact of the campaign on farmer's awareness, knowledge and attitudes toward IPC, the pretest-posttest control group design was followed. Based on Campbell and Stanley's (1973) visual depiction, the experimental design takes the form:

R	O_1	X	O_2
R	O_3		O_4

LESSONS FROM THE CAMPAIGN

In the course of project implementation, our experience suggests five important lessons in communicating IPC to farmers:

1. WHAT MAY BE TRIVIAL TO PROFESSIONALS OR SCIENTISTS MAY BE CRITICAL TO FARMERS.

In conceptualizing the visuals for the posters, one overriding consideration was our notion of farmers' visual literacy since farmers in rural Philippines are largely exposed to the visual media. Thus, the prototype posters had visuals which showed rice plants outlined in black, a farmer wearing a white shirt, and a gray background to set a somber mood. As it turned out, the majority of the farmers asserted a negative reaction to the colors used and suggested realistic colors instead, i.e., green rice plant, dark short and a light blue sky.

2. UTILIZING PRETEST RESULTS CAN RESULT IN SAVINGS FROM INVESTMENTS ON INEFFECTIVE COMMUNICATION MATERIAL.

Had we proceeded to produce 10,000 copies of the 10 prototype posters without the benefit of a pretest, we would have wasted our limited resources. As earlier mentioned, only 3 out of the 10 initial set of posters worked with farmers in terms of comprehensibility and other measures of effectiveness.

3. SELECTING AND PRIORITIZING MESSAGES BASED ON FARMERS' NEEDS ENSURE GREATER ATTENTION AND INTEREST.

In designing and developing messages for the campaign, selection was based on the key issues which emerged during market analysis. Thus, the campaign focused only on those aspects of IPC which farmers had very little knowledge about and consequently, minimized information overload.

4. COMMUNICATION MATERIALS STIMULATE DISCUSSION AND INFORMATION-SEEKING BEHAVIOR AMONG FARMERS.

After exposure to posters and audio cassette dramas, farmers discussed with co-farmers the IPC message carried by these communication material. At neighborhood stores where posters were displayed, farmers who gathered for informal talks frequently used the poster's message as their conversation piece and often asked why the posters did not specify the natural enemies or what chemicals should be applied for certain rice pests and diseases.

5. THROUGH THE SYSTEMATIC USE OF COMMUNICATION MEDIA, FARMERS CAN BE MOTIVATED TO LEARN IPC AND TO DEMAND TRAINING.

The skillful combination of posters and audio cassette dramas mixed with a certain level of community organizing brought about awareness among farmers of the potential of IPC. Once awareness was created, an increased need for IPC information was articulated by farmers. By being careful not to supply the IPC information sought, the campaign was able to motivate farmers in all campaign areas to demand IPC training.

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FACTORS AFFECTING THE SUCCESS OF EXTENSION-COMMUNICATION STRATEGIES USED IN A RICE PEST SURVEILLANCE PROGRAM IN THAILAND

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The concept of pest surveillance in rice as an integral part of Integrated Pest Control (IPC) has been practised on a systematic basis in Thailand since about 1982. The Thai-German Plant Protection Program – a joint project of the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ or the German Agency for Technical Cooperation), the Department of Agricultural Extension, and the Department of Agriculture of the Ministry of Agriculture and Cooperatives – has been instrumental in creating a functional nationwide system. This program initially emphasized developing and strengthening the capabilities of the Plant Protection Service itself, with data collection on the pest and predator taking up most of the time and energy of surveillance technicians. There was too little scope left for extension work with farmers. However, since 1985/86 the program has shifted more to working with the target group of rice farmers. The main themes of messages being directed to the farmers are :

- survey your fields for pests and diseases weekly,
- do not spray if the economic threshold is not reached,
- know your rice pests, but also your beneficials,
- know appropriate varieties,
- know the appropriate chemicals, their dosages and application methods,
- take safety precautions when handling pesticides,
- practicing this will result in increased benefits, higher profits, safer environment, and
- if you have any questions, ask the district extension officer or the plant protection officer for advice.

Although the Plant Protection Service Units (PPSU) were already making use of multi-media strategies to different degrees to communicate these messages, the project will help increase and, where necessary, improve the extension-communication activities during its final phase.

ORGANIZATION OF SURVEILLANCE AND EARLY WARNING SYSTEM (SEWS) AND EXTENSION

The Plant Protection Service Division is one of many divisions within the Department of Agricultural Extension of Thailand. The Division has six

regional offices, and a total of 30 units located at the provincial level. Plant protection activities in agricultural extension in Thailand reaches only the provincial level. Nevertheless, at all of the 30 PPSUs throughout the country, a team of four technicians has carried out SEWS-extension to the farmers. This work was done in addition to data collection on pests, beneficials, and agronomic criteria.

The schedule of activities for these technicians has been adapted to accommodate more extension input for more than a year. A typical two-week schedule of activities of a surveillance team at one plant protection service unit is as follows:

- Week 1, for three days of the week, they are expected to conduct farmers' training in Plant Protection Farmer Centers, and
- Week 2, join in fortnightly trainings of Sub-District extension officers ("Kaset Tambon") and do "trouble-shooting" together with them in problem areas.

A closer link to the general agricultural extension system has also been initiated. With more than 6000 extension agents working at the village level with contact farmers using the "Training and Visit" (T & V) system, it is expected that through the Kaset Tambon, a larger portion of the project target group will be reached. In economically impacted areas of the project (at least 21 provinces), the Kaset Tambons have received instructions to set up surveillance demonstration fields and plant protection displays at Farmers' Centers. The function of the surveillance technicians themselves becomes more and more that of "Subject Matter Specialists" giving technical support to the general extension agents.

OVERVIEW OF EXTENSION METHODS

A relatively large variety of extension methods and channels has been used by the project since its beginning (Table 1).

The Plant Protection Farmers' Centers, which can be regarded as "satellite stations" of the PPSU in the surveillance areas, can accommodate most of the extension methods and channels used. Much of the display material is fabricated by the surveillance technicians themselves.

The use of Plant Protection Farmers' Centers with exhibits, meetings, and discussion groups held there, as well as the introduction of posters to help explain the principles of the pest surveillance system to a larger audience, may presently be regarded as the main communication support concept of the project.

RESULTS

At present, the program can only verify results on the transfer of SEWS technology within the agricultural extension structure itself. In most impact areas extension agents (Kaset Tambon, Kaset Amphoe) have been trained 1-2 days on the subject matter once or twice (approximately 4000). All rice subject matter specialists, down to the provincial level, have been trained at least once by the plant protection surveillance staff, either in a monthly technical workshop

Table 1. Overview of extension methods and channels that have been used for SEWS extension during different periods of project implementation.

Extension method[a]	Channel	Location[b]	Date of introduction
Personal discussion ***	verbal, demonstration	farmers' house PPSU	1982
Group discussion ****	verbal, demonstration,audio visuals	farmers' centers schools, temples	1982
Notice boards ****	written	farmers' centers	1984
Handouts **	leaflets on pest information	PPSU, farmers' centers	1983
Bulletins ***	weekly pest warning leaflets	PPSU, farmers' centers, provincial district agricultural offices	1984/1985
Samples of pests and beneficials (conserved) ***	display, exhibit	RPPSO, PPSU, farmers' centers district agricultural offices	1984/1985
Mass media **	radio: - regional - national	homes	1983
*	television: - regional - national	homes	1987
*	posters	farmers' centers PPSU, RPPSO, district and sub-district agricultural offices	198[illegible]
Field days *	displays, leaflets	agri. fair - regional, national and temples, etc.	1982
Training for farmers **	lectures, audio visuals, demonstrations, displays	schools, temples, farmers' centers PPSU	1984

[a]Degrees of use: * seldom, ** often, ***very often, **** mostly. [b]PPSU = Plant Protection Service Unit, RPPSO = Regional Plant Protection Service Office.

(T & V system), or in a so-called task force training activity conducted by the RPPSO (approximately 16 persons).

Each of the 30 PPSUs have from 3 to 12 Farmers' Centers each as their responsibility. The average is estimated to be 5 Farmers' Centers per PPSU. With the size of farmer participant groups (contact farmers) being between 5 and

40 persons (average estimated at 20), it can be assumed that at least 3000 contact farmers countrywide practise surveillance, and depending on their skill to pass on this technology as many as 30,000 farmers may be in the process of adopting it and presumably practising it.

Since increasing the cooperation with the general agricultural extension agents (Kaset Tambon), even higher figures may be expected. It is also well-known that the subject matter presented and discussed during the fortnightly meetings of the T & V system contain as much as up to 70% plant protection topics including SEWS. This gives rise to optimism as far as dissemination rates of the surveillance concept is concerned.

DISCUSSION

Three main factor areas influencing the success of rice pest surveillance extension to farmers, measured in adoption rates, may be identified:

1. the attractiveness of the technology package offered,
2. the extension/communication strategy, and
3. the structure and quality of the organization of plant protection extension.

Attractiveness of the Technology Package Offered

A new technology is most readily adopted by Thai farmers if it appears to have an advantage, is simple, compatible, available for trial, and observable (Pontius 1983). These characteristics can be influenced by the makeup and credibility of the message and channel.

Although it has been proven that at a certain adoption rate (Neutatz et al. 1985) the use of the SEWS concept brings a substantial economic benefit to the country, in many areas where rice is grown on a subsistence level of technology in Thailand or where higher value crops dominate, this is not the case, or only very marginal, and can hardly be felt by the individual farmer. In the latter situation, other benefits must be stressed to convince the farmers of its use, benefits such as increase of knowledge about integrated pest control and/or a healthier environment. In these areas the task for the extension agent is very difficult because his arguments are often not taken seriously. Consequently pest surveillance technology in rice needs to be focussed on areas of higher impact. This again leaves the Plant Protection Extension Service in a dilemma because of sociopolitical commitments to give assistance to poorer areas and especially to the poorest farmers first.

The Extension-Communication Strategy

Apart from the fact that not all farmers have the same opportunity to obtain infor nation because of a selective focussing of promotional efforts for new technology by government agencies to the most progressive villages, a typical farmer's communication behavior exists in Thailand (Pontius 1983).

Farmer interaction with an information source is reduced in proportion to their distance from the source. At the village level, most contact exists between

farmers of the same social status within the village, and not so much with those in neighboring villages. There exists, however, a tendency for those who have gained firsthand knowledge of a new technology not to pass it on readily to their fellow farmers. It is, therefore, of utmost importance in extension programs that the farmer leader or contact farmer is one that is sufficiently open-minded and willing to pass on new knowledge for the benefit of the broader community.

The use of mass media (radio, television) has proved to be insufficient for communicating extension information. Active-seeking behavior by farmers themselves at information sources in the village, and even in larger urban centers (agricultural office, dealers of agricultural production goods, etc.) seems to be the most important determinant in the adoption of new technology. If the economic benefit of the technology is very obvious, farmers themselves will initiate the adoption process on the local level. However, presently in Thailand, information supply to farmers is still too inadequate in quantity and quality to facilitate rapid adoption of new technologies.

The Structure and Quality of Plant Protection Extension

As has been stressed previously, the staff of the plant protection service is insufficient in number to transfer the project's technology package to a large number of farmers. At least 50% of the surveillance technicians are already very good communicators and the project has been actively engaged in increasing their practical skill in this subject. Nevertheless, their role remains a dual one – technician and extension agent – because they are still responsible for the Surveillance Crop Loss Fields in their respective surveillance areas. Cooperation with the Kaset Tambon should be stressed to improve overall effectiveness of plant protection extension. With increasing recognition of the importance of the National Agricultural Extension System by farming communities throughout the country, the sub-district extension agent will continue to become more effective as a tangible source of information for the farmer. A continuing input of adequate operational funds from the Department of Agricultural Extension, both for the field activities of the Plant Protection Service Division and of the Kaset Tambon through the Provincial Agricultural office, will be needed during the remaining 8–10 years of the project, and beyond.

CONCLUDING REMARKS

In view of the above discussions, it is pertinent to ask how we can improve the extension/communication situation for a better diffusion of the SEWS technology.

We believe that, using the Plant Protection Farmer Centers and the recent introduction of two attractive posters containing comprehensive information on the use of pest surveillance and the economic threshold, the Thai-German Plant Protection program is on the right track to reach its specific target. However, many more Farmer Centers are needed. Preparations are underway to create a "slogan" type of poster which shows the particular benefits of SEWS in a very

simple and penetrating way for large-scale distribution. A joint activity with the FAO-IPC in Rice Regional program will be undertaken in the near future to develop Knowledge-Attitude-Practice (KAP)-based extension materials on IPC in rice. The project will also look into the possibilities of producing good quality radio and/or television programs particularly in cooperation with the Agricultural Public Relations Division of the Department of Agricultural Extension (Garforth 1985).

The plant protection service should be active in supporting the Kaset Tambon's plant protection extension work and in upgrading their knowledge of the surveillance concept. Only repetitive extension activities will guarantee project success. An adequate budget for project operations at the field level is a prerequisite without which many of the above-stated intentions would remain only a play on words.

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THE ORGANIZATION OF THE THAI-GERMAN PLANT PROTECTION PROGRAM: A BILATERAL TECHNICAL COOPERATION PROJECT

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In the late 1970s, the government of the Kingdom of Thailand introduced the Integrated Pest Management (IPM) concept in agricultural plant production through the Ministry of Agriculture and Cooperative (MOAC), using its Department of Agriculture (DOA; in charge of research) and its Department of Agricultural Extension (DOAE).

One of the most essential components of IPM is an effective plant pest surveillance system. In order to accelerate the introduction of this technology, the Thai government requested the government of the Federal Republic of Germany (FRG) for technical cooperation in this field.

Beginning in 1981 the technology – since then named Surveillance and Early Warning System (SEWS) – has been developed on a bilateral arrangement by researchers of the DOA, the plant protection service of the DOAE, and experts from Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), the executing agency of FRG's Ministry of Economic Cooperation (BMZ). Due to the urgency associated with its implementation and to guarantee timely attainment of the set targets in a smooth, effective, and efficient way, the joint project was organized into what was eventually called the Thai-German Plant Protection Program (TG-PPP).

PROBLEMS

Whenever two or more countries work together on a common project, different management systems confront each other. This is due to the fact that management systems in use reflect the culture, values, and organizational behavior of the countries involved. For example, a conventional centralized system of one partner-country would conflict with a rather decentralized system prevalent in the other partner-country. Many developing agriculture-oriented countries largely influenced by western management systems claim to follow a decentralized style of organization by creating territorial structures like region, province, district, sub-district, and village operations. However, in reality, many of these countries have a rather centralized decision-making system.

Problems in working relationships also result from differences between the people-oriented organization in Thailand and the task-oriented system in industrialized countries. Furthermore, because there are no local well-established procedures, staff members of the implementing host agency negotiate at random with their expatriate colleagues about project activities. These examples

exemplify the problems in implementing bilateral cooperative projects, since any of them could cause delays, doubling of efforts, and confusion in objectives.

SOLUTION

From the above, it is obvious that the working relationship between cooperating partners must be properly organized. Further, it is a reality that the bureaucracies of cooperating partners are usually not flexible enough to change their structures under short- or even medium-term aspects. Therefore, in order to effectively integrate the expatriate partner contribution into the host system, a matrix organization setup is proposed for project implementation. The success of this further assumes that both partners maintain a generally healthy and open-minded attitude and an open-system orientation.

The Case of TG-PPP

In the case of the TG-PPP, after an initial analysis of the organizational infrastructure of the two implementing host agencies, the DOA for research on SEWS, and the DOAE for large-scale field trials, SEWS organization and implementation, and surveys on the impact of technology at the farmer's level, a project committee was formed consisting of DOA, DOAE and GTZ staff members in order to regularly discuss and decide on administrative matters. Simultaneously, persons from DOA and DOAE were identified and their duties and responsibilities within the project defined. The project committee was subsequently dissolved and replaced by a Coordination Committee chaired by a Deputy Permanent Secretary of MOAC with members representing DOA, DOAE, GTZ, and the Department of Technical and Economic Cooperation (DTEC), which plans and monitors all technical cooperation programs in Thailand.

The Coordination Committee exercises a project monitoring function, and decisively intervenes when major problems occur during project implementation. The Coordination Committee then appoints a project management team. The selection of the team members, one each from DOA, DOAE, and GTZ, is carried out in such a way that dual authority is eliminated. Further, the TG-PPP Administrative Sub-Committee (also called Executive Sub-Committee) was created as the center of decision-making on a more routine basis. The membership of this committee consists of leading project personnel from DOA, DOAE, and GTZ. This committee convenes every two to three months. Discussions and decisions are made on the budget; local and foreign training activities; assignment of short-term consultants; and on project strategies, priorities, procedures, outside linkages, and other matters. The committee usually considers proposals submitted by the expatriate expert team as well as by two Technical Committees appointed each by DOA and DOAE.

Since all these committees deal mostly with administrative matters, a strong need was felt during the mid-term period of the project to form a TG-PPP Combined Technical Committee. The MOAC instituted this committee, which consists of the expatriate project team as well as the technical staff of DOA and

DOAE Head, Regional, and selected Provincial Offices (Plant Protection Service Units), which directly supervise the implementation of project activities. The major objective of this committee is to facilitate the information flow from research to extension through the biannual turnover of research recommendations to the extension plant protection staff for large-scale testing and implementation. Further, by means of this committee, the plant protection extension staff contributes valuable information from the farm level which influences the direction of project research.

Since the beginning of 1987, and based on recommendations resulting from a mid-term evaluation, the project has emphasized the dissemination of technology developed at farm level in economic impact areas. With this modified direction in project policies, naturally there will be a change in the membership of the Technical Committee of the DOAE and the Combined Technical Committee by adding persons in charge of (general) extension and training as well as monitoring and evaluation.

Thus TG-PPP is using a complicated form of matrix organization (Figure 1), which includes the top and middle management of DOA and DOAE. There was no need to include DOAE's operational management level in the matrix organization because the SEWS field testing and its implementation has become part of DOAE's regular activities by institutionalizing the SEWS organization, which is linked to another extension system, the National Agricultural Extension Project (T & V System).

It is evident that this cooperative program follows the conventional "trickle down" approach in technology dissemination. Development banks have reported bad experiences using this approach. However, initial results from field surveys seem to indicate that TG-PPP may be successful in applying this approach.

DISADVANTAGES

Matrix organizations like the one described above also have their disadvantages. One is that the project-assigned personnel, unlike those in similar situations in industry or military, continue to perform the usual duties in their units. In planning a matrix setup this must be carefully taken into consideration. In our experience, there is hardly any case where an officer is available for more than 50% of the time for the cooperative project.

Another disadvantage is that during project implementation (mostly towards the end!) a strong need often arises to create a new regular position, e.g. the position of a SEWS database management information officer. The creation of a new position is extremely difficult. At best, this is done only on a medium- or long-term basis.

Further, a matrix organization in a bi- or multilateral program has a definite tenure during which the expatriate project contribution phases out. However, this does not mean that the project collapses. To ensure the transfer of technology developed by a project, there is a need to institutionalize it with the host implementors while the project is still ongoing. Even with this safeguard a considerable slow-down in activities is expected as soon as the bilateral project ends.

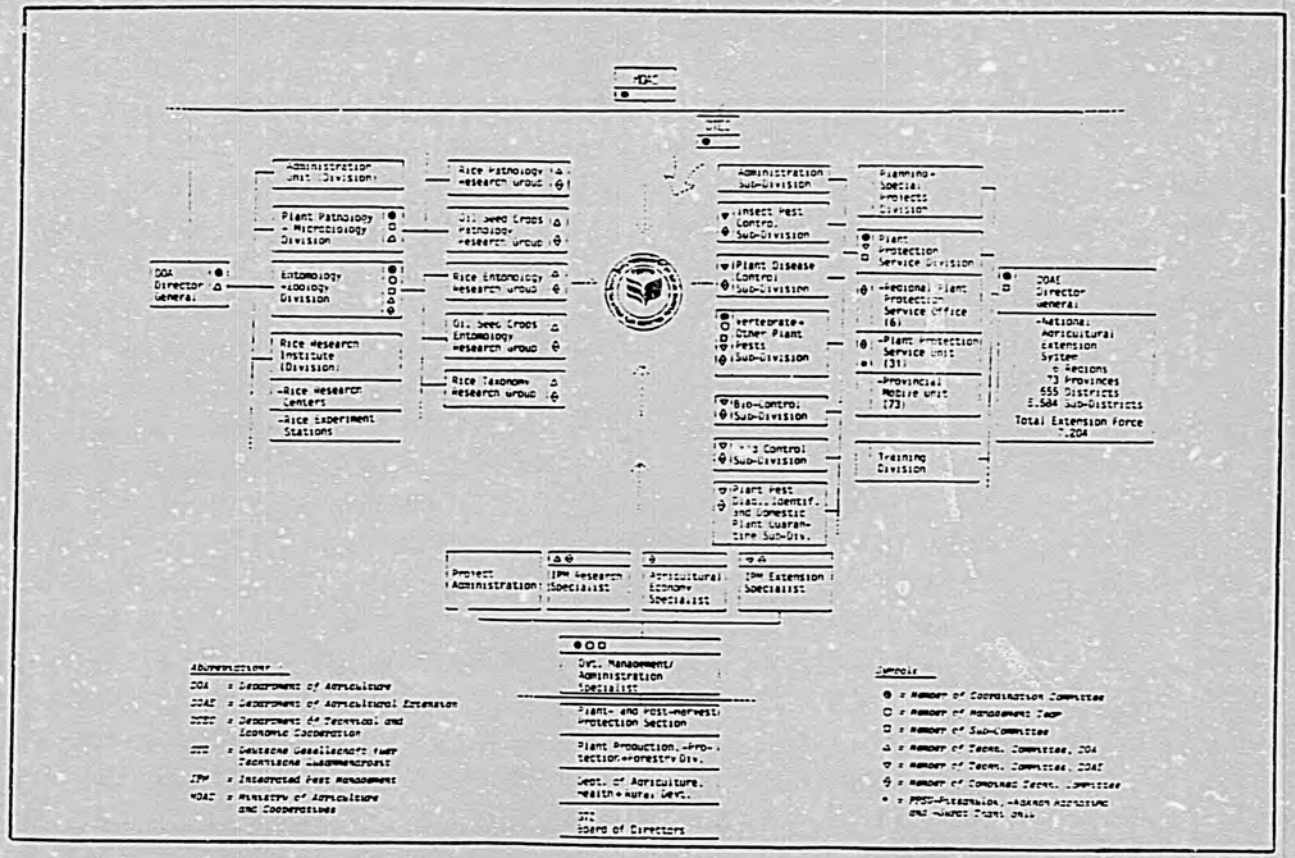

Figure 1. The matrix organization of the Thai-German Plant Protection Program (TG-PPP)

ADVANTAGES

The TG-PPP experience clearly indicates that the advantages outweigh the disadvantages of using a matrix organization. The following are the advantages that we experienced with the matrix project setup:

- The administrative integration in host agencies is assured,
- Coordination and cooperation with regular programs of host agencies is facilitated,
- More rapid technology development and implementation is feasible using regular programs of the local counterpart agencies,
- Activity monitoring and evaluation is improved, resulting in greater transparency of project affairs and faster reactions to new needs, and
- Outside linkages are improved and more effectively utilized.

Naturally, an organization is only as good as the quality of its people. This is specially so in a government or government-matrix organization dealing with complexities which require a high degree of flexibility and creativity. Further, they are expected to have above average skills in planning, organizing, communicating, negotiating, motivating, leading, resource-generating, and controlling. Therefore, most of the TG-PPP Committee members have been exposed to various types of management training, particularly in development management designed according to Southeast Asian conditions.

I would like to go as far as to say that these management training programs, even if they have little to do with plant protection in a narrow sense, have contributed significantly to the success of TG-PPP.

RECOMMENDATIONS

Based on the TG-PPP experience in project implementation, the use of matrix organizations for implementing bilateral or multilateral technical cooperation programs is to be recommended. However, appreciation of the local internal organization and management culture is imperative, especially on the part of the expatriate experts and specialists. This is so because ultimately, when the technical cooperation project phases out, it is the local organization and management system that will carry on the further implementation of any innovation developed from the project.

It is a grave mistake to ignore the organization and management aspects of a project, simply because they are not the focus of the technical design of the project. Worse yet would be to hinder the development and implementation of innovation from the technical cooperation project with the organization and management system of the expatriate partner. This can result from imposing the organization and management system on the local implementors, no matter how modern it may be according to the perception of the expatriates.

Any existing practical weakness in the local organization and management system that could constrain eventual implementation of innovation from the technical cooperation project can be sensitively and gradually improved through training and technical advice. Improvement must be compatible with the

existing legal, sociocultural and political system. Any radical organizational and management innovation that contradicts the basic local tenets will, in the end, be rejected and lost. It is, therefore, necessary that a bilateral or multilateral technical or financial cooperation project seek collaboration with a management institution familiar with local organization and management culture. This should be done instead of collaboration with institutions or management experts from other countries or regions who have poor knowledge and sensitivity to local conditions, or who may have no familiarity with the technical content of the project.

THE ORGANIZATION AND IMPLEMENTATION OF THE SURVEILLANCE AND EARLY WARNING SYSTEMS IN THAILAND

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The total land area of Thailand is 51.4 million ha, of which 37.76% (19.4 million ha) is under agriculture. Paddy lands constitute 50.62% (9.6 million ha) of the agricultural area. The annual production of paddy rice is about 24 million metric tons. Yield losses in rice due to pests (insects, diseases, weeds, rodents, etc.) are estimated to be 15–30% per year. The farmers' pest control programs still rely largely on chemical applications, which may result not only in high costs of production and ineffectiveness, but also increase the "3 Rs" – resistance, resurgence and residues. In an attempt to minimize all these factors, and to enhance the use of effective and efficient methods of plant protection by farmers, the so-called "Surveillance and Early Warning System" (SEWS) was initiated in farmers' fields to serve as an introduction to the Integrated Pest Management Program throughout the country. This program has been implemented since the mid-1980s with the assistance and cooperation of the Thai-German Plant Protection Program (TG-PPP) and the FAO Inter-country Integrated Pest Control (IPC) in Rice Program. The objectives of the SEWS program are 1) to safeguard farmers' rice production, 2) to reduce farmers' costs of production, and 3) to safeguard the environment. More details of program targets are discussed in other papers presented in this book.

ORGANIZATIONAL ASPECTS

Objectives

The operational objectives of the SEWS program are to ensure 1) that pest information is stored and available for planning in early warning and control, 2) that Economic Threshold Levels (ETLs) are adopted by every Plant Protection Service Unit (PPSU), and 3) that modified and simplified SEWS technology is introduced and practised by farmers.

Organizational Setup

The Department of Agricultural Extension (DOAE) is the national agency charged with plant protection in Thailand, and consists of nine divisions, among which is the Plant Protection Service Division (PPSD). The Kingdom of Thailand is administratively divided into six regions, each of which has one

Regional Plant Protection Service Office (RPPSO), and all are under the control of the PPSD headquarters. In practice, the PPSD has 31 operational sites in 31 provinces throughout Thailand, each site being under the charge of a Plant Protection Service Unit (Sri-arunotai & Schaefer 1983)

A province is in turn divided into three surveillance areas (SA), covered by three surveillance technicians (ST) plus one surveillance team leader (STL). One SA is composed of five surveillance crop loss fields (SCF) and three surveillance technology transfer field (STF). The distance between fields is about 3-5 km. The SCFs serve as pest data collection sites and for testing the Economic Threshold Levels (ETLs) of each PPSU. Each SCF is composed of three contiguous fields, one each for ETL testing, a check and a farmer's plot.

The STF serves as the major means of technology transfer and training for farmers. It is in reality a farmer center containing extension and teaching aids such as posters, leaflets, flipcharts, boards, and specimens. During a typical week, an ST will work one day in SCF fields, three days in STF fields, and one day back in the office for discussion about the pest data they have collected. This information will then be summarized and distributed to the farmers via warning notices, Kaset Tambon (sub-district extension agent), radio broadcasts, newspapers and other mass media.

In spite of the apparently hierarchical nature of the DOAE organization for plant protection, there is in fact much interchange of information between the different levels. Furthermore, attempts are made to regularly communicate with the research equivalent of the DOAE, the Department of Agriculture (or DOA).

Sampling Procedures for Pests

The main aspects of the sampling procedures used to collect data from farmers' fields are presented as follows:

SAMPLING UNIT This is one hill for transplanted rice and a group of ten tillers for broadcasted rice.

SAMPLING METHOD The sampling method used is systematic.

SAMPLE SIZE This is ten sampling units (SU). However, another ten SUs are taken if the ETL is exceeded.

SAMPLING FREQUENCY Sampling frequency is weekly.

SAMPLING TECHNIQUE This is either visual observation or the use of sweep nets (ten sweeps). Special instructions are to walk diagonally from corner to corner and observe one sampling unit after every ten paces. Another ten SUs are taken when the pest has reached the ETL.

Sampling Procedures for the Crop

TILLER The actual number of damaged tillers or leaves is counted, together with the number of insects of the sampling unit.

GROWTH STAGE CODE The following numeric code is used:

0 Germination to emergence
1 Seedling or transplanting
2 Tillering
3 Stem elongation
4 Booting (beginning with panicle initiation)
5 Heading
6 Flowering
7 Milk stage
8 Dough stage
9 Mature grain

YIELD Five randomly selected plots with 2 m^2 each are harvested in every surveillance field at harvest time. After threshing, the paddy rice is weighed and its moisture content measured. The average of the five plots is recorded.

OTHER AGRONOMIC DATA Every season agronomic and economic data are collected from each surveillance field in order to find out the impact of the farmer's agricultural practices on harmful organisms, the impact of the farmer's crop protection measures and their change in effectiveness, and the farmer's costs and returns from crop protection. This information serves as an essential extension aid for future recommendations. The agronomic data sheets are forwarded to the Regional Plant Protection Office for evaluation at the end of each season.

Sampling Procedures for Other Organisms

PREDATORS Actual counts are taken of predator numbers per ten sweeps. The main predators are spiders, dragonflies, damselflies, Coccinellidae, Staphilonidae, Dermaptera, Carabid beetle, and Cyrthorhinus sp.

WEEDS Total weed infestation is indicated as a percentage of soil cover per surveillance field. For Broadleaved weeds, the frequency in terms of percentages in the whole weed population is taken. The same is done with sedges, grasses and algae.

TREATMENT THRESHOLDS FOR MAJOR RICE PESTS

The specific treatment thresholds, with their accompanying sampling techniques, are presented in Appendix I.

CONCLUDING REMARKS

Based on our experience so far with implementing the SEWS in Thailand, we can conclude that:

1. the PPSUs know the pest situation of the duty area by analyzing the pest data collected,

2. some ETLs have been adapted according to the testing on SCFs and on local situations such as market price of the paddy rice,
3. analysis of the agronomic data shows that it is possible for the PPSUs to determine farmers' practices and their cost-benefit returns.
4. the dissemination of SEWS technology to farmers through the STFs is adequate, but still limited to localities. At present, we have started to spread this technology to Kaset Tambon (sub-district extension agents), 30% of whom have been trained by PPSU technicians. We expect to train all Kaset Tambon by the end of 1987. Therefore, the simplified technology will become widely transferred to farmers throughout Thailand in accordance with our plans and targets.

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APPENDIX I

Sampling technique and treatment thresholds of major rice pests in Thailand.

Pest	Sampling technique	Threshold[a]	Growth stage	Remarks
1. Insects				
1.1 Rice thrips (THR) *Baliothrips biformis*	count number of rolled leaves	20 rolled leaves/SU with 1/3–1/2 of leaves rolled	1	seedbed/seedling
1.2 Armyworm and Cutworm (ACW) *Spodoptera* spp. *Mythimna* spp.	count number of damaged leaves	16 damaged leaves/SU	1	seedbed/seedling
		15(10) damaged leaves/SU	2-4	vegetative stage
		8(5) damaged leaves/SU	5-7	reproductive stage
1.3 Rice whorl maggot (RWM) *Hydrellia* spp.	count number of damaged leaves	30(20) damaged leaves/SU	2	
1.4 Brown planthopper (BPH) *Nilaparvata lugens*	count number of insects	15(10) adults/SU	2-5	
		1.5(1) adults/SU in case of virus disease	1-5	virus diseases: - Grassy stunt - Ragged stunt
1.5 Green leaf hoppers (GLH) *Nephotettix* spp.	count number of insects	10 adults/sweep	1-5	virus diseases
		0.5 adults/sweep	1-5	- Tungro - Gall dwarf - Yellow dwarf

Continued on next page

APPENDIX I *continued*

Pest		Sampling technique	Threshold[a]	Growth stage	Remarks
1.6	Zigzag leaf hopper (ZLH) *Recilia dorsalis*	count number of insects	10 adults/sweep 0.5 adults/sweep	1-5 1-5	virus diseases: - Gall dwarf - Orange leaf - Tungro
1.7	White-backed planthopper (WBP) *Sogatella furcifera*	count number of insects	10 adults/sweep	1-5	
1.8	Rice stemborers (STB) - *Scirphophaga incertulas* - *Sesamia inferens* - *Chilo suppressalis* - *Chilo poiychrysus*	count number of deadhearts and/or whiteheads	1.5(1) deadhearts/SU 0.8(0.5) whiteheads/SU	2-4 5-6	vegetative stage reproductive stage
1.9	Rice gall midge (RGM) *Orseolia oryzae*	count number of silver shoots	(0.5) silver shoots/SU 0.8(0.5) silver shoots/SU	1 2-4	seedbed/seedling vegetative stage
1.10	Rice leaf folder, Rice leaf roller, Rice skipper (RLF) - *Cnaphalocrocis medinalis* - *Susumia exigua* - *Pelopidas mathias* - *Telicota augias*	count number of folded or rolled leaves	15(10) folded or rolled leaves/SU 9(6) folded or rolled leaves/SU	2-4 5-7	vegetative stage reproductive stage
1.11	Caseworm (CWM) *Nymphula depunctalis*	count number of scraped leaves	(20) scraped leaves/SU 30(20) scraped leaves/SU	1 2-4	seedling/seedbed vegetative stage
1.12	Rice bug (RBG) *Leptocorisa gratorius*	count number of insects	0.8(0.5) insect/SU	7-8	milk and dough stage

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APPENDIX I *continued*

Pest	Sampling technique	Threshold[a]	Growth stage	Remarks
1.13 Rice black bugs (RBB) - *Scotinophara coarctata* - *Scotinophara* spp.	count number of insects	15(10) insects/SU	2-6	
1.14 Green stink bug (GSB) *Nezara viridula*	count number of insects	15(10) insects/SU	2-6	
1.15 Rice mealy bug (RMB) - *Pseudococcus sacharida* - *Trionymus* spp. - *Paracoccus* spp.	count number of infested tillers	not yet available; count number of infested tillers/SU	2-7	if found, pull out damaged plants
1.16 Rice hispa (RHI) *Dicladispa armigera*	count number of damaged leaves	(16) damaged leaves/SU 15(10) damaged leaves/SU 8(5) damaged leaves/SU	1 2-5 5-7	seedbed/seedling vegetative stage reproductive stage
1.17 Rice grasshoppers and crickets (GHP) - *Hieroglyphus banian* - *Locusta* spp. - *Patanga* spp. - *Oxya* spp.	count number of damaged leaves	(16) damaged leaves/SU 15(10) damaged leaves/SU 8(5) damaged leaves/SU	1 2-4 5-7	seedbed/seedling vegetative stage reproductive stage
2. Crabs (CRA) Crustacea	count number of damaged tillers	if damage symptoms are found, control immediately	1-9	

Continued on next page

APPENDIX I *continued*

Pest	Sampling technique	Threshold[a]	Growth stage	Remarks
3. Rats (RAT) - *Rattus* spp. - *Bandicota* spp.	count number of damaged tillers	if damage symptoms are found, control immediately	1-9	
4. Birds (BIR) *Ploceus* spp.	count number of infected panicles	if damage symptoms are found, control immediately	1-9	
5. Diseases				
5.1 Virus diseases				
- Grassy stunt (GRV) - Ragged stunt (RVS)	count number of insects	1.5(1) insect vector/SU	1-5	vector: Brown planthoppers
- Tungro (YOL) - Gall dwarf (GDV) - Yellow dwarf (YDW)	count number of insects	0.5 insect vector/sweep	1-5	vector: Green leafhoppers
- Tungro (YOL) - Gall dwarf (GDV) - Orange leaf (OLM)	count number of insects	0.5 insect vector/sweep	1-5	vector: Zigzag leafhoppers
5.2 Fungal diseases:				
5.2.1 Brown spot (BSP) *Helminthosporium oryzae*	count number of infected leaves	(30) infected leaves/SU	1 and	only count leaves with a minimum of 3 spots per leaf
		45(30) infected leaves/SU	4-7	seedbed/seedling

Continued on next page

APPENDIX I *continued*

Pest		Sampling technique	Threshold[a]	Growth stage	Remarks
5.2.2	Narrow brown leaf spot (NBS) *Cercospora oryzae*	count number of infected leaves	45(30) infected leaves/SU	4-7	
5.2.3	Leaf blast (BLA) *Pyricularia oryzae*	count number of infected leaves	(10) infected leaves/SU	1	only count leaves with typical blast lesions
			20(15) infected leaves/SU	2-5	seedbed/seedling
5.2.4	Neck and node blast (NBL) *Pyricularia oryzae*	count number of infected tillers	0.8(0.5) infected tillers/SU	6-7	
5.2.5	Stem rot (RSR) *Helminthosporium sigmoideum*	count number of infected tillers	0.8(0.5) infected tillers/SU	6-7	only count panicle-bearing tillers
5.2.6	Sheath rot (SHR) *Sarocladium oryzae*	count number of infected tillers	1.5(1) infected tillers/SU	2-6	
5.2.7	Bakanae (BAK) *Gibberella fujikuroi*	count number of infected tillers	not yet available; count number of abnormal tillers/SU	1-2	pull infected plant out; seed treatment in the following season is necessary
5.2.8	Sheath blight (SHB) *Rhizoctonia solani*	count number of infected tillers	4(2.5) infected tillers	3-7	seed treatment in the following season is necessary

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APPENDIX I *continued*

Pest	Sampling technique	Threshold[a]	Growth stage	Remarks
5.2.9 False smut (FSM) *Ustilaginoidea virens*	count number of infected panicles	not yet available; count number of infected panicles/SU	8-9	
5.2.10 Dirty panicle (DPA) - *Curvalaria lunata* - *Fusarium semitectum* - *Cercospora oryzae* - *Acrocylindrium oryzae* - *Helminthosporium oryzae*	count number of infected panicles	not yet available; count number of infected panicles/SU	8-9	
5.3 Bacterial diseases				
5.3.1 Bacterial leaf blight (BLB) *Xanthomonas campestres* pv. *oryzae*	count number of infected tillers	(0.5) tillers/SU (Kresek) 4(2.5) tillers/SU	1 and 4-7	seedbed/seedling
5.3.2 Bacterial leaf streak(BLS) *Xanthomonas campestres* pv. *oryzicola*	count number of infected tillers	4(2.5) tillers/SU	2-6	
6. Weeds				
6.1 Total weed infestation (TWI) - Broadleaved weeds (BLW) - Sedges (SED), Algae (ALG) - Grasses (GRS), Ferns (FRN)	look at the % area covered by weeds	20% soil cover of total weed infestation	2	recommend hand-weeding after transplanting

[a]Number outside parenthesis is the threshold level for transplanted rice; number within parenthesis is the threshold level for broadcasted rice.

RADIO-BASED COMMUNICATION CAMPAIGNS: A STRATEGY FOR TRAINING FARMERS IN IPM IN THE PHILIPPINES

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This paper is intended to highlight the potential contribution of mass media and communication technology, in particular a radio-based communication campaign, to a more cost-effective crop protection extension. It is also a prologue for discussing the idea that the autonomous process of diffusion known as the "trickle down effect" may not be as effective as claimed by its supporters. The statements by Shepard and Litsinger (1985) on Integrated Pest Management (IPM) are particularly relevant to the discussion in this paper:

> Although the concept of IPM has been around for about 20 years, it is still more of an aspiration than reality in developing countries. And the gap between the concept and practice is large. The IPM philosophy came about largely due to the recognition of unsoundness brought about by total reliance on chemical control. In developing countries lack of understanding and support for IPM has slowed its progress to the extent that there are few programs currently in place.

The IPM or Surveillance Early Warning System (SEWS) concept, which calls for an intelligent approach to crop protection in rice, has been in place for several years in the Philippine-German Crop Protection Program (PGCPP) and respective thresholds for all the major insect pests have been established. In this respect, the PGCPP, with its professional staff, has graduated from the "fireman" attitude in plant protection to a "need-based", selective, and intelligence-gathering crop protection service. Unfortunately, this technical innovation, which includes a strong cost-reducing component for the farmer, has not been disseminated by the extension service to the farming community. In addition, group training exercises experienced and implemented by a multilateral donor did not prove to be a realistic instrument in the technology diffusion process. Put simply, even if the number of farmers being trained in one year were to rise to 20,000, it would still take 150 years to educate all 3 million Filipino rice farmers in IPM technology!

DIMENSIONS OF A RADIO-BASED COMMUNICATION CAMPAIGN

Do we have alternatives to the traditional extension concept? Alternatives are available if we shift our direction to Mass Media and Communication

Technology. In this respect it is no surprise that extension practitioners are looking with interest at the potential contribution of the work of mass media and communication technology (Garforth 1982). At the same time, there is a growing recognition of the need to support the extension worker in the field, both by contributing to the general information environment within their work, and, more directly, by providing them with extension aids and updating their own technical expertise and knowledge (Bunting 1985, Jones 1965).

Mass media and extension aids, ranging in technological complexity from simple posters, followed by radio commercials and drama productions up to computer-based communication systems, have been used in extension for many years (Garforth 1985). Whatever the nature of the mass media and extension aids, a number of issues must be confronted if the potential contribution of new communication technology to rural extension is to be realized (Jones 1967).

1. The use of communication technology to support extension must contribute to the relative advantage of the poorer and more isolated groups.
2. Conscious efforts are needed, both to use those technologies that are more widely accessible and to increase people's access to those technologies that extension agents choose to use.
3. The chosen media should play an important role in reducing the unit cost per recipient considerably.
4. The acquisition of equipment often tends to outstrip the agency's capacity to use it effectively. Mobile video units without petrol, or video tapes without trained production staff, printing presses without graphic artists or adequate supplies of paper contribute little to rural extension.

With all these in mind and the knowledge of the inadequacies in the extension services as well as the resistance of rural communities, the PGCPP, assisted by Dr. Chris Garforth (a lecturer on Mass Media and Communication Technology at the Agricultural Extension & Rural Development Center, University of Reading, England, and hired as consultant to the project), designed in 1984, a radio-based communication campaign on crop protection for nationwide implementation.

After the conduct of a baseline study on "Farmers' Knowledge, Attitude and Behavior towards Crop Protection and Pest Control" and a careful evaluation of potential radio production and recording companies in the Philippines, the Broadcast Production & Training Center (BPTC), Cebu, was commissioned to design and produce the broadcast materials necessary to implement the information campaign project on IPM. The actual work of the BPTC centered on the production of 48 IPM radio plugs or commercials and 36 IPM drama productions covering the more important issues of IPM in rice. Both the radio plugs (with 60--90 second each) and the radio dramas (with an average length of 25 minutes) have been produced in the two major languages, Tagalog (Pilipino) and Cebuano.

The relevance of the production was explored by conducting a rapid and inexpensive pre-test exercise covering both languages in three different locations. The pre-test was primarily aimed at determining the respondents' perceptions of the attractiveness, comprehensibility, acceptability, and self-involvement of the radio plugs and mini-dramas on IPM.

Two further points can be made. With the redesign of the IPM radio material, all major findings of the pre-test were considered and incorporated into the final production. The mass production of the IPM radio plugs and mini dramas was the next important step as part of a well-planned IPM marketing concept. This marketing concept centered on two channels of disseminating the broadcast materials, namely, the "Philippine Federation of Rural Broadcasters" and the information arm of the Ministry of Agriculture and Food through their network of more than 60 farmcasters all over the Philippines. The IPM plugs for the awareness phase were first aired through more than 150 Radio Stations countrywide in June 1986, followed by the introduction of the 36 IPM drama cassettes on 1 December 1986.

PRESSURE ON FIELD STAFF AND ECONOMICS OF COMMUNICATION INVESTMENT

Communication technology can undoubtedly support and enhance the work of field extension staff. A more radical view of extension emerges from the fact that the IPM-technology aired by radio in the Philippines has been selected and recorded purposely in an incomplete manner to encourage farmers to seek additional pieces of information and to force the extension worker to go to the field. More generally, radio-based communication campaigns may raise the expectations of rural people. They then look to extension staff to fulfill these expectations, thus presenting a professional challenge to them. In many developing countries this may be the only way to get the extension staff moving towards an acceptable performance and a higher credibility.

With this in mind, and for the purpose of reinforcing the IPM radio programs, the extension staff of the Ministry of Agriculture and Food are contributing to the Information Campaign by demonstrating and explaining the ideas communicated by radio.

This complementarity of media and extension workers further requires that printed reference material for the extension workers be produced and disseminated on time.

CONCLUDING REMARKS

It is particularly pertinent to pose the question: What returns can we expect from investing in communication technology? This question is imperative if we look at the actual costs (Table 1) of the design, production, dissemination as well as the monitoring and evaluation of our "IPM Radio-based Communication Campaign."

Reviewing relevant literature, there are serious conceptual and methodological difficulties in trying to assess the benefits in terms of economic returns (Oakley 1985, Rolls et al. 1985). It seems to be very difficult to separate the effects of media from other influences on rural people's behavior and, in any case, the effectiveness of media is heavily dependent on the quality of the content which they carry. Therefore, it is more meaningful to ask how communication technology can be used to increase the cost-effectiveness of rural

Table 1. Expenses for the design and development of the "Radio-based Communication Campaign" and the costs for production and dissemination of IPM-radio materials.

Consultancy and purchase orders	Costs	
	Phil. pesos (₱)	US dollars ($)
Baseline studies and design of the "Radio-based Communication Campaign on IPM"	265,000	21,000
Three local contracts for pre-testing testing broadcast materials	85,000	12,000
Design and production of printed materials	370,000	21,600
Production of broadcast materials (48 IPM plugs and 36 IPM radio dramas)	602,000	100,000
Mass production of IPM tapes and cassettes	127,000	7,000
Promotion and dissemination of broadcast materials	234,000	11,600
Monitoring and evaluation expenses	103,000	5,800
	1,786,000	179,000

Note: The peso and US$ cost columns are separate expenditures, i.e., total cost of each item is peso plus US$ cost.

extension, and what function of extension can it help or contribute to, for a more efficient delivery system. Whether communication technology, including the introduced "IPM Radio-based Communication Campaign" and numerous printed material, will make a significant contribution to crop protection extension depends ultimately on our ability to adjust our organizational structures and plant protection approaches to take maximum advantage of the potential it offers.

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OVERVIEW OF PESTICIDE RESISTANCE PROBLEMS IN SOUTHEAST ASIA

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When synthetic organic pesticides were first introduced, they provided an effective measure for plant protection. However, this now faces serious problems as a result of the development of pesticide resistance in insects, pathogens, weeds, and vertebrates. Although the resistance of insects to insecticides has a history of more than 70 years, serious repercussions have been observed only during the last 40 years, following the extensive use of synthetic organic insecticides such as DDT, BHC, and parathion. At least 447 species of insects and mites, 100 species of plant pathogens, 48 species of weeds, 2 species of nematodes, and one mammal (the rat) have developed resistance to pesticides. Other than American, European and Far Eastern countries, pesticide resistance problems are now known to occur in Southeast Asian countries as well. The diamondback moth, the brown planthopper, the rice stemborers, aphids, mosquitos, and stored grain pests have developed pesticide resistance in Southeast Asian countries.

Development of resistance to pesticides in an organism is an evolutionary process and a universal phenomenon throughout the extensive range of organisms known to be pests. The definition of resistance given by the World Health Organization is: "The development of ability in a strain of insects to tolerate doses of toxicants which would prove lethal to the majority of individuals in a normal population of the same species". There are many concepts and suggestions for measures to overcome resistance in pests. However, strategies to avoid or delay the development of resistance in target pests are also needed. In this paper, I will review the development of future tactics and discuss the obstacles to their development in Southeast Asia.

STATUS OF RESISTANCE

Available records, including institutional reports and private communications, indicate that at least 13 species of insects have developed resistance to insecticides in Southeast Asian countries (Appendix I).

During a symposium on the Major Insect Pests of the Rice Plant held at the International Rice Research Institute (IRRI) in the Philippines during September 1964, many entomologists from Southeast Asian countries reported on their work in major rice insect pests (IRRI 1964). It was recorded that the brown planthopper *Nilaparvata lugens* had become a rice pest; however, this insect was not important except in localized places in the Philippines. The introduction of

the new high-yielding rice varieties, which were highly fertilizer-responsive and lacked pest resistance genes, resulted in increased pest attacks, especially by the brown planthopper. This in turn required increased pesticide applications.

Resistance problems in rice plant pests are found in the brown planthopper (Morallo-Rejesus & Bernardo 1973) and the green rice leafhopper *Nephotettix cincticeps*, which have both developed high levels of resistance and multiple resistance. The brown planthopper migrates for long distances between Southeast Asian countries, and also to Japan. Brown planthopper insecticide resistance in Japan depends primarily on the resistance level of immigrants (Nagata & Mochida 1986), with the consequence that this becomes not only a domestic problem but also an international one.

The most serious pesticide resistance problem in Southeast Asia is that of the diamondback moth, *Plutella xylostella*. This insect has become a limiting factor on the production of crucifers in the Philippines (Magallona 1986) and is also known to be a problem in Indonesia, Malaysia, Thailand, and Taiwan (Cheng et al. 1984, Sun et al. 1978). Teh et al. (1982) have stated that unfortunately, the present situation with regard to control programs of insect pests in general, especially in the Cameron Highlands, holds little hope for the future.

Grain protection from stored product insects is one of the major problems in both small farms and large warehouses (Lim 1974). Malathion is commonly recommended for sack and seed treatment and several insects have developed resistance to malathion.

FUTURE TACTICS

Georghiou and Taylor (1986) classified the factors influencing selection of resistance into three categories – genetics of resistance, biology/ecology of the pest, and the control operations used. The first two categories are beyond the operator's control, but knowledge of their contribution serves to enable an assessment of 'resistance risk'. The last category is under the direct control of the operator, and can be altered to any extent necessary and feasible depending on the risk of resistance that is revealed by the genetic and biological factors.

The commonly adopted tactics against pesticide resistance are: increase in the dosage of pesticides; introduction of alternative pesticides which have no cross resistance; and usage of synergists (Barroga & Morallo-Rejesus 1975-76, Cheng et al. 1983, 1985, Liu et al. 1982, Mochida & Basilio 1983). Table 1 shows the diamondback moth situation, with insecticides treatment histories, in the Cameron Highlands area of Malaysia. Under prevailing chemical control measures used by farmers in the Cameron Highlands, pesticide resistance has continued to be a problem and there appears to be no solution in sight.

Due to the difficulty of developing new pesticides (Morallo-Rejesus 1985) efforts to practice sound insect control, such as selective insecticide use (Feng & Wang 1984, Mani & Krishnamoorthy 1984, Sivapragasam et al. 1986) to retard the development of pesticide resistance are needed. For this purpose, selection pressure should be reduced, and the prediction and immediate recognition of pesticide resistance are important. Because biological and operational factors

Table 1. Some of the insecticides used in the Cameron Highlands, Malaysia, against *P. xylostella*, since the early 1960s (Sudderuddin & Pooi-Fong 1978, modified).

Plutella situations[a] INSECTICIDE	OB 1964	OB 65	OB 66	OB 67	HI 68	OB 69	HI 70	HI 71	HI 72	HI 73	HI 74	HI 75	HI 76	HI 77
DDT	+													
Dimethoate	+	+	+	+	+	+	+	+	+	+				
Malathion	+	+	+	+	+	+	+	+	+	+				
BHC	+	+	+	+	+	+	+	+	+	+				
Diazinon	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Trichlorphon		+	+	+	+									
Dimethoate			+	+	+	+	+	+	+	+				
Dichlorvos				+	+									
Methomyl	+	+											+	+
DDT+malathion					+	+	+	+	+	+				
Methamidophos (Tamaron 50%)							+	+	+	+	+	+	+	+
Methamidophos (Monitor 50%)									+	+				
Cartap										+	+	+	+	+
Resmethrin												+	+	+
Triazophos												+	+	+
Fenvalerate													+	+
Prothiophos											+	+	+	+
Watathion®													+	+
Chlordimeform HCL														+

[a] OB = Outbreak, HI = High incidence.

influence the rate of development of resistance in a pest, and the genetic factors may also differ, local differences in resistance must be considered (see Figure 1).

The most accurate way to monitor resistance is through bioassay, and many relevant methods, such as topical application, dipping and spraying, have been reported in the literature. Such procedures are useful in determining resistance levels in the laboratory (Cheng 1981). However, large numbers of specimens and prolonged testing are required to obtain significant results, which even then can be ambiguous, especially when the resistance is real and the population is heterogeneous. Simple biochemical tests for resistance have been proposed for detecting organophosphate and carbamate resistance in populations of the brown planthopper and the green rice leafhopper (Miyata & Saito 1984). By these methods, individual insects of the population can be monitored in preliminary field surveys. Recently a network project, FAO/IRRI/12 for Southeast Asian countries, was initiated to monitor the susceptibility levels of rice pests such as the brown planthopper, leaffolder and green rice leafhopper.

Table 2 shows the results of studies on the mechanisms of resistance to insecticides in the diamondback moth. We have some tactics to delay the development of phenthoate and fenvalerate resistance in the diamondback moth.

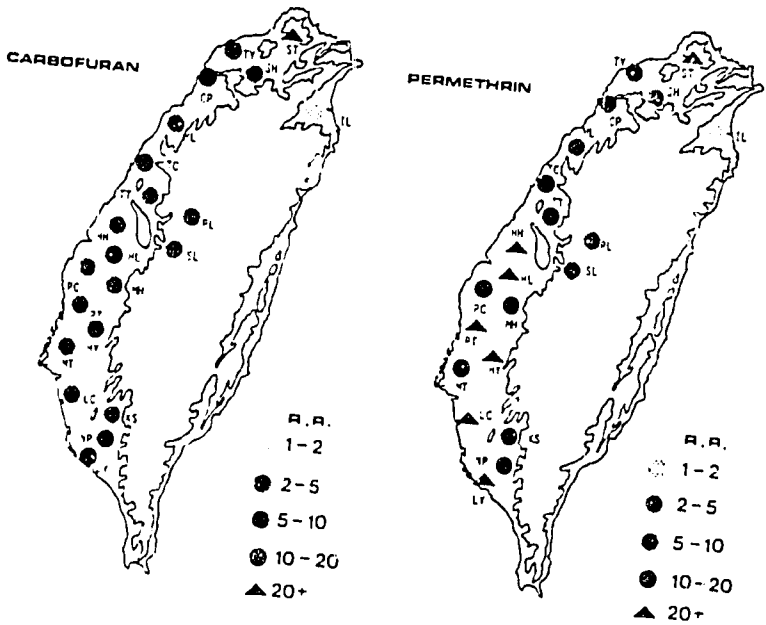

Figure 1. The geographic distribution of resistance in *P. xylostella* in Taiwan, 1980–1981 (Cheng 1981, modified)

Table 2. The mode of resistance to insecticides in *P. xylostella* (Noppun et al. 1983, 1984, 1986, 1987).

Phenthoate resistance	Fenvalerate resistance
Reduced cuticular penetration	Reduced cuticular penetration
Increased metabolism	Increased metabolism
Insensitive AChE	
High cross resistance to prothiophos, cyanophos and methomyl	Cross resistance to phenthoate, prothiophos, cyanophos, and methomyl
Low cross resistance to dichlorvos and cartap	
No cross resistance to acephate and fenvalerate	No cross resistance to cartap
Synergism to TPP	Synergism to TPP and PB
Unstable resistance?	Unstable resistance?

The alternating use of insecticides and the combination of synergists appear to be effective in delaying the development of resistance.

One additional important tactic on resistance management, apart from IPM, is forecasting of the pest population density. The light trap and the pheromone

trap are expensive. A yellow sticky trap for the diamondback moth could be used for forecasting adult population density in the field (Sivapragasam & Saito 1986). However, even if the above tactics are available, their adaptation to farm practices and acceptance by extension persons or farmers have to be determined (Saito 1975).

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APPENDIX I

Cases of field resistance to insecticides in Southeast Asia.

Insect	Insecticide	Location	Source
Rice insect pest			
Nilaparvata lugens	Monocrotophos	Bay, Philippines	Morallo-Rejesus and Bernardo 1973
	Parathion X13 BPMC X4	Taichung, Taiwan	Ku et al. 1976
	MTMC X19	Mat Chandu, Malaysia	Heong 1983
	Chlorpyrifos+ BPMC Acephate	IRRI, Philippines	Mochida and Basilio 1983
Nephotettix cincticeps	Fenthion X 7 Fenitrothion X13	Iri, Korea	Lee and Yoo 1975
	BPMC X64 Carbaryl X11 Malathion X80 Methyl parathion X680	Taichung, Taiwan (1975)	Ku et al. 1976
	BPMC X92 Carbaryl X16 Malathion X97 Methyl parathion X748	Taichung, Taiwan (1976)	Ku and Wang 1975
	Malathion X9 Dimethoate X6	Jiuxin, Thejian	Chen et al. 1978
Laodelphax striatellus	Malathion X27	Jinjo, Korea	Choi et al. 1975
Inazuma dorsalis	DDT	Taiwan	Ma 1965[a]
Chilo suppressalis	Fenthion X3	Yong In, Korea	Kim et al. 1970
	Fenthion X6 Fenitrothion X3	Joan, Korea	Lee and Yoo 1975
Tryporyza incertulas	∂-BHC X7 Parathion X3	Chin Shan, Shanghai	Res. Group on Resistance 1977
	Parathion	Taiwan	Ma 1965[a]
Leptocorisa acuta	BHC, cyclodiens OP	Thailand	Chakrabandhu 1965[a]
Leptocorisa varicornis	Methoxychrol, BHC, Cyclodiens	Thailand	Chakrabandhu 1965[a]
Scotinophara lurida	BHC, cyclodiens	Taiwan	Ma 1965[a]

Continued on next page

APPENDIX I *continued*

Insect	Insecticide	Location	Source
Vegetable insect pest			
Plutella xylostella	DDT	Lembang, Indonesia	Ankersmit 1953
	Methyl parathion X288-1753 Malathion X18-822 DDT X10-397 Dichlorvos X15-172 Diazinon X15-172	College, Daet, Ligao, Bugies, Atok, Guinobatan, Philippines	Barroga and Morallo-Rejesus 1975-1976
	Malathion X2096 Chlorpyrifos-Methyl X620 DDT X530 ∂-BHC X64 Dichlorvos X40 Cartap X16 Methomyl X12 Methamidophos X6 Carbaryl X6 Resmethrin X5 Fenvalerate X5	Cameron Highland, Malaysia	Sudderuddin and Pooi-Fong 1978
	Malathion X11 Diazinon X8 Dichlorvos X13 Mevinphos X9	Lu-Zhon, Taiwan	Lee and Lee 1979
	Phenthoate X16	Cong-Shan, Taiwan	
	Endosulfan X9	Lu-Zhon, Taiwan	
	Carbofuran X33	Sheh-Tzu, Taiwan	Cheng 1981
	Mevinphos X11	Lu-Chu, Taiwan	
	Cartap X4	Shui-Li, Taiwan	
	Permethrin X75	Hsi-Hu, Taiwan	
	Fenvalerate X75	Lin-Yuan, Taiwan	
	Malathion X3650 Diazinon X413 Dichlorvos X300 Permethrin X110 Fenvalerate X2880 Cartap X199 etc.	Ban-Chau, Taiwan	Liu et al. 1982
	Permethrin X754	Cameron Highland, Malaysia	Teh et al. 1982

Continued on next page

APPENDIX I *continued*

Insect	Insecticide	Location	Source
Stored product insect			
Sitophilus zeamais	Lindane	Alor Star, Penang, Malaysia	Lim 1974
Rhyzopertha domonica	Lindane	Alor Star, Malaysia	Lim 1974
Tribolium castaneum	Malathion, lindane	Alor Star,Batu Caves,Kuala Lumpur, Penang, Malaysia	Lim 1974
	Malathion	Jatibarang, Cianjur, Semarang, Irian Jaya, Sumatra Selatan, Indonesia	Osman and Morallo-Rejesus 1981

[a]Data from Metcalf 1984.

PESTICIDE RESISTANCE PROBLEMS IN MALAYSIA

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Pesticide resistance was recorded as long ago as 1911 when extensive fumigation of citrus trees had selected a strain of scale insect resistant to hydrogen cyanide gas (Busvine 1976). The widespread use of pesticides after the Second World War, and the dependence on them, meant that when pesticide resistance became prevalent, the phenomenon had a profound effect on pest control both in the agricultural and public health sectors. The growth in incidence of pesticide resistance since 1947 was accelerated by the introduction of large-scale usage of new synthetic pesticides. On a worldwide basis, 52 agricultural species and a similar number of medically important species had developed resistant strains by 1958. In subsequent years, however, the number of agricultural pests that developed resistant strains have far exceeded the number for medical species. It was reported in 1976 that 225 of the 364 (305 confirmed and 59 suspected) arthropod species resistant to pesticides were of agricultural importance (Georghiou & Taylor 1976). Recently, on record at least 447 species of insects and mites have developed resistance to insecticides (Georghiou 1986).

Resistance to almost every conceivable type of pesticide has been reported. Hitherto, resistance has been reported for such diverse and new pesticides as the insect chitin inhibitors Dimilin in *Musca domestica* L. (Cerf & Georghiou 1974); the insect's own hormone, synthetic juvenile hormone in *Tribolium castaneum* Herbst. (Dyte 1972); the microbial insecticide *Bacillus thuringiensis* in *M. domestica* (WHO 1986); the anticoagulant rodenticide warfarin in rat *Rattus norvegicus* Berk.(Drummond 1966) and mouse *Mus musculus* L. (Rowe & Redfern 1965); and the highly toxic herbicide paraquat in *Erigeron philadelphicus* L. (Watanabe et al. 1982).

In Malaysia, various groups and types of pesticides have been used over the past three decades. It is surprising to note that with the widespread and/or continuous use of herbicides, and to a lesser extent molluscicides and nematicides, no case of resistance has been reported. Since the general review of insecticide resistance in agricultural pests in Malaysia in 1979 by Sudderuddin (1979), a few more cases of resistance have been reported. The aims of this paper are to discuss a) cases of biochemical mechanisms involved in resistance, b) possible ways to overcome resistance problems, and c) regional as well as international cooperation, particularly within the Southeast Asian region.

CASES OF PESTICIDE RESISTANCE IN MALAYSIA

Insecticide Resistance

A literature search showed that the resistance in insects is not widespread in Malaysia. After three decades of insecticide usage, the number of species which have developed resistance is only eight for agricultural insect pests and ten for public health insects. The figures are surprisingly low, particularly for the agricultural sector. They may not reflect the real current situation because no concerted effort has been made in the past to assess and report incidences of resistance. The reported cases of resistance in Malaysia were quite variable in their authenticity, ranging from mere subjective impressions to careful laboratory experimentation. These cases are discussed in the following sections.

AGRICULTURAL INSECTS

i) Coleopterans – The strains of three beetle species suspected to have developed resistance are all pests of stored products. An unpublished report by B. R. Champ submitted to MARDI noted that *Tribolium castaneum* Herbst. collected from Alor Setar, Batu Caves, Kuala Lumpur and Penang, was resistant to lindane and malathion (Lim 1974). *Sitophilus zeamais* Motsch. collected from Alor Setar and Penang, and *Rhyzopertha dominica* F. from Alor Setar had developed tolerance to lindane (Lim 1974).

ii) Hemipterans – It was shown that local populations of brown planthoppers (*Nilaparvata lugens* Stal.) in Tanjong Karang, Selangor, had become more tolerant to m-tolyl methylcarbamate. Between the years 1977 and 1982, the resistant factor for the brown planthoppers had increased nineteenfold (Heong 1983). In a recent survey with different populations of green leafhoppers (*Nephottetix virescens* Distant), collected from seven different rice-growing areas in Peninsular Malaysia, only those collected from Sekinchan, Selangor (where there was intensive usage of insecticides), showed resistance. The resistance factor detected was 4 x for BPMC; 9 x for carbofuran; and 21 x for phenthoate (Lim & Tan 1986).

iii) Lepidopterans – Observations on maize borer (*Ostrinia nubilalis* Hubn.) in Serdang, suggested that the borer was resistant to endrin and HCH (Lim 1974), while a rice stemborer (*Chilo suppressalis* Walker) in the Kedah region was suspected to have developed resistance to HCH (Lim & Ting 1973). For the two lepidopteran borers no details of resistance were given.

The diamondback moth (*Plutella xylostella* L.) has been subjected to high insecticidal pressure since the early 1950s. Suspicions of insecticide resistance in the moth have been reported (Henderson 1957, Lim 1974, Yunus & Balasubramaniam 1975). Work conducted in 1976 by Sudderuddin and Kok (1978) showed that a strain collected from a farm in the Cameron Highlands had developed resistance to all groups of modern synthetic insecticides. The resistant factor for the various insecticides tested were, for DDT, 520 x; HCH, 64 x; methamidophos, 6 x; dichlorvos, 40 x; chlorpyrifos-methyl, 626 x; malathion, 2096 x; methomyl, 12 x; carbaryl, 6 x; fenvalerate, 5 x; and for resmethrin, 6 x.

P. xylostella moths collected from the same locality in 1978 showed a resistant factor of 700 x to permethrin (Teh et al. 1982). This indicated that within a short period of two years, the resistant factor towards a pyrethroid insecticide had increased considerably. Furthermore, the development of multiple resistance in *P. xylostella* has had a serious impact on the control measures taken against the moth in the Cameron Highlands (Ooi 1979).

INSECTS OF PUBLIC HEALTH

i) Non-dipterans – The bedbug (*Cimex hemipterus* Fabricius) and the head louse (*Pediculus humanus capitis* De Geer) were reported to have developed resistance to DDT but no details were given (WHO 1986).

ii) Dipterans – Seven mosquito species have developed resistance to organochlorine insecticides, of which two species *Aedes aegypti* L. and *A. albopictus* Skuse were also resistant to organophosphorus insecticides (WHO 1986). *Culex quinquefasciatus* Say has developed resistance to malathion and fenthion (Thomas 1970). However, recently it has also developed resistance to pyrethroids – permethrin and cypermethrin. The recently determined resistant factors in 1986 for two strains of *C. quinquefasciatus* larvae collected from two localities, one in the mainland and the other on the island of Penang State, were for malathion, 4 x and 5 x; for DDT, 9 x and 10 x; for dieldrin, 8 x and 13 x; cypermethrin, 8 x and 10 x; and permethrin, 8 x and 7 x, respectively (Setakana, personal communication).

The housefly (*Musca domestica* L.) in Cameron Highlands has developed resistance to several insecticides. The resistant factors recorded for adults were for DDT, 2 x; lindane, 6 x; methamidophos, 6 x; methomyl, 2 x; and pirimicarb, 9 x (Lau & Sudderuddin 1981). This strain of housefly is known to have been exposed to a wide variety of insecticides used against the diamondback moth because of its breeding in manure, particularly prawn dust, used in vegetable farming. This is a positive case in which application of agricultural insecticides has exerted a selective pressure on an insect of public health importance.

Rodenticide Resistance

Warfarin, an anticoagulant rodenticide, has been in use in Malaysia since the sixties. Some degree of tolerance to warfarin in rats (*Rattus tiomanicus* Miller) was detected in oil palm estates, and was attributed to behavioral changes probably caused by faults in baiting techniques or the bait itself (Wood & Liau 1977). However, the first case of physiological resistance in Malaysia was exhibited by the Malaysian feral rat (*Rattus rattus diardii* Jentink), collected from a cocoa estate in Teluk Intan, Perak. When subjected to a 'no-choice' test, the feral rat was significantly more tolerant than laboratory-reared rats (Lam et al. 1982). Subsequently, *R. rattus diardii* caught from a mixed cocoa/coconut and oil palm estate showed a resistant factor of 3.3 x to warfarin when compared with susceptible rats (Lam 1984). Considering that warfarin has been used for

almost three decades, it is expected that biochemical or physiological resistance could have developed but not been detected in other rat species that have been exposed.

BIOCHEMICAL/PHYSIOLOGICAL STUDIES ON RESISTANCE

Resistance may arise as a result of alterations in any of the processes which determine the cuticular penetration, distribution or target site interaction of a pesticide. It is a preadaptive phenomenon caused by mutation in a population prior to selection. This fact was proven in *Escherichia coli* where a resistant strain arose by mutation of sensitive cells independently of the action of a virus (Luria & Delbruck 1943). In insects, it has been observed that invariably, resistance has been entirely dependent on selection and has not developed because of sub-lethal doses of an insecticide (Crow 1957). It is important to determine whether a resistant strain has developed cross or multiple resistance through biochemical or physiological studies. Cross resistance denotes a resistance in a strain to compounds other than the selective agent, due to the same mechanism, while multiple resistance is the resistance of a single strain to several different/unrelated compounds but resulting from different mechanisms. The various biochemical and physiological resistances have been reviewed by Brown (1983), and Oppenoorth & Welling (1979). Biochemical resistance develops through the selection of an aberrant gene responsible for the production of an enzyme with different properties by altering its amino acid sequence, while physiological resistance develops by selecting regulatory factors which determine the quantity of the normal enzyme produced. Some preliminary determination of resistance mechanisms may be conducted by simple experiments involving the use of synergists which inhibit certain processes of detoxification. Synergists like tributyltrithio phosphate (DEF), 1,1-bis (4-chlorophenyl)-trifluoromethyl carbinol (F-DMC) and piperonyl butoxide may be used to inhibit esterases, DDT-ase and mixed function oxidases respectively.

In Malaysia, biochemical and/or physiological studies on resistant strains are scarce. Electrophoretic and *in vitro* esterase studies on a Cameron Highlands resistant strain of housefly revealed an extra and more active acetylcholinesterase isoenzyme and two less active carboxylesterase isoenzymes when compared with the corresponding susceptible strain (Lau & Sudderuddin 1981).

The strain of the green leafhopper resistant to both organophosphorus and carbamate insecticides showed qualitative changes in the electropherograms of esterases in comparison with susceptible strains (Lim, personal communication).

Current studies on larval extracts of the two resistant strains of *C. quinquefasciatus* mentioned earlier, indicate that genetical changes have occurred. Induced biochemical changes in esterase isoenzymes were observed in the electropherograms of the two strains. Both resistant strains had the same number of isoenzymes. Each strain had two carboxyl- and an aryl-esterase in comparison with a carboxyl- and two aryl-esterases in the susceptible strain. The slow migrating carboxylesterase in both the resistant strains had identical relative mobilities, while the other two isoenzymes had different mobilities between the two strains (Setakana, personal communication). The differences in

relative mobilities of a carboxyl- and an aryl-esterase between the resistant strains showed that they had independently developed a similar mechanism to detoxify carbamate and organophosphorus insecticides, especially malathion, which was commonly used for vector control. Similar studies should be conducted on resistant strains of other insects, especially on *P. xylostella*, to determine objectively the mechanism or mechanisms involved in cross and multiple resistance respectively.

IMPACT OF RESISTANCE ON PEST CONTROL

The development of resistance has definitely affected, and in some cases severely impeded, the control of pest species (Sivaprasagam 1983, Sudderuddin 1979). For insect vectors that have developed cross or multiple resistance, the reliability of organochlorine or organophosphorus insecticides which are relatively cheap, safe, and efficient would be seriously curtailed. As a result of cross resistance to pyrethroid insecticides, mosquito coils have been observed to be ineffective against *C. quinquefasciatus* in many areas of Penang (Yap, personal communication).

For the diamondback moth in Cameron Highlands, the resistance problem is so severe that the reliability of insecticides for their convenience and efficiency has been seriously challenged (Sivaprasagam 1983, Tan et al. 1982). The problem has escalated the cost of control, which in turn has reduced profits because farmers have resorted to applications of insecticidal cocktails with increasing doses and frequencies.

COUNTERMEASURES AGAINST THE DEVELOPMENT OF RESISTANCE

The continuous and widespread use of pesticides would inevitably select for genetic mutations that manifest themselves as resistance. Once resistance has developed in a population, it is irreversible in an ecologically closed population. There has been much research on resistance in the past thirty years. However, it is sad to note that no simple way has been found to combat resistance. Nevertheless, several countermeasures may be taken, as discussed in the following sections.

Delaying Resistance Development

This may be done by allowing susceptible populations to mix with the population in the treated area. Untreated individuals and immigrants would contribute unselected genes to subsequent populations. This would thus delay the increased frequency of selected genes appearing in a treated population through the Hardy-Weinberg equilibrium. Such an approach may be achieved or maximized through one or a combination of the following methods: a) by applying chemical control when it is necessary, i.e., when population level is high or above an empirical economical threshold (Lim & Heong 1984); b) by limiting chemical application to areas with high populations (Lim & Heong

1984); c) by using selective pesticides with relatively short persistency; d) by using novel chemicals (Tan 1976, Tan & Loke 1984), or non-chemical methods where possible as supplementary methods when they are cost-effective; and e) by using sub-lethal doses of pesticides which have known antifeeding (Tan 1981b), or irritancy effects (Tan 1982).

Alternative Pesticides and Control Methods

When pesticide resistance affects operational economics, the search for an alternative pesticide or control method is inevitable. In the search for an alternative pesticide, the mechanism of resistance of the target species should be studied. Reference to experience gained by studies of different types of resistances, patterns of cross or multiple resistance and interaction of resistance mechanisms in other species should be taken into account for selecting the prospective pesticides. Then field selection trials should be conducted to select suitable alternative pesticides. In the case of *P. xylostella*, in which multiple resistance has probably developed, a good alternative pesticide would be a microbial insecticide (Sivaprasagam 1983, Sivaprasagam et al. 1984), or an insect growth regulator, especially one that inhibits chitin synthesis (Tan 1981a, Tan & Loke 1984). The use of natural enemies (Ooi 1981) may be considered as an alternative control method.

In view of possible resistance problems, hazardous effects and environmental contamination that may arise through widespread application of pesticides, plus the inevitable use of certain pesticides for animal and plant protection in the foreseeable future (Lim & Heong 1984), an ecological approach to pest control, particularly for insect pests, is probably the soundest and safest approach and should be encouraged (Tan et al. 1982). There is, however, an important role for pesticides when used judiciously within the context of an integrated pest control (IPC) program. Nevertheless, the implementation of an IPC program in Malaysia has its constraints (Lim et al. 1981, Lim & Ooi 1984), which can be overcome by careful studies and planning by researchers together with proper coordination and cooperation of the agencies involved.

RECOMMENDATIONS AND CONCLUDING REMARKS

The problems related to pesticide resistance in Malaysia are many. Some problems may be dealt with at the institutional or national level, and others through international cooperation especially at the regional level within Southeast Asia with assistance and funding from international organizations. It is therefore recommended that:

1. In view of the importance of accurate and reliable data on pest resistance, susceptibility tests should be conducted by trained staff. Results of these studies should then be forwarded promptly to a central coordinating national agency or institution.
2. Information on all aspects of resistance for any species and any country should be compiled and distributed.
3. A national insecticide reference laboratory should be established to

investigate reported cases of resistance. All types of susceptibility (inclusive of biochemical and physiological) tests to determine type(s) of mechanism(s) should be performed. The laboratories should also maintain standard susceptible colonies of various pest species.

4. Staff training to acquire bioassay, biochemical and biostatistical techniques, be organized at the national or international level.
5. Countermeasures against pesticide resistance should be studied to extend the usefulness of a pesticide, taking into consideration the bionomics of the target pest species and possible contamination of ecosystems.
6. Behavioral studies such as pesticide effects on host searching, and on the use of semiochemicals in combination with pesticide and/or traps should be undertaken.
7. The following activities related to pesticide resistance be promoted and funded by international organizations:
   a) an updated inventory of current research projects, institutions and investigators be compiled and circulated;
   b) preventing movement of resistant strains between neighboring countries, especially wind-borne pests such as the leafhoppers and planthoppers by inter-country cooperation; and
   c) contacts between scientists for the mutual exchange of ideas and techniques through workshops and symposia.

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PESTICIDE RESISTANCE PROBLEMS IN THAILAND

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The circumstances under which pesticide resistance may develop in any insect (arthropod) population are immensely variable, usually highly complex and, in our present state of knowledge, only partially understood. Resistance is not limited to insects and insecticides. A range of other organisms including fungi, weeds, and rodents develop resistance to chemicals intended to control them. The number of species of arthropods resistant to insecticides has increased almost linearly, from 1 in 1908 to 5 in 1928, 14 in 1948, 76 in 1957, 224 in 1967, 364 in 1975 and 432 in 1980 (Georghiou & Taylor 1977, Georghiou & Mellon 1983). It is estimated that approximately 500 species of arthropods show resistance to one or several groups of toxic chemicals. From almost a century of experience, it would also appear that resistance is not an isolated phenomenon but rather that, when a species showing enough variability is exposed to intensive treatments, it will most likely adapt to the toxicants.

Pesticide resistance in a pest commonly manifests itself when field applications fail to give the desired level of control, thus presenting a problem to the farmer. Resistance to pesticides is not just found among insects since it has also been reported for spider mites to acaricides, nematodes to nematicides, bacteria to antibiotics, fungi to fungicides, and rodents to rodenticides. It must be mentioned that sometimes, resistance may have a beneficial aspect when it concerns beneficial organisms such as an egg parasite Trichogramma, or fungus or entomopathogenic bacteria on agricultural crops.

Because of serious problems associated with the development of resistance to pathogens, the chemical industry, under the auspices of GIFAP (Groupement International des Associations Nationales de Fabricants de Pesticides, or International Group of National Pesticide Manufacturers' Associations), organized a seminar on the topic in Brussels in 1981. This subsequently led to the creation of Fungicide Resistance Action Committee (FRAC). Phytopathologists generally recognize resistance as a practical problem. The most prominent cases of field resistance have occurred against dicarboximides in *Botrytis*, against acylalanins in certain foliar oomycetes and against benzimidazoles in *Fusarium* and more recently in *Pseudocercosporella* on cereals. Very serious cases of fungicide resistance appear to be based on alteration of the target site of action of the fungicide whereas insecticide resistance commonly results from increased metabolic detoxication.

It is well-known that the diamondback moth (DBM) *Plutella xylostella* is a cosmopolitan pest of cruciferous crops. Between 1978 and 1980, DBM was found to be resistant to 15 insecticides from all groups (Sinchaisri et al. 1980,

Sudderudin & Kok 1978, Sun et al. 1978). A pest genus common in many countries is *Spodoptera*, different species of which have demonstrated levels of resistance to insecticides ranging from organochlorates to synthetic pyrethroids. Special mention must be made of *Spodoptera exigua*, the control of which is getting extremely difficult in Thailand (Rachatapakornchai et al. 1986). Another case is *Spodoptera littoralis* (the Egyptian leaf cotton worm) which seems to be developing resistant strains to pyrethroids. *Heliothis* is another pest which presents a high risk of resistant behavior. From the end of the last decade, cases have been reported in Thailand and Australia (Wangboonkong 1986a, 1986b); *Heliothis armigera* has been found resistant to synthetic pyrethroids in New South Wales and Queensland.

Herbicide resistance is also becoming a problem, although it is still localized in small areas. Since the mid-1970s, reported cases have almost exclusively involved the triazines, with problem weeds such as *Poa annua* in Belgium and Holland, *Brachypodium distachyon* in Israel, Amaranthus in the corn belt in U.S.A., and *Senecio vulgalis* in the United Kingdom.

EVIDENCE OF INSECTICIDE RESISTANCE TRENDS IN THAILAND

Pesticide application is a prominent part of modern agriculture in Thailand. Farmers prefer to spray several compounds in their cultivated crops and when the compounds decrease in effectiveness, they are replaced by new compounds, almost in a regular manner. Improper use of pesticides by farmers is the major cause of resistance.

Resistance phenomenon has been observed in vegetable and cotton pests since the late 1970s. Frequent spraying with several synthetic organic compounds is the main cause of pesticide failure in the field. Organophosphates were the first group found ineffective for *Plutella xylostella*, *Heliothis armigera* and *Spodoptera exigua*, and it is interesting to note that at present, many farmers have stopped using organophosphates for the control of these pests. Subsequently, carbamates such as carbaryl methomyl became common, but even these soon developed resistance. The case of *Heliothis* is a good example of field failure with the synthetic pyrethroids (Figures 1, 2). A sharp decrease in percent control was observed from 1981–1985. The same trends have been observed in *Plutella* (Sinchaisri et al. 1980). It is unfortunate that no one was making similar observations with *Spodoptera exigua* even though it was recognized as a potential problem.

It was not too long ago that the newest group of insect growth regulators (IGR), Dimilin®, Alsystin®, Atabron®, and Nomore®, were welcomed in the vegetable growing industry. Poor control is now being obtained with some of these, but toxicologists is doubtful when this started. Dimilin, the oldest of these IGRs, is almost ignored by farmers due to its low effectiveness with both *Plutella* and *Spodoptera* since 1984. The main question we have asked concerns with the time at which the pests develop resistance to IGR, followed by the mechanism. It is fortunate that IGRs have not been widely used in many crops because of their high cost. Research to clarify the mechanisms of DBM

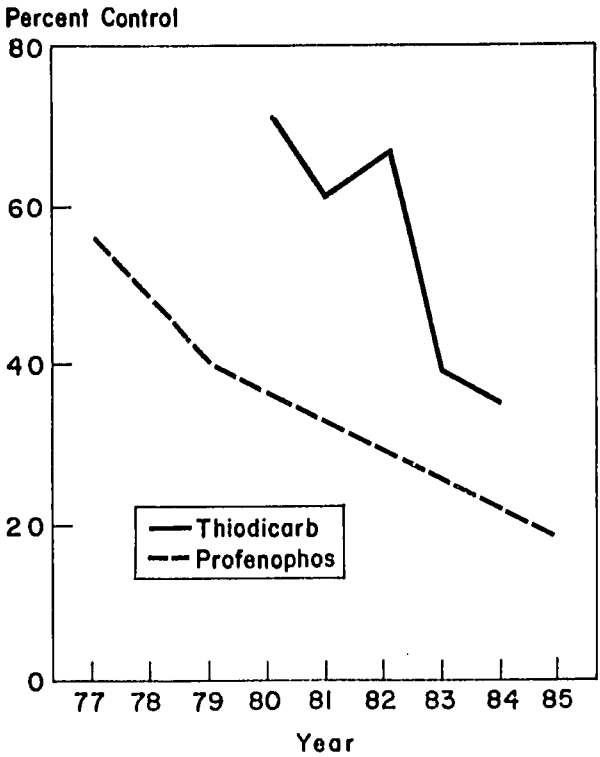

Figure 1. Trend of loss of the effectiveness of organophosphate and carbamate compounds in the control of *Heliothis armigera* in cotton, Thailand.

resistance to several compounds has been reported in Japan (Miyata et al. 1985, Noppun et al. 1986) but not in Thailand.

Development of resistance to fungicides and antibiotics has resulted in farmers preferring to apply alternative compounds for suppressing any severe infection. Common diseases caused by key pathogens (Sommart T., personal communication) such as *Plasmopara viticola*, *Colletoticum* sp. and *Phythopthora palmivora* and *P. parasitica* in grape and orange have been found to have resistance but, so far, intensive investigations to elucidate and identify the level of resistance have not been reported.

PESTICIDE RESISTANCE JUSTIFICATION THROUGH THE FIELD FAILURE

It is important that the reasons for failure of chemicals to perform in the field be understood. In Thailand, some possible reasons are as follows:

a) "Misconduct" in pesticide application – improper timing, poor spraying technique, use of pesticide "cocktails";
b) Applications using expired chemicals – the commercial product available in the market is not provided with a label showing expiration date; poor storage, particularly in local retailer shops, may accelerate the insensitivity of chemicals, thereby causing low effectiveness; and

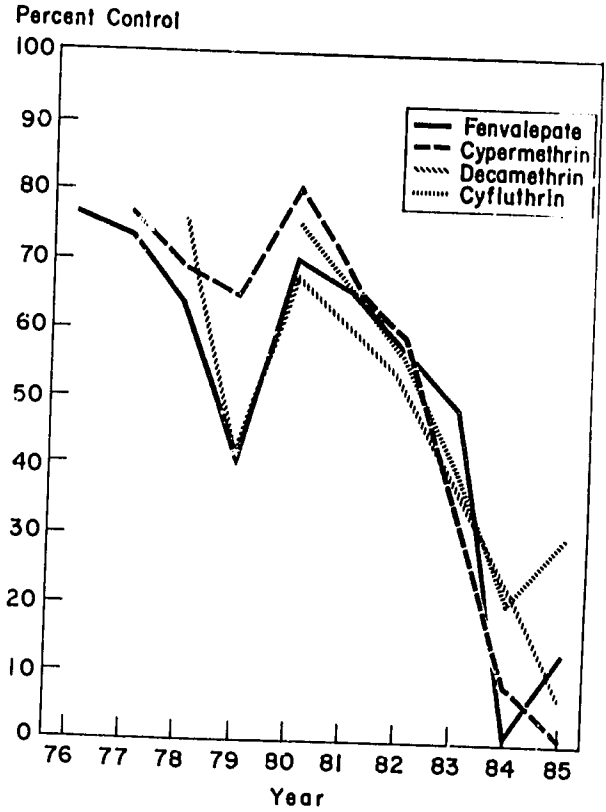

Figure 2. Trend of the efficacy of synthetic pyrethoids in controlling *Heliothis armigera* in cotton, Thailand.

c) Incorrect active ingredients used in the re-formulation of certain commercial products, sometimes due to the profit-mentality of dealers.

The above factors may lead to the detection of "pseudo-resistance" in the field, since normally susceptible individuals avoid the lethal doses of chemicals applied. Intensive studies are needed to confirm that truly resistant strains exist.

MECHANISMS OF RESISTANCE

Excellent information about the mechanisms of DBM resistance to organophosphates and synthetic pyrethroids has been provided by Miyata et al. (1985). Cross resistance was also reported by these workers. To differentiate the true or "physiological" resistance from other forms, factors influencing enzymatic detoxification and the penetration of toxic products into resistant strains or increased excretion were all examined. Meanwhile, some scientists have proposed that the existence of the Kdr gene or Super Kdr gene, which controls the modification of the nerve cell membranes is important. From a practical viewpoint, it is useful to know which pesticides are involved in cross-resistance phenomena. It is also important to note that several independent genes may confer resistance to one pesticide, and that pesticide resistance may be

monogenic (or monofactorial resistance) or polygenic (or polyfactorial resistance).

RESEARCH NEEDED

Detection of the Resistant Strain

Failures in field application of pesticides may often be due to reasons other than the development of resistance. And conversely, although one strain of a pest may have developed resistance, that does not necessarily mean that field failures will occur. In general, the only way to confirm resistance is to compare the sensitivity of a sample to a control. The most common method for detecting resistant strains is to use increasing doses of pesticides to determine the relationship between dose of toxicant and mortality. Regression analysis will then give the LD_{50} value from the derived equation. The level of resistance may be quantified as a **Resistance Index**, calculated as

$$\frac{LD_{50} \text{ of resistant strain}}{LD_{50} \text{ of susceptible strain}}$$

In some cases resistance may be determined using bioassays or biochemical methods, assuming the mechanism of resistance is well accepted. The enzymes involved may be hydrolases, carboxylesterases or Gusathione-S-transferase (Miyata et al. 1985, Oppenoorth & Welling 1976). An electrophoretic technique is often used in the rapid detection of resistance in the brown planthopper in Japan.

Identification of the Level of Resistance

After the level of resistance has been identified as discussed above, then it would be feasible to proceed with mapping the level of resistance among the colonies collected from different locations. This is the most important area for which research is urgently needed.

Unfortunately, there are few Thai toxicologists or entomologists who are working on this aspect of the pesticide resistance phenomenon. There is a lot to challenge Thai researchers, in addition to the research needed on the mechanisms of resistance and the development of cross resistance in the key pests in the country.

CONCLUDING REMARKS

For serious pests of cruciferous crop and cotton in Thailand such as the DBM *Heliothis* and *Spodoptera exigua*, research to strengthen our knowledge of pesticide resistance must be emphasized. It is impractical to consider a regular alternation with new insecticides as the solution to the present situation. As a matter of fact, it is probably difficult to introduce alternative insecticides with no known cross resistance when insects already show resistance to certain insecticides. Miyata et al. (1985) discussed the use of synergists to delay the rate of resistance development but, so far, an effective synergist to overcome

insecticide resistance in DBM has not been discovered. It is also becoming increasingly difficult and expensive for pesticide manufacturers to develop new pesticides. Therefore, the establishment of IPM programs for DBM (or other key pests mentioned) is quite essential, at least in terms of minimizing chemical spraying.

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PESTICIDE RESISTANCE IN THE PHILIPPINES – AN ENIGMA WAITING FOR SOLUTION

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Insecticide resistance is a widely observed phenomenon that has caused problems not only for practicing entomologists, farmers, and the chemical industry, but also for government planners. The 392 arthropod species reported to be resistant to various types of pesticides (FAO 1979) represents just the "tip of the iceberg" as far as the problem is concerned. Many of these species are also resistant to more than one pesticide, thus aggravating the problem.

The Philippines is no exception as there have been numerous reports of loss of pesticide effectiveness against certain pests, and while it may be true that there are other factors affecting pesticidal efficacy, there is no doubt that a major cause is resistance development. A problem affecting attempts to determine an accurate picture of the situation lies in the manner in which data are reported – there is no central point or mechanism for reporting data or for verification. The importance of verification should not be overemphasized because most of the reports on resistance are made by farmers who often use "off-the-cuff" criteria for judgments on pesticide efficacy. Chemical companies generally do not support studies of this nature, or if they do, the data are not highlighted. Consequently, if a pesticide has resistant pest populations, it is simply forgotten.

It is not my intention to present an exhaustive review of resistance development in the Philippines. Rather, this paper will limit itself to the diamondback moth (DBM) to illustrate the enormity of the problem as well as to call attention to difficulties involved in research dealing with resistance.

THE DIAMONDBACK MOTH (*Plutella xylostella*)

This is the major insect pest of crucifers in the Philippines. This insect was considered only a minor pest in the 1950s; the major pests were the sulfur butterflies, *Pieris* spp. (Cendana, personal communication). The sulfurs were edged out by the DBM, which was better adapted to the chemicals then in use (see also Barroga 1980a, 1980b). Support for the above speculation is indirect. Agpad (1954) reported that DBM was an insignificant pest of 'petsai', (*Brassica campestris* spp. *chinensis*) and that endrin, diazinon, ryania, and rotenone were effective against the cabbage moth *Crocilodomia-bionotalis* Zeiler. De los Reyes (1960) and Retuerma (1961) also focused attention on the cabbage moth, a serious pest at that time, and tested endrin, diazinon, and DDT for controlling this insect. It was only later that insecticides were tested against DBM (Barroga 1967, Cadapan & Gabriel 1972, Calora et al. 1968, Sanchez et al. 1968). Even granular insecticides were tested (Calora et al. 1968, Pajarillo 1978).

The development of resistance is further attested to by the number of compounds which were effective against DBM when first introduced, only to become ineffective later – Barroga (1980) gave an extensive summary of these. Furthermore, in a survey of 155 farmers in 1982, it was shown by this author's group (Magallona et al. 1982) that cypermethrin, triazophos, *B. thuringiensis*, cartap, fenvalerate, deltamethrin, and methamidophos were most widely used (Table 1). These compounds, especially the pyrethroids, were introduced only in the 1970s.

Some limited topical toxicity data is also worth mentioning, keeping in mind that to a limited extent, it serves as a verification technique. Barroga (1974) conducted a survey of DBM populations for resistance. In general, DBM populations from 12 vegetable-producing areas were highly resistant to methyl parathion, malathion, DDT, diazinon, and dichlorvos, in that order. These compounds were earlier widely used for DBM control. Barroga (1974) further selected two of these resistant populations for testing against four newly introduced organophosphate and carbamate insecticides, namely, acephate, methomyl, methamidophoss, and quinalphos. The populations used were the mevinphos-resistant Baguio strain and the mevinphos-susceptible College strain. Filter paper impregnation and foliage treatment were used. The College population was resistant to methomyl and quinalpos. On the other hand, the mevinphos-resistant population exhibited cross-resistance to acephate and methamidophos, whereas the mevinphos-susceptible strain was still susceptible to these two compounds. Both populations were resistant to methomyl and quinalphos. At the present time, none of these four compounds are effective against the DBM.

Magallona et al. (1982) also reported the comparative topical toxicity of selected insecticides over time (Table 2). It will be observed that on the average, there was a 100 times increase in LD_{50} value in the 1982 collections compared to the 1978 collections in the Baguio-La Trinidad area.

To get around the problem of resistance, farmers resort to mixtures of two or more compounds. The 1982 survey showed that about 50% of the farmers interviewed used mixtures (Magallona et al. 1982). A 'hit-or-miss' method is practiced and transfer of knowledge is by word of mouth.

Table 1. Main insecticides used in Baguio-La Trinidad Area, 1982.

Insecticide	Users	%
Cypermethrin	29	18.7
Triazophos	26	16.8
B. thuringiensis	21	13.5
Cartap	19	12.2
Fenvalerate	19	12.2
Decamethrin	18	11.6
Methamidophos	11	7.1

Table 2. Changes in toxicity of different insecticides tested against DBM.

Insecticide	LD_{50} (mg/kg) 1978	1982
Deltamethrin	0.0005	0.09
Fenvalerate	0.001	0.45
Rotenone	0.002	0.28
Mevinphos	0.002	0.07
Triazophos	0.01	2.8

Some researchers have tried to provide a rational basis for the practice. Thus, Morallo-Rejesus and Eroles (1973) tried pairing such compounds as EPN, mevinphos, malathion, dichlorvos and carbaryl while Barroga (1980a) elucidated the mechanism of joint action of insecticides on malathion-resistant DBM.

DIFFICULTIES IN RESISTANCE STUDIES

Notwithstanding the enormity of the problem, why is it that so little has been done? Why has the farmer been left to his own devices in dealing with the problem, short of continuous introduction (and subsequent withdrawal) of insecticides? To better understand the problem requires an examination of the realities in developing countries:

a. An inadequate pool of expertise – In the Philippines, which prides itself with having the most advanced research culture in Southeast Asia, there are very few people who are capable of doing research on insecticide resistance. They are also involved in what they perceive as other important areas of research. Furthermore, the pool of academic and line agency administrators is usually drawn from the circle of scientific people who distinguish themselves, further diminishing available scientific manpower.
b. Inadequate support – There is generally inadequate financing of research projects at the local level. Furthermore, while the problem is appreciated by administrators, there is the priority-setting exercise which places resistance studies low in the budgetary totem pole. A more serious problem for an in-depth study is the lack of appreciation for the need of support facilities, e.g., a synthesis laboratory.
c. Absence of focus on using end results – The main issue that we have to grapple with is: Of what use will the knowledge on resistance mechanisms be, and who is going to take advantage of this knowledge? I submit that there is not much a scientist in a developing country can do. In the end, it is the multinational chemical companies that will profit. So the question could be tossed back to them – Why not invest on resistance research, especially on a consortium basis?

CONCLUDING REMARKS

The researchers on pesticide resistance can do only so much under the present circumstances, notwithstanding their own realization of the problem as well as their sympathy for the small farmer. Government and private agencies should spur further work on this topic in line with their commitments to a better future for mankind.

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THE STATUS OF PEST RESISTANCE TO INSECTICIDES IN INDONESIA

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Rice is the main food crop in Indonesia and has been grown for centuries. More than 70 species of insect pests are recorded on rice in Indonesia, among which 20 species such as plant and leaf hoppers, stemborers, leaffolders, and gall midge are major pests often causing significant economic losses. There are also minor pests on rice, and these cannot be ignored as they may become major pests whenever the conditions are suitable (Suhardjan & Iman 1974).

The brown planthopper (BPH) *Nilaparvata lugens* Stal, previously considered a minor pest, has become a major threat to rice production since 1970, especially in the main rice growing areas of Java, Sumatra, and Sulawesi. Although it is difficult to determine the losses due solely to insect pests precisely, field observations and experiments have shown that proper application of insecticides can reduce damage and yield loss (Dandi 1974).

Cabbage is a cruciferous crop facing potentially serious insect problems. The diamondback moth, *Plutella xylostella* L. and *Crocidolomia binotalis* are two major pests reducing production in terms of yield and quality. Heavy infestations of diamondback moth in the dry season cause up to 100% yield loss if no insecticides are used (Sudarwohadi 1975), while in the wet season the yield loss is 30% (Sudarwohadi and Eveleens 1977).

INSECTICIDAL CONTROL

Various control measures have been adopted in order to overcome insect pest problems. The IPM concept was initiated in 1974 and improved from year to year. Major tools which are widely practiced by farmers for controlling brown planthoppers are the use of resistant varieties, cultural practices and insecticides.

The introduction of resistant varieties has led to the development of BPH biotypes in Indonesia. The use of insecticides has also increased simultaneously with the increase of BPH infestation and total area planted. Among the insecticides distributed, diazinon and carbaryl have been used for the longest time in Indonesia for general rice pest control including BPH. Since the early years, many other compounds including granular formulations have been introduced. Whenever a sudden outbreak of BPH occurs, aerial spraying with an ULV formulation is often done to cope with large areas affected and to obtain quick control.

The extensive use of insecticides in horticulture, particularly on cabbage, was done earlier than on rice. It started with arsenicum, pyrethrum, and derris in the 1930s and was followed by DDT in the 1940s and Toxaphene in subsequent years (Ankersmit 1953).

More than 100 insecticide trade names belonging to the organophosphate, carbamate, synthetic pyrethroid compounds and its combinations, are registered for food crop protection in the country (Anon. 1985). The ratios of organophosphate and carbamate compounds expressed in percentages are shown in Table 1. The yearly increase in total amount of insecticides distributed for the intensification program of rice and secondary crops is shown in Figure 1 and the total land planted with rice is shown in Figure 2. Despite the cultivation of resistant varieties due to fear of crop failure, many farmers are applying insecticides routinely, and very often, excessively.

INSECTICIDE RESISTANCE

Insecticides have been well adopted by farmers and are widely used because of their quick effects against insect pests. On the other hand, it is well known that large-scale and inappropriate use of insecticides may create serious environmental and ecological problems. The continuous use of insecticides has also led to the development of resistance in many places (Nagata and Morita 1974).

The first evidence of insecticide resistance in Indonesia was recorded in 1951, when DDT became ineffective against the diamondback moth *Plutella xylostella*. This compound was replaced first by Toxaphene, and then by BHC. Up to 1982, no study was done on insect resistance even though organophosphates and synthetic pyrethroids were intensively used for controlling the insect.

In 1982, Dandi et al. (1982) reported that *P. xylostella* collected from Lembang, West Java, were resistant to permethrin, and Iman et al. (1985) recorded differences in insect susceptibility to organophosphate and synthetic pyrethroid depending on the locality and origin of insects. Detection of insecticide resistance of rice pests has focused on BPH, the number one pest in Indonesia, which has undergone selection pressure with several insecticides.

In 1977, we initiated a study on BPH resistance to insecticides. Eight populations of BPH collected from West and Central Java were treated individually with diazinon and carbaryl using a micro topical application method. Based on the LD_{50} values, no differences of susceptibility level among the

Table 1. The ratio of organophosphate and carbamate compounds distributed in Indonesia, expressed in percentages.

Compound	1978	1979	1980	1981	1982	1983	1984	1985	1986
Organo-phosphate	86	85	78	72	72	71	70	70	65
Carbamate	14	15	22	28	28	29	30	30	35

Source: Badan Pengendali Bimas, Jakarta.

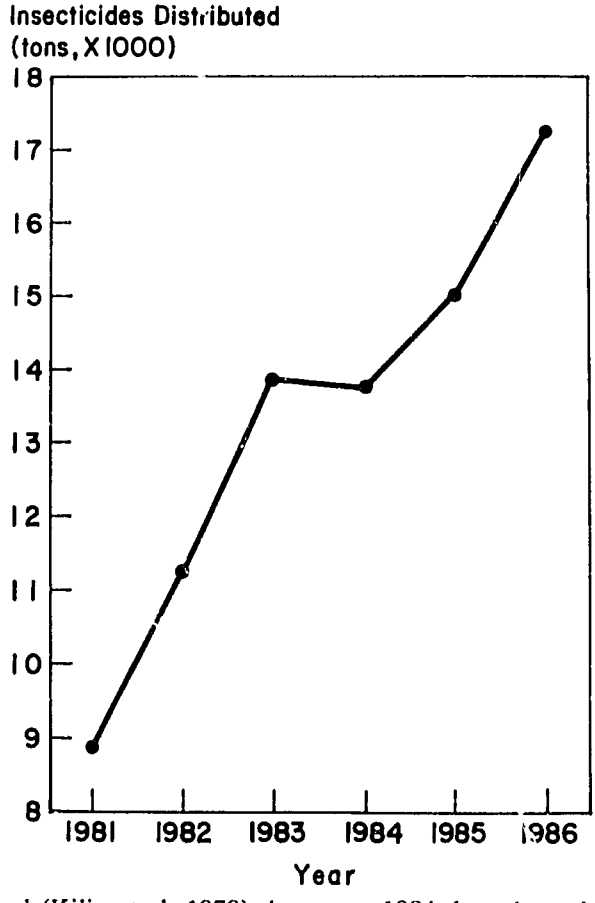

Figure 1. Total volume of insecticides distributed in Indonesia, 1981–1986.

populations were obtained (Kilin et al. 1979); however, 1984 data showed a threefold increase of LD_{50} values (Sutrisno, BCPIF, unpublished).

In 1986, four populations of BPH collected from Segunung, Bantul, Sleman and Boyolali, Java, were tested with several insecticides, including diazinon and carbaryl. A comparison of the obtained LD_{50} values with previous data showed there was no clear evidence of insecticide resistance in the insect. A maximum of fivefold increase of LD_{50} values was detected with carbaryl and the lowest LD_{50} value (4.1 ng/female insect) was recorded in the BPH collected from Segunung, the mountainous area where insecticides are mainly used for vegetable crops (Kilin et al. 1987).

From this study, no clear information of BPH resistance to any insecticide marketed in Indonesia was found. This may be due to several factors, such as the low amount of insecticide applied to rice (average being less than 1.0 kg/ha, Table 2), and the frequent change of insecticides due to the availability of many compounds.

A more extensive study is underway to detect resistance phenomena in BPH populations collected from several places in North Sumatra, West, Central, and East Java.

Figure 2. Total area planted in rice in Indonesia, 1981–1986.

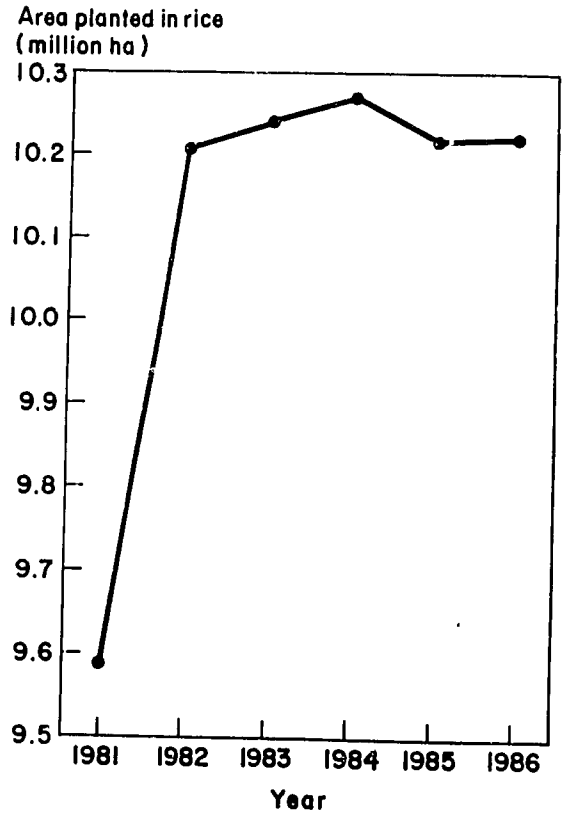

Table 2. Annual use of insecticides in Indonesia (two cropping seasons per year).

Year	1981	1982	1983	1984	1985	1986
l or kg per ha	0.93	1.10	1.35	1.34	1.47	1.69

Source: Badan Pengendali Bimas, Jakarta.

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PESTICIDE RESISTANCE: THE REALITIES

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Natural ecosystems are often represented as stable and balanced, and in a sense, they are. The balance, however, involves life or death competition amongst the species present. Evolutionary advances by one species that alter the balance in its favor thus are made at the expense of others. The forces of evolutionary change are no less at work in agriculture. Agricultural practices reduce the competition offered to crops and animals so they will be more productive. Most crops and domestic animals would not survive long in the absence of that care. It is thus essential that crops and animals be protected and pesticides have a vital role to play in this care.

Resistance has been a problem since the beginning of agriculture. Resistance also does not result exclusively from the use of pesticides against pests. Pests may also evolve resistance to introduced biological controls, including pathogenic parasites and predators; to control measures based upon physical factors; and to mechanical action (CAST 1983). For example, in England and Australia, strains of rabbits resistant to the disease Myxamatosis have appeared. The ploughing of land for the control of weeds has contributed over the centuries to weeds that not only survive such action, but prosper under these conditions. In fact, our most serious weeds thrive only when the soil is disturbed frequently. The development of resistance is part of the endless process of evolutionary adaptation. This phenomenon of resistance is also exploited by plant breeders in the development of new varieties.

THE BACKGROUND ON PESTICIDE RESISTANCE

The discovery of resistant strains of insects, fungi, and weeds is not a recent event. The resistance of insects to certain specific agrochemicals was first reported 79 years ago. Similar observations involving plant pathogenic fungi were made 28 years ago and a resistant weed species was confirmed in 1964.

A survey in 1981 by Georghiou (Georghiou & Mellon 1983) showed that 428 species of arthropods out of an estimated 20,000 insect species had developed strains that were resistant to one or more insecticides that were once effective against them. However, only about 20 out of the 428 are economically important agricultural pests. In 1983, Ogawa et al. (1983) reported 90 or more species of plant pathogens with resistance, and in 1982 LeBaron and Gressel (1982) reported 36 species of weeds with resistance.

The development of resistance is an ever present risk in agriculture. It is the responsibility of all those involved in agriculture – farmers, officials, government, and industry – to ensure that development of resistance does not prevent the continued maximum benefits from the use of existing agricultural practices.

Resistance to pesticides can be explained by current concepts of genetics. The heritable characteristics of organisms are controlled by many genetic elements, the assemblage of which is similar, but not identical in the various individuals that comprise the population. When a pest population in an area is treated with a pesticide, some may survive. These may have genetic properties that protect them against the pesticide. With competition from the susceptible individuals eliminated, the survivors (susceptible as well as resistant) multiply to fill the ecological niche formally occupied by the total population. Repetition of this process will select a pest population containing a high proportion of resistant individuals. Since the selection process involves a change in the genetic character of a population in successive generations, the rate at which resistance develops is greater with pests having short life cycles, e.g., development of a resistant population may take many years with weeds, but as little as two days with intestinal bacteria.

In other words, true resistance occurs when an organism from a population which was initially controlled by a pesticide has lost its susceptibility to the point that it now resists control with that pesticide. Resistance in a pest population progresses through a process of natural selection. This principle of the "survival of the fittest" means that resistance is genetically based and not the result of some adaptation that might occur within the lifetime of given organisms. Contrary to popular belief, resistance to pesticides does not require action on the genetic material by the pesticide.

STRATEGIES TO COMBAT RESISTANCE

Pesticide resistance is of concern to everyone: the farmer, the public, governments and the pesticide manufacturer. It follows that strategies to address the issue must involve all interested parties.

This presents a challenge to the pesticide industry. The industry must supply products to existing agricultural systems over which it has no direct control. At the same time, it must anticipate future problems with resistance and the development of new systems when developing new products. It must also develop methods and strategies to prevent resistance to currently available products.

Two obvious counter-measures can be used:

- A continuing series of pesticides with new modes of action and subject to new pathways of detoxification could be developed, so that new ones are available should the old ones lose their effectiveness.
- A range of pesticides with different modes of action can be used, so that pests are unlikely to develop all of the genetic characters required to acquire resistance simultaneously.

Until recently, resistance was usually overcome by changing to a pesticide with a different mode of action from that to which resistance had developed. However, there are limits to the continued development of pesticides with new modes of action, one of which is the extremely high cost of developing a new compound. Furthermore, existing pesticides are an extremely valuable resource and every effort should be made to retain their usefulness.

In order to do this, fundamental research on resistance is being undertaken. This has already led to the practical use of combinations of pesticides which have delayed or prevented the problem in several fungal diseases. Sequential use of pesticides from different chemical groups has also been shown to be a viable technique in managing resistance problems with mites and insects.

Management plays a vital role in the delay and moderation of pesticide resistance. IPM systems have special relevance, since they are based on harnessing all factors that operate against a pest. Disasters such as occurred in Thailand, whereby the cotton crop was devastated by *Heliothus* through the buildup of resistance to pyrethroids, is an example where a concerted effort by government, industry, and the farmer to implement strategies for the appropriate use of pesticides, could be of major economic significance.

The farmer is by no means helpless in the face of resistance. Practical measures he can take include:

- use of crop varieties resistant to pests and diseases,
- biological control, such as bacteria to control caterpillars,
- strict crop hygiene, which removes sources of infection,
- crop rotation to avoid build-up of a particular pest,
- alternating the use of pesticides,
- using a product containing two or more pesticides with different modes of action,
- following closely the recommendations on dose rate and time of application, and
- varying sowing dates to avoid peak risk periods.

Industry is giving the problem high priority and is playing an important role in the efforts to develop new management systems for dealing with pesticide resistance.

Government and industry must help to promote the dissemination of information about pesticide resistance. More monitoring of crops in the field must be carried out in order to detect the early signs of pesticide resistance, so that strategies can be implemented sooner.

Under the auspices of GIFAP, two groups have been formed: the Fungicide Resistance Action Committee and the Insecticide Resistance Action Committee, which consist of specialists from industry and meet regularly to study the phenomenon of resistance development (GIFAP 1984).

The judicious and strategic use of pesticides to avoid or delay pesticide resistance is in keeping with current concepts of IPM and is vital to the success of such programs.

CONCLUDING REMARKS

Our battle against pests is not inevitably a losing one. There is no indication that we have reached any fundamental limits in our capacity to protect crops. We must realize resistance is a natural phenomenon and one which must be fought with all available weapons to keep the balance in our favor. The resistance problem can be contained, but it requires the understanding and cooperation of everyone.

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HEALTH HAZARDS DUE TO THE USE OF PESTICIDES IN INDONESIA: DATA COLLECTION AND SURVEYS

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The use of pesticides in Indonesia has increased significantly since 1969, with the major usage of these chemicals being in the agricultural sector (Anonymous 1986a, 1986b). It should be noted that 60% of the Indonesian labor force are farmers and most of them are smallholder farmers (Anonymous 1983a, 1984a). The main consumer of pesticides in public health is the Malaria Control Program, as about 12 million Indonesians are threatened by malaria (Anonymous 1984a). Pesticides have been used for a long time and are generally recognized by most people. However, based on field observations, it is known that the public's knowledge and understanding of pesticide toxicity and hazards are very poor, particularly in the rural areas. Consequently, accidents due to pesticide poisoning are not uncommon. Moreover, pesticide residues are frequently found in the environment outside the application target. To solve the problems identified above requires a treatment and prevention program, as will be discussed in this paper.

THE PESTICIDE SAFETY PROGRAM IN INDONESIA

Health hazards arising from the use of pesticide are considered a public health problem in Indonesia. Therefore, since 1 April 1979, the Ministry of Health, through its Directorate of Environmental Health, has been implementing a Pesticide Safety Program to minimize the health hazards of pesticides usage in the country.

The Goal of the Program

The goal of the program is to create a healthy situation for humans and the environment, which is free from the hazards and toxicity of pesticide usage.

Objectives of Program

1. To monitor pesticide poisoning cases,
2. To control pesticide exposure among pesticide applicator groups, and
3. To control pesticide management.

Program Organization

The program has four hierarchical levels:

1. At the central level is the Sub-Directorate of Pesticide Safety, the Directorate of Environmental Health, and the Directorate General of Communicable Disease Control and Environmental Health (CDC & EH). in Jakarta, all with shared responsibility for the program;
2. At the provincial level are the Environmental Health Section (Ministry of Health, Regional Office) and the Sub-Service of Environmental Health (Local Health Services) in 27 provinces;
3. At the regency level are the Environmental Health Section (Regencial Health Services) in 298 regencies; and
4. At the sub-district level are health centers in 3550 sub-districts.

Surveillance units of the Directorate General of CDC & EH and the Provincial Health Services are also involved in the management of the program, especially when pesticide poisoning outbreaks occur. If laboratory confirmations are needed, this work is done by the Provincial Health Laboratory. In this case the Provincial Health Laboratory is under the technical direction of the "Pharmacological Research Center, Institute for Health Research and Development" in Jakarta.

As part of program implementation, 35 personnel (Public Health Officers and doctors) were trained as program managers at the central and provincial levels, and 295 personnel (Public Health Officers) were trained as regency managers during 1980–1984. Training on the Pesticide Safety Program for program managers in the sub-districts has not been conducted due to the lack of a budget. Apart from the training aspects, success of the whole program depends on close coordination of pesticide control in general, especially among the Ministry of Industry, the Ministry of Trade, and the Ministry of Home Affairs (Anonymous 1983b).

PESTICIDE POISONING CASES IN INDONESIA

Acute pesticide poisoning cases in Indonesia are treated as "unusual events." This means that every case of pesticide poisoning is reported within 24 hours to the Directorate General of CDC & EH in Jakarta, and an epidemiological investigation is done to determine the source and cause of the poisoning (Anonymous 1984b). The main performers in acute poisoning control in the field are doctors and sanitarians of the Health Centers and Public Health Officers of the Regencial Health Services.

Suspected pesticide poisoning cases that commonly seek medication in the Health Center are those that show symptoms of severe and moderate poisoning. It is rare that those with symptoms of mild poisoning, particularly rural inhabitants, seek medication at the Health Center or the local hospital. By interviewing some farmers during field visits in seven villages in Java, it was found that, generally, the farmers experienced some symptoms and signs of mild poisoning such as headache, dizziness, fatigue, and malaise. Some of them believed that the symptoms resulted from working too hard. Others considered

that the symptoms were due to influenza and a small sample felt that the symptoms were because of inhaling pesticide. However, all the farmers in the survey felt there was no need to go to a health center, and they believed that the symptoms would disappear the next day.

In a period of eight years (1979–1986), 72 regencies (24%) reported that pesticide poisoning cases had occurred in their working area, and almost all of the reported cases were outbreak events. In Central Java and West Java Provinces, cross checking on the recording of acute pesticide poisoning cases in five regencies was done during January 1987. It is known that during the five years of 1982–1988, in the five regencies concerned, 570 acute pesticide poisoning cases (those that sought medication at Health Centers) were recorded. Only 152 cases (27%) were reported to the Sub-Directorate of Pesticides, Directorate General of CDC & EH in Jakarta. Obviously, 418 single cases (73%) were not reported at all. It should be noted that at the Health Centers, doctors had received no special training to recognize and manage pesticide poisoning. Data on pesticide poisoning cases during the period 1979–1986 in 18 provinces in Indonesia are presented in Table 1.

The cause of acute poisoning accidents is mainly food contaminated with toxic chemicals. An example is a poisoning outbreak which occurred in Boyolali Regency in October 1982. The number of cases was 386, with three deaths. In order to identify the cause of the poisoning, laboratory tests were done on suspected foods. The results showed that residues of DDT, aldrin and dieldrin were found in the samples. Vegetable oil was found to contain eldrin of 2.083 ppm and DDT of 0.917 ppm. Two popular local foodstuffs, "limpung" and fried "tempe", contained DDT of 26.824 ppm; fried cassava contained endrin of 0.032 ppm, dieldrin of 0.003 ppm and DDT of 0.592 ppm; "tempe bongkrek" contained DDT of 1.140 ppm; "sambel pecel" contained DDT of 2.381 ppm; "fried bakwan" contained aldrin of 41.758 ppm, dieldrin of 4.260 ppm and DDT of 51.385 ppm. Victims' vomits were also examined but pesticide residues were not found.

Table 1. Summary of pesticide poisoning cases in Indonesia, 1979–1986.[a]

	Reported by				Toxicant				
Year	Prov	Reg	Case	Death	OP/C	OC	R	PCP	Others
1979	4	24	450	26	7	10	-	46	387
1980	2	7	100	10	-	-	20	17	63
1981	7	11	133	17	51	44	1	-	37
1982	7	16	701	54	-	-	-	-	701
1983	8	11	320	52	220	6	36	-	58
1984	11	11	153	18	74	1	1	8	69
1985	9	15	444	27	93	12	30	-	309
1986	6	13	404	32	37	12	10	-	345
TOTAL			2705	236	482	85	98	71	1969

[a]Prov = Province, Reg = Regency, OP/C = Organophosphate/Carbamate, OC = Organochlorine, R = Rodenticide, PCP = Pentachlorophenol.

A second major cause of acute pesticide poisoning was occupational poisoning, which particularly occurred among pesticide applicators. During 1979-1980, in a sawmill in Central Kalimantan, 63 cases of PCP poisoning with eight deaths were reported.

Pesticide poisoning cases among sprayer groups of farmers were reported to increase during the periods when the density of rice pests was also increasing. However, due to the lack of proper epidemiological investigation in the areas concerned, no quantitative data is available.

Acute poisoning accidents due to ignorance are still prevalent. A very clear example is 'Klerat' poisoning that occurs in transmigrant groups of farmers. 'Klerat' RM rodenticide is brodifacoum with rice bait in the form of released grain. Because of a shortage of food, the transmigrants use this as their food source. Consequently, Klerat poisoning resulted, as follows: in 1980, 20 cases with 6 deaths; 1983, 36 cases with 17 deaths; 1985, 26 cases with 3 deaths; and in 1986, 9 cases with 3 deaths.

The pesticide poisoning data collected in the program were used for:

1. Evaluation of the pesticide safety program,
2. Annual planning of the pesticide safety program,
3. Considering inputs in decision making related to program development, and
4. Interdepartmental consideration of inputs in regulating pesticide management.

Up to 1980 PCP was frequently used in sawmills in seven provinces in Indonesia. Because of the serious PCP poisoning accident, distribution and usage of PCP are not presently allowed by the Ministry of Agriculture. Klerat RM distribution was also revoked and Klerat RM-B replaced.

PESTICIDE APPLICATORS AND THE POTENTIALLY HAZARDOUS SITUATION IN RURAL AREAS

Pesticide applicators are chronically exposed to pesticides, and thus are considered a "high risk" group (West 1969). Because of a lack of understanding on the toxicity and hazards of pesticides, the applicators often create hazardous situations for themselves and their families, for the public and their environment. The Pesticide Safety Program in Indonesia therefore has to control pesticide exposure among the applicator groups, particularly those who live in rural areas. This controlling activity is performed by a team of two public health officers, two analysts and one doctor. During the control activity, two objectives are also fulfilled, namely,

1. The level of organophosphorus pesticide exposure is measured by determining the cholinesterase activity in the blood of pesticide applicators using the Watson & Edson method with a portable Tintometric field kit (Widodo et al. 1978);
2. The Knowledge Attitude and Practice (KAP) of the pesticide applicator groups is studied through field observations and interviews using a prepared questionnaire. The observations particularly aim at collecting data about applicator practices in handling pesticides.

Each respondent was informed of the results of the measurement on cholinesterase activity in his/her blood. Based on the KAP data of the pesticide applicator group, instructions about the safe use of pesticides were then given to villagers and their formal leaders. The results of these surveys are presented in Tables 2, 3.1, and 3.2.

All of the respondents in the rice and horticulture farmer groups were males, while in cacao farmer groups, we found female applicators as well. In plantation XXVI LTD, 9 persons (15%) were female and in Glenmore LTD, 50 persons (75%) were female. Pesticide applicators work part-time only. Their main jobs are farming, trading, etc. In terms of educational background, 36% had never attended any school, while 61% were primary school graduates or non-graduates (Anonymous 1984a).

Based on the KAP study, the situation with farmer sprayer groups in Tiyudan village, Tulungagung, is not encouraging. For the knowledge (K) 63% of them are 'bad'; for the Attitude (A) 73% of them are 'bad'; for the practices, 82% of them are 'bad' in using protective clothing, 69% are 'bad' in personal hygiene and 78% are 'bad' in pesticide waste disposal and in washing spray cans.

The second measurement of cholinesterase activity in the blood of pesticide applicators in Tiyudan village showed a decrease in the pesticide exposure level, from 69% normal in January 1984 to 98% normal in September 1985. The impact of the Health Education in decreasing the pesticide exposure level in this

Table 2. Chronic exposure levels among pesticide applicator groups in Indonesia, 1984–1986.[a]

Pesticide applicator groups	Number of applicators examined	Exposure level			
		Severe	Moderate	Mild	Normal
Rice farmer					
Tulung Agung, East Java					
January 1984	59	-	-	18	41 (69%)
September 1985	60	-	-	1	59 (98%)
Horticulture farmer					
Karo, N. Sumatera					
January 1986	136	-	7	36	94 (68%)
Malang, East Java					
March 1986	128	-	5	11	114 (89%)
Chocolate plantation worker					
Banyuwangi, East Java					
XXVI LTD, Oct. 1986	60	-	1	3	56 (95%)
Glenmore LTD, Oct. 1986	67	-	10	27	30 (45%)

[a]Pesticide exposure levels are based on measurement of cholinesterase activity in the blood, using the Edson method.

Table 3.1 Knowledge and attitude of pesticide applicator groups in Indonesia, 1984–1986.

Pesticide applicator groups	Number of applicators examined	Knowledge		Attitude	
		Good	Bad	Good	Bad
Rice farmer					
Tulung Agung, East Java					
January 1984	59	22(37%)	37(63%)	16(27%)	43(73%)
September 1985	-	-	-	-	-
Horticulture farmer					
Karo, N. Sumatera					
January 1986	137	50(43%)	67(57%)	50(43%)	67(57%)
Malang, East Java					
March 1986	123	55(45%)	68(55%)	64(52%)	59(48%)
Chocolate plantation worker					
Banyuwangi, East Java					
XXVI LTD, Oct. 1986	60	39(65%)	21(35%)	33(55%)	27(45%)
Glenmore LTD, Oct. 1986	67	38(57%)	29(43%)	39(58%)	28(42%)

Table 3.2 Condition of the practices of pesticide applicator groups in Indonesia, 1984–1986.

Pesticide applicator groups	Number of applicators examined	Protective clothing		Personal hygiene		Pesticide waste disposal	
		Good	Bad	Good	Bad	Good	Bad
Rice farmer							
Tulung Agung, East Java							
January 1984	39	7 (18%)	32 (825)	12 (31%)	27 (69%)	8 (21%)	31 (79%)
September 1985	-	-	-	-	-	-	-
Horticulture farmer							
Karo, N. Sumatera							
January 1986	45	22 (49%)	23 (51%)	17 (35%)	28 (65%)	15 (39%)	30 (61%)
Malang, East Java							
March 1986	42	22 (53%)	20 (47%)	15 (36%)	27 (64%)	17 (40%)	27 (60%)
Chocolate plantation worker							
Banyuwangi, East Java							
XXVI LTD, Oct. 1986		-	-	-	-	-	-
Glenmore LTD, Oct. 1986	46	10 (22%)	36 (78)	42 (91%)	4 (9%)	43 (93%)	3 (7%)

group still needs to be proven. In interpreting the data, it is necessary to know that in Tiyudan village, several acute pesticide outbreaks had occurred before, e.g., in 1983 there were 20 deaths out of 48 cases reported; in January 1984, no deaths out of 6 cases reported: and in September 1985, 4 deaths out of 4 cases.

The knowledge and attitude of the pesticide applicator groups in cocoa plantations are relatively better than the other farmer groups studied. However, based on the measurement of cholinesterase activity in the blood of the pesticide applicator groups in Glenmore LTD, 37 persons (55%) were in conditions of mild and moderate poisoning. Field observations proved that female pesticide applicators in Glenmore Ltd Plantation, when applying the pesticide, were not provided with the recommended protective clothing. They used only casual clothing. These experiences show that every pesticide management company, besides performing the training of applicators in application techniques, should also provide recommended protective clothing and information about safe use of pesticides for every pesticide applicator (Anonymous 1983a).

THE DDT FORMULATING PLANT AND ENVIRONMENTAL POLLUTION IN INDONESIA

The main environmental pollution problem attributed to pesticides in Indonesia is pesticide pollution in bodies of water. The pollutant may threaten the health of people, from those who stay along streams to those far away from the source of pollution. Based on field observations and other information, it can be concluded that pesticide pollutants originating from pesticide formulating and wood preservation plants have high priority to be investigated. Pesticide pollution problems in water are aggravated by agricultural waste and by the bad habit of pesticide handlers of dumping unused pesticides in open bodies of water. These problems are serious since most of the rural population still use ponds, streams and rivers as their water supply. The government has set targets for providing clean water to rural inhabitants; in 1984/1985 the target was 36.2% of the total population, while for 1990 it is 60% (Anonymous 1985).

Although clear evidence of disease resulting from pesticide pollution in the physical environment in Indonesia is not available, it is obvious that long-term surveillance efforts on pesticide residues that may escape to critical areas are needed. Because of the lack of resources and experienced personnel, monitoring of environmental pollution is still limited to the DDT formulating plant located in Cicada village, Bogor Regency. A series of samples consisting of water, soil and air has been taken from private residences surrounding the plant. There are five point sampling locations. Point A is about 150 m on the northeast side of the plant, point B about 250 m on the east side of the plant, point C about 300 m on the northwest side of the plant, point D about 200 m on the west side of the plant, and point K as a control site about 3 km northwest of the plant. All water samples are taken from open wells. Air samples are taken based on the Greenburg-Smith impinger system (Mann, undated). Monitoring of the DDT formulating plant has been done periodically and the results fed back to the West Java Province Pollution Control Team, to corrective action if necessary. The results of the monitoring activity are presented in Table 4.

Table 4. Total DDT content in a series of samples taken from residential environments surrounding the DDT formulating plant in Cicadas Village, Bogor Regency, 1985/1986.

Time of examination	Sampling point location[a]	Total DDT contents in: Air samples (n, g/m3)	Water samples (ppb)	Soil samples (mg/kg)
January, 1985	A	255,37	-	37,97
	B	113,97	1,81	9,90
	C	65,00	not found	146,44
	D	96,90	0,78	57,61
November, 1985	A	161,41	-	0,10
	B	8,81	not found	0,13
	C	7,34	not found	3,17
	D	3,21	0,42	0,11
	K	1,00	0,04	0,02
March, 1986	A	36,23	-	4,34
	B	19,46	0,27	0,33
	C	16,43	0,19	1,78
	D	22,27	0,37	0.19
	K	11,90	0,12	0,17
September, 1986	A	-	-	0,11
	B	5,93	0,06	0,42
	C	5,13	0,04	0,17
	D	-	0,02	0,61
	K	not found	0,03	0,07

[a]A = ±150 m Northeast side of the plant, B = ±250 m East side of the plant, C = ±300 m Northwest side of the plant, D = ±200 m West side of the plant, K = ±3 km Northwest side of the plant.

Cicadas Village and the surrounding villages are free from malaria, and the formulation plant has been in operation since mid-1984. The highest level of DDT pollution in the air, water and soil were detected during January 1985, while in the last examination in September 1986, the level of pollution had significantly decreased. This decrease proves that corrective action done by the team is effective. However, we still consider the monitoring for pollutants as insufficient since the formulating plant is operated 24 hours daily. Thus, the surveillance unit attempted to monitor acute respiratory infectious diseases, particularly in infants and those under five years of age. It must be remembered that DDT pollutants in the air may be brought in by air from as far away as 3 km from the source (Oka & Mulyani 1981). The rainy season from October to April further influences the pollution level in the soil.

CONCLUDING REMARKS

Most acute pesticide poisoning cases seem to occur in rural areas among village inhabitants and farmers. This is where the potential hazard area is.

Therefore, the strategy of the pesticide safety program should be focused on people who handle pesticides in the rural areas, especially farmers. All companies involved in pesticide management – manufacturers, importers, distributors, retailers, and plantation companies – should work towards minimizing the hazards in pesticide management. They should also have a budget for pesticide safety equivalent to what is provided for promoting the use of the pesticide. The government on its own cannot solve all the problems associated with pesticides. It may also be time to consider the licensing of all those involved in pesticide handling, such as distributors, users, and pesticide retailers, especially those located in the rural areas.

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PESTICIDE POISONING DATA COLLECTION IN THE PHILIPPINES

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The Philippines is a developing country with a population of about 52 million and an economy which is agriculture-based. The use of pesticides has assumed a very important role in agriculture and public health programs. The demand for pesticides has increased steadily, parallel with the government's massive program to expand agricultural production.

It is unfortunate that the technology of pesticide safety has not paralleled the transfer of agricultural technology in the country. There have been reports of acute pesticide poisoning cases at home, in formulating plants, and in the field. In Nueva Ecija, which is one of the rice granary provinces of the country, reported deaths from pesticides averaged 38 annually between 1973 and 1977 (Maramba 1987). Casanova et al. (1984) cited 253 cases of pesticide poisoning from four government hospitals in Bulacan from 1976 to 1979, with five deaths. Benguet General Hospital in the Mountain Province, which is a major vegetable growing area, reported 97 cases of pesticide poisoning from 1980 to 1982 with 14 deaths. Records at the Philippine General Hospital in Manila reveal that pesticides, particularly organophosphates and carbamates, have ranked among the top three etiologic agents in acute poisoning since 1973.

Reports regarding acute pesticide poisoning in hospitals of the Ministry of Health showed a total of 238 cases in 1982, 563 in 1983, 824 in 1984 and 79 in 1985. The incidence rate was 3.27 per 100,000 from 1982–1985. The type of pesticides involved in these poisoning included organophosphates in 42% of cases, organochlorines in 19%, and carbamates in 14% of cases (Table 1). There was no information in 16% of the cases. Other agricultural chemicals, which include potassium nitrate, urea, plant regulators and others, account for 2% of the cases. Pyrethroids, chlorophenoxy compounds, rodenticides, fungicides, and herbicides comprised less than 3% of the total cases.

Table 2 shows that the peak incidence of pesticide poisoning is in the first four decades of life, with a slight predominance of cases among males (57%). As to the manner of poisoning, suicide accounts for 63% of the cases, occupational for 18%, and accidental for 16% of the cases (Table 3). Case fatality rate was highest for organochlorine poisoning (49%) followed by organophosphorus compounds (16%), as shown in Table 1.

Through a memorandum of agreement between the Ministry of Health (MOH) and the Fertilizer and Pesticide Authority (FPA), all government hospitals are requested to complete and submit pesticide poisoning forms either quarterly or semi-annually to FPA. The Agromedical Services of the FPA then

Table 1. Type of pesticide and case fatality rate, 1982–1985.

Type of pesticide	Cases		Deaths		Case fatality rate
	No.	%	No.	%	
Organophosphorus compounds	714	42.0	116	35.0	16.2
Organochlorine compounds	326	19.1	161	48.5	49.4
Carbamates	238	14.0	10	3.0	4.2
Pyrethroids	20	1.2	-	-	0.0
Chlorophenoxy compounds	18	1.1	1	0.3	5.6
Rodenticides	21	1.2	-	-	0.0
Fungicides	2	0.1	-	-	0.0
Herbicides	22	1.3	2	0.6	9.1
Mixture[a]	36	2.1	3	0.9	8.3
Other agricultural chemicals[b]	39	2.2	3	0.9	7.7
No information	268	15.7	36	10.8	13.4
Total	1704	100.0	332	100.0	19.4

[a]Includes organophosphate and carbamate, organochlorine and organophosphate, organophosphate and pyrethroid, etc. [b]Includes potassium nitrate, plant regulator, urea, etc.

Table 2. Age and sex distribution of cases of pesticide poisoning admitted to government hospitals, 1982–1985.

Age group (years)	Males	Females	Total	
			No.	%
0-10	32	28	60	3.5
11-20	334	295	629	36.9
21-30	352	233	585	34.4
31-40	128	98	226	13.3
41-50	71	40	111	6.5
51-60	31	20	51	3.0
More than 60	26	7	33	1.9
Not specified	5	4	9	0.5
Total	979	725	1704	100.0

Table 3. Manner of poisoning, 1982–1985.

Manner of poisoning	1982	1983	1984	1985	Total	
					No.	%
Suicide	161	487	380	50	1078	63.3
Occupational	33	181	72	17	303	17.8
Accidental	30	145	97	10	282	16.5
No information	14	11	14	2	41	2.4
Total	238	824	563	79	1704	100.0

collate and interpret the data from the forms, which includes information such as the name and address of the person treated; the name of the pesticide; location and date of the poisoning; the route of absorption (oral, dermal, inhalational); the manner of poisoning (occupational, suicidal, accidental); whether the person was hospitalized, and if so, where; symptoms such as headache, anorexia, coughing, etc.; what action was taken to treat the person; and a cholinesterase test.

The FPA instituted the National Pesticide Safety Program in 1979 with the primary objective of training medical and paramedical personnel on the recognition, treatment, and management of pesticide poisoning cases. Through the Ministry of Health, monitoring of pesticide poisoning cases are undertaken at the rural health units, emergency, provincial, and regional hospital levels. To date, about 3705 doctors and paramedical personnel have attended the agromedical seminars. About 412 first aid kits containing supplies for the initial management of pesticide poisoning cases were distributed to the rural health units and the hospitals. Training modules have also been conducted for agropesticide dealers, pesticide applicators and agricultural technicians.

There is under-reporting of pesticide poisoning cases, since cases seen at private hospitals and by private physicians are not included in the monitoring. Likewise, occupational pesticide poisoning cases, particularly in the formulating plants, may not be reported to the authorities.

There is a lack of data regarding effects of chronic exposure to pesticides. A review of aplastic anemia cases at the Philippine General Hospital from 1979 to 1981 revealed that 29% of patients had positive exposure to pesticides ranging from 6 months to 15 years (Giongco-Baylon et al. 1982). Insecticides were implicated in 20 of 70 patients, 12 were farmers, and the rest with varied occupations.

Monitoring of pesticide poisoning cases provides evidence of human exposure to pesticides, determines the exposure trends, and serves as an early warning of emerging problems. It assists the FPA and interested researchers identify studies which should be conducted, determines the focus of the training programs and the effectiveness of existing regulations, and indicates directions for regulatory change.

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PESTICIDE POISONING STUDIES AND DATA COLLECTION IN MALAYSIA

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In Malaysia, the frequent and continuous use of pesticides has brought along with it related problems such as declining efficacy and increasing tolerance among target pests, which have in turn led to increased dosages and, in some cases, more potent compounds to combat these pest problems. Associated with the increased use of pesticides has been an increase in pesticide poisoning cases detected in the country.

Prior to 1985, no official attempt was made in Malaysia to study and record cases of pesticide poisoning. However, figures on pesticide poisoning were compiled by the Malaysian Department of Chemistry from poisoning cases referred to them for analysis of the poison samples. The Ministry of Health, through its hospitals, also kept records of poisoning but these were not officially compiled. The records also did not strictly indicate poisoning from pesticides, but rather, combined all cases of poisoning, whether from drugs, detergents, pesticides or other chemicals.

The Pesticides Act of 1974, which was subsequently enforced in 1976, created improved awareness among the Malaysian public of the dangers of pesticide misuse. It also led to increased attention by the public and government agencies on pesticide poisoning. Incidences of pesticide poisoning then began to be reported with increasing frequency in the mass media. The Department of Agriculture, which also services the Pesticides Board, was aware that the increased use of pesticides was beginning to pose a serious hazard to the health and safety of those handling the chemicals. It was thus prompted to make a serious investigation into this matter, the methodology and results of which are reported in this paper.

SURVEY ON PESTICIDE POISONING

A study was conducted in 1985 by the Department of Agriculture on the pesticide poisoning situation in the country to determine the prevailing status of pesticide usage through systematic information collection (Ramasamy & Aros 1986). The survey was conducted throughout Peninsular Malaysia by staff of the Department. Respondents were classified into four main categories – rice farmers, vegetable growers, smallholders, and estate workers. Interviews were carried out using a standard form containing questions on the crops planted, pesticides used, dosages, poisoning symptoms experienced, remedial action taken, protective clothing worn, and so on.

Results of the survey were sent to the Department's headquarters in Kuala Lumpur for analysis.

RESULTS OF THE SURVEY

The survey showed that there was a 54% incidence of pesticide poisoning amongst all agricultural workers. The highest was noted among estate workers, followed by rice farmers and smallholders. The commonly experienced symptoms were giddiness, skin rash, nail damage, and nasal bleeding. Poisoning incidences were highest among those using paraquat and organophosphate insecticides. With regard to protective clothing used while handling the pesticides, it was found that most common work attire consisted of long trousers, a long-sleeved shirt, hat, and shoes. Some estates were beginning to provide protective equipment such as boots, gloves, face masks, and plastic aprons to their workers. Most of the estates also provided some kind of medical facility and supervision during handling of chemicals for their country workers.

The Pesticides Board has an administrative agreement with the Ministry of Health under which any case of pesticide poisoning received at any government hospital is reported to the nearest agricultural office, which then relays such information to the Board's Secretariat in Kuala Lumpur. For these purposes, a standard form is used. This form (Appendix I) was modeled after the one used by the Ministry of Health to record cases of pesticide poisoning in their hospitals.

Since the Board began collecting reports of poisoning cases due to pesticides in 1985, a total of 75 reports have been received using the prescribed form. Other cases reported came from hospitals. In addition to this, the Pesticides Board also follows reports in the newspapers on pesticide poisoning; based on these, certain cases have been investigated.

ESTABLISHMENT OF A POISON CONTROL CENTER

The Pesticides Board has initiated efforts to establish a Poison Control Center in Malaysia to compile reports on poisoning due to all chemicals (including pesticides) and also to give advice on the treatment of such poisoning. This center is expected to be set up in the near future and will be located within the National University's Department of Pharmacology. It is hoped that with the establishment of this Center, data and statistics on poisoning in this country, including pesticide poisoning, will be better compiled and managed.

ACKNOWLEDGEMENT

The author wishes to express her thanks to the Director-General of Agriculture, and Chairman of the Pesticides Board, Malaysia, Dato' Abu Bakar bin Mahmud, for his continuous encouragement and support in her work, including the publication of this paper. Grateful thanks must also be given to the Ministry of Health for all the cooperation rendered in the Department's efforts to compile reports of pesticide poisoning in the country.

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APPENDIX I

Abstract of form used to report pesticide poisoning (English translation)

REPORT ON PESTICIDE POISONING

Directions - Tick (√) in the appropriate box. One form for one patient.

I. BASIC INFORMATION

1) Name of patient:
2) Identity card no. (if any):
3) Address (home):
4) Age:
5) Sex: [ ] Male [ ] Female
6) Race: [ ] Malay [ ] Indian
   [ ] Chinese [ ] Others (Specify): _____
7) Occupation:
   [ ] Permanent worker [ ] Temporary worker
   [ ] Contract worker
8) Name of person interviewed (if not the patient):
   Relationship to patient:

II. PARTICULARS OF POISONING

9) Date of incident:
10) Where incident happened:
11) How incident happened (accident, suicide, occupational, unknown)
12) If answer to (11) is "accident" or "suicide", answer the following questions:
    12(a) How did accident/suicide happen? (swallowed/drank, splashed on skin, inhaled vapor/spray, others)
    12(b) If "swallowed/drank", how much ?
    12(c) Name(s) of pesticides involved:
13) If answer to (11) is "occupational", then answer the following:
    13(a) State work done when poisoning occurred (spraying pesticide, mixing pesticide, working in pesticide store, others)
    13(b) Name(s) of pesticides involved:
    13(c) How did poisoning occur (inhaled, spilt/splashed on skin, sprayer leaked, others)
    13(d) Equipment used at time of incident (knapsack sprayer, motor blower sprayer, spinning disc sprayer, motorized power sprayer, others):
    13(e) Type of clothing worn at time of incident:
    13(f) When was equipment first provided by employer?
    13(g) Is worker supervised while working?

13(h) Is worker given advice/training in correct handling of pesticide and also safety measures?

14) Poisoning symptoms (giddy, headache, nausea/vomit, stomachache, skin rash, diarrhoea, eye rash, labored breathing, other)
15) Treatment (at hospital, at clinic/dispensary, self-treatment, other)
16) Was patient admitted to hospital?
17) Result of poisoning (died, injured)
18) If treated at clinic/hospital, give address.
19) Date treatment received.
20) Details of poisoning.

III. INFORMATION ON ESTATE (IF APPLICABLE)

21) Address of estate:
22) Has worker ever undergone medical examination using pesticides?
23) Is there a clinic/dispensary on this estate?
24) If yes, when is it open?
25) How often does the medical officer/hospital attendant visit the estate?

Name of Reporting Officer:
Office Address:
Date

PESTICIDE POISONING STUDIES AND DATA COLLECTION IN THAILAND

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The Division of Epidemiology, Ministry of Public Health (MPH) has primary responsibility for collecting insecticide poisoning data in Thailand from epidemiological surveillance activities all over the country. The cumulative data on insecticide poisoning shows a significant number of cases among the 54 notifiable diseases (Table 1).

The National Environmental Board is the government agency that has the most need for data on pesticide poisoning and, therefore, collates such data from multiple sources (Table 2). In 1985, a total of 4046 pesticide poisoning cases were recorded, including 289 deaths from 55 provinces. The conclusion is that most of the poisoning cases are farmers who are exposed to pesticides.

The data in Table 2 were collected through questionnaires. It is assumed that not all the poisoning cases in the country are represented. However, the data do indicate that pesticide poisoning is an important health hazard in this country.

PESTICIDE POISONING STUDIES

No single organization in Thailand is responsible for studying all aspects of pesticide poisoning, and there is no authorized center to allow collaboration in this matter. Many educational and private institutes conduct their own studies and surveys on the different modes of pesticide poisoning.

Table 1. Insecticide poisoning in Thailand, 1977–1986.

Year	Poisoning cases	Cases/100,000	Deaths
1977	1,013	2.33	32
1978	876	1.97	25
1979	1,835	4.04	18
1980	1,851	3.98	15
1981	2,159	4.55	17
1982	2,187	4.51	10
1983	2,353	4.76	17
1984	3,213	6.37	12
1985	2,094	-	-
1986	2,339	-	-

Source: Epidemiological surveillance report.

Table 2. Data collected by the National Environmental Board in 1985.

Chemicals	Poisoning cases		Death cases	
	No.	%	No.	%
Insecticides	3,045	54.38	210	64.81
Herbicides	522	9.32	68	20.99
Rodenticides	441	7.88	10	3.09
Household insecticides	38	0.68	1	0.31
All pesticides	4,046		289	
Others	1,554	27.74	35	10.80
Total	5,600	100	324	100

Acute Poisoning

In some hospitals, biological specimens are analyzed only when laboratory facilities are available. An example of such analyses is that done by Siriraj Hospital (Table 3). The analyses are organized into major groups of pesticides – organophosphate, carbamate, organochlorine, pyrethroid, and some individual pesticides such as paraquat, 2,4-D, zinc phosphide, and arsenic. The data included all cases of accidental, suicide, and occupational poisoning. The results

Table 3. Pesticide poisoning reported in Siriraj Hospital.

Chemicals	1980	1981	1982	1983	1984
Insecticides					
Organophosphate	110	99	50	137	69
Carbamate	20	28	33	20	18
Combined	31	17	20	17	34
Organochlorine	5	17	14	-	8
Other	105	76	98	108	72
Herbicides					
Paraquat	11	5	25	28	24
2,4-D	2	-	-	2	-
Other	15	15	-	-	10
Rodenticides					
Arsenical	27	7	9	13	3
Zinc phosphide	60	41	18	66	34
Combined	8	20	21	4	1
Thallium	-	1	-	2	-
Warfarin	-	1	4	-	16
Other	42	35	46	33	50
Total	436	362	338	430	339

are used as confirmation of diagnosis, normally made from knowledge of the history of exposure and from clinical findings; suitable treatment is decided on by clinicians after consulting all these data.

Pesticide poisoning cases have also been recorded in other hospitals in Metropolitan Bangkok. In interpreting pesticide poisoning data for this area, it should be remembered that there are some plantations near Bangkok. Some investigators (Wongphanich et al. 1985, Pothisiri et al. 1983) have also reported high incidences of pesticide poisoning in selected provinces.

Occupational Poisoning

Under the Health and Safety Regulations of the Labor Law, pesticide formulating plants are required to have their workers checked for cholinesterase levels. Data from one source (Table 4) shows that some workers do have symptoms associated with exposure to cholinesterase inhibitors. Wongphanich

Table 4. Serum and blood cholinesterase levels in worker.

Factory/no. of workers		Subnormal	%
CHI	84	23	27.38
	116	13	11.21
	66	7	10.60
	60	10	16.66
	91	6	6.59
COX	4	-	-
	31	-	-
	28	-	-
	30	1	3.33
	44	2	4.55
HEA	16	-	-
	33	-	-
	27	-	-
	24	-	-
	21	-	-
TIO	5	2	40.00
	17	4	23.53
	18	3	16.66
	20	1	5.00
	17	-	-
SWA	21	-	-
	20	1	5.00
	23	4	17.39
	18	4	22.22
	20	-	-

Source: Thai Industrial Toxicolab Ltd.

et al. (1985) have also reported on a study to determine cholinesterase levels in two groups of pesticide users – farmers and gardeners.

Environmental Exposure

Pesticide residues have been found in the environment and in the food chain, and it is postulated that these may have resulted from extreme use of pesticides and improper safety procedures on the part of those concerned. The Agricultural Toxic Substances Division, Department of Agriculture, Ministry of Agriculture and Cooperatives (MOAC) has a study on good agricultural practice and has also surveyed residues in agricultural products and in the environment. In addition, export commodities are analyzed for pesticide residues.

The Division of Food Analysis, Department of Medical Sciences, MPH has reported on pesticide residues in food (Vongbuddhapitak et al. 1973, 1977, Leelamiar et al. 1976) and on pesticide residues intake (Vongbuddhapitak et al. 1983) and residues in the blood of consumers. The Division of Environmental Health, Department of Health, MPH has conducted studies on residues in soil and water.

Some educational institutes are interested in the study of pesticide residues in food and humans. There are a number of reports, with unpublished data, presented in scientific meetings. In 1987–1989, the National Environmental Board plans to survey pesticide residues in the whole country.

CONCLUDING REMARKS

There are many organizations studying pesticide poisoning in the country, although most of these studies are not well coordinated. An authorized center to facilitate collaboration should be established. This center should also have the capability of supporting investigations in terms of facilities and funding. Methodology for surveys and other aspects of pesticide poisoning data collection would have to be standardized so that the data is of value to policy makers.

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PESTICIDE POISONING: IMPROVING AND EVALUATING PESTICIDE DATA COLLECTION IN SOUTHEAST ASIA

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Pesticides are extensively used in agriculture and in the control of vector borne diseases in the developing world. The situation is unlikely to change in the near future in view of the considerable benefits to agriculture and public health provided by pesticides. At the same time, it needs to be appreciated that such benefits are often associated with hazards to human health, a problem which is of particular relevance to the developing world.

The term "developing world" is one of many terms in current use to describe an important sector of the world, e.g., "nations of the south", "industrializing nations" and "underdeveloped world". It is estimated that the developing world accounts for approximately 73% of the world's population, over 70% of the earth's land mass and about 70% of the world's work force. Thus, the so-called "Third World" is in fact "three-quarters of the world". Furthermore, it is in a growth situation, particularly with regard to the labor force. The International Labor Organization (ILO) estimates that by the end of 1987, six workers out of 10 will live in Asia, one in Western Europe, one in Africa, one in the Soviet Union, and one in the Americas (ILO 1980).

DEFINITION OF PESTICIDE POISONING

The term "pesticide poisoning" refers collectively to any disease or death to which a pesticide or pesticides may have contributed. Further, it is important that a distinction be drawn between acute pesticide poisoning and chronic pesticide poisoning, as the former is a major concern in the nations of the developing world. Acute poisoning implies an acute situation when overt reactions follow closely upon exposure to an agent. Chronic poisoning refers to the situation when the toxic reactions appear gradually after an interval during which exposure to the agent is prolonged. Acute pesticide poisoning situations may be further classified as follows:

1. National
   - 1.1 environmental contamination
   - 1.2 disasters
2. Individual
   - 2.1 accidental
     - 2.1.1 non-occupational

2.1.2 occupational
2.2 intentional
2.2.1 suicide
2.2.2 homicide

In this paper I shall mainly focus on the issue of accidental acute pesticide poisoning of individuals with particular reference to the working population.

MEASURE OF EXTENT OF ACUTE PESTICIDE POISONING

It is important to appreciate the rationale for the need to measure the extent of the problem of acute pesticide poisoning. The main reasons for the collection of such data in the countries of Southeast Asia, part of the developing world, is to provide a basis for controlling the problem, particularly in a manner similar to how it has been controlled in the nations of the industrialized world (World Health Organization 1986).

While the problem seems to have been contained in the countries of the industrialized world in spite of the extensive use of pesticides, it appears that unintentional acute pesticide poisoning is a serious health problem among the countries of the developing world. However, it is also recognized that the problem of acute unintentional pesticide poisoning can be controlled by appropriate safeguards.

Some baseline data on the extent of the problem is necessary before it can be controlled. Unfortunately, the nations of the developing world, in particular the nations of Southeast Asia, have little or no data on the extent of pesticide poisoning in their countries – a situation which needs to be remedied if corrective measures are to be instituted. It was the paucity of such data which necessitated the World Health Organization (WHO) (1973) to make an estimate of the extent of the problem in 1973. It suggested that globally, approximately 500,000 cases of accidental pesticide poisoning occur annually. This estimate was subsequently revised in 1986 and the WHO (1986) then suggested that approximately 1 million cases of unintentional acute pesticide poisoning occur annually with an overall case fatality percentage ranging from 0.5% to 2.0%.

Jeyaratnam (1985) has estimated that globally, approximately 2.5 million cases of acute pesticide poisoning occur annually. But whatever the exact figure, the important issues that emerge are (i) that the problem of acute pesticide poisoning is serious, and (ii) there is a great need for further data on acute pesticide poisoning. It is a tragedy that data is most lacking in the countries of the developing world where the problem is greatest. It is stated that though the industrialized world uses 80% of the world's agrochemicals, it suffers less than 1% of all deaths due to acute pesticide poisoning. This indicates that the problem of acute pesticide poisoning in the industrialized world has been controlled and is no longer a major concern to these nations. Their major concern about pesticides today centers around the possible chronic or long-term health effects, e.g., carcinogenicity, teratogenicity, mutagenicity, etc., which may arise from pesticide usage, whereas the concern in the developing countries must center around the acute health effects, i.e., acute poisoning arising from pesticide usage. The main issues relating to health hazards from pesticides in the

industrialized world is totally different from that of the developing world. It is important that this difference is appreciated and it is for that reason that this paper deals with the issue of acute pesticide poisoning.

Sources of Data

HOSPITAL RECORDS Much of the existing data on acute pesticide poisoning is derived from hospital morbidity and mortality records. Hospital records pertain to 'in-patient' or 'out-patient' situations; the latter suffer from a lack of completeness and hence are of little value for scientific analysis. Further, it must be recognized that even 'in-patient' records are seldom adequate for anything but relatively superficial analysis. The other limiting factor of hospital records on acute pesticide poisoning as a measure of the extent of the problem is that it reflects only a small fraction of the real problem. In a large percentage of patients poisoned, the condition is self-limiting and often requires no active treatment or patients may treat themselves, or seek alternate forms of medical care, hence bypassing the hospital system. The other problems relating to the interpretation of hospital records are:

(i) The lack of denominator data: the episodes of poisoning do not relate to a specific population at risk, hence the data cannot be used to develop morbidity and mortality rates. This feature limits the use of such data for purposes of comparison either internally or with that of other countries.

(ii) Limitation of representativeness of data: the data from one hospital does not represent the situation on a national basis. Thus, it may be necessary that either all hospital data be studied or data from a representative sample of hospitals be studied.

(iii) Validity of diagnosis of acute pesticide poisoning: the diagnosis of pesticide poisoning in the hospital situation is mainly a clinical diagnosis with the criteria for diagnosis being variable and dependent on the characteristics of each individual patient. The use of such diagnostic criteria is unsuitable for epidemiological studies where questions of sensitivity and specificity arise. If the criteria of poisoning for epidemiological studies are too sensitive, then a large percentage of false positives are likely to be included as cases of poisoning. On the other hand, if the criteria are too specific, then some of the positive cases are likely to be left out, thereby increasing the number of false negatives in the study. This problem of validity is particularly relevant to the situation of acute pesticide poisoning as these symptoms are also encountered in many other common clinical conditions. Thus it is necessary to ensure that the criteria for the diagnosis of acute pesticide poisoning be established clearly in any study attempting to assess the extent of the problem.

SURVEY OF EXPOSED POPULATIONS Another approach available to gather data on the extent of acute pesticide poisoning is to undertake a morbidity survey of exposed populations such as (i) agricultural workers; (ii) public health workers, e.g., in malaria, filaria control programs; and (iii) factory workers, e.g.,

in manufacture, formulation, and parking of pesticides. Such methods are time consuming, expensive and need to be well planned. Further, within each category of workers exists great variations of work practices and exposure to pesticides, a feature which is particularly important if attempts are to be made to extrapolate the findings of a study in a given situation. A recent study undertaken by Jeyaratnam et al. (1987) among a community of agricultural workers in Indonesia, Malaysia, Sri Lanka, and Thailand (Table 1) indicated that the problem was quite extensive, confirming the view that hospital records only show a fraction of the real problem.

CONTROL OF ACUTE PESTICIDE POISONING

Finally, the purpose of collecting any data is to identify the factors causing the problem in order that action be instituted to contain the problem. Studies done in the Southeast Asian region show that the major factors contributing to acute pesticide poisoning, particularly among occupational groups, are (i) lack of knowledge among users, (ii) poor implementation of existing legislative controls, (iii) lack of practical protective clothing for pesticide users, (iv) poor maintenance of spray equipment, and (v) unnecessary use of pesticide mixtures. A strategy needs to be developed to remedy the identified deficiencies in order to contain the problem of acute pesticide poisoning. Often the problem encountered is to establish in the minds of decision makers the importance of and the urgency to control the problem of acute pesticide poisoning. This is particularly so in Ministries of Health as they often believe that other health problems have a greater priority. This is not necessarily correct, as studies in Sri Lanka (Jeyaratnam et al. 1982) have shown that the problem of acute pesticide poisoning is greater than those health problems traditionally recognized as being important. For instance, in 1978 more than 1000 deaths were due to acute pesticide poisoning, whereas a total of only 572 deaths were due to poliomyelities, diphtheria, tetanus, and whooping cough, while malaria did not cause a single death.

Table 1. Percentage of workers with pesticide poisoning among agricultural workers and pesticide users (Jeyaratnam et al. 1987).

Country	% agricultural workers ever poisoned	% agricultural workers poisoned/year[a]	% pesticide users ever poisoned	% pesticide users poisoned/year[a]
Indonesia	4.1	0.08	13.8	0.3
Malaysia	13.3	6.7	14.5	7.3
Sri Lanka	4.6	2.7	11.9	7.1
Thailand	8.1	NA	19.4	NA

[a]NA = data not available

Data on acute pesticide poisoning, therefore, helps to establish important considerations for its control. Firstly, the data on acute pesticide poisoning indicates the priority it should be afforded as a health concern in the respective countries. Secondly, the data identifies the sectors of the population at risk and the factors contributing to the poisoning.

CONCLUDING REMARKS

The responsibility for the control of the problem of acute pesticide poisoning revolves around (i) the user, (ii) the national government, and (iii) the agrochemical industry. The participatory role of each of these sectors to make it a joint effort must be recognized by each of the sectors. Too often, confrontational situations have emerged with each sector trying to blame the other, an approach which is without doubt counter-productive. Nevertheless, although a joint effort by different sectors is necessary, Jeyaratnam (1985) stated that the "ultimate responsibility for the control of pesticides must be devoted to national governments but unfortunately controls either do not exist or where present, are poorly implemented". Operationally, a primary health care system should be closely allied to the agricultural sector to ensure the prevention, recognition, and treatment of acute pesticide poisoning.

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ESTIMATING THE IMPACT OF POISONING: CHANGING PATTERNS OF MORTALITY IN CENTRAL LUZON, PHILIPPINES, IN RELATION TO PESTICIDE USE

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The spread of modern cereal varieties, and the adoption of modern farming practices and agrochemicals have made possible major increases in agricultural production in Southeast Asia. However, widespread use of synthetic pesticides by farmers and agricultural laborers, under inadequate safety conditions, has also exposed large numbers of people to occupational intoxication.

The hazards that these workers face may be substantial. "Endrin", an organochlorine insecticide of high oral and dermal toxicity, has been widely marketed in the region. Based on results of a recent study (Lloyd 1983), a person applying the insecticide with a backpack sprayer in good repair, using concentrations typical in the Philippines, and leaving unprotected (as is often the case) his hands, lower legs and feet, would come into direct contact with 41 mg of active ingredient per hour. At that rate, a worker weighing 55 kg would be exposed to 33% of the mammalian dermal LD_{50} (the lethal dose for 50% of a population) in treating an average holding once with endrin. This figure does not include exposure during handling of the concentrate and in mixing, which may be substantial though highly variable.

Efforts to estimate the actual impact of pesticide exposure on the health of field workers in developing countries encounter important methodological problems. Clinical signs of intoxication, notably acetylcholinesterase depression, provide an objective measure. However, the uncertainty of the relationship between cholinesterase levels and morbidity (Anonymous 1985), and difficulties in monitoring representative samples of small farmers or laborers over significant periods, limit the conclusions that can be drawn by this method.

Retrospective studies based on reported cases have also been conducted. In Sri Lanka for example, 13,000 people are admitted to hospital each year for pesticide poisoning, of whom some 1000 die (Jeyaratnam et al. 1982). However, the accuracy of such estimates depends crucially on proper diagnosis and complete reporting. In developing countries, misdiagnosis of poisoning is made more likely by the absence of diagnostic tools, high patient-doctor ratios, unfamiliarity of health workers with the signs and symptoms of poisoning, and lack of access by the poor to the formal health care system.

A different form of retrospective analysis is employed in the present study. In an area of Central Luzon, Philippines where pesticide use has been relatively well studied and where the comparative ease of access to government services makes gross under-reporting of at least adult mortality unlikely, specific changes are predicted in death rates from what is known of the temporal and spatial patterns of use and the clinical toxicology of the compounds in question. A close fit between observation and expectation then allows one to estimate the excess mortality that has occurred. Specifically, it is hypothesized that: (1) increased mortality due to occupational intoxication will be concentrated among men, who are primarily involved in pesticide application; (2) no such effect will be apparent in unexposed urban groups; (3) the trend of death rates over the years will parallel that of pesticide use; (4) within the year, increased mortality will be concentrated in the months of greatest pesticide use and will closely reflect changes in the cropping pattern; (5) the specific death rates of the conditions most likely to be confounded with pesticide poisoning will rise disproportionately and (6) these rates will be significantly correlated with that of diagnosed fatal poisoning.

Hypotheses regarding misdiagnosis are possible as well. In Central Luzon, two types of pesticide of marked acute toxicity have been widely used by small farmers: organophosphate (OP) and cyclodiene and hexachlorocyclohexane (CYC-HCH) organochlorine insecticides. Intoxication by each type can occur by the dermal, respiratory, and oral routes. Symptoms of severe OP poisoning include generalized convulsions, psychic disturbances, intense cyanosis, bradycardia, pulmonary oedema, and coma (Doull et al. 1980, Kaloyanova 1982). Pneumonia, asthma, and bronchospasm are frequently encountered sequelae (Gembitskiy et al. 1981, Bryant 1986, Astolfi 1970). Unpublished observations by Dr. Nelia Maramba and her colleagues at the Philippines General Hospital indicate that when rural doctors were presented with the signs and symptoms of acute OP intoxication in mock examinations, they most frequently diagnosed a variety of cardiovascular and respiratory conditions. Therefore, as the use of OP insecticides rises, misdiagnosis of poisoning will most likely inflate the combined death rates of cardiovascular and respiratory diseases.

CYC-HCH intoxication expresses itself very differently. The primary locus of action of these compounds is the central nervous system (CNS) and severe poisoning is marked by convulsions, generally epileptiform in nature (Ecobichon & Joy 1982, Hayes 1982). Kubrich and Urban (1973) describe a case of apparent dermal intoxication by endrin that under other circumstances would have been diagnosed as stroke. Thus, increasing use of and intoxication by CYC-HCH insecticides will also most likely be followed by rising death rates attributed to epilepsy, brain tumor, stroke, and related conditions (cerebral hemorrhage, embolism, aneurysm etc.) as a result of misdiagnosis.

METHODS

Pesticide use on the Central Luzon Plain, an area of intensive rice cultivation, rose markedly following the adoption of modern varieties in the late 1960s, and particularly as a result of the Masagana 99 credit scheme, introduced

in 1972. A series of insect and virus disease outbreaks, beginning in 1971, served to increase insecticide use. Between 1966 and 1979, insecticide applications on rice rose more than 500%. Compounds in widespread use during the 1970s included carbofuran, endrin, methyl parathion, and monocrotophos (Cordova et al. 1980, Worthing 1979). The liquid formulations sold in Central Luzon are classified as "extremely" or "highly hazardous" by the World Health Organization (WHO).

Aliaga, Jaen, and Zaragoza are rural municipalities (combined 1980 population of 96,000) in Nueva Ecija province. In typical villages, more than 80% of household heads are engaged in rice farming. Farmers typically applied insecticides 4–5 times per crop and treatments were concentrated in the vegetative stage, particularly during the month subsequent to transplanting. Men generally applied insecticides by backpack sprayer without protective clothing (locally unavailable). Since the late 1970s farmers' consumption of insecticides has remained constant or declined slightly.

Cabanatuan (population 138,000) is a nearby center within which are both urban neighborhoods, where occupational exposure to insecticides is likely to be low, and rural rice-producing villages.

Population estimates were taken from the national censuses of 1960, 1970, 1975 and 1980 (DCI 1960, 1970, 1975,1980) and by interpolation. Mortality statistics for 1961–84 were obtained from the civil registries, derived from death certificates. The causes ascribed were noted and entries assigned to one of four age classes: 1–5 years, 6–14 years, and men and women 15–54 years. Deaths due to traumatic causes were excluded, save non-suicidal poisonings ascribed to pesticides or unspecified substances.

As consistent census breakdowns of the rural and urban populations of Cabanatuan were not available, indices of mortality by age class were calculated as the number of deaths in the urban or rural areas divided by the city's population in that year. This will be proportional to the death rate if the urban-rural mix remains constant. Cabanatuan has grown rapidly in recent years as a result of rural immigration and if, as appears likely, most immigrants settled in the urban neighborhood, a given proportionate change in the index of mortality would overestimate the true change in death rate in the urban areas and underestimate it in the rural areas.

For men and women, death rates in the rural municipalities and indices of mortality in Cabanatuan were adjusted to the city's age distribution in 1960 by the direct method.

Trends in mortality in the 1–5 years and 6–14 years age classes were analyzed by means of Armitage's test (Armitage 1971), and by least squares regression of arc sine-transformed rates for men and women (as these had been age-adjusted). However, as the use of insecticides has increased unevenly (rapidly in the years after 1972, slowly or not at all since the late 1970s), a more appropriate analysis of trend would consider mortality in relation to two periods, one of low use (1961–71) and one of high use (1972–84). The t-test was used to compare mean arc sine-transformed rates except in the case of diagnosed poisoning, where a more conservative non-parametric method, the Mann-Whitney U-test was employed because of the few deaths in the early period.

Changes in the proportions were analyzed by means of the appropriate Chi-square test.

RESULTS

Mortality by Age and Sex Classes

While non-traumatic mortality increased significantly since 1961 among men, there was a marked decline among women (Figure 1). The death rate fell as well among children 1–5 years (χ^2 = 58.5, P<0.001) and 6–14 years (χ^2 = 7.20, P<0.01). For men there was no evidence of trend in the 11 years prior to 1972 (r = -0.05, ns), the year that low cost credit became widely available to farmers, nor in the years 1976–84, a period of rough constancy in insecticide use (r = -0.37, ns). Comparing the periods before and after 1972, the mean non-traumatic death rate increased 27.4%, from 2.15 to 2.74 per 1000 (t = 4.09, P<0.001).

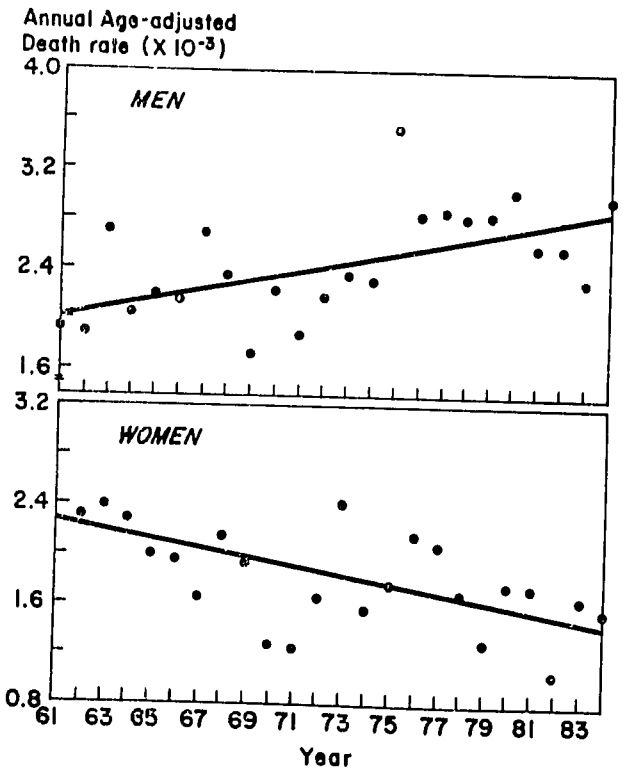

Figure 1. Trends in non-traumatic mortality among men (A) and women (B) 15-54 years in three rural municipalities in Nueva Ecija, Philippines. The regression equations are: A) Y = -41.8 + 0.0226X (n=24, r=61, P<0.01) and B) Y = 46.9 - 0.0225X (r=-0.58, P<0.01), where Y is arc sin-transformed death rate.

Urban/Rural Comparisons

Significant and opposite changes in male mortality occurred in the urban and rural sections of Cabanatuan (Table 1): the index increased 29.3% in the villages ($t = 2.28$, $P<0.05$) but declined 37.2% in the urban neighborhood ($t = -3.14$, $P<0.05$). If, as suggested earlier, the city became more urban over the period, both trends would have been accentuated. Among women in rural Cabanatuan, the index of mortality did not increase significantly ($t = 1.12$, ns), whereas in parallel with men, there was a marked decline in the urban areas, amounting to 52% ($t = -5.45$, $P<0.001$).

Causes of Death

Mortality due to diagnosed poisoning increased 247% ($U = 29$, $P<0.01$) and that due to potentially related conditions 41% ($t = 4.53$, $P<0.001$) between the periods of low and high use of insecticides (Table 2). As expected, there was a

Table 1. Trends in indices of mortality among men 15–24 years old in rural and urban areas of Cabanatuan, Philippines.

	1961–71	1972–84
Rural	1.84±0.180 *	2.38±0.138
Urban	1.64±0.210	1.03±0.058

*Mean index/1000, ± standard error.

Table 2. Trends in specific death rates among men 15–54 years in three rural municipalities in Nueva Ecija, Philippines.

	1961–71	1972–84
Diagnosed pesticide poisoning	2.39±1.34*	8.29±2.30
All potentially confounded conditions	130±9.20	183±7.10
Cancer (all sites except brain)	21.1±3.49	25.9±4.02
All other causes	62.0±6.04	41.1±4.62

*Mean rate/100,000, ± standard error.

significant correlation between the two time series ($r = 0.47$, $0.01 < P < 0.02$). The detailed pattern of increase in these cases has been similar to the trend of overall male mortality: death rates were low prior to 1972 (fatal diagnosed poisonings were recorded in only three of 11 years between 1961 and 1971), rising rapidly thereafter and remaining roughly constant after the late 1970s. In contrast, the death rate from all other causes, except cancer, declined 33.7% ($t = -2.78$, $P < 0.02$) over the period.

Though this paper focuses on the impact of acute intoxication, chronic effects are also expected. Several insecticides in widespread use in Central Luzon are suspected carcinogens, including DDT and endrin (IARC 1974, 1979). Though overall cancer rates (excluding brain tumor) have not increased significantly (Table 2), marked changes have occurred in the death rates for specific cancers, notably leukemia. Growing evidence suggests a link between exposure to insecticides, both organochlorine and organophosphate, and subsequent development of this disease (Lorand et al. 1984, Linos et al. 1978, Blair et al. 1983). In the three rural municipalities, mortality among men attributed to leukemia increased 480%, from 0.6 to 3.6 x 10^{-5} between the 1961–71 and 1972–84 periods ($\chi^2 = 4.5$, $P < 0.05$). The rise has been most marked in recent years: 7 of the 11 cases recorded since 1961 occurred in the six years 1979–84.

The proportion of deaths attributed to acute pesticide poisoning and the conditions potentially confounded with it has increased significantly in both the rural municipalities ($\chi^2 = 20.7$, $P < 0.005$) and the rural sections of Cabanatuan ($\chi^2 = 15.7$, $P < 0.005$). No significant change is apparent in the urban neighborhoods ($\chi^2 = 1.78$, ns) (Table 3).

Among the conditions that were likely to be confounded with CYC-HCH intoxication, by far the most frequently recorded in the study area was stroke.

Table 3. Proportion of deaths attributed to diagnosed pesticide poisoning and the conditions potentially confounded with it among men 15–54 years in three rural municipalities, and in rural and urban sections of Cabanatuan, Philippines.

Location	1961–71	1972–84
Rural municipalities	46% (378)*	60% (755)
Cabanatuan:		
rural	49% (412)	61% (908)
urban	53% (368)	58% (384)

*Values in parentheses are total deaths during the period.

While the specific death rate for all men rose significantly between the 1961–71 and 1972–81 periods ($\chi^2 = 49$, $P<0.005$), the increase was greater among younger men normally at low risk of stroke (Table 4, A). Among those 15–24 years, no deaths attributed to stroke had been recorded before 1972, whereas 20 were noted from 1972 to 1982.

During the wet season of 1982, the Philippines Fertilizer and Pesticide Authority banned the use of endrin, previously the most widely used and acutely toxic CYC-HCH insecticide available to small farmers. In the following two years, the mortality attributed to stroke declined for all men compared to the incidence immediately before the ban ($\chi^2 = 4.8$, $P<0.05$), but again to a significantly greater extent in the younger age class ($\chi^2 = 3.8$, $P<0.05$; Table 4, B).

The Monthly Distribution of Mortality

In the vicinity of Cabanatuan, the wet season crop is generally transplanted in late July and August. Also, since the completion of a large irrigation scheme in 1976, a dry season crop is planted in late January and February. As insecticide use is greatest immediately following transplanting, one would expect the increase in acute occupational poisoning to be concentrated in these months.

Figure 2 illustrates the monthly ratio of observed-to-expected mortality during two periods, where the expectation is taken from the monthly distribution of deaths from 1961 to 1971 when insecticide use was low. During the 1972–75 period (Figure 2, A), before irrigation made two crops a year possible, the ratio was greatest in August, the month of maximum insecticide use in the wet season. When double-cropping became widespread (Figure 2, B), the two largest peaks are observed in February when insecticides are most intensively used

Table 4. Mortality attributed to stroke among men 15-54 years in Cabanatuan and three rural Philippine municipalities combined in: (A) periods of low and high endrin use; (B) the two years immediately prior and subsequent to the ban on endrin's use.

Age class (years)	A Death rate[a] 1961–71	A Death rate[a] 1972–82	A % Change	B Death rate[a] 1981–82	B Death rate[a] 1983–84	B % Change
15–34	4.59 (12)[b]	18.0 (70)	+291%	26.0 (27)	9.91 (11)	-62%
35–54	33.2 (41)	80.9 (135)	+144%	91.2 (38)	79.1 (34)	-13%

[a]per 100,000. [b]Values in parentheses are numbers of deaths.

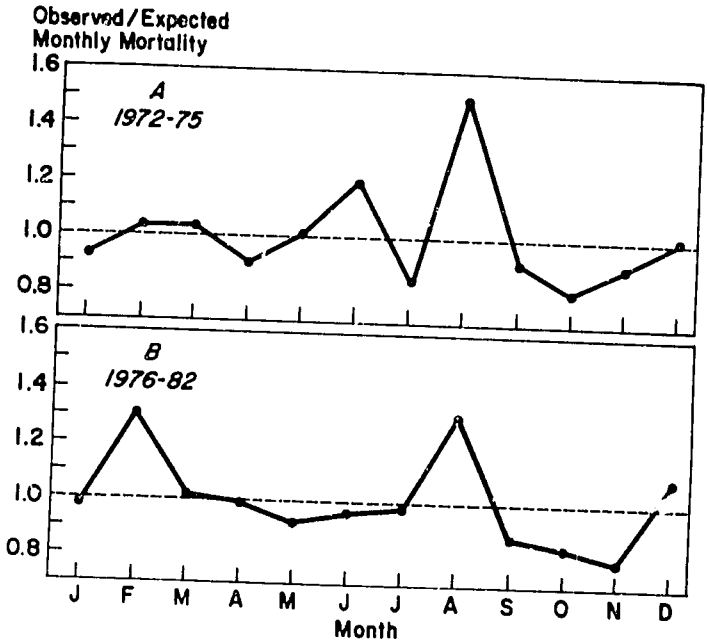

Figure 2. Ratio of the observed to the expected number of deaths among men 15-54 years in the rural areas of Cabanatuan, Philippines. A: a period of intensive insecticide use and predominantly single cropping. B: a period of intensive insecticide use and predominantly double cropping.

during the dry season crop, and again in August. A straightforward method of testing the significance of this pattern is to calculate the prior probability of the two highest peaks coinciding with the months of greatest insecticide use in the wet and dry seasons: $P = 1/12 \times 1/11 = .008$.

Despite local differences in cropping schedules, August is a major period of transplanting and insecticide application during the wet season in the three entirely rural municipalities. Taking all rural areas together, the proportion of deaths among men during August rose from 7.3% in 1961–71 to 10.1% in 1972–82 ($\chi^2 = 4.7$, $P<0.05$).

DISCUSSION

The data presented here provide strong evidence linking a marked increase in mortality in Central Luzon to occupational exposure to insecticides. Only men in rural areas have been affected, both within and between years; male death rates have reflected the pattern of insecticide use, and increased mortality has been concentrated in those conditions potentially confounded with pesticide poisoning. This latter trend is most striking in the close relationship between endrin use and

deaths attributed to stroke. The evidence is retrospective in nature; however, the close fit between observation and expectation lends credence to the postulated causal relationship.

It is important however to consider other factors that may have contributed to the observed changes in mortality.

1) Impoverishment due to falling rural incomes in the region (Cordova et al. 1980) might in part account for the changing monthly distribution of mortality, if its impact is greatest during periods of notable stress. These may occur for men early in the agricultural season during land preparation. However, widespread reduction in the food supply of near-subsistence communities is generally thought to affect young children in greatest measure (Gupta 1979), whereas in the study area only death rates among men were found to have risen.
2) Increased tobacco consumption among men might contribute to some of the observed trends, notably an increase in respiratory and cardiovascular diseases. Conflicting results emerge from studies concerning the link between smoking and stroke (Doll & Hill 1964, Nomura et al. 1974, Abbott et al. 1986), however, none report a disproportionately increased risk for those under 35, or even 25 years, as found here. Moreover, though smoking appears to be at least as prevalent among urban as rural men, mortality has fallen markedly in the urban neighborhood.
3) Greater efficiency in the reporting of vital events would result in an apparent but spurious rise in death rates. However, specific biases in reporting are required to account for the selectiveness of the observed increases: death rates for men have risen faster than for women, those in August faster than in the rest of the year, etc.

The overall increase in non-traumatic mortality among rural men between the periods of low and high use of insecticides was estimated at 27%. The actual occurrence of fatal poisoning may well be greater than this figure suggests, if one assumes that in the absence of exposure, mortality would have declined as it did among women and children in the rural areas and among men in urban Cabanatuan. Extrapolating, even on the basis of the 27% value, to other rice-growing areas in the Philippines and elsewhere in Asia where pesticides have been widely adopted suggests an annual excess mortality of several tens of thousands. The figure of 10,000 deaths worldwide from accidental and occupational poisoning that is often cited (WHO 1973, Copplestone 1977, Boguerra 1985) must, on this evidence, be considered a serious underestimate. That it is economically-active men, often the heads of households, who are most at risk of intoxication implies that the overall social impact is greater than such numbers alone indicate.

CONCLUDING REMARKS

Further epidemiological research may be required to catalyze the political will to effectively confront the issue of poisoning in smallholder agriculture. Rigorous prospective or case-control studies may be impossible to carry out ethically and under rural conditions with the resources generally available to

researchers. Techniques similar to those discussed in this paper may be used in other areas where the registering of deaths has been reasonably complete, and the pattern of pesticide use adequately documented. Participatory research techniques may also be considered as a means of awakening concern among a population at risk of intoxication. A number of alternatives to exclusive reliance on synthetic insecticides in rice cultivation now exist, including varietal resistance, cultural and biological controls. These will require vigorous adaptive research to make them accessible to the majority of farmers. It is important that, as far as possible, medical and agronomic research and extension be integrated, and that the diagnosis of the medical problem be followed by testing of pest control techniques that reduce exposure without sacrificing farm revenues.

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PESTICIDE RESIDUES IN THAILAND

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Pesticides are now used more extensively in crop protection in almost every country in Southeast Asia. Tropical areas are generally characterized by high temperature, precipitation, and humidity. This condition permits the continuous presence of certain insects and diseases, which pass through more generations than in temperate climates. Crop losses and reduction in productivity vary from year to year and region to region, but an average of approximately 15–30% of annual crop produce is lost to insects, diseases, and weed competition. Plant protection measures, mainly with the use of chemical pesticides, are regularly applied to crops, especially those which give substantial returns. The results from pesticide usage have generally been economic, effective, and convincing. But after years of intensified use of pesticides, ecological shifts in insects and diseases, increasing costs of plant protection, resistance to pesticides, pesticide residues, environmental pollution, and pesticide poisoning have created serious problems.

PESTICIDE USE IN THAILAND

Thailand, which is a major food exporter, has the same problems as other countries in the region concerning pesticide management. The major food crops comprise rice, cassava, maize, etc., and have been under pest infestations for many years. Pesticides, including herbicides and fungicides, have been employed for pest control purposes using a number of application techniques. More than 60% of pesticides in Thailand are applied for the control of rice, cotton, and vegetable pests. The rate of consumption of pesticides has increased rapidly over the past twenty years; the quantity of pesticides imported between 1976–1985 are shown in Figure 1.

The pesticides imported into Thailand during the early years were in the form of finished products. Technical grades of active ingredients were subsequently imported and formulated locally.

One of the problems associated with pesticide effectiveness is the low quality of the pesticides sold in the market in Thailand. A survey was done by the Division of Agricultural Toxic Substances in 1983 on 373 randomly selected pesticide formulations. These were collected from farmers and markets, and then analyzed for active ingredients. The results showed that only 56% of the samples had the active ingredients correctly labeled. The other 44% of the samples included about 5% of compounds entirely different from what was claimed on the labels. The problem of falsified products needs to be improved by strong enforcement of the pesticide regulations, because not only will it lead to failure in pest control, but will create residue problems later on.

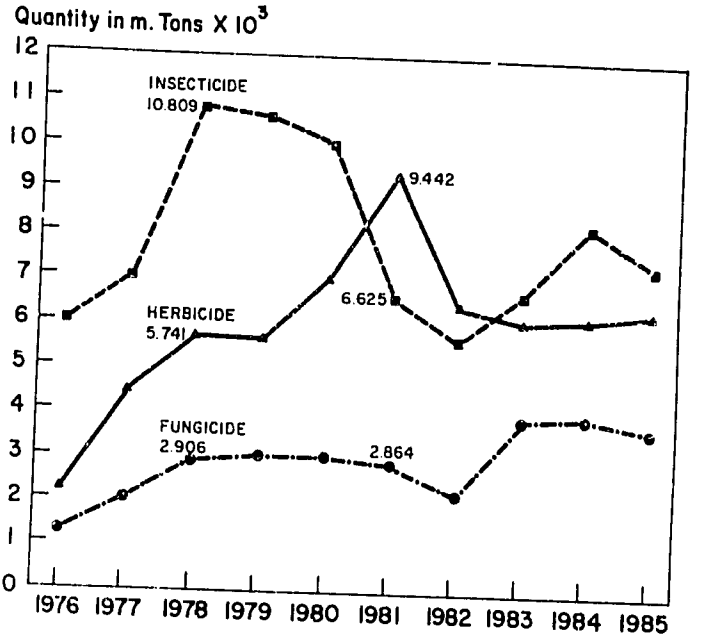

Figure 1. Quantity of pesticides imported into Thailand, 1976–85.

PESTICIDE RESIDUES IN ENVIRONMENT

A large amount of data on persistence, metabolism, and movement of organochlorine insecticides in the environment, and their probable entry into crops, has been made by many researchers all over the world. The findings have indicated the relatively long persistence of certain organochlorines, which have been in use since 1945. In Thailand, the survey and monitoring of pesticide residues in the environment has been conducted by many institutes since 1976, with the main activity by the Division of Agricultural Toxic Substances, Department of Agriculture. The results obtained are presented in Table 1.

Table 1. Pesticide residues detected in the analysis of environmental samples, 1976–1985.

Type of samples	Collection sites	No. of analyzed samples	Positive samples No.	%
Water	rivers, canals and reservoirs	1644	831	50.5
Sediment	rivers, canals and reservoirs	602	542	90.0
Soil	agricultural areas, crop fields and orchards	1005	971	96.6
Fish and shellfish	markets, rivers and canals	1283	1162	90.6

The analyses showed that trace amounts of organochlorine persisted in 50% of 1644 water samples and 90% of 602 sediment samples collected from 30 main canals, rivers and water reservoirs for drinking. Besides several kinds of organochlorines, traces of organophosphates such as dimethoate, diazinon, malathion, methyl parathion, fenitrothion, and profenophos were also found in water, sediment and soil, especially in the soil taken from cropped fields and orchards.

Organochlorine insecticides -- mainly DDT, endrin, aldrin, and dieldrin – which were most frequently found in environmental samples, have been used for more than two decades in plant protection, and DDT also in malarial eradication in Thailand. Until recently, with the evidence that DDT has become widely distributed in the food chain and the environment, and that it is a dangerous substance, its use in agriculture has become limited. DDT is now permitted only for the control of malaria. The insecticide, endrin, was subsequently banned from use in Thailand in 1981 for the same reasons. The persistent organochlorine pesticides appear to have been widely distributed in all agricultural areas through ditches and canals, to accumulate in sediment and soil and end up in living organisms such as fish and wildlife. For example, 90% of samples of fish and shellfish, both marine and fresh water, collected from market places and water sources in central Thailand contained residues of DDT, aldrin, and dieldrin. However, the levels detected were not alarming.

An investigation on pesticide residue levels in birds was conducted in 1980 by Tayaputch and Mahittikurin (1980). Ninety birds collected from the central plain area were classified into 30 species and divided into 5 groups according to their feeding habits. Results of analyses for pesticide residues in stomach contents, livers and tissues are shown in Table 2. Traces of 14 organochlorine pesticides were identified, with the most commonly found being DDT and dieldrin. The concentration of residues varied from tissue to tissue and the results indicated that DDT and dieldrin detected in the samples were related to feeding habits of birds. The pesticide levels found were mostly lower than 1 ppm, which has been reported in several studies to be harmless to treated birds in laboratory experiments (Bernard 1966). However, the combined effects of multiple residues on birds and their long-term consequences should be carefully examined.

Table 2. Pesticide residues in ppm (ug/g) in stomach contents, livers and tissues of five groups of birds (fresh wet weight).

Group	Residues of total DDT			Residues of dieldrin		
	stomach	liver	tissue	stomach	liver	tissue
Carnivorous	0.09	0.17	0.10	0.08	0.09	0.03
Herbivorous	0.10	0.17	0.05	0.07	0.12	0.03
Omnivorous	0.20	0.11	0.04	0.14	0.08	0.03
Insectivorous	0.19	0.31	0.12	0.09	0.12	0.06
Birds of prey	0.25	0.30	0.13	1.05	0.03	0.16

PESTICIDE RESIDUES IN AGRICULTURAL PRODUCTS

The preliminary surveys carried out by the Department of Agriculture from 1972 to 1981 on more than 2000 samples of agricultural products revealed that a relatively large number of samples were contaminated with residues of the organochlorines. The more extensive studies from 1982 to 1985 (Table 3) showed that besides organochlorine, organophosphate and carbamate were also found to be present in the collected samples. In this study, the organochlorine residues were mainly BHC, heptachlor and its epoxide, aldrin, dieldrin, endrin, DDT, and metabolites. The organophosphate residues were Dimethoate, methyl parathion, parathion, methamidophos, mevinphos, monocrotophos, diazinon and dichlorvos. The carbamate residues were mainly Methomyl and carbofuran. Fungicide residues were Captan, benomyl, and mancozeb. Miticide residues was Dicofol.

PESTICIDE RESIDUES IN HUMANS

Pesticides can be introduced directly or indirectly into the human body by exposure to or consumption of food containing residues. The persistent pesticides accumulate in the human body through food chains and find their way into fat deposits in the liver, and to the kidney, brain, blood, and breast milk. During 1980–1983, about 392 samples of blood (DOA 1980, 1983) were drawn from 112 farmers and 280 other people of unidentified professions and analyzed for pesticide residues. Residues of organochlorines – mainly DDT, heptachlor and its epoxide, and dieldrin – at ppb levels were discovered in about 20% of the blood samples, with average levels substantially higher in the farmers' group.

Pesticide residues in breast milk were first reported in 1951 by Laug et al. (1951), who found DDT in 30 of their 32 samples. Since 1951 and particularly since the introduction of multiresidue screening by gas chromatography, various studies have reported on levels of organochlorine pesticides in breast milk throughout the world.

Table 3. Pesticide residue analyses on agricultural products during 1982–1985.

Type of sample	No. of samples analyzed	Component
Vegetables	66	Cabbage, cauliflower, Chinese kale, string bean, green mustard, sweet corn.
Fruits	85	Grape, rose-apple, jujube, rambutan, orange, watermelon, strawberry.
Grains	606	Rice, mung bean, maize
Oil crops	225	Soy bean, sesame
Field crops	253	Cassava, sorghum
Meat	90	
Egg	112	

Table 4. Organochlorine residues in breast milk samples from 1980-1986 (Whole milk basis).

Pesticide residues	Mean, ppm			Positive Samples, %		
	1980 N=208	1983 N=229	1986 N=192	1980 N=208	1983 N=229	1985 N=192
p,p' - DDE	0.125	0.127	0.198	100	94.7	100
p,p' - DDT		0.036	0.036		41.1	44.8
dieldrin	0.	0.014	0.041		18.3	7.3
hept & H.E.		0.028	0.059		1.3	0.5

Investigations of organochlorine residues in breast milk have been conducted during 1980, 1983, and 1985–86 by the Department of Agriculture in Thailand. The samples were collected from lactating mothers in hospitals and analyzed for residues on a whole milk basis. The first batch of samples were analyzed only for residues of DDT, whereas the second and third studies included more organochlorine pesticides. The mean values of pesticide residues in breast milk for 1980, 1983, and 1986 are shown in Table 4. The levels of organochlorine residues from the three surveys remained about the same. Reports of work done by scientists from different countries such as the United States, Australia, France, Germany, Japan, India, Uruguay, and Costa Rica (Currie et al. 1979) on breast milk samples have also shown similar pesticide residue levels.

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PESTICIDE RESIDUE STUDIES IN MALAYSIA

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Malaysia is basically an agricultural country, and as such uses a large amount of pesticides for agricultural production. To date there are 210 active ingredients of pesticides registered in the country with herbicides accounting for 75% of the total value of pesticides used (Balasubramaniam et al. 1984). With the increasing use of pesticides, there is growing concern in the country that the environment and the food being produced may be contaminated with pesticide residues. Studies were subsequently carried out by various agencies in the government to determine the levels of pesticide residues in food (particularly vegetables), and also in the environment. Some of the studies are reported in this paper.

CONTROL OF PESTICIDE RESIDUES

There are several laws in operation in Malaysia for the control of pesticides, namely,

- The Poisons (Sodium arsenite) Ordinance 1949
- The Hydrogen Cyanide (Fumigation) Ordinance 1953
- The Pesticides Act 1974
- The Food Act 1983

Of the above, the Pesticides Act 1974 and the Food Act 1983 have provisions for the control of pesticide residues in food. The Pesticides Act is a comprehensive act for the control of various aspects of pesticides and it is being implemented by the Pesticide Board with support services provided by the Department of Agriculture. The Food Act, on the other hand, is being implemented by the Ministry of Health, and it covers all aspects of food quality. Maximum residue limits (MRLs) for pesticides in food are stipulated in the Food Regulations 1985, under the Food Act.

Besides administering the acts, the Department of Agriculture and the Ministry of Health are also involved in carrying out studies on various aspects of pesticides, especially studies on pesticide residues in food. Other agencies conducting studies in these aspects are Malaysian Agricultural Research and Development Institute (MARDI), the Chemistry Department, the Department of Environment, and local universities.

In addition, a project with the GTZ (German Agency for Technical Cooperation) of the Federal Republic of West Germany, called the Malaysian-German Pesticides Project, was started in 1984 with the purpose of strengthening the facilities in the Department of Agriculture for implementation of the Pesticides Act 1974. Under the project, several activities related to pesticide residues were initiated and implemented.

STUDIES ON PESTICIDE RESIDUES IN FOOD AND THE ENVIRONMENT

Preliminary work in 1982 by the Department of Agriculture on three vegetables in the Cameron Highlands area – Chinese cabbage (*Brassica chinensis* L.), round cabbage (*B. oleracea* L.), and tomatoes – revealed that residue levels of phenthoate, acephate, methamidophos, and prothiofos on these crops were below the MRLs proposed by the FAO/WHO Codex Alimentarius Commission (Table 1). Analyses done to detect residues of some organochlorines like HCH, dieldrin, DDT, and quintozene, and synthetic pyrethroids like permethrin, fenvalerate, and cypermethrin, also showed traces of these chemicals, all of which were below the MRLs. The chemicals analyzed were those known to be commonly used by vegetable growers in the Cameron Highlands (Ramasamy & Ong 1982). The same study indicated that the levels of pesticides of the organochlorinated group, the organophosphorus esters, and the synthetic pyrethroids, were generally not excessive in vegetables at the time of the study.

In a follow-up study conducted in 1985 by the Department of Agriculture on vegetables from various retail markets in the country, some increase in the levels of methamidophos and the ethylene bis dithiocarbamates (EBDCs), particularly in leafy vegetables, was found. Methamidophos was found in 16.6% of the samples analyzed while EBDCs were found in 37% of the vegetables respectively (Tables 2, 3). Synthetic pyrethroids and organochlorine insecticides were not detected in many of the samples analyzed.

Lim et al. (1983) obtained similar results when they analyzed tomatoes collected from various markets in Kuala Lumpur in 1983. The tomatoes were found to contain residues of EBDCs in excess of the MRLs of 3 mg/kg CS2 set by the FAO/WHO Codex Alimentarius Commission. However, Lim et al.

Table 1. Pesticide residues in vegetables from Cameron Highlands.

Kind of vegetable	Pesticide residues in mg/kg			
	phenthoate	acephate	methamidophos	prothiophos
Brassica chinensis (10 samples)	0.05	trace (0.74)	0.02-0.08	n.d.
Brassica oleracea (9 samples)	0.05	n.d.	trace (0.06)	n.d.
Tomatoes (11 samples)	0.05	n.d.	0.02-0.08	n.d.

n.d.= not detected.
Source: Crop Protection Branch, Department of Agriculture.

Table 2. Residues of organophosphorus insecticides in vegetables.

Kind of vegetable	No. analyzed	No. found exceeding MRLs in Food Regulations 1985
Chinese mustard	20	4 (methamidophos)
Chinese kale	19	5 (methamidophos)
Mustard hybrid	10	2 (methamidophos)
Lettuce	2	0
White mustard	5	1 (methamidophos)
Spinach *(A. viridis)*	2	1 (methamidophos)
Long bean	1	1 (methamidophos)
Yam bean	2	0
Okra	2	0
Chinese cabbage	2	0
Sweet potatoes	2	0
Round cabbage	2	0
Yam	2	0
Tomato	2	1 (methamidophos)
Cucumber	2	0
Bitter gourd	2	0
French bean	2	0
Kangkong (*Ipomea*)	2	0
Brinjal	2	0
Chilli	2	0
4-angled gourd	2	0
Total	82	15

Source: Crop Protection Branch, Department of Agriculture.

Table 3. Residues of EBDC fungicides in vegetables.

Kind of vegetable	No. analyzed	No. with EBDC levels exceeding MRLs in Food Regulations 1985
Por choy	5	2
Garland chrysanthemum	5	4
Indian mustard	4	4
Mustard hybrid	4	0
Tomato	7	2
Chinese mustard	5	0
Chinese kale	4	0
Pak choy	1	0
Kangkong (*Ipomea*)	1	0
Spinach	1	0
Total	35	13

Source: Crop Protection Branch, Department of Agriculture.

(1983) also found out that washing removed 50–80% of the residues. Subsequent degradation studies showed that residue problems were unlikely to arise if a preharvest interval of two weeks was followed.

Besides vegetables, analysis of cocoa beans for residues of the isomers of HCH and DDT were also done by the Department of Agriculture with the assistance of the GTZ laboratory in Darmstadt. Results showed that only trace levels of DDT and less than 0.1 ppm of gamma-HCH was present in the cocoa beans; other HCH isomers in Malaysian cocoa were also not a problem. Nevertheless, the Pesticides Board decided not to register pesticides containing mixed isomers of HCH, with the exception of the granular formulation, which is mainly used by paddy farmers.

To date little is known about pesticide residues in water, soils, and animals in this country. Water samples taken from a river flowing through vegetable areas in the Cameron Highlands, when analyzed, did not show the presence of organochlorine insecticides such as HCH and its isomers, chlordane, heptachlor, heptachlorepoxide, aldrin, dieldrin, endrin, and DDT (Anonymous 1984). Water collected from paddy fields where dead fish were found often contained significant levels of endosulfan but not alpha- or gamma-HCH (Lee & Ong 1983). Analysis of dead fish tissues showed high levels of endosulfan. However, endosulfan is not recommended for use in paddy fields where fish production is important.

Fish caught in rivers flowing through industrial zones were also reported to contain from 0.1 ppm to 0.241 ppm mercury (Chia & Tong 1981). These levels are below the maximum permissible levels of 0.5 ppm set by the United States Food and Drug Administration. No significant results were found in sea-water fish when they were analyzed for organochlorine pesticides.

STUDIES ON PESTICIDE DEGRADATION

Degradation studies to determine the preharvest interval for some commonly used pesticides have been carried out on vegetables. The results of the studies (Lim et al. 1983, Hatzold et al. 1986) are as follows:

Pesticides (% a.i.)	Vegetables	Preharvest interval (days)
Methamidophos (0.06%)	*B. rapa*	14
	B. oleracea	14
Endosulfan (0.02%)	*B. rapa*	7
Permethrin (0.02%)	*B. rapa*	7
EBDC (0.4%)	tomatoes	14
Cypermethrin (0.01%)	*B. oleracea*	3
	B. rapa	3
EBDC (0.2%)	*Chrysanthemum coronarium* L.var.spatiosum Bailey	14

More studies are being carried out to determine the preharvest intervals for other pesticides on other crops and this information will be incorporated on pesticide labels for farmers to follow.

CONCLUDING REMARKS

Pesticide residue studies conducted so far even though limited, give some indication of the extent of pesticide residue problems in food, particularly in vegetables in Malaysia. Except for some leafy vegetables and tomatoes, the levels of pesticide residues in vegetables are generally very much lower than the MRLs set by FAO/WHO. The problem of pesticide residues is presently not considered serious, but this does not mean that there is cause for complacency, since it is not expected that the quantity of pesticides used in the country will decrease in the future. There is certainly a need to continue monitoring pesticide residues in food and the environment.

Several positive approaches have been initiated by the government with the ultimate aim of minimizing pesticide residue problems in Malaysia. These are :

- Enforcement of the Pesticides Act 1974 and the Food Act 1983.
- Education and training of farmers in the proper use and handling of pesticides.
- Research on alternative pest control methods with emphasis on the development of Integrated Pest Management (IPM), particularly in vegetables.

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PESTICIDE RESIDUES IN THE PHILIPPINES

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Pesticide residues will always remain a concern because of their potential as health hazards and as environmental contaminants. Consequently, many countries have legislation to ensure safety from pesticide residues. In foodstuffs, for example, a certain level of pesticide residue is assumed to be safe based on toxicological considerations. In international regulatory circles, this level is known as the tolerance limit or maximum residue limit (MRL). Unfortunately, residue data under tropical conditions are generally lacking or unavailable for international evaluation as a basis of setting MRLs (FAO/WHO 1978). In the absence of a database most scientists assume that pesticides degrade faster in the tropics, which has more intense environmental factors than temperate areas. Therefore, a MRL based on data from the temperate regions is not expected to be exceeded in the tropics when the same insecticide is used on the same crop provided the crop protection practices and pest problems are identical.

The generation of residue data simulating actual use conditions is still important in tropical countries like the Philippines. In fact, the country is one of the few expected to generate pesticide residue data in the tropics, as noted by the FAO/WHO Joint Meeting of Experts on Pesticide Residues (FAO/WHO 1978). Because of limited resources, however, pesticide residue data generation must be aligned with national priorities.

STATUS OF RESEARCH

In the Philippines, the Pesticide Chemistry and Toxicology Laboratory of the National Crop Protection Center (NCPC), University of the Philippines at Los Baños (UPLB) and the Pesticide Residues and Formulation Control Laboratory of the Bureau of Plant Industry (BPI) are responsible for the bulk of the activities in pesticide degradation and pesticide residues. The BPI Laboratory, established under the Philippine-German Crop Protection Program, is currently better equipped and has been involved in the monitoring of tobacco, vegetables and even environmental samples. The UPLB Laboratory, on the other hand, was the first laboratory in the Philippines to be equipped for research on pesticide residues. Its current research thrusts include the conduct of material balance studies using model ecosystems to reflect tropical conditions, the evaluation of the effect of transfer and degradation factors on a pesticide, and field residue trials for agricultural crops.

Pesticide residue research in the Philippines is mainly on insecticides and uses both field residue trials and 'market-basket' studies to generate residue data.

Some advantages and limitations are inherent in these two approaches, prompting Magallona et al. (1981) to adopt a system in which the merits of both approaches are retained at the same time that the limitations are minimized. The system consists of (a) selecting a major growing area for the commodity of interest, (b) conducting pesticide management surveys in the area to pinpoint the more commonly used insecticides, (c) arranging for farmer cooperators who will be monitored closely, (d) getting samples for residue analysis from cooperators and other farmers, (e) conducting residue trials in experiment stations with popular pesticides used by farmers but using heavy and farmer-level application regimes, and (f) conducting 'market-basket' type sampling in major urban markets. Ancillary studies on the effect of washing and cooking may also be done to give a complete picture of the pesticide in the crop of interest. The system has been applied to 'pechay' (*Brassica campestris* spp. *chinensis*) (Magallona et al. 1981) and string beans (*Vigna sesquipedalis* Fruw.) (Tejada et al. 1983). The merit of the modified approach is its capability to go back to the farmers with positive advice on what to do in order to reduce pesticide levels without jeopardizing their crop protection practices. This is necessary since the local marketing system does not allow for disposal of produce because of high residue content. The recommendation on pesticide usage and preharvest intervals (PHIs) would now have greater impact because it is supported by actual data.

There were few reports on pesticide residues prior to 1977 (Saplala 1954, Pablo 1965, Magallona & Sanchez 1968, Barril et al. 1974). At present, the residue database includes insecticide residue levels in agricultural produce like vegetables (cabbage, pechay, string beans, green beans, tomato, and bush sitao); cotton (seed, oil, cake); tobacco; banana; grains (rice, corn); dried fish; and the components of the rice paddy environment (soil, paddy water, rice plant, fish, and snails). Residue levels are also studied in humans (milk, abdominal fat, urine, and blood).

INSECTICIDE RESIDUES IN FARM PRODUCE

String Beans

Using the above-mentioned modified approach, Tejada et al. (1983) conducted insecticide residue trials on string beans. Table 1 shows the levels of diazinon and methyl parathion residues in string bean samples taken from farmer cooperators in Carmona, Cavite. Only traces of diazinon were detected three days after the last spray application, and no detectable residues of methyl parathion after five days. Washing reduced the residues of diazinon by 20% to 33% and methyl parathion by 33% to 49%. In the field residue trials at UPLB, no mevinphos residue was detected even three hours after spray application (Table 2). For monocrotophos and malathion, no residue was detected two days after spraying. The most persistent insecticide was triazophos with 0.9 mg/kg residue even after five days. The use of double the recommended dosage resulted in higher initial residue level, but loss was also faster. Except for triazophos, which still had a relatively high residue level by the fifth day (1.9 mg/kg), a 5- to 7-day PHI may be recommended. On the other hand, of the 96 string bean

Table 1. Residues (mg/kg) of diazinon and methyl parathion in string bean samples taken from a farmer cooperator. Cavite, 1981.

PHI[a] (days)	Diazinon			Methyl Parathion		
	unwashed	washed	% reduction	unwashed	washed	% reduction
3 hrs	1.8	1.3	26	2.1	1.1	49
1	0.2	0.1	32	1.0	0.8	20
2	0.2	0.1	33	0.3	0.3	33
3	0.05	0.04	20	0.2	ND	
5	traces	ND[b]		0.03	ND	
7				ND	ND	

[a] PHI = Preharvest interval; [b] ND = not detectable at minimum detection level of 0.01 mg/kg; MRL = 1.0 mg/kg for methyl parathion.

Table 2. Residues of some organophosphate insecticides in string bean samples at different preharvest intervals at the recommended dose of 2–3 tbsp/19 L. UPLB, 1981.

PHI[a] (days)	Mevin-phos	Monocro-tophos	Malathion	Methyl Parathion	Tetra-chlor-vinphos	Triazo-phos
3 hrs	ND[b]	1.8	0.1	0.5	1.6	6.8
1		1.6	ND	0.3	1.4	2.2
2		ND		0.1	1.2	
3				0.01	0.1	1.5
5				ND	ND	0.9
7				ND	ND	

[a] PHI = Preharvest interval; [b] ND = not detected at minimum detection level of 0.01 mg/kg for methyl parathion and mevinphos, 0.04 mg/kg for malathion and tetrachlorvinphos and 0.05 mg/kg for monocrotophos and triazophos; MRLs = 0.1 mg/kg for mevinphos, 0.2 mg/kg for monocrotophos, and 1.0 mg/kg for methyl parathion.

samples from various markets in Metro Manila, only 15 were found to contain insecticide residues. Since the samples were not washed, about 20% to 50% of residues were expected to be removed by washing. The samples were positive for diazinon, methyl parathion and mevinphos.

Green Beans

The residue data in Table 3 for the four insecticides tested on green beans *Phaseolus vulgaris* L. (Tejada et al. 1977) show that they are all readily lost

Table 3. Residues (mg/kg) of some organophosphorus insecticides on field treated green beans. UPLB, 1977.

PHI[a] (days)	Methyl Parathion (2.5 tbsp/11.5L)	Monocrotophos 3 tbsp/19 L	Tetrachlorvinphos 4 tbsp/19 L	Triazophos 1 tbsp/19 L
3 hrs	0.3	1.7	1.2	1.9
1	0.7	1.9	0.2	0.7
2	0.1	1.1	ND[b]	0.4
3	0.01	0.4	ND	ND
5	ND	ND	ND	ND
7	ND	ND	ND	ND

[a] PHI = Preharvest interval; [b]No detectable residues at minimum detection limit of 0.01 mg/kg for methyl parathion, 0.02 mg/kg for mevinphos, and 0.05 mg/kg for tetrachlorvinphos, triazophos, and monocrotophos; MRL = 1 mg/kg for methyl parathion, 0.1 mg/kg for mevinphos and 0.2 mg/kg for monocrotophos.

from the plant surface, such that no residues were detected five days after the last application. The least persistent insecticide was mevinphos since the residues could not be detected as early as three hours after applications.

Pechay

A field residue trial on pechay was conducted at UPLB by Magallona et al. (1981) using the modified approach. Of the three insecticides evaluated, methyl parathion was the most persistent and trace residues were still observed seven days after spraying (Table 4). A 5- to 7-day PHI appears reasonable for methyl parathion based on the FAO/WHO recommended MRL of 0.2 mg/kg. The results also showed that rainfall contributed to the reduction of methyl parathion residues. On the other hand, in higher elevation areas like Lucban, Quezon, the dissipation of methyl parathion was slower because pechay samples taken from a farmer's field at 3–5 days after spraying still showed residue levels (about 0.9 mg/kg) corresponding to about one day PHI under equivalent conditions in an experiment station. For Lucban, therefore, it may be prudent to recommend about a 10-day PHI for methyl parathion. Washing caused 37%, 70%, 56%, and 32% reduction of methyl parathion, mevinphos, triazophos, and malathion residues respectively, while boiling removed 81%, 91%, 63%, and 72% of the residues, respectively.

Of the 64 pechay samples collected for the 'market-basket' study, only three gave positive results. Similarly, the Bureau of Plant Industry laboratory noted two positive results out of the 15 samples examined: one sample with methyl parathion (0.1 mg/kg) and another with endosulfan (0.01 mg/kg). These results are quite reassuring to the public.

Table 4. Residues of three organophosphate insecticides on pechay samples at different preharvest intervals. UPLB, 1979.

PHI[a] (days)	Mevinphos (6 ml/4 L)		Triazophos (4ml/4 L)		Methyl Parathion (4 ml/4 L)	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
3 hrs	0.2	ND	0.5	0.6	5.8	13.7
1	0.05		ND	ND	1.4	2.1
2	ND[b]				1.0	0.4
3					0.6	0.2
5					0.2	ND
7					0.04	ND

[a]PHI = Preharvest interval; [b]ND = not detected at minimum limit of 0.02 ppm for mevinphos, 0.01 ppm for methyl parathion and 0.05 ppm for triazophos; MRL = 0.2 mg/kg for methyl parathion, PHI 2-3 weeks, none for triazophos and mevinphos but lettuce has an MRL of 0.5 mg/kg for mevinphos, PHI 1-3 days.

Cabbage

In a field residue trial conducted by Magallona et al. (1977), no detectable mevinphos and triazophos residues were found in the heads when the wrapper leaves and outer leaves were removed (Table 5). This is to be expected since the wrapper and outer leaves protect the cabbage heads from contact with insecticide spray. Also, most of the residues were found on the leaves where the pests were expected to be present. The data shown in Table 5 also indicate that the potential of high residue intake from cabbage is reduced considerably by removing the wrapper leaves. A very important point that deserves mention here is the use of cabbage leaves for feed. Since the insecticides are concentrated in this substrate, safety considerations would need to be exercised in this regard.

Table 5. Residues (mg/kg) of mevinphos and triazophos on cabbage. UPLB, 1977.

PHI[a] (days)	Mevinphos			Triazophos		
	Leaves	Wrapper	Head	Leaves	Wrapper	Head
3 hrs	2.5	0.8	ND[b]	2.5	0.2	ND
1	1.0	0.3	ND	2.0	ND	
2	0.5	0.3		1.2		
4	0.3	0.2				
6	0.1	ND		0.6		
8	ND	ND		0.06		
12	ND	ND		ND		

[a]PHI = Preharvest interval; [b]ND = No detectable residues at minimum detection limit of 0.05 mg/kg for mevinphos and 0.01 mg/kg for triazophos; MRL = 1 mg/kg for mevinphos.

Grains

Tables 6 and 7 show the residue data on shelled corn of malathion and pirimiphos methyl, respectively, as reported by Varca et al. (1975). At three months, malathion residues averaged 1.4 ppm and after nine months, 1.0 ppm (Table 6). For pirimiphos methyl, the residues ranged from 0.6 ppm to 2.8 ppm and 0.4 ppm to 2.5 ppm after three and six months of storage, respectively (Table 7). For both insecticides, the 3-month storage resulted in residues below the recommended tolerance levels of 8 ppm for malathion (EPA 1971) and 7 ppm for pirimiphos methyl (FAO/WHO 1974).

In a separate survey, rice samples from different government warehouses were found to contain malathion residues of 0.05–0.90 ppm (NCPC 1978). A

Table 6. Malathion residues in shelled corn stored in sack dipped in insecticide solution. UPLB, 1975.[a]

Concentration	Storage time (mos)	Residue level (ppm)
2%	3	1.2
	6	1.0
	9	1.0
4%	3	1.4
	6	1.2
	9	1.0

[a]Minimum limit of detection 0.2 ppm; EPA tolerance level 8.0 ppm.

Table 7. Residues (ppm) of pirimiphos methyl in stored corn. UPLB, 1975.[a]

Formulation	Storage time	Concentration Applied	Residue level (ppm)
EC	3 mos.	10	1.3
		15	1.5
		30	2.2
	6 mos.	10	-
		15	1.3
		30	2.3
Dust	3 mos.	10	0.6
		15	1.5
		30	2.8
	6 mos.	10	0.4
		15	1.2
		30	2.5

[a]Minimum limit of detection 0.01 ppm, FAO/WHO Tolerance Level 7 ppm.

more in-depth study of the insecticide residue problem in stored rice was conducted by Magallona and Celino (1977) using malathion and pirimiphos methyl at 10, 20, and 30 ppm spray applications. After one week, the grains were analyzed and the results are presented in Table 8. Greater percentage loss of residues was obtained with malathion than pirimiphos methyl. Washing and cooking resulted in about 50% loss of pirimiphos methyl and about 80% loss of malathion. Simple washing resulted in 15–18% and 9–14% reduction in malathion and pirimiphos methyl residues, respectively.

Cotton

Cotton harvested two months after the last spray application of monocrotophos (6 tbsp/16 L) and carbaryl (8 tbsp/16 L) was analyzed for residues by Pablo and Bello (1977). The residues in the cake, seed, and oil were 1.1, 1.0, and 0.8 mg/kg, respectively. For monocrotophos, the observed residues were 2.3, 0.9, and 1.4 mg/kg respectively.

Tobacco

In 1974, prompted by the threat that Philippine tobacco would lose its competitiveness in international markets because of high DDT residues, BPI implemented a DDT-ban program for 1975-1977. The results of the two-year program were reported by Hernais et al. (1977). In general, a declining trend in DDT residue level was observed on leaf tobacco; but many areas, especially malaria-infected places, still showed excessive residue levels sporadically. Analysis of the leaf samples collected at random for the 1975–76 crop season showed an average DDT residue of 0.53 mg/kg (Ilocos Region) and 2.64 mg/kg (Cagayan Valley). For the 1976–77 crop season, the average DDT residues were 0.75 mg/kg (Ilocos Region) and 1.8 mg/kg (Cagayan Valley). These levels were still above the tolerance limits (0.1 mg/kg for the Federal Republic of Germany, for example), although much lower than the DDT levels found before the program started.

Table 8. Effect of washing and cooking on the residues (mg/kg) of malathion and pirimiphos methyl on rice grains. UPLB, 1977.

Treatment (ppm)	Uncooked	Cooked unwashed	Washing	Washed and cooked
Malathion				
10	93.0	3.8	3.8	ND[a]
20	19.7	10.1	3.7	3.5
30	29.7	11.8	4.6	4.1
Pirimiphos methyl				
10	9.9	7.9	1.2	4.8
20	23.9	17.8	2.8	11.0
30	29.0	25.8	2.9	14.3

[a]ND = not detected at the minimum detection level of 0.05 mg/kg.

Human Tissue

Most studies on the pesticide residue levels of Filipinos have not been published and are basically inaccessible to the general public (Simbul-Nuguid et al. 1985, Bautista et al. 1985, Librojo 1985). In 1977, however, Barril et al. (1977) reported that 90% of 64 human milk samples had total residue levels above the WHO recommended maximum concentration of 0.05 mg/kg total DDT on a whole cow's milk basis. The most common residues found were DDE, DDT and DDD. Other chlorinated hydrocarbon insecticides observed were lindane, heptachlor, aldrin, and chlordane. The number of pesticide residues in a sample ranged from 2 to 7. In a related study conducted by Simbul-Nuguid et al. (1985) 161 abdominal fat samples analyzed for DDT and DDE showed a combined samples range of 0.15 ppm to 11.53 ppm.

COMPONENTS OF THE RICE PADDY ENVIRONMENT

The potential hazard from pesticide application on agricultural crops is not only from the harvested produce, but also from the overall contamination of the environment. In the rice paddy ecosystem, for example, the bulk of the insecticides will not remain with the target plant, but will be deposited in paddy water from where it will disperse to the soil, plants, and animals present in the paddy (Librojo 1985). In addition, the insecticide may contaminate other bodies of water when the paddy is drained during the later stages of rice growth. For the past several years the NCPC residue laboratory, as part of its impact monitoring program, has been evaluating the fate of insecticides in the rice paddy ecosystem using nuclear techniques (Bajet & Magallona 1982, Zulkifli et al. 1983, Varca 1983, Tejada & Magallona 1985a, 1985b).

Isoprocarb

Bajet and Magallona (1982) have studied the chemodynamics of isoprocarb in rice paddy ecosystems. The granular insecticide, at the rate of 2 kg/ha (3.9 mg/L), was applied at tillering stage and a maximum concentration of 2.7 mg/L was detected one day after broadcast application. A rapid decline was then observed followed by a relatively slower degradation after three days. Hydrolysis is the major degradation route in water and this is influenced by diurnal fluctuations of pH and temperature (Sieber et al. 1978, Catahan 1977). Half-life in unflooded and flooded soils were 6.4 and 38.5 days, respectively. Radioactive-labelled isoprocarb could be detected in the stem and older leaves of rice plants six hours after exposure. After two days, radioactivity was concentrated on the tip of the leaves. Isoprocarb was found in *Tilapia nilotica*, edible snails *Pila luzonica*, and kangkong *Ipomoea aquatica*, one day after exposure. Radioactivity was higher in kangkong than in rice plants, implying effective uptake and storage of pesticide in the latter.

Table 9. Residues (ppm) of carbosulfan and carbofuran on rice leaves.

Days	Carbosulfan	Carbofuran
0	3.5	0.3
1	2.2	2.5
2	0.8	1.0
3	0.2	0.2
5	0.01	0.08
7	ND	0.01

Carbosulfan

The fate of carbosulfan in a rice paddy environment was determined by Tejada and Magallona (1985a). The extent of pollution through drainage water was likewise monitored in a simulated lake ecosystem. There were five spray applications and the rates of uptake, distribution, and loss were determined within a 30-day period. The results showed that carbosulfan was rapidly converted to carbofuran in all components of the rice paddy ecosystem (water, soils, snails, and rice plants) except on rice leaves where it remained up to 7 days (Table 9). The partitioning pattern of carbosulfan in the model ecosystem (Tejada & Magallona 1985b) 3 h after spray application was 72% in plants, 11.4% in water, 9.4% in snails, 1.1% in fish, and 0.03% in air. At equilibrium (72 h), the partitioning pattern was 9.5% in plants, 19.1% in water, 40% in snail, 0.4% in fish, and 0.03% in air. As carbosulfan residues decreased, carbofuran levels increased. Rainfall contributed to its fast degradation. At harvest time, carbofuran residues were concentrated on the leaves, followed by the stem, and least on the grains. In paddy water, carbofuran was detected up to 15 days and repeated application did not result in the accumulation of carbofuran residue. Maximum residue in paddy water ranged between 0.04 ppm and 0.07 ppm while the minimum ranged between 0.01 ppm and 0.03 ppm. This is much lower than the theoretical level of 0.4 ppm at prevailing water levels and application rates. Hydrolysis is the major degradation route (t 1/2 = 5-8 days); occurring faster at higher pH and temperature. Carbofuran remained up to 30 days in the soil (t 1/2 = 4 days). Siddaramapa and Watanabe (1979) reported that degradation of carbofuran in flooded soil was slow due to strong adsorption. In *P. luzonica*, about 50% of carbofuran residues were obtained on the shell surface. Maximum uptake was obtained one day after spray application with no detectable residues in the flesh after seven days.

In the simulated lake ecosystem, carbofuran was detected in water up to 15 days (t 1/2 = 3 days). The concentration in water (0.09 ppm) was biomagnified in *T. nilotica* (10.5 ppm) up to 117 times. The carbofuran residue was still detected 30 days after last spray application. In *I. aquatica*, uptake was observed up to 20 days but declined thereafter.

From the half-life values of carbofuran in fish (3.8 days), water (5.8 days), soil (4 days), and rice plants (1.5 days), no parent compound or metabolite could

be detected with the usual practice of draining the field 40 days after last spraying.

Carbofuran

Carbofuran when applied to the soil is usually absorbed by the growing plant. The residues in the rice plant and grains, arising from the root-zone application of 0.5 kg ai/ha was determined by Iman and Morallo-Rejesus (1977). Accumulation of carbofuran residues occurred mainly in the leaves, the highest concentration at 45 days after treatment and gradually declining thereafter (Table 10). The concentrations in stems, roots, and grains were low. The observed residues were below the tolerance levels of 0.2 to 0.5 mg/kg for grain, hay, or forage in rice.

BPMC

Application of BPMC in rice fields at the rate of 60–80 ml/19 L gave residues of about 50% of the theoretical (0.2 mg/L) three hours after application (Zulkifli et al. 1983). There was rapid loss of BPMC in paddy water with a half-life of 0.8 days. No residues were detected at 7 days after treatment. Hydrolysis is the major degradation route, occurring faster at higher pH. When the paddy water was allowed to drain into the pond, the resulting concentration in pond water was 0.03 mg/L. The half-life of BPMC in pond water is 0.6 days with no detectable residues after 5 days. Although BPMC concentration was low, a relatively high residue level was obtained in fish. Rapid assimilation and distribution of BPMC occurred from three hours after water inflow, up to two days, followed by a slow phase. BPMC residues were concentrated in the entrails (6.2 ppm), followed by fillet (2.1 ppm), and least in the head (1.2 ppm). No fish mortality was observed in the pond since the LC_{50} of BPMC is 0.9 mg/kg in *T. mosambica* (Santiago & Magallona 1982).

In a related study, Varca (1983) observed a gradual loss of BPMC in paddy mud as opposed to rapid decline in paddy water after two days, showing that BPMC is adsorbed in the soil. The rate of loss was faster in flooded soil (t 1/2 = 1.5 days) than in unflooded soil (t 1/2 = 2.2 days). In the rice plant, the residues were highest in the leaves, followed by the stems, and least in rice grains. After

Table 10. Carbofuran residues (mg/kg) in the different portions of the rice plant at application rate of 0.5 kg/ha.

Days after treatment	Leaf	Stem	Root	Grains
45	4.0	0.2	0.2	-
65	1.7	0.1	0.1	-
85	0.3	0.1	0.1	-
100	1.2	0.1	0.1	0.1
140	0.3	0.2	0.2	0.1

one day, almost 90% of the residues were removed from the leaves. On rice grains, the residues were higher on rough rice than on milled rice but the decline is faster on rough rice.

CONCLUDING REMARKS

In spite of limited resources, the Philippines has contributed to knowledge on pesticide residues in the tropics. The studies reviewed in this paper confirm the assumption that pesticide degradation is faster in the tropics than in temperate countries. The existing local practices with regards to marketing and food preparation could contribute further to reduction of residues. Since climatic conditions play a major role in pesticide dissipation, PHI recommendations should be made on a region-to-region basis.

Residue studies in the rice paddy ecosystem showed that paddy-reared fish could bioaccumulate residues beyond allowable limits. This is a problem to consider since the rice-fish culture is being promoted in Asia.

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PESTICIDE RESIDUE TRIALS IN RICE IN INDONESIA

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The IPM concept for controlling rice insect pests in Indonesia was initiated in 1974, several years after the brown planthopper (BPH) had continuously caused heavy damage to the rice crop. Rice cultivars with resistance to BPH were introduced nationwide, and economic thresholds for BPH and other major insect pests have been developed in order to minimize the use of insecticides. However, despite the introduction of this technology, most farmers are still applying insecticides based on a calendar system and often, more than is needed for control. As the total acreage of cultivated rice has increased from year to year (9,589,507 ha in 1981 to 10,221,755 ha in 1986), so too has the amount of distributed insecticides increased from 8,911.247 tons in 1981 to 14,976.210 tons in 1986 (Anonymous 1986).

The study on pesticide residues reported in this paper was done in 1978 at the Bogor Research Institute for Food Crops. Due to the high cost of this study, particularly the cost of chemicals needed for residue analysis and the limited funds available, only part of the data are presented. Studies on insecticide residues were undertaken as follows.

RESIDUES OF DIAZINON AND MIPC IN RICE PLANTS AND PADDY SOIL

In separate trials two granular insecticides [diazinon (the most widely used) and MIPC (the most effective for controlling BPH)] were applied at various times and numbers of application (Kanazawa et al. 1983a, 1983b). Single applications were made at 72, 39, and 24 days respectively before harvest, and each treatment had three applications (72, 39, and 24 days before harvest).

Parts of the rice plant (straw, hulled grain) and soil were analyzed for pesticide residues. As shown in Table 1, total MIPC residues in all samples were relatively low. The closer the time of application was to harvest, the higher the level of residues found in the three samples. The highest level of MIPC residue in the grain was 0.18 ppm, which is far below the permissible level (0.2 ppm) for MIPC residue in Japan. The highest residue level was detected in the straw, 0.398 ppm, followed by the grain and the paddy soil. The lowest level of residue, found in soil, indicated that MIPC seems to degrade faster in the soil than in the rice plant. Moreover, the residue levels in the three samples were influenced by the frequency and time of application. Therefore, MIPC may be considered a moderately persistent pesticide in the crop and soil.

Table 1. Residues of MIPC in rice plants and paddy soil (Kanazawa et al. 1983a).

MIPC application[a]		MIPC residue (ppm)[b]		
Frequency	Days before harvest	Hulled grain	Straw	Soil
1	72	ND	0.020	0.002
1	39	0.007	0.171	0.007
1	24	0.073	0.329	0.010
3	72			
	39	0.180	0.398	0.026
	24			
0		ND	ND	ND

[a]dose of 1.6 kg a.i. per hectare per application. [b]average of 2 replicates, ND = not detected.

The level of diazinon residues in hulled rice grains, straw, and paddy soil was relatively low (Table 2). The residues in milled grains were below 0.02 ppm, i.e., below the permissible level of 0.1 ppm (in Japan). In the straw, relatively high residues were found. The highest, 0.211 ppm, was found in straw with three applications. The residue levels in straw were generally influenced by the preharvest interval rather than by the frequency of application. Residue levels in paddy soil were relatively low and were almost the same in all plots.

Table 2. Residues of diazinon in rice plants and paddy soil (Kanazawa et al. 1983b).

MIPC application[a]		MIPC residue (ppm)[b]		
Frequency	Days before harvest	Hulled grain	Straw	Soil
1	72	0.009	0.030	0.023
1	39	0.010	0.052	0.031
1	24	0.013	0.170	0.031
3	72			
	39	0.012	0.211	0.031
	24			
0	-	0.009	0.035	0.013

[a]dose of 1.2 kg a.i. per hectare per application. [b]average of 3 replicates.

RESIDUES OF CARBOFURAN, DIAZINON, FONOFOS AND QUINALFOS IN THE RICE-FISH ECOSYSTEM

Granular formulations of carbofuran, diazinon, fonofos, and quinalfos were evaluated for their effectiveness towards major rice pests and for their effects on carp *Cyprinus carpio*, in a rice-fish ecosystem (Soekarna et al. 1986). The insecticides were applied three times, the first at one day before transplanting, and the second and third at 30 and 60 days after transplanting, respectively. The dosage used was 0.60 kg a.i. for carbofuran, 1.50 kg a.i. for diazinon, and 1.25 kg a.i. per ha each for fonofos and quinalfos. Either one week after the first application of insecticides or one week after transplanting, 75 carps of 5-gram weight were released in each plot of 5x15 m^2. The fish were kept in the paddy fields for 2.5 months. The evaluation of efficacy to rice insect pests was done at 15 and 35 days after transplanting for whorl maggot infestation; 25 and 35 days after transplanting for stemborer, gall midge infestation, and BPH population; and 15, 35, and 55 days after transplanting for natural enemies. Fish mortality, weight gain, and pesticide residues in fish were recorded. Residues were determined in paddy water, soil, and rice plants (straw and grain). Whorl maggot and gall midge infestations and BPH populations were very low. Stemborer infestation in all treated plots except diazinon were significantly lower than control. High crop yields were obtained from treatments with fonofos (3.947 ton/ha), carbofuran (3.894 ton/ha), and quinalfos (3.603 ton/ha). The diazinon and control treatments gave 2.974 ton/ha and 2.413 ton/ha respectively, both significantly less than the three earlier mentioned insecticides.

Fish mortality was generally low, the lowest being on fonofos (2.37 %), followed by carbofuran (5.20 %), diazinon (6.02 %) and quinalfos (6.37 %). Pesticide residue levels in water seven days after the first application were low, being 0.0018 ppm for carbofuran and 0.0047 ppm for diazinon, while quinalfos and fonofos were not detected. Residue levels in water at the harvest time of fish were also very low: 0.0002 ppm for diazinon, 0.0021 ppm for carbofuran, 0.0003 ppm for fonofos, and 0.0516 ppm for quinalfos. Residue levels of insecticides in soil taken 29 days after the first application were low: 0.0236 ppm for carbofuran, 0.0210 ppm for diazinon, and 0.0178 ppm for quinalfos. No fonofos residue was detected. Residues taken from soil at harvest time of fish showed 0.0831 ppm fonofos, 0.1032 ppm quinalfos, and 0.0128 ppm diazinon, with no carbofuran detected.

Residues in the intestines of fish which lived in treatment plots with three insecticide applications were 0.0035 ppm diazinon, 0.0062 ppm carbofuran, and 0.0100 ppm fonofos. No quinalfos was detected. In fish meat, the residues found were 0.0027 ppm diazinon, 0.0031 ppm carbofuran, 0.1032 ppm quinalfos, and 0.0049 ppm fonofos. The level of residue in meat was much lower than that in intestines.

In the straw, residue levels detected were 0.0079 ppm diazinon, 0.0400 ppm fonofos, and 0.0984 ppm quinalfos, with no carbofuran detected. In hulled grain, no residue of any insecticide was detected. This study showed that carbofuran, quinalfos, and fonofos were effective against stemborers and increased yield significantly over the control and diazinon treatments. Low toxicity of all tested

insecticides to fish was observed. There was no indication of any accumulation of residue in soil after three applications. Very low residue levels were detected in fish meat and residue levels of all insecticides in straw were low. In milled rice, no residue of any insecticide was detected.

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PESTICIDE RESIDUE CONTROL AND MONITORING IN INDONESIA

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Pesticides are commonly used in crop production in Indonesia, especially in areas where endemic pests are a problem. Since Indonesian farmers generally find pesticides to be effective against crop pests, easy to apply, and not too costly, many of them consider pesticide use the best way to solve their pest problems. Consequently, farmers tend to use pesticides on any crop which is likely to be attacked by pests. This situation has brought about an increase in pesticide use in agriculture, fishery, forestry, public health, and households.

Because of the toxic nature of most pesticides, the increasing use of pesticides has given rise to a concern for the undesirable side effects of pesticides on human health and the environment. A number of accidental poisoning cases have been reported to occur during storage, transportation, dilution, and application of pesticides. Other cases of animal intoxication and environmental pollution have also been attributed to improper handling and injudicious use of pesticides.

Realizing that pesticide use is indispensable to agriculture, and recognizing the potential hazards of pesticides to man and the environment, the government of Indonesia introduced the Pesticide Act of 1973 to regulate the use of pesticides. The government has taken steps, complementary to the Act, to develop good practices in pesticide management with a view to promoting safety and efficiency in pesticide use. One important aspect of pesticide safety is the presence of residues in food and the environment. In recent years, several government agencies have initiated efforts and studies to control residues. This paper deals with the efforts and studies carried out by some agencies in the Ministry of Agriculture.

PESTICIDE REGISTRATION AND RESIDUE TRIALS

The Pesticide Act of 1973 governs the distribution, storage, and use of pesticides. It is stipulated in the Act that all pesticides shall be registered with the Minister of Agriculture, and only those that are approved for their intended purposes may be distributed.

The provisions of the Act empower the Minister of Agriculture to control pesticide use through a registration scheme and an inspection system (Directorate of Food Crop Protection 1985a). The Act also provides for the control of all matters of public health within the jurisdiction of the Minister of Public Health. This implies that the protection of consumers from the hazards of pesticide residues in food is the responsibility of the Minister of Public Health.

An advisory body, comprising authorities and experts from the ministries concerned, was established to aid in the implementation of the Pesticide Act. The body, which is called the Pesticides Committee, assists the Minister of Agriculture in administering pesticide registration, and formulating policies regarding pesticide control and management.

To administer the registration of pesticides, the Pesticide Committee has developed a system of pesticide evaluation which involves research institutes, universities and other agencies concerned to test the efficacy, toxicity, residue levels, and other potential aspects of pesticides. Pesticide companies which apply for the registration of their products are required to submit to the Pesticides Committee information and data, including residue data, necessary for evaluating the safety and efficacy of the products.

The following general principles are adopted in pesticide registration for the control of pesticide residues to protect consumers and the environment, and to avoid difficulties in the export of agricultural commodities:

1. The registration of pesticides which are highly persistent, biologically accumulative, or highly toxic will only be considered if such pesticides are intended for use on non-food commodities.
2. The registration of persistent pesticides proposed for a particular use, even if not food-related, should not be accepted if safer non-persistent pesticides have already been registered for the same use.
3. In case non-persistent and low toxic pesticides are not available for a particular purpose, the registration of persistent and highly toxic pesticides for that purpose can be accepted, but licenses are required for the distributor and user of such pesticides.
4. The use of pesticides on particular food commodities will not be granted registration if such use is proved to result in residues exceeding the safety maximum limits.

Local residue trials are required in the registration of pesticides used for the protection of stored grains. The trials are intended to provide data to determine the minimum waiting period between the time of pesticide application and the time the treated stored grains are allowed for consumption. Local trials on residues are also required by the Pesticides Committee for pesticides proposed for use on major food crops and certain commodities if the chronic toxicities of the pesticides are relatively high, as indicated by low no-effect level or acceptable daily intake (ADI) values. The residue data from these trials are used by the Committee to consider the safe interval between the last application of pesticides and the crop harvest proposed by the applicant companies.

All the field trials and the laboratory analysis of residues are conducted by research institutes, universities, or other agencies appointed by the Pesticides Committee. The trial protocols and the methods of residue analysis should be agreed upon by the Committee, the applicant companies, the executors of the trials, and the analytical laboratories. As the trials are funded by the pesticide companies applying for the registration, the data generated from the trials belong to the applicant companies, and hence cannot be publicized without the consent of the companies.

MONITORING OF PESTICIDE RESIDUES

Data on the actual levels of residues resulting from pesticide use by farmers for crop protection indicate the extent of the residue problem if pesticide use were to increase and no efforts are made to control residues (Daryanto 1985). Based on residue data and other data on pesticide use, decisions can be made on the need to in prove training and education of farmers in safe and efficient use of pesticides, and to take the necessary steps, including regulatory action, to control residues. The data on residues in various crops, collected for many years from different areas, are also very important for setting up realistic maximum residue limits which fairly bridge the differences in interest of farmers beth as producers and consumers of the crops.

Recognizing that the issue of pesticide residues in food is associated with the protection of food crops against pests, the Directorate of Food Crop Protection has launched a residue monitoring program. The main objectives of the program are to determine the actual levels of pesticide residues in food crops, to evaluate the trends, and to provide baseline data for establishing national statutory residue limits. The program has been carried out to monitor pesticide residues in rice and some vegetable crops from selected areas where farmers are used to applying pesticides for the protection of their crops.

In the monitoring carried out in the provinces of West Java, Central Java, East Java, South Sumatera, and North Sumatera from 1980 to 1985, samples of crops and soil were taken from the fields of progressive farmers at harvest or a few days before harvest (Directorate of Food Crop Protection 1985b). Based on the information provided by local agricultural extension agents and plant protection agents on the agronomic situation and pesticide use, each area of each crop was divided whenever necessary into sub-areas with different intensity of pesticide use, and the fields, from which crop and soil samples were taken, were randomly selected. The minimum number of samples taken from different points in each plot was five, and the minimum size of samples from each plot

Table 1. Residues in soil from different vegetable areas in West, Central, and East Java, and North Sumatera in 1983-1985.

	Highest(H), mean(M) and lowest(L) residue (ppm)								
	1983			1984			1985		
	H	M	L	H	M	L	H	M	L
Chlorpyrifos	.013	.007	0				.24	.10	.04
Diazinon				.007	.001	0	.02	.015	.005
Dichlorvos							.05	.04	.035
Endosulfan				.10	.03	0			
Fenitrothion							.01	.008	.002
Fenthion				.04	.008	0	.025	.02	.01
Lindane	.023	.013	.003	.20	.08	0			
Metacrifos							.003	.002	.001

Table 2. Pesticide residues in crops from different areas in West Central and East Java, and in South and North Sumatera in 1980–1985.

Crop and pesticide	Highest (H) and mean (M) residue (ppm)												FAO-WHO recommended MRL (ppm)
	1980		1981		1982		1983		1984		1985		
	H	M	H	M	H	M	H	M	H	M	H	M	
Cabbage													
Chlorpyrifos							.005	.001					
Diazinon	.05	.02			.003	.002	.47	.11	.007	.005	.002	.002	.7
Endosulfan							.34	.056					2.0
Fenitrothion							.17	.028					.5
Fenthion							.03	.006					1.0
Lindane					.001	.008	.001	.003	.03	.02			.5
MIPC							.05	.008					
Phenthoate							.001	.0002					
Dithiocarbamates											.038	.022	
Carrot													
Diazinon	.007	.007			.07	.07	.17	.14	.004	.002			.5
Endosulfan							.63	.35	.1	.05			.2
Fenitrothion							.005	.002					
Fenthion							.11	.04					
Lindane							.03	.012	.2	.1			3.0
Phentoate									1.1	.53			
Quinalphos							.06	.02					
Chinese cabbage													
Diazinon	.23	.13							.04	.02			.7
Fenthion									.005	.003			1.0

Continued on next page

Table 2 *continued*

Crop and pesticide	Highest (H) and mean (M) residue (ppm)												FAO-WHO recommended MRL (ppm)
	1980		1981		1982		1983		1984		1985		
	H	M	H	M	H	M	H	M	H	M	H	M	
Onion													
Diazinon									2.69	2.69	.002	.002	.5
Malathion	.14	.14											3.0
Potato													
Benomyl											8.53	4.56	.1
Chlorpyrifos											.005	.005	
Diazinon	.011	.006			.066	.066	.17	.08	.012	.006	.003	.002	.5
Dithiocarbamates											6.28	3.26	
Endosulfan							.024	.01	.03	.01			.2
Fenitrothion							.39	.13					
Fenthion									.004	.001			
Lindane							.05	.02					.05
MIPC							.004	.001					
Rice													
Diazinon	.02	.01	.04	.04	.02	.017	.01	.005					.1
MIPC							.03	.01					
Tomato													
Diazinon	.01	.003			.19	.19			.02	.01			.5
Dithiocarbamates											5.36	1.44	1.0
Endosulfan									.021	.017			2.0
Fenitrothion	.07	.02							.013	.07			.5
Lindane									.034	.026			2.0

was one to two kilograms depending on the type of crops to be sampled. The samples were transported and stored with minimal degradation of residues and minimal contamination with pesticides. The residues present in the crop and soil samples were determined in the laboratory of the Directorate of Food Crop Protection by using gas-liquid chromatography and high performance liquid chromatography analysis. The data on residues in soil and crops obtained from the monitoring are summarized in Tables 1 and 2, respectively.

Data in Table 1 show that all residues in soil during 1983–1985 were insecticides at the mean levels of 0.001–0.1 ppm for organophosphates and 0.013–0.08 ppm for organochlorines.

Table 2 shows that residues present in crops during 1980–1985 were insecticides and fungicides, and that most of the residues did not exceed the maximum residue limit (MRL) recommended by FAO and WHO. Only residues of some pesticides in certain crops sampled during 1983–1985 were higher than the MRL, viz., endosulfan in carrot in 1983, diazinon in onion in 1984, benomyl in potato in 1985, and dithiocarbamates in tomato in 1985. The residue levels of most insecticides were far below the MRL, but those of most fungicides were above the MRL. Residues in cabbage, chinese cabbage and rice were in general much lower than the MRL, and all were insecticides except dithiocarbamate fungicide in cabbage which were found only in 1985.

Although some residues of endosulfan, diazinon, benomyl and dithiocarbamates in carrot, onion, potato, and tomato respectively, were higher than the MRL recommended by FAO and WHO, it is estimated that the amounts of residues of those pesticides taken unintentionally by Indonesian consumers through their food consumption are lower than the acceptable daily intakes set up by FAO and WHO on the basis of toxicological data. The residues of those pesticides are therefore considered toxicologically acceptable to the Indonesian consumers. However, the high residues, particularly of benomyl and dithiocarbamate fungicides in potato and tomato, suggest that the use of pesticides should be limited to a minimum by reducing whenever possible the rate of application (Soekardi & Sumatera 1982). More training and education are needed to encourage farmers to use pesticides only when necessary, and not shortly before crop harvest.

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PESTICIDE RESIDUES IN FOOD AND THE ENVIRONMENT: WHAT DO THE LEVELS REALLY MEAN?

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Worldwide losses from pests and diseases in the field have been estimated at 20–40% of total crop production, even with current crop protection measures. In developing countries, these losses may be even higher (FAO 1981). Conservative FAO estimates indicate that at least 10% of the total world population is seriously under-nourished (FAO 1981). This figure barely does justice to the daily physical deprivation of human beings which damages health and growth and seriously reduces the capacity of children to learn and adults to work. At best, the figure means that one person in six in the developing world outside China (for which data are not available) is forced to exist on a diet too poor for human life. In reality, the true situation can only be more grave (FAO 1981).

During the years 1950–80, population growth more than doubled the world demand for food and agricultural products. By the year 2000, the world population (currently estimated at 4.5 billion) is forecast to grow to more than six billion. This will require an increase in agricultural output of some 50–60% in the period 1980–2000. During the same period, the demand for food and agricultural products in developing countries is expected to double (FAO 1981).

Agriculture directly provides the means of livelihood of almost half the world's population (FAO 1981). Improved efficiency in agricultural production is essential if a higher proportion of the working population is to become free to work in manufacturing or service industries, to yield sustained economic growth, particularly in developing countries.

Without current pest control practices, it is reasonable to anticipate that present losses would be doubled – with catastrophic health, social and economic consequences.

In theory, a number of different means can be used to protect crops. In practice, only one – the use of pesticides – has proved effective on a large scale, in producing results which can be achieved with a fair degree of certainty.

The responsible and efficient use of pesticides has an important role to play in improving the quality and quantity of future agricultural production. This is along with other measures such as the improved use of fertilizers, simple cropping systems, improved irrigation, mechanization, use of high yielding plant varieties, and the use of cultural practices which minimize potential pest survival and which encourage natural enemies of pests, wherever possible.

The concept of integrated pest control, even though it advocates reliance on more than one pest control technique, includes the judicious use of pesticides (FAO 1981).

Apart from their agricultural usage, pesticides are also of enormous benefit in public health programs. The success of DDT and other insecticides to help control vector-borne diseases such as malaria has been spectacular. Millions of lives have been saved, and the health of hundreds of millions of people have improved as a consequence of the control programs initiated in the 1950s and 1960s.

In addition to malaria, pesticides have helped eradicate or reduce numerous other debilitating and lethal diseases in the last four decades, including trypanosomiasis, schistosomiasis, filariasis, leishmaniasis and bilharziasis. An example of recent success in vector control is the onchocerciasis control program in West Africa, where operations in 1975 have led to the interruption of onchocerciasis transmission in much of the area. In particular, an estimated three million children born since the start of the program have been saved from blindness (GIFAP 1986).

The factors which dictate that pesticide use in agriculture should be part of an integrated pest management program are the ones which also mitigate in favor of the use of integrated control measures in public health programs. Nevertheless, it is the opinion of several expert groups that in integrated public health control systems, chemical control will still remain an essential part (WHO 1983).

The beneficial uses of pesticides in agriculture, forestry and public health programs do, of course, lead to the presence of residues in our environment. There is no dispute that pesticides, if improperly used or without sufficient knowledge of their side effects, could endanger man and animals due to their toxicity. There is also additional concern that future hazards to human health and wildlife might be created by residues of the more persistent chemicals becoming widespread, particularly in our food supplies. There is thus general acceptance from industry, government and the general public that there is a need to evaluate the toxicity of pesticides and their potential side effects before they are introduced into the marketplace. The burden of proof of a pesticide's safety rests with industry, which accepts government's duty to regulate the handling and use of these chemicals.

The significance of pesticide residues to man and to our environment depends upon two, interrelated factors, namely, 1) the nature and level of residues in food, feed and the environment, and 2) their toxicity to man and to other life forms.

The mere presence of a pesticide residue does not, by itself, indicate a hazard. Neither does a high toxicity of a pesticide alone mean that a danger is necessarily present in the environment. Rather, both features must be considered in combination. Both are studied in parallel during the pre-marketing development of a new pesticide.

PLACE OF SAFETY EVALUATION IN THE DEVELOPMENT OF A PESTICIDE

The development of a new pesticide chemical, from discovery to full marketing, usually spans 7–10 years. During this period, three overall areas of activity proceed in parallel. These are the manufacturing chemistry aspects (including finalizing patent claims, the scale-up from laboratory synthesis to manufacturing scale and the development of preferred formulations), the biological aspects – to define use recommendations and limitations – and the product safety aspects. Product safety includes the health of the manufacturing employee, of the user in the field, environmental safety, and the safety of those who consume the treated crops whether human or animal. Safety relates to manufacture, formulation, packing, storage, transport and use of the pesticide and to disposal of the used container.

In conducting a safety evaluation on a potential pesticide, a manufacturer first seeks to satisfy himself that the product will be safe to use as recommended, including during minor predictable deviations from the proposed use. Subsequently these data are presented to governmental regulatory bodies when seeking approval for sale. The current cost of producing the normal package of pre-marketing safety data on a new pesticide is in the order of US$6–10 million, and sometimes higher, depending upon the compound and the proposed use patterns. These costs are increasing, as also is the number of research chemicals which has to be screened for possible pesticidal activity to yield one which can be developed successfully.

The extent of the safety data which is required at any one time depends upon the stage of development of a new compound. At the early stage (and depending upon what is known about the toxicology of the new compound), comparatively little data may be needed to provide adequate assurance that crops treated during initial, small-scale trials may be sold into normal commercial channels. More data become available as the compound proceeds to later development stages. This embodies the principles of phased registration which are recommended by FAO (FAO 1985) and which is practised by governments in many developed countries, including the USA, UK, and France.

SAFETY EVALUATION: PHYSICAL AND CHEMICAL PROPERTIES

The data required on physical and chemical properties, as recommended by the Second *Ad Hoc* FAO/Government Consultation on the International Harmonization of Pesticide Registration Requirements, in Rome, 1982, are intended to ensure the quality of products offered for sale. Particularly important is the requirement to declare the name and address of the manufacturing source of the product. This requirement is intended to provide reassurance that the safety studies submitted in support of a registration request have been carried out with materials of appropriate quality. Also implicit is an understanding that the registrant will ensure that the product subsequently marketed will comply with the quality described in the registration submission.

PRE-MARKETING STUDIES OF PESTICIDE RESIDUES IN FOOD

As stated earlier, when pesticides are used to protect crops during their growth or during storage after harvest, traces of the pesticide or its metabolites may remain on the marketed crop. These so-called "residues" are usually present at very low levels - often below 1 ppm (1 mg of pesticide per kg of food). Frequently, sensitive methods of analysis, capable of detecting residue levels down to 0.01 mg/kg, must be developed.

The fate of the chemical after application to the plant must be studied, usually using radioactive-labelled materials. The chemical may be metabolized or chemically degraded by hydrolytic, oxidative or photolytic mechanisms. The nature of the major decomposition products (usually called "metabolites") must be identified and their significance to the total crop residue determined.

Several crop types are often used in residue studies. From the findings, and a knowledge of toxicology and small animal metabolism, it is possible to decide which compounds form residues of potential toxicological concern and thus need to be measured routinely. Not all components of a residue need always to be analyzed.

Many uses of pesticides do not leave detectable residues in crops at harvest. Early season uses, e.g., herbicides at pre-planting and pre-emergence, tend to fall into this category.

Many foods are not raw agricultural commodities; they are derived by various food processing operations. The effects of these processes on residue levels can be very significant and have to be studied. As an example, dichlorvos, which is used to protect stored grain, can give rise to residues of 2 mg/kg in the grains, but these levels will fall to below the limit of analytical determination (0.01 mg/kg) in the bread. In some countries tecnazene is mixed with stored potatoes at a rate which would yield an initial residue of 134 mg/kg, to suppress sprouting and fungal diseases; some of this residue is lost by volatilization during handling and storage, and yet more is lost during processes such as washing, peeling and cooking, so that at the point of consumption residues are of the order of 0.05 mg/kg or less.

The use of pesticides on forage crops, or on crops of which parts are used for animal feed, raises a possible need to study residues in foodstuffs of animal origin, depending upon the extent to which residues of the pesticides are found in animal feeds. This need can also arise when pesticides are used to control ectoparasites. In all events, the transfer of residues to foodstuffs of animal origin is usually very small. Typically, when ^{14}C-radioactive-labelled organophosphate or carbamate insecticides are administered orally to lactating cows or goats, only about 0.3–0.5% of the radioactivity is transferred to the milk, and then mainly in a detoxified form (i.e., dephosphorylated or decarbamylated). Residue levels of the photostable synthetic pyrethroid, permethrin, in milk, meat and eggs of farm animals are 100–1,000 times smaller than the dietary residue levels which give rise to them, and they decline noticeably when the animals are returned to a permethrin-free diet.

TOXICOLOGICAL ASPECTS OF RESIDUES IN FOOD

Residue levels must, of course, be acceptable toxicologically. The foundation of modern toxicology rests on the tenet that "the dose makes the poison." Indeed, without specifying amounts, the word "toxic" is meaningless. Many dietary components which at low levels are harmless or even essential to health can be toxic at higher levels – Vitamin A is an example. Thus an estimate is required of a level of pesticide residue intake below which the risk to health is too small to be of concern. This level of intake is normally referred to as the acceptable daily intake (ADI) which is defined as the amount of a chemical which can be consumed every day for an individual's entire lifetime with the practical certainty, on the basis of all the known facts, that no harm will result. This concept was introduced at the Joint Meeting of the FAO Panel of Experts on Pesticide Residues and the Environment, and the WHO Expert Group on Pesticide Residues (JMPR), to consider the residues of various pesticides occurring in foods in international trade. Many pesticides now have ADIs assigned to them by the JMPR.

ADIs are derived from the results of long-term feeding studies with laboratory animals. The studies encompass an assessment of possible carcinogenic, mutagenic and teratogenic potentials. The possibility that a residue might be neurotoxic or have a reproductive effect is also considered. The intake causing no toxicologically significant effect in animals when given daily over their life span is determined, and the ADIs are derived by the application of generous safety factors (usually 100) to the no-observed toxicological effect level in the most sensitive species studied.

The ADI is expressed in terms of milligrams of the residue ingested per kilogram of body weight per day. In this context, man is usually reckoned as having a typical weight of 60–70 kg in developed countries and 50 kg in many developing countries. It should perhaps be stressed that in appraising residues in foods one is virtually never concerned with short term or "acute" toxic hazard - residues arising from good agricultural practice never reach levels anywhere near those that could pose an acute hazard. Rather, one is concerned with possible longer term effects from ingestion of very small amounts over a lifetime.

ACTUAL RESIDUES IN FOOD IN THE LIGHT OF THEIR TOXICOLOGY

In practice, pesticide residue levels in food are invariably small and do not pose a threat to human health when judged by the foregoing criteria. The levels are commonly much lower than might be expected. This is borne out by some interesting comparisons derived from data in the USA, between maximum theoretical intakes and actual intakes (Table 1).

There are many reasons for this:

- Not all of each crop is treated with each pesticide.
- Pesticides are not always applied at the highest recommended application rate or at the latest time before harvest.

Table 1. Comparisons of actual daily intakes, theoretical daily intakes and acceptable daily intakes, USA 1974–76.[a] (Bates and Gorbach 1982)

Pesticide	Theoretical potential daily intake (mg/person/day)	Actual daily intake (mg/person/day)	ADI applied to a 60 kg person (mg/person/day)
Captan	18	0.001	6
Methoxychlor	10	0.0004	6
Dieldrin	0.06	0.002	0.006
Parathion	0.8	0.00006	0.3
Carbaryl	5.6	0.001	0.6

[a]All ADI figures cited in this paper are from JMPR evaluations.

- A large proportion of the residue in the raw agricultural commodity can be discarded with inedible portions.
- Residue levels often dissipate further during storage, transport, or commercial processing and during domestic preparation and cooking.
- It is unlikely that a person will consume in the same day all the commodities on which the product can be used.

National authorities and official institutes in several countries have initiated surveillance and monitoring programs for the determination of the actual amount of residues in food at the time it reaches the consumer. Thousands of samples are analyzed each year for the presence of all kinds of pesticides. Many of the results obtained remain in the hands of officials or are reported in publications of limited circulation and do not reach the general public. The published work of governments has been surveyed by the Groupement International des Associations Nationales de Fabricants de Pesticides (GIFAP) Residue Committee in a paper titled *Pesticide Residues in Food*, which is available both in a longer version for the technically qualified and a shorter version intended for members of the general public. Meanwhile, since pesticides continue to play a vital role in the production of adequate food of satisfactory quality, it is right that the use of pesticides, and the monitoring of their residue levels in food and feed, should continue. The overall data available from various national surveys demonstrate a similar and reassuring situation in different countries. In practice, pesticide residues in food are invariably small and do not give rise to public health concerns.

ISSUES SURROUNDING ASSESSMENT OF CARCINOGENIC POTENTIAL

The pre-marketing assessment of the carcinogenic potential of a new pesticide is routinely made through long-term rodent bioassays. The interpretation of the tumor findings can sometimes become difficult because of variations in the naturally-occurring incidence of various tumors in the test animals. In these cases, the problem often becomes one of interpreting what could be called marginal findings.

In regulatory terms, the US Environmental Protection Agency (EPA) essentially stands alone in failing to differentiate between the induction of benign, non-invasive, non-life-threatening tumors on the one hand, and the induction of malignant, life-threatening tumors which pathologists would all agree as being evidence of a true carcinogenic response in the test system used on the other. There is a second point. Many toxicologists would agree that statistics provide a useful aid to a sound biological interpretation. The EPA, however, has tended to rely rather heavily on the work of the biostatistician. Thus, a statistically significant difference in tumor incidence, regardless of the weight of biological evidence or the naturally occurring variation in incidence of a given tumor type in the strain of test animal used, has on several occasions formed the basis for the EPA to classify a compound as a carcinogen when regulatory bodies in other countries, or the WHO Expert Panel of the JMPR, reached a different conclusion on the same evidence. Thus when noting that the EPA has classified a compound as oncogenic, care must be taken in the use of that conclusion, in the absence of any similar appraisals by other respected, competent bodies.

In the absence of other information, e.g., in man, clear-cut evidence that a compound is a rodent carcinogen has to be taken as indicative of a potential for carcinogenic effect in man. However, such an extrapolation does not always apply. There is, for example, mounting evidence that the induction of certain hepatic tumors in rodents by various phenoxy and diphenylether herbicides is not predictive of a carcinogenic response in man. Then there is the case where tumors seen in long-term rodent bioassays may be secondary to extensive tissue damage, or other toxic effects, which can result from feeding test compounds for prolonged periods at extremely high dietary inclusion rates which have no relevance to the practical situation. Where there is sufficient evidence that the compound is not interacting directly with genetic material, then it can be argued that the establishment of an adequately high dietary "no effect" level in rodents for the initial toxic response provides a basis from which to estimate an Acceptable Daily Intake for man without fear of an attendant threat of cancer.

For compounds where the evidence is clear that they are rodent carcinogens, the issues involved in setting a safe exposure level for man are more difficult. In biological systems it is normal to find a dose-response relationship for the various effects of chemicals. In principle one could ask why the mechanisms of carcinogenesis should not also be the subject of dose-response relationships. On the other hand, concerns about the consequences of the interaction of chemicals with DNA, a lack of a full understanding still of various aspects of the mechanism of cancer induction and the nature of the disease itself all point to the need for a cautious approach. Where there is an overriding need for the use of a pesticide and no better way of assessing the data, it may be that the approach of mathematical risk modelling, such as that now used by FPA, provides the most useful way forward.

In the context of toxicological evaluations, it is important to note that the WHO Panel of the JMPR is made up of specialist toxicologists from government and academia. They are chosen to serve as individuals, because of their special expertise and experience. Thus the WHO Panel's toxicological

evaluations of pesticides should be accorded the standing which this expertise and experience demands.

ENVIRONMENTAL SAFETY

The wholesomeness of any food supply depends in part on the quality of the total environment, i.e., the soil, water, and the air in which the food is grown, processed, and consumed. Any acute contamination of these basic natural resources, whether by pesticide residues or other pollutants, has to be a matter of concern. That concern relates not only to the safety of food products, but also to matters such as water supplies, wildlife preservation, and outdoor recreation. Nations are actively seeking to protect and manage these resources in the interests of greater safety and human welfare.

The significance of pesticide residues in our environment depends both on the levels present and their toxicity to environmental organisms. The mere presence of a residue does not, of itself, indicate a hazard. Thus the environmental safety studies which are generally conducted may be subdivided broadly into environmental chemistry and ecology.

Environmental chemistry studies involve physical and chemical degradation, mobility, metabolism, field dissipation, and accumulation. Physicochemical degradation studies identify residues which are formed through the action of water or sunlight on a product. Metabolism studies identify residues formed when the product reaches the plant, soil or water. Mobility studies predict the movement of the pesticide and its residues outside the treated area, through leaching, volatility, adsorption, or dispersal by water. Field dissipation studies are conducted under actual use conditions at several sites to confirm data generated from laboratory studies. Accumulation studies assess the possibility of the pesticide or its residues collecting in rotational crops, fish, and other living organisms.

The ecological studies include direct toxicity measurements under laboratory conditions on fish, birds, fish food organisms, and other species of wildlife. The environmental chemistry data are then evaluated together with the ecotoxicity data, to assess the potential hazards to man, fish, wildlife, or other non-target organisms resulting from the proposed use of the pesticide. The effects of the pesticide on micro-organisms such as nitrifying bacteria which affect soil fertility is studied, as well as its potential to harm beneficial species of insect, such as the honeybee and natural predators and parasites of pests.

The total requirements are very complex, but the depth and range of studies needed depend largely on the use pattern and situations in which the pesticide is used, as well as the specific physicochemical and toxicological properties of the material. The need to progress towards simulated field tests, and possibly to later full scale environmental (field) testing, will depend on the results of the earlier, simpler tests.

As in the case of the mammalian toxicology studies mentioned earlier, the professionalism and integrity of those conducting the studies, and of those interpreting the findings, are extremely important in foreseeing potential problems. Often, it is not the direct effects of a compound in the environment

which will be of major practical concern but potentially unforeseen side effects. As just one example, the use of herbicides for aquatic weed control may not, of itself, be directly toxic to fish. However, extensive deoxygenation of the water during the decay of the weeds, which may occur if too large a body of weeds is controlled at any one time, has the potential to be toxic to fish.

SOME CURRENT ENVIRONMENTAL ISSUES

Water

In a paper of this length, it is not possible to address all questions about the effects – or sometimes the alleged effects – of the use of specific compounds in specific outlets. However, certain general issues are worthy of comment.

Water contamination is at present a controversial issue in the USA and parts of Western Europe. Pesticides are applied to crops and soils in various formulations and with various application methods. Under some circumstances, pesticides can reach surface water, the most likely routes being spray drift and "run off" from the surface of treated fields. Sometimes pesticides are developed for the control of weeds or insects in water. There is much published information in the scientific literature on the fate and effects of individual pesticides in surface water.

In recent years, some pesticides have been detected in ground water at trace levels which, in the main, are present well below those that could cause harmful effects. Generally speaking, agricultural chemicals are unlikely to reach ground water when they are used according to label directions and good agricultural practice. However, certain infrequent combinations of permeable soils, high water tables, highly soluble pesticides, and direct soil application practices can increase the probability of trace amounts reaching groundwater.

Because there are differences in toxicological behavior between pesticides of different chemical structure, toxicological risk assessments must be made on an individual case basis. Meanwhile the available evidence indicates that in the overwhelming majority of situations, existing pesticide residue levels in water should not give rise to toxicological concerns for man.

The distinction needs to be made, of course, between the use of pesticides according to label recommendations (including minor predictable deviations) and their grossly improper misuse or disposal, which cannot be condoned. In those situations where pesticides are improperly used, or where spillage or improper disposal occurs, the likelihood that pesticides will reach surface or ground water is clearly greater.

Soil

In parts of Western Europe at present, persistence of pesticide residues in soil in their own right, irrespective of whether there is any reasonable likelihood of a health consequence for man or our environment, is a source of debate. The extent of pre-marketing environmental safety assessment studies which are routinely conducted on new pesticide chemicals nowadays has been reviewed above. It can actually be very misleading to consider one aspect of the safety

data, such as chemical persistence in soil, in isolation. The point at issue is, or should be, whether or not the presence of residues in soil leads to any harmful consequences in practice. In fact, it then becomes necessary to consider the whole set of safety data in perspective. When this is done, it is rare indeed to find persuasive evidence of a harmful effect in soil. It is worth remembering also that even traditional farming activities, such as plowing, can have a marked effect on some soil micro-arthropod populations.

Birds and Beneficial Insects

At the beginning of this paper, I stated that the responsible and efficient use of pesticides has an important part to play in improving the quality and quantity of agricultural production, alongside measures such as cultural practices which minimize potential pest survival and which encourage the natural enemies of pests, wherever possible. There are, unfortunately, certain unavoidable situations where the use of some pesticides to control one group of insects can have adverse effects on populations of beneficial insects – albeit temporarily. Where this is known to be a problem, application of the product should normally be delayed until the infestation reaches a point where the need for control outweighs the drawbacks of using the product.

The safety of pesticides to birds can raise complex issues. There can be no argument that populations of rare birds need to be protected. Equally there are circumstances in which the excessive presence of some common avian species can constitute a pest, causing unjustified crop losses. As in all aspects of the safe and effective use of pesticides, the matter should be one for benefit/risk judgement in the circumstances which will usually apply locally.

When developing seed treatments and certain rodenticide uses, pesticide manufacturers are obliged to consider potential effects on overall populations of birds which may eat the treated material. However, equally important (as mentioned earlier) is the need to foresee the potential for problems which might not have been so obvious, such as possible secondary toxicity to scavenging species which may predate upon moribund species in areas where rodenticides have been used.

BENEFIT/RISK EVALUATIONS

No field of human endeavor is entirely free of risk. All aspects of our daily life are surrounded by some degree of risk. Even to do nothing can incur a risk! In every case, we have to consider all risks of any activity in the light of all its benefits. This applies equally to the safe and effective use of pesticides.

The acceptable balance of benefit over risk will inevitably be different under the vastly different circumstances which apply in different parts of the world.

It should be remembered too that differences in use recommendations for a given product can differ quite legitimately between countries. Different crops are grown in different climates and are generally subject to differences in the nature and extent of infestation by pests and diseases, according to climate. Moreover, the fact that a product is not registered in one country is not necessarily a valid

reason for that product not to be used in another country. Many developing countries, for example, situated in tropical and sub-tropical regions, experience pest, disease, and weed control problems which have no equivalent in the more temperate countries which usually develop and produce pesticides. Commentators enjoying the benefits of sufficient wholesome food and proper shelter in industrialized countries are generally in no position to pass judgement on the suitability of the use of pesticides under the conditions which in practice prevail in many developing countries. In this respect, paragraph 38 of the report of the First Asian Regional Consultation on Harmonization of Pesticide Registration Requirements (Baguio City, Philippines; 24–29 October, 1983) is to be welcomed, where it is stated:

> "The use of a pesticide should be permitted only if the benefits outweigh the risks involved. The balance between benefit and risk will differ greatly under different socio-economic conditions, and it is important for each country to study its own priorities when deciding what compounds may be registered and not be too much influenced by decisions made elsewhere."

Let us consider an example. In the developed world, most uses of the more persistent organochlorine insecticides have been phased out, often in favor of less persistent organophosphates. Viewed solely from an environmental perspective, it is supportable as a desirable move even though it has to be noted that the evidence regarding the causes of eggshell thinning in birds can be a matter for debate. We also need to remember, however, that some of the organophosphates are more acutely toxic than earlier organochlorines, which in practice had a good record of user safety. Thus, it would be imprudent to consider the environmental perspective in isolation. Rather, the totality of the benefits and the whole package of safety data need to be considered, in perspective. Sadly, the consequences of removing DDT from use in malarial mosquito control programs have already been demonstrated.

Let us remember also that fashions in safety evaluations have tended to change with time. Topics which at one moment were thought to be particularly worrisome became less so as greater technical understanding evolved.

The issues surrounding benefit/risk judgements on pesticides are not always simple or straightforward. The need for flexibility of choice to meet specific requirements from within a range of acceptable pest control measures, is essential. Meanwhile, as far as pesticide residues in food and the environment are concerned, it can be argued that the largest potential dangers arise from misuse and not from recommended use. In this context, the availability of quality pesticides which will perform the required task is essential. So too is continued training in the safe and efficient use of pesticides. On the basis of the available evidence, which is enormous, it is legitimate to argue that if these aspects of the supply and use of pesticides can be kept in good order, residue levels in food and the environment will continue not to be a source of overriding safety concern for man.

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WHAT DO PESTICIDE RESIDUE LEVELS IN THE ENVIRONMENT REALLY MEAN IN SOUTHEAST ASIA? AN NGO PERSPECTIVE

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The International Organization of Consumers Unions (IOCU) is representative of non-governmental organizations (NGOs) worldwide, and some information on it is necessary in order to understand the perspectives presented in this paper. IOCU is a federation of consumer organizations dedicated to the protection and promotion of consumer rights worldwide through information, research and education activities. An independent, non-profit foundation, IOCU links the activities of 148 consumer organizations in over 52 countries. It maintains three offices: the Central Office at the Hague, Netherlands; the Regional Office for Asia and the Pacific in Penang, Malaysia; and the Regional Office for Latin America and the Caribbean in Montevideo, Uruguay.

The IOCU Regional Office for Asia and the Pacific is also the Regional Coordinating center for the Pesticide Action Network (PAN). PAN is a worldwide coalition of citizen groups and individuals who are opposed to the irrational spread and misuse of pesticides. As part of its work on pesticides, IOCU has produced five books within two years: *The Pesticide Handbook: Profiles For Action* provides data on 44 pesticides; *The Pesticide Poisoning Report: A Survey of Some Asian Countries* examines what some Asian countries are doing to monitor the ill effects of pesticide use on human health and on the environment; *The Lessons of Bhopal: A Community Action Resource Manual on Hazardous Technologies* presents an overview of the Bhopal disaster and an analysis of the relevant policy issues and numerous ideas for action; *The Bhopal Syndrome: Pesticide Manufacturing and The Third World* documents how the spread of pesticide technology threatens communities and workers around the world; *Problem Pesticides, Pesticide Problems: A Citizens' Action Guide to the International Code of Conduct on the Distribution and Use of Pesticides* is a guide to help NGOs understand and monitor the implementation of the FAO's International Code of Conduct on the Distribution and Use of Pesticides.

A GLOBAL PROBLEM

In February 1987, the American Association for the Advancement of Science held a special symposium during its annual meeting to bring the pesticide problem to the attention of the U.S. Congress and other governmental agencies. At that meeting Robert Metcalf, professor of biology and entomology

at the University of Illinois, highlighted one of the problems of pesticide use. He said, "The human race, packing more pesticides than common sense, has lost the war with the insect kingdom and inadvertently created armies of superbugs that nothing can kill."

This is not surprising when one looks at the prevailing insect control effort and the large amounts of pesticides being used worldwide. Presently, more than 4 billion pounds of pesticides with an end value of over US$14 billion are produced annually – more than one pound for every person on earth (Weir & Schapiro 1981). A handful of multinational companies, based in the United States, United Kingdom, Europe, and Japan, dominate the worldwide trade in expensive and hazardous pesticides (Weir 1983). Five top companies dominate 50% of the world market and a mere two dozen firms dominate virtually all sales worldwide of agrochemicals (Weir 1983). Often, as with such billion dollar profit businesses, when commercial interests contradict the interests of the community at large, human health, environmental quality, and food security take second place.

It is noteworthy that the involvement of the Third World in the pesticide trade, both in production and consumption, has been steadily escalating over the years. During one recent six-year period, for instance, the Philippines increased its imports of pesticides fivefold (Norris 1982). However, in many Taird World countries, the legal structures have not kept pace with the increasing production, marketing, and use of pesticides. According to a FAO study, less than 40% of Third World countries had specific legislative control on the sale and use of pesticides (Abraham 1987). Even when present such legislation is, in many cases, either inadequate or characterized by shoddy implementation. Many Third World governments are also blindly committed to increasing agricultural production at any cost, unmindful of the inimical effects of agrochemicals on human health and the environment.

Worse still, Third World pesticide users face many difficulties that hinder safe pesticide practices, including widespread illiteracy, lack of protective clothing or equipment, lack of access to adequate medical care, lack of training in safety procedures, and restrictions on the right to organize for safe working conditions. Under these circumstances, pesticides are easily misused and overused, causing a number of well-documented problems. One basic symptomatic problem, the direct result of this indiscriminate use of pesticides, is pesticide residue in food and the environment.

In 1983, in what has been reported as a great ecological disaster, Thailand experienced a mammoth fish kill which officials blamed on agrochemicals (Deema 1983). In Malaysia, pesticide poisoning has decreased fish yields, causing rice farmers to lose an important supplementary income and a cheap source of valuable proteins (Buli 1982). The decline of migratory egrets in the state of Kedah, Malaysia, is also said to be the indirect effect of pesticides in water systems (Foo 1985).

And from the Philippines comes this report: "Previously, the farmer easily provided for his meals by catching fish in the rice field, the last routine in his early morning work in the farm before coming home for breakfast. But not any

more. Fish in the rice fields are disappearing. So are snails, oysters, crabs, shrimps, frogs and other aquatic creatures." (Bull 1982).

In South Kalimantan, Indonesia, 58 people were poisoned after eating fish killed with the insecticide phosphamidon and 34 died.

These examples highlight some serious cases of environmental contamination by pesticide residues. Although some systematic monitoring is being done on pesticide residues in food, there is little information available on levels in the environment.

Pesticide residues, however, are merely signals of a technology that has gone wrong. They are the tail end of the problem and trying to find solutions to the problems of pesticide residues is like treating the symptoms without really trying to cure the disease. To overcome the problems of pesticide misuse and overuse, we have to confront and fundamentally change the present way in which pesticides are perceived and used in our society.

HOW NECESSARY ARE PESTICIDES?

Proponents of pesticides argue that they are needed in developing countries to feed rapidly growing populations. Yet pesticide sales in Africa multiplied fivefold from 1964 to 1978, while food production decreased by one percent (Malaret 1985).

Furthermore, at least half of all the pesticides used in underdeveloped countries are applied not to food crops consumed locally, but to luxury items (coffee, tea, etc.) and to non-food crops (cotton, rubber) grown for export to the US., Japan, Europe, and other industrialized countries. Therefore, the major argument advanced in favor of Third World pesticide use – helping feed the hungry – is a highly questionable one.

Ironically, evidence is mounting that pesticide use is not necessary to maintain food production, at least not in the quantities currently being applied.

THE LACK OF INFORMATION

In the course of research for this paper to establish the extent of the problem of pesticide residues in this region, I encountered one monumental barrier – the lack of information and the correctness of the information I received. This blanket of secrecy over such essential health and safety data was very disturbing and unacceptable.

In some countries in Asia and the Pacific, leaking of information about pesticides can cost conscientious officials their jobs. In some cases, anyone who reveals the results of government studies about the dangers of pesticides can be sent to jail. And reporters try to do their jobs under restrictions that their counterparts in the industrialized world would consider outright censorship and repression.

Consequently, the public becomes distrustful of government statements and results of research on pesticides. In addition, it helps build a blissfully ignorant and totally unaware citizenry, which will be unable and unwilling to participate

in programs to curb indiscriminate use of pesticides that leads to poisoning of people and the environment.

THE IBT SAGA

Pesticide registration and/or certification procedures in most countries require that manufacturers, prior to marketing, provide adequate health and safety data to the relevant government authority. The data is then reviewed and the pesticide approved or not approved. However, in the wake of the Industrial Bio-Test Laboratories (IBT) episode, there has been growing concern over the possibility that significant proportions of such health and safety data could have been based on experiments poorly done, falsely reported or not conducted at all.

In 1977, the United States Government discovered that the Chicago-based IBT had deliberately falsified research findings on a massive scale, as is clearly reflected in the percentage of IBT tests that were subsequently considered invalid — 99% of tests on cancer; 76% of tests on birth deformities; 50% of tests on mutations, neurotoxicity, and medium term tests on a variety of other ill-effects; and 30% of tests on toxicity if swallowed, breathed, or absorbed through the skin (Abraham 1987).

Most disturbing was the fact that at least four major pesticide manufacturers had been aware of the falsified research data on potential carcinogenicity experiments that IBT had submitted to the United States Government. According to the United States government, IBT had deliberately omitted evidence of potential hazards from some reports, fabricated other data, and later shredded the results upon learning that they were under investigation. In 1983, four senior executives of IBT were brought to trial, charged with conspiring to defraud clients and government agencies by writing and distributing false and fraudulent research reports.

There is reason to believe that IBT data was instrumental in several national and international regulatory decisions on the sale and use of pesticides, and that even the WHO, which sets international safety standards for exposure to potentially hazardous substances had, to an appreciable degree, relied upon IBT test results.

It seems that Third World countries have not only to bear the brunt of the dumping of pesticides that are banned or severely restricted in their countries of origin, but also the hazards of pesticides that might have gained certification on grounds of falsified test results churned out by unscrupulous laboratories like IBT. The gravity of the situation demands urgent and appropriate action by all Third World governments to re-examine the validity of health and safety data supporting currently registered pesticides.

THE SOLUTIONS

Given the prevailing conditions, how are we going to fundamentally change the value systems so that the health and safety of both people and the environment is paramount, superceding any technical or commercial considerations? There are three basic needs that have to be taken into account —

1) freedom of information, 2) education and people's participation, and 3) support for international initiatives.

Freedom of Information

Freedom of information is a tool by which citizens and reporters can dig out relevant data about chemical issues and other matters of public concern from government files that normally remain inaccessible. Freedom of information laws can establish the framework for democratizing technology. Armed with more accurate information, citizens can better judge the costs and benefits of allowing pesticides to be used in their communities. Thus informed, they are better prepared to participate in decisions which can ultimately determine not only their economic well being, but also the state of their health as well as that of their children.

Education and People's Participation

In order to build a citizenry actively involved in shaping the policy decisions that affect their future as well as present well-being, they must be educated on the pesticide problems that beset their communities, countries, the region, and the world they live in, the basic sources of these problems, and the safe control alternatives available.

In June 1985, the Pesticide Action Network launched a worldwide public education and media effort which focused on 12 hazardous and widely-used pesticides. This "Dirty Dozen" Campaign has several important aims: (1) to ensure that all policy decisions affecting pesticide use and trade will take into consideration first human safety and environmental health; (2) to strengthen pesticide regulatory and information systems in all countries and international agencies; and (3) to generate support for sustainable agriculture. Through such efforts, NGOs have not only raised public consciousness about pesticide issues, but also trained and encouraged citizens to participate in all decisions about pesticide use.

SAFER PEST CONTROL STRATEGIES THROUGH INTEGRATED PEST MANAGEMENT Third World farmers and their governments have come to believe that pesticide use equals high yields and no pesticides means low, unprofitable yields. But the choice is not between pesticides and no pesticides. Third World farmers and governments can choose a hazardous and potentially ineffective or counter-productive dependence on a pest management strategy based solely on the uncontrolled application of chemicals. Or they can choose a pest management strategy that is both safer and more effective — a strategy that includes traditional pest management techniques and that integrates these with the use of the safest possible chemical pesticides only when necessary, to deal with pest problems as a part of a system that includes people, crops, beneficial insects, fish, and livestock, as well as pests and chemicals. This is a basis of integrated pest management (IPM). I will not go into a discussion of IPM.

Suffice it to conclude that IPM techniques should be further developed and seriously implemented in this region.

Support for International Initiatives

The FAO's International Code of Conduct on the Distribution and Use of Pesticides, unanimously adopted in November 1985, covers principles of pesticide management, government registration and control schemes, health safeguards, international information exchange, labelling, and advertising practices. What is significant is that the Code addresses problems prevalent in many Third World countries, like the reusing of pesticide containers, pesticides being sold near foodstuffs and repackaging of pesticides in beverage and other containers. Thus, though the Pesticide Code may be weak in some areas, following its recommendations would definitely put an end to some of the most dangerous practices found in developing countries and this will produce an impact on residue levels in the environment and in food.

Although unanimously supported by 158 member countries of the United Nations, the FAO Code must be fully implemented through national legislation to be effective. Governments must also establish the necessary mechanisms for its enforcement.

Another useful instrument is the "Consolidated List of Products whose Consumption and/or Sale have been Banned, Withdrawn, Severely Restricted, or Not Approved by Governments". It is an essential reference list containing legislative or regulatory actions taken by governments, names of producers and trade name of products. More than one third of the products are pesticides.

Using the UN directory, governments, especially in the Third World, will be able to check the regulatory status of pesticides in other countries and thus make informed decisions to regulate pesticides at home. What is needed now is support for the list, and regular submissions to the UN of information on regulatory actions on pesticides by the governments concerned.

Pesticide Residues: What can be done

EFFECTIVE CONTROL ON THE AVAILABILITY AND USE OF PERSISTENT ORGANOCHLORINE PESTICIDES Although some of the organochlorides present relatively little occupational hazard, they present a threat to the environment and, therefore, there is still a need to restrict their use. (This is not to be taken as advocating the use of the less persistent but more toxic organophosphates or carbamates instead). Since many of these chemicals are banned or severely restricted in the pesticide exporting countries, there is special responsibility when they are exported and sold to Third World countries. That is why there is a need for mutual responsibility in the form of the principle of prior informed consent (PIC).

PRIOR INFORMED CONSENT PIC simply means that before a pesticide that is banned or restricted in its country of origin can be exported to another country, an authorized government agent in the importing country must (1) be

notified about the impending import and the reason the pesticide is restricted in the country of origin and (2) give positive consent to the pesticide's importation.

PIC is based on the principle that every country has the right to determine whether or not a hazardous product should cross its borders. As summed up in a 1977 resolution of the UNEP governing council, governments should "take steps to ensure that potentially harmful chemicals, in whatever form or commodity, which are unacceptable for domestic purposes in the exporting country, are not permitted to be exported without the knowledge and consent of appropriate authorities in the importing country".

MONITORING OF PESTICIDE RESIDUES The regular and systematic monitoring of soil, air, and water for pesticide residues is essential. However, monitoring requires substantial and sustained funding, which is normally provided through public funding. Governments should investigate ways in which pesticide registrants can share the costs of monitoring and of prevention and treatment measures. It seems only fair that those who make the poisons should share some of the financial responsibility for controlling and preventing their ill-effects.

CONCLUSION

In conclusion, I would like to relate this very famous story:

"You go in and save a drowning baby; and then there is another drowning baby, and you go in and save the second drowning baby, and then a third, a fourth, a fifth. You are so busy saving drowning babies that you have no time to look up from the river to see that there is a man there throwing babies into the river".

In many issues, one has to look at the source of the problem. Here, basically, in the words of American author and ecologist Barry Commoner, "We have produced a chemical system antagonistic to life which is essentially overwhelming it". Only by curbing the spread of agrochemicals around the world can the problems of pesticide misuse and overuse be overcome. To do that we need a new alertness, increased knowledge, a concerted effort of all concerned parties, and most of all, the public and political will to act locally and globally. One concerned party, the Pesticide Action Network, has already begun to create this global conscience and will to action, to move away from pest control techniques that are inherently hazardous and wasteful towards those that are humanized and ecologically sound.

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MANUAL ON THE USE OF PESTICIDES UNDER BANK-FINANCED PROJECTS*

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The Asian Development Bank's developing member countries (DMCs) have enjoyed substantial benefits from the use of pesticides in terms of increased production of food and industrial crops. Because of this, the scope of pesticide usage will continue to expand for some time to come. However, DMCs have expressed concern over the potential adverse effects of pesticides on man and the environment – often for the same reasons that led developed countries to question the use of pesticides.

In view of these factors, as well as the concerns expressed within the Bank, in early 1986 staff consultants were engaged to review the overall situation in selected DMCs with respect to pesticide use and regulation, and to make recommendations as to how the Bank should proceed to ensure environmentally sound practices in its agriculture projects. The following DMCs were selected and visited — Bangladesh, Indonesia, Malaysia, Nepal, Pakistan, the Philippines, Sri Lanka, and Thailand. In all of these countries, agriculture is the backbone of the economy and plant protection has played a major role in developing the production of food and industrial crops. The review was undertaken with full consideration of the work of relevant international and regional organizations with regard to pesticide use practices, particularly existing guidelines and codes of practice.

In the light of the consultants' findings, the Bank undertook the production of a technical manual on the use of pesticides in Bank-financed projects. The manual is designed to guide Bank staff in the selection, procurement, and safe and cost-effective usage of pesticides. It was produced consonant with the varying requirements of the DMCs and international practice and the need for effective and environmentally sound practices of pesticide use.

BACKGROUND

Pests are serious problems in many of the major crops grown in the Asia/Pacific region, causing annual yield losses estimated at 30–60%. Although

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* The manual has now been published as "Handbook on the Use of Pesticides in the Asia-Pacific Region", and may be obtained from Dr. Bindu Lohani, Head, Environmental Unit, Asian Development Bank.

biological, cultural, and mechanical means of control have been introduced, progress has been slow in their implementation in farmers' fields and at present such means are not considered viable. Consequently, the use of chemical pesticides will continue to be the most convenient and accepted form of pest control for the foreseeable future.

Pesticide usage among DMCs has increased annually at an average of 10% for the past five years and is expected to continue at this rate. In the eight DMCs studied, the total pesticide market for 1984 was US$566 million. Insecticides accounted for 58% of the market, followed by herbicides at 34%, fungicides at 7%, and nematicides and rodenticides at 1%. The bulk of the insecticides are used on rice, cotton, and vegetables, while herbicides are mainly used on rubber, oil palm, and tea plantations. Fungicides are used for control of diseases of vegetables and fruit.

With this increased use of pesticides has come an awareness of potential hazards and the need for regulation. From the early 1970s to 1980, nearly all the Bank's DMCs promulgated legislation governing the registration and use of pesticides. International organizations responded with guidelines and codes of practice.

The study by staff consultants, covering the laws, regulations, and registration procedures in selected DMCs, revealed a wide gap between the written law and the adequacy of actual procedures and their implementation. Although laws conform to existing international guidelines, in practice the interpretation of the legislation and its implementation differ widely, ranging from very sophisticated systems to a total absence of regulation.

A number of international agencies, including the World Bank (IBRD), Food and Agriculture Organization (FAO), World Health Organization (WHO), and United Nations Environment Program (UNEP), have developed guidelines to assist governments in the safe use of pesticides. The importance of these guidelines as general references has been broadly accepted. However, many DMC officials have expressed a desire for more specific and practical guidelines relevant to the variable and often unique conditions of the countries involved.

On the basis of their findings — anticipated increased use of pesticides, lack of effective alternatives to pest control, a wide gap between written regulations and their implementation, variation in the registration and regulatory schemes from one country to another, and the deficiencies of available guidelines -- the consultants recommended the preparation of a technical manual on the use of pesticides under Bank-financed projects. The consultants also recommended that in addition to coverage of those countries reviewed in their study (as country profiles), coverage should include other DMCs — India; Burma; the People's Republic of China; the Republic of Korea; Papua New Guinea; Fiji; Western Samoa; and Taipei, China.

THE MANUAL

The resultant Manual consists of three parts:

Part I	-	Technical Resource Materials
Part II	-	Country Profiles

Part III - Pesticide Industry and Product Profiles.
Details of these parts are presented in the following sections.

Part I. Technical Resource Materials

Part I consists of technical information and operational procedures which the Bank, in consultation with a particular DMC, can use in the selection of pesticides for Bank-financed projects. The procedures draw upon the following selection criteria:

- Cost-effectiveness
- Health and safety considerations
- Environmental impacts

These criteria need to be weighted in the context of the crop pest and country situation. The most cost-effective choice may not necessarily be acceptable in terms of health and safety or other environmental concerns. Pesticides, being toxic and highly persistent, create adverse effects on agro-ecosystems, livestock, wildlife, and other non-target organisms, as well as human health and safety.

The selection process requires assessment of available options to pesticide use. Biological control measures utilize naturally occurring organisms to regulate pest populations at acceptable levels. Plant resistance, the inherited ability of a plant species to withstand or tolerate insect pests or diseases, is another means of pest control. Cultural control consists of crop protection methods used consciously or unconsciously by farmers to improve yield. Integrated pest management (IPM), another control measure, utilizes all suitable techniques and methods in a compatible manner, and maintains the pest populations at levels below those causing economically unacceptable damage or loss.

In addition to the above selection criteria, several other inter-related factors which may affect the source and supply of pesticides need to be considered. They include: registration and other regulatory policies and procedures, factors affecting imports of technical materials, and distribution networks and institutional factors affecting the marketing of products.

Knowledge of the existing pesticide usage in selected DMCs and regulatory practices are essential in determining the monitoring and training needs in the Asia-Pacific region. Emphasis is given on quality control of formulations and analyses of pesticide residues in food.

Of the pesticides used in the future, it is expected that herbicides will show the greatest increase. There will be an increase in resistance to pesticides by insects, fungi, and by the increasing dominance of resistant weed genotypes. The organochlorines will be phased out as residues and environmental concerns grow in importance. Nonetheless, the consultants felt that pesticides will continue to be the main weapon in crop protection for many years. Meanwhile, a tremendous effort will need to be made to develop IPM programs, train farmers when to take action, establish economic threshold levels, and to use alternative control measures wherever appropriate.

Procurement of pesticides is to be undertaken in accordance with the general policies set forth in the Bank's existing *Guidelines on Procurement* and taking into consideration the factors enumerated.

A brief section is included on critical publications from FAO, WHO, USAID, ARSAP, IOCU, OXFAM, and relevant handbooks.

For details of topics discussed in Part I, refer to the Table of Contents in Appendix 1.

Part II. Country Profiles

Part II consists of individual country profiles on registration, pest management practices, industry statistics, environmental concerns, key pesticides, major crops, and pests, etc., for the following developing member countries of the Bank: Bangladesh, Indonesia, Malaysia, Thailand, Philippines, Sri Lanka, Pakistan, Nepal, Burma, India, Korea, China (PRC), Papua New Guinea, Western Samoa, Fiji.

It should be noted that the data collected do not include public health and household uses of pesticides.

The population in the 15 DMCs accounts for 95% of the population in the 29 DMCs of the Bank and nearly 50% of the total world population.

Part III. Pesticide Industry and Product Profiles

Part III provides users with important background information on the pesticides industry and product profiles including the market size and annual growth rate of selected countries, the role of the public and private sectors and the major products currently used in the Asia-Pacific region.

A product profile has been developed for 40 of the most widely used pesticides in the Asia/Pacific region; it covers common name(s), trade name(s), classification, common formulations, selected chemical properties, toxicology, persistence, special warnings, antidote, efficacy, uses and application methods on major crops within the region, and use restrictions or bans in donor countries or the Bank DMCs.

CONCLUDING REMARKS

During the last 10–15 years, developing countries have used increasingly larger quantities of pesticides in an attempt to intensify food production. However, both governments and private individuals have expressed growing concern about the possible adverse impacts generated by pesticide application. Thus, the major challenge confronting the Bank is to deploy realistic, pragmatic procedures for safe and cost-effective pesticide selection and use and, if necessary, to recommend appropriate measures to mitigate pesticide-related hazards. Such procedures must allow flexibility in evaluating the risks and benefits of pesticides according to prevailing environmental and socio-economic conditions and regulation and administration needs in the Bank's developing member

countries (DMCs). To the extent possible, they must also be acceptable to international organizations.

To help address these problems, the Asian Development Bank has prepared a manual to assist the Bank's staff in the selection of safe and cost-effective pesticides under Bank-financed projects. It also contains information on the general activities in the Asia-Pacific region and on specific countries as 'Country Profiles'.

The manual is designed to make the Bank's project officers more aware of the many complex and interrelated issues associated with pesticide usage so that each case may be considered on its own merit and with due consideration to regulatory practices and existing legislation.

APPENDIX I

Table of contents of Pesticide Manual used by Asian Development Bank.

INTRODUCTION

A. Background
B. Objectives and Scope of the Manual
C. Format and Limitations

CHAPTER I: AVAILABLE PEST CONTROL MEASURES

A. Biological Control Methods

1. Characteristics of Parasites and Predators
2. Management and Conservation of Parasites and Predators

B. Plant Resistance

1. Types of Plant Resistance to Insect Pests
2. Types of Plant Resistance to Diseases

C. Cultural Control Methods

1. Examples of Cultural Control Methods
2. Advantages and Disadvantages of Cultural Control Practices

D. Chemical Control Measures

1. Types of Spray Programs
2. Economic Threshold Levels - Concepts and Applications
3. Types of Pesticides Formulations and Application Techniques

E. Integrated Pest Management

1. IPM Concept and Practices
2. Selective Use of Insecticides in IPM Programs
3. Implementation of IPM Concept

CHAPTER II: POTENTIAL ENVIRONMENTAL AND HEALTH EFFECTS

A. Toxicity and Persistence of Pesticides
B. Effects on Agro-ecosystems

APPENDIX I *continued*

C. Risks Associated with Certain Cropping Systems

1. Irrigated or Paddy Rice
2. Cotton Production Systems
3. Vegetable Production Methods

D. Effects on Wildlife and Livestock
E. Effects on Non-Target Organisms
F. Residues on Food
G. Pesticide Resistance
H. Effects on Health and Safety

1. Degree and Measurement of Toxicity
2. Classification of Hazards
3. Toxic Properties of Some Chemical Groups

CHAPTER III: PESTICIDE REGISTRATION AND REGULATORY SYSTEMS

A. Need for Regulations
B. Regulatory Procedures
C. Legislation and Enforcement Schemes

1. Date Requirements
2. Data Evaluation
3. Label Requirements and Classification of Pesticides
4. Enforcement of Mechanisms
5. List of Banned and Restricted Pesticides

D. Post-Registration and Other Regulatory Policies

CHAPTER IV: PESTICIDE USAGE IN SELECTED DMCs

A. Major Crops and Important Pests
B. Common Pest Control Practices
C. Pesticide Consumption and Use Patterns
D. Key Pesticides Used in Selected DMCs
E. Environmental, Health and Safety Concerns in the Selected DMCs

1. Health Hazards
2. Effects on Fish, Soil and Water
3. Environmental Pollution
4. Pest Resistance

F. Pesticide Regulatory Practices in the Region

APPENDIX I *continued*

G. Monitoring and Training Needs in the Region

1. Quality Control
2. Residue Monitoring
3. Environmental Monitoring
4. Occupational Health Monitoring
5. Training Requirements

CHAPTER V: FRAMEWORK FOR THE SELECTION OF PESTICIDES UNDER BANK-FINANCED PROJECTS

A. General Approach
B. Criteria for Selection of Pesticides Under Bank-funded Projects

1. Cost-effectiveness
2. Health and Safety Consideration
3. Environmental Impacts

C. Health and Environmental Checklist

CHAPTER VI: PROCUREMENT OF PESTICIDES UNDER BANK-FINANCED PROJECTS

A. Effects of Regulatory Policies
B. Considerations Affecting Importation of Technical Materials
C. Distribution Networks and Other Institutional Forces Affecting Marketing of Pesticide Products
D. Approaches to Pesticide Procurement

CHAPTER VII: PESTICIDES INFORMATION SOURCES

A. Summary of Selected International Pesticides Publications
B. Directory of Organizations Involved in Pesticides

GLOSSARY OF TERMS

LIST OF REFERENCES

A COMPARATIVE STUDY ON THE OCCUPATIONAL EXPOSURE OF SPRAY WORKERS USING KNAPSACK AND SPINNING DISC SPRAYERS

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In Peninsular Malaysia, as much as 75% of all pesticides used annually are herbicides (Balasubramaniam et al. 1984). The non-motorized hydraulic knapsack sprayers are by far the most widely used spray equipment for herbicide application (Ramasamy & Aros 1986). Since the early eighties, spinning disc (SD) sprayers have also been used for this purpose. With rising costs as well as scarcity of plantation labor, this equipment proved practical as it required less water, was suitable in hilly terrain, and operators could cover a larger area per unit time (2–2.5 ha/day) compared to the knapsack sprayer (1 ha/day). Their use gradually increased, particularly in some plantations in the country (Ramasamy & Aros 1986). Initially they were reported to be used for the application of glyphosate for the control of weeds like lalang (*Imperata cylindrica*). It was also reported to be used with other herbicides like trichlopyr (Lee 1983) and paraquat (Maclean 1984) for general weed control. These herbicides were invariably used with the SD equipment at concentrations higher than were normally recommended with the knapsack sprayer. For example, paraquat concentrations recommended for use with knapsack sprayers were about 1:80–1:160 dilutions of a 25% active ingredient (paraquat dichloride) product. These were increased to as much as 1:25 dilution for use with the SD applicators (Maclean 1984).

Although occupational exposure of spray workers has been studied extensively in other countries (Crome 1985) only limited studies have been done in Malaysia. Swan (1969) carried out two field trials in Malaysian rubber plantations to study the exposure of spray operators who applied paraquat for weed control with hand-operated knapsack sprayers. This was followed by a study on the health of Malaysian plantation workers with particular reference to paraquat spraymen (Howard et al. 1981) and another on the occupational exposure of Malaysian plantation workers to paraquat (Chester & Woollen 1981). More recently, Lee & Chung (1985) estimated from droplet counts the potential contamination of spray operators using flame orange fluorescent tracer. In view of the above, it was felt that there is a need for further studies to determine the potential exposure of spray operators using the SD and knapsack sprayers under local conditions so that necessary recommendations can be made to ensure their safe use.

There has been little standardization on methods for the evaluation of operator exposure. The World Health Organization (WHO) developed one for such an evaluation in 1975 (WHO 1975) and later revised it in 1982 (WHO 1982). Another method was developed by the Operator Protection Research

Group (OPRG), Ministry of Agriculture, Fisheries and Food, United Kingdom, for the measurement of potential exposure of spray operators using tracer dyes such as lissamine green, orange G or Waxoline red 'O'.

MATERIALS AND METHODS

The OPRG method using lissamine green was selected for this study because it was relatively simple and adequately sensitive. Potential dermal exposure of spray workers to pesticides was established by determining the amount of any pesticide used that will be deposited on the workers' clothes over a measured period. Spray workers were dressed in normal working clothes covered with patches, folded in half, of 20 x 10 cm spun-bonded polyethylene (Tyvek®). Each worker had 19 of these patches fixed to various parts as shown in Appendix I, about 10% of the total body surface area. Clean cotton gloves were worn for the measurement of contamination of their hands. However, no attempt was made to measure the penetration of spray solutions through the operators' clothes.

Inhalation exposure was determined by providing each spray worker with a standard half-face respirator where the filter had been modified as shown in Appendix II.

Six spray workers were engaged to carry out this study. Four workers did the spraying, two for each of the knapsack and the SD sprayers, while the other two mixed and supplied the spray solutions as is normally practiced in several plantations in this country.

The Micron Herbi 77® fitted with a red restrictor was used as the SD equipment in this study. This was compared with the 10-liter non-motorized hydraulic knapsack sprayer fitted with a 7/64 adjustable fan jet nozzle, which is commonly used for herbicide application.

Spray solutions containing lissamine green were used in this study in place of pesticides. The dye was preweighed and given to the mixers who prepared the spray solutions and filled their respective spray equipment. The concentrations of the spray solutions were approximately 0.02% for the knapsack sprayers and 0.4% for the SD sprayers. These concentrations were selected to facilitate analysis.

The spray workers then carried out inter-row strip spraying among young rubber trees. Those using knapsack sprayers walked forward waving the spray lance to widen their swath width. Since the weeds (mainly *Paspalum conjugatum*, *Ottochloa nodosa*, and spots of *Mikania* sp.) were about 0.6 to 0.75 m high, the SD sprayers were carried on the operators' shoulders slanting downwards in front as recommended. This whole operation was carried out for about an hour's effective spray time each day for three days. Patches which had become excessively wet were replaced with fresh ones. At the end of each day the patches, which had been placed in marked plastic bags, were brought to the laboratory for extraction and analysis of the tracer dye that had been deposited onto them. Extraction was done using appropriate quantities of 10% v/v acetone in distilled water. The extracts were then filtered through membrane filters (pore

Table 1. Operator exposure (ml spray solution per hour).

Operator	Head & neck	Body front	Body back	Thigh front	Thigh back	Arms	Leg front	Leg back	Hand right	Hand left	Nose	Whole body
Day 1												
KS-1	1.32	.041	3.77	2.39	1.07	.368	20.03	1.013	2.25	1.50	.0010	33.75
KS-2	.072	.520	1.04	.217	1.11	.228	16.94	.663	1.14	2.74	.0012	24.67
SD-1	.055	.044	.270	.386	.018	.093	28.96	.213	.980	1.15	.0026	32.17
SD-2	.0016	.021	.020	1.37	.010	.024	27.63	.090	.017	.100	.0047	29.29
MIXER-KS	.0018	.439	.082	1.25	.053	.015	.275	.017	13.84	20.31	.0039	36.29
MIXER-SD	.0017	.0057	.0055	.0008	.0025	.0041	.0016	.0006	.058	.037	.0047	.12
Day 2												
KS-1	.113	.298	3.73	5.68	.239	.567	18.14	3.25	1.27	3.00	.0066	36.29
KS-2	.114	.251	5.33	.580	2.53	.668	13.30	1.69	3.08	2.42	.0058	29.70
SD-1	.025	.089	1.32	.902	2.18	.033	27.79	.874	4.80	3.03	.0001	41.04
SD-2	.028	.025	.484	.255	.033	.0056	32.69	1.92	.048	.072	.0001	35.56
MIXER-KS	.056	1.02	.266	.479	.877	.280	1.04	.576	10.21	33.86	.0063	48.67
MIXER-SD	.0006	.0068	.0032	.0086	.0016	.0028	.017	.0015	.401	.226	.0002	.67
Day 3												
KS-1	.059	.434	1.52	.833	.623	.436	7.29	1.45	13.44	.0065	.0039	26.10
KS-2	.072	.246	.377	1.13	.332	.245	11.24	1.37	.715	.760	.0038	16.50
SD-1	.0038	.0519	.047	.886	.151	.028	15.46	1.44	.016	.450	.0002	18.53
SD-2	.0028	.0757	3.88	.090	1.64	.037	22.87	2.02	2.77	.684	.0002	34.07
MIXER-KS	.068	.483	.466	.860	.315	.401	.286	.394	20.31	4.41	.0053	28.00
MIXER-SD	.0026	.0051	.0057	.011	.0055	.0064	.0032	.0044	.099	.065	.0002	.21

KS = knapsack, SD = spinning disc.

size 0.45 um) prior to spectrophometric determination at a wavelength of 640 nm.

RESULTS

The occupational exposure of the operators to the spray solution is summarized in Table 1. Operators using the knapsack sprayers experienced an average of 27.84 ml/h exposure compared to 31.78 ml/h for those using the SD sprayers. This difference was non-significant.

It was noted that the front leg region of the workers was the most severely exposed of all using both types of equipment. Two other areas with high exposure were the back of the body (especially for those using the knapsack sprayer) and the hands of the mixers. Potential inhalation exposure varied from 0.0010-0.0066 ml/h (knapsack) and 0.0001-0.0047 ml/h (SD) and could be considered minimal. The percentage exposure of the various parts of the operator's body as compared to the whole body is as shown in Table 2. This

Table 2. Percentage of the operator's body exposed to sprays.

	% of whole body						
Operator	Head & neck	Upper body	Thighs	Arms	Legs	Hands	Nose
Day 1							
KS-1	3.91	11.29	10.25	1.09	62.35	11.11	0.00
KS-2	0.29	6.32	5.38	0.92	71.35	15.73	0.00
SD-1	0.17	0.98	1.26	0.29	90.67	6.62	0.01
SD-2	0.01	0.14	4.70	0.08	94.64	0.42	0.01
Mixer-KS	0.00	1.44	3.59	0.04	0.80	94.11	0.01
Mixer-SD	1.39	9.17	2.70	3.36	1.80	77.74	3.84
Day 2							
KS-1	0.31	11.10	16.31	1.56	58.94	11.77	0.02
KS-2	0.38	18.79	10.47	2.25	49.56	18.52	0.02
SD-1	0.06	3.43	7.51	0.08	69.84	19.08	0.00
SD-2	0.07	1.43	0.81	0.02	97.33	0.34	0.00
Mixer-KS	0.12	2.64	2.79	0.58	3.32	90.55	0.10
Mixer-SD	0.09	1.49	1.52	0.42	2.76	93.68	0.03
Day 3							
KS-1	0.23	7.49	5.58	1.67	33.49	51.52	0.01
KS-2	0.44	3.78	8.86	1.48	76.42	8.99	0.02
SD-1	0.02	0.53	5.59	0.15	91.20	2.51	0.00
SD-2	0.01	11.61	5.08	0.11	73.05	10.14	0.00
Mixer-KS	0.24	3.39	4.19	1.43	2.43	88.28	0.02
Mixer-SD	1.25	5.19	7.93	3.08	3.65	78.81	0.10

KS = knapsack, SD = spinning disc.

indicated more clearly the extent of exposure on the various parts of the body experienced by the operators. The percentage exposure of the legs to the whole body was significantly higher for the SD operators (86.12%) compared to that of knapsack sprayer operators (58.68%). The hands of mixers were the most contaminated part of the body while the backs of operators handling the knapsack sprayer were more contaminated than those using the SD sprayers. Inhalation exposure contributed negligibly to the total exposure of the three groups of operators.

DISCUSSION

The total spray volume per hour exposure experienced by operators using the two types of sprayers were not significantly different. However, it is pertinent to note that in practice the concentrations of pesticide spray solutions used in SD sprayers are often 4 to 8 times higher than those with the knapsack sprayers. Since hazard is a function of toxicity and degree of exposure it would therefore be more hazardous to use a SD sprayer than a knapsack sprayer under the conditions described.

The high percentage of spray solution falling on the legs and thighs of spray operators using knapsack sprayers was also shown in an exposure study carried out in the United Kingdom to determine the total and regional potential dermal and respiratory exposure of agricultural workers during the application of 2,4-D with five types of application equipment typically used in the country (Bonsall 1985). The tendency of operators to walk through the spray mists before the droplets settled on the target and also to walk into the sprayed areas, particularly where foliage was thick, contributed to the higher exposure in the leg region.

Since hazard to spray operators can be reduced if exposure can be minimized, it is clear that for both types of sprayers, operators should wear proper boots which cover as much of the legs as possible. These boots should be made of rubber or other suitable materials and be comfortable for hot and humid conditions. They should also be suitable for walking through the undulating terrain which is common in the plantations. An alternative to these boots would perhaps be the use of leggings made from suitable materials which can prevent penetration of the pesticide spray solutions. Results of this study indicated that through the use of proper footwear more than 58% for knapsack and 86% for the SD sprayer of the total exposure of spray solution to operators could be reduced. This would mean that if good safety standards could be achieved, then the use of SD sprayers might be acceptable for the more toxic pesticides. Presently however,there is a lack of such suitable protective clothing for spray operators working in the tropics. In view of this it may be prudent for spray operators to adopt clean working practices and good personal hygiene, and maintain their equipment well.

It was observed that contamination of the back of the spray operators' clothing was due mainly to loose capping and spillage of spray solution during refilling. Hence, proper design of equipment which would minimize spillage during refilling should be encouraged. It may also be wise for the spray operator to wipe off any spillage before starting to spray. In addition, a piece of plastic

or other impermeable material placed between his shirt and the sprayer could minimize spillage contact with the body.

Although this study did not determine the amount of spray solution absorbed by the body tissues of spray operators, it does provide a convenient means of indicating the potential exposure of spray operators using different types of sprayers under different working conditions. Since the present study was carried out in a typical rubber estate simulating the application of herbicides, the exposure of operators working under other conditions or using different sprayers or nozzles may be different. Similar studies could be carried out in other situations using the above technique.

ACKNOWLEDGEMENT

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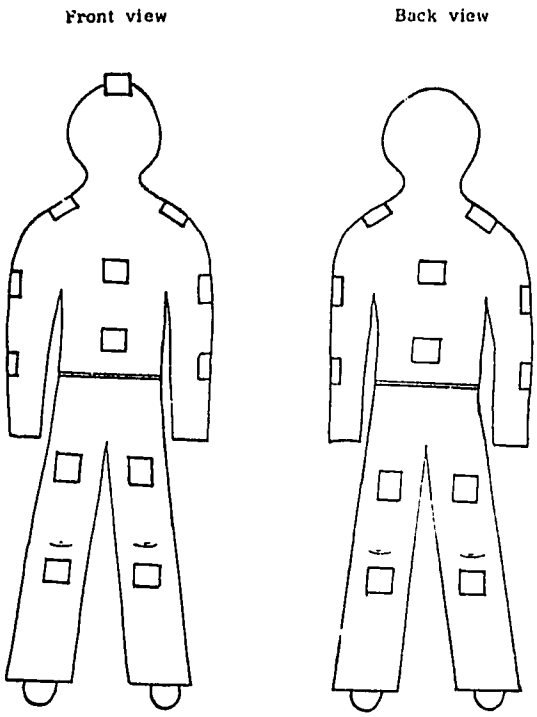
APPENDIX I

Positions of patches on various parts of the body.

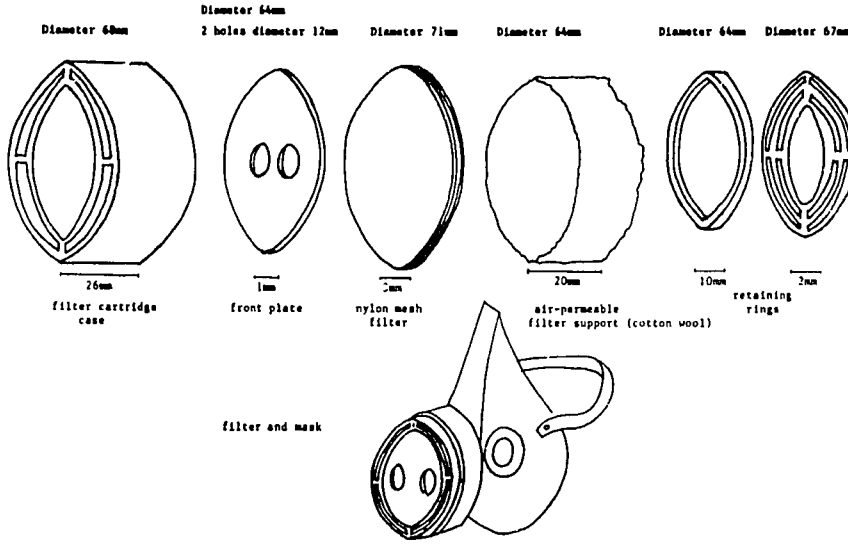


Area of single patch = 100 cm^2

Number of patches = 19

APPENDIX II

Air sampling respirator and filter assembly.



A PRELIMINARY STUDY ON EXPOSURE OF RICE FARMERS TO PESTICIDES

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The Philippines is a developing country with a population of about 52 million. Agricultural production in the country has increased considerably in the past few years and pesticides have played an important role in boosting agricultural yields. With increased use of pesticides, there has been a growing concern and awareness of its adverse effects both on man and the environment.

A study on occupational pesticide exposure among Filipino farmers in San Leonardo, Nueva Ecija (located in the northern part of the country) was conducted by Dr. Maramba and Dr. Castaneda in 1985. This study revealed that farmers were inadequately protected. All of the farmers did not wear boots and gloves, 74% did not wear any mask when spraying, and 71% wore long sleeves and long pants while applying pesticides (Figure 1)

Several studies have been undertaken to assess the exposure of workers to pesticides, such as the study of occupational pesticide exposure among certified pest applicators in Metro Manila (Maramba 1986); the study of occupational pesticides poisoning conducted by the Institute of Labor and Management Studies (1979–1981); and the study of pesticide problems in Bulacan and Metro Manila (Casanova et al. 1984). However, dermal exposures of Filipino farmers under local conditions have not been investigated.

The immediate objectives of this preliminary exposure study are as follows:

1. To study the WHO protocol for field exposure studies and adapt them to local conditions.
2. To develop a method to determine the degree of exposure associated with the use of liquid insecticides using hand-pumped knapsack sprayers.
3. To determine the exposure limits of this type of application and to design further studies to cover establishment of safe re-entry periods, appropriate protective clothing, and proper training at farm levels on safe handling of pesticides.

MATERIALS AND METHODS

The method used in this study was based on the WHO standard protocol on field survey of exposure to pesticides (WHO 1982).

Two laboratories, the Bureau of Plant Industry (BPI) and the Philippines Institute of Pure and Applied Chemistry (PIPAC), a private institution, carried out parallel trials to validate the sampling, extraction, and analytical procedures to be used. The following were investigated:

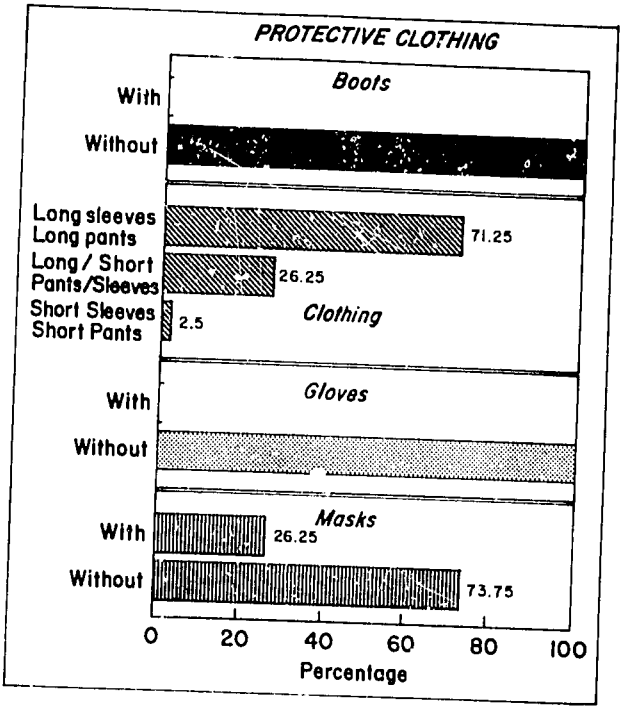

Figure 1. Results of a study on the use of protective clothing in San Leonardo, Nueva Ecija province, 1985.

1. Limits of detection.
2. Percentage recovery of methyl parathion.
3. Stability testing of methyl parathion on cotton swatches.

Recoveries of between 80% and 95% were obtained from the series of experiments conducted at a 3–5 ppm limit of detection using gas chromatography.

After the method validation, a dry run was performed. The dry run was conducted in Bulacan located in the rice granary of the Central Plain of Luzon (Figure 2). Two volunteer farmers were involved in the spraying of methyl parathion 50 EC. The application rate was 30 ml/16 L of water using a knapsack sprayer. The total area covered was one hectare. Protective clothing and gloves used were made of cotton material. The exposure pads, measuring 10 x 10 cm were of gauze material.

The dry run was done in late 1986. The two subjects were first made to try the cotton coveralls for pre-marking of sections for sampling and placement of exposure pads (Figure 3). The exposure pads were placed inside the gloves-palm portions and thigh portions of the coveralls with leukoplast (plaster) and safety pins, backed up with aluminum foil. The farmers were then made to wear the marked coveralls and gloves with exposure pads and to go through normal spraying operations. The time of spraying and the total amount of pesticides used by each farmer were recorded.

After spraying, sectioning of samples was done without removal of coveralls from the subjects' bodies to avoid possible cross contamination and

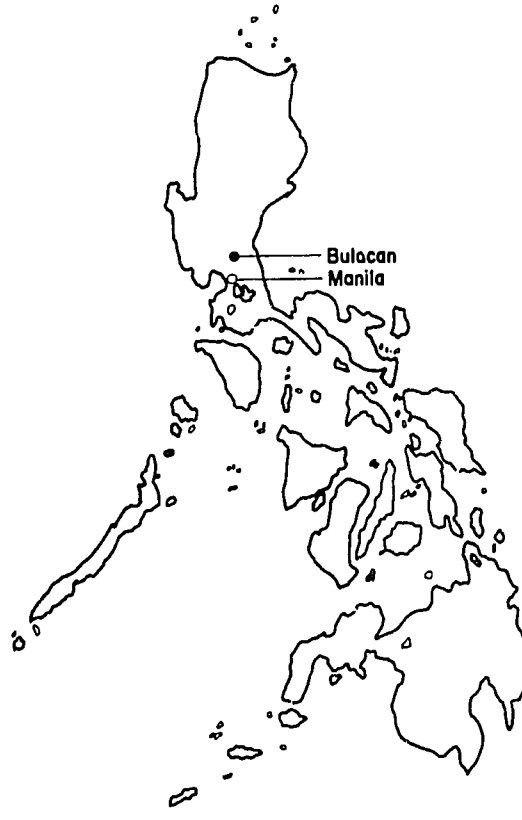

Figure 2. Map of the Philippines and location of dry run.

further exposure. The gloves and sectioned samples were wrapped in aluminum foils, placed in pre-labelled polyethylene bags and refrigerated in the van provided with a portable refrigerator for pesticides samples. The refrigerated samples were then delivered to the respective laboratories for analysis.

All analytical work from the dry run was carried out using gas chromatography. The two laboratories conducted the extractions and analytical determinations. The samples of clothing were measured, shredded and soaked in acetone. Extractions were done several times depending on the sample size. Aliquots of the extracts were taken and injected into the G.C. column. Reference samples of a standard solution of methyl parathion were injected into the column periodically for calibration purposes.

RESULTS AND DISCUSSION

In the field the following were noted:

1. Cotton coveralls were not suitable for the farmers and certain adjustments in marking the samples to be sectioned had to be made, which contributed to the delay in the actual spraying.

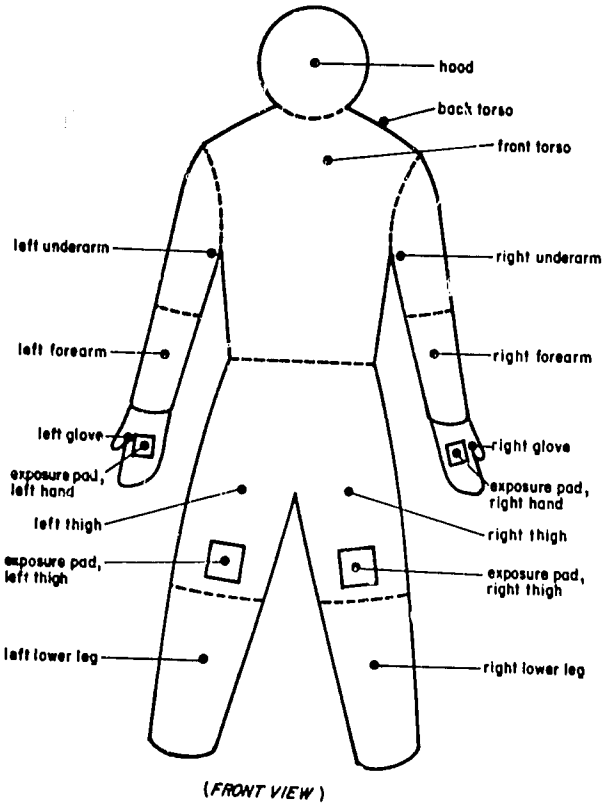

Figure 3. Coveralls, gloves, location of exposure pads, and section samples.

2. The subjects had to spray under the extreme heat of the sun causing them to perspire and wet the coveralls. This removed the markings thus making it difficult to cut the sections properly. Mud/dirt especially at the leg portions obscured the markings as well.
3. The pads made of surgical gauze were inadequate as exposure pads.
4. Difficulty in the proper placements of the pads was encountered, especially on the gloves. Also the tape of choice (leukoplast) was unsatisfactory resulting in the loss of one exposure pad and others were almost detached.
5. The sectioning of the samples was done while on the subjects' bodies since it was difficult to have them remove the coveralls due to wetness of the cloth especially on the trunk portions.
6. Environmental parameters such as temperature, humidity, wind speed and direction were not properly recorded.

In the laboratory, the following observations were noted:

1. Although the two laboratories agreed to conduct similar extraction procedures, modifications were done on the manner of extracting methyl parathion from the sectioned samples.
2. GC parameters were also different.
3. Wetness and mud contributed to the weight of some sectioned samples.

CONCLUDING REMARKS

The study reported in this paper was initiated by the Fertilizer and Pesticide Authority with the purpose of developing the methodology for field exposure studies adaptable to local conditions. It must be emphasized that this study has been limited to defining methods for the potential dermal exposure of farmers applying methyl parathion through hand-pumped knapsack sprayers. Possibilities of expanding this study to cover the determination of re-entry periods, recommendations for the proper protective clothing and training of extension workers on safe use of pesticides will need to be explored in further studies.

It may be stated that with improvements and modifications, a more comprehensive study should be undertaken in the future to determine the limits of exposure of rice farmers to pesticides so that protective measures may be recommended to ensure the safe use of the chemicals.

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DESTRUCTION OF PESTICIDES AND CHEMICAL WASTES BY MEANS OF A CEMENT KILN

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Destruction of small quantities of chemical wastes without polluting the environment is generally a concern in the field of plant protection. Different methods are used for the treatment and/or destruction of various kinds of pesticides depending on their chemical composition. The common pesticides encountered may be grouped as follows:

- Carbamates
- Chloronitrophenol derivatives
- Organochlorine compounds
- Organophosphorus compounds
- Organomercury compounds
- Organotin compounds
- Pyridyl derivatives
- Phenoxyacetic acid derivatives
- Pyrethroids
- Triazine derivatives
- Thiocarbamates
- Inorganic compounds
- Organic solvents

Methods of waste management may also be grouped as follows:

Treatment	Storage	Disposal
incineration	impoundment	injection wells
chemical alteration	tanks	impoundment
physical alteration	waste piles	landfills
biological decomposition	containers	land treatment

Incineration by means of special incinerators is the easiest method of waste management and normally is not harmful to the environment. However, inorganic substances (e.g., cupric oxide, cupric sulfate, cyanamide, hydrocyanic acid, potassium cyanide, phosphine, zinc phosphide, thallous sulfate) and pesticides which contain heavy metals (e.g., mercury compounds, tin and zinc compounds) are not suitable for incineration. These substances should be treated chemically or stored in chemical dumps.

Biological decomposition, e.g., of halogenated aromatic substances, can be done with the help of certain microorganisms. Unfortunately, this method is still being developed (Wagner & Hempel 1985). Small quantities of pesticides can be sprayed on to fields and allowed to degrade.

The majority of pesticides are commonly incinerated by means of special incinerators. The temperature of the incinerators may vary from 1200°C to 1600°C depending on the model of the incinerator. These temperatures are necessary to decompose the chemical substances into their harmless components. The disadvantages of these special incinerators are:

- High initial costs: The price range for incinerators lies between DM500,000 for a small one and a few million DM for a big one. Expensive but necessary accessories for incinerators are a smoke washing plant and a measuring and control device, which enables one to follow the process of combustion and to measure the exhaust gas.
- Maintenance and service: Skilled workmen are necessary for the operation, maintenance and service of an incinerator.
- The appropriate capacity of the incinerators: Incinerators should run continuously, because they are sensitive to the process of cooling down when switched off. Therefore, enough waste should be available to keep the incinerators in operation continuously, and to justify the investment and the cost of maintenance.

The ordinary methods of waste management are impractical for most developing countries. An alternative method for small quantities of pesticide waste and organic solvents is the incineration by means of rotary kilns, which are used in cement plants. This is a technically simple and comparably cheap method for the destruction of chemical waste and, at the same time, does not pollute the environment.

DESCRIPTION OF THE ROTARY KILN

The cement plant used for the waste disposal experiments reported here meet the latest technical requirements. The rotary kiln, which forms the heart of the cement plant, has a diameter of 4.3 m and a length of 73 m.

In the rotary kiln, limestone and shale are burnt to cement clinker. The temperature measured on the inside wall of the front of the kiln is 1450°C. At the end of the kiln the temperature measured in the hot clinker is approximately 1200°C. The actual combustion temperature is more than 1850°C. The air supply is 30%. The residence time in the rotary kiln is approximately 1 hour. These temperatures are reached by an oil burner. The three fuel storage tanks, containing 400 tons of oil, supply the oil burner with approximately 7.5 tons of oil per hour. The plant is equipped with highly efficient electrostatic precipitators and filters for dust recovery of 99.5%. The emission of the dust in the environment is only 100 mg dust/m^3. Routine quality control, which is done automatically, determines the standard of production for each day. The process of combustion in the rotary kiln is continuously monitored by a camera. The capacity of the cement plant is 160 tons cement per hour.

TEST PROCEDURE

In the laboratory, chemical waste containing organic solvents and pesticides is collected in special safety containers. Waste has to be in a liquid form for combustion in the cement kiln. Solid waste is dissolved in kerosene while concentrated liquid waste is diluted with kerosene. The mixture of waste and kerosene is brought to the cement plant where it is poured into the fuel storage tank of the rotary kiln. The chemical waste is diluted with the oil in the storage tank. From there it proceeds to the oil burner in the kiln where combustion takes place. The advantages of dissolving/diluting the pesticide waste in the fuel are that the concentrated pesticides are diluted considerably and the pesticide waste is not incinerated all at once, but over a period of time.

RESULTS

According to the list of pesticides by Perkow (1983/85), which contains 486 active ingredients, 43 substances are not suitable for incineration by means of rotary kiln, 18 substances are organic compounds, and 25 substances contain metals. Chemical waste containing the following substances are not suitable for combustion in the cement kiln:

- Heavy metals: Pb, Zn, Sn, Cr, Cu, Cd, Hg, Tl
- Highly halogenated compounds
- Inorganic compounds

Examples:

Mercury compounds	Phenyl mercury acetate, Phenyl mercury chloride
Zinc compounds	Propineb, Methylmetiram, Zineb, Ziram, Mancozeb)
Tin compounds	Azocyclotin, Cyhexatin, Fenbutatin oxide, Fentin acetate, Fentin hydroxide
Compounds containing bromine	Methyl bromide, Naled, Bromopropylate, Dibromchlorpropane, Ethylen dibromide
Inorganic compounds	Potassium cyanide, Hydrocyanic acid, Calcium cyanamide, Sodium-cyanide, phosphine, Zinc phosphide, Thallous sulfate.

Cement kilns can also be used for the destruction of pesticide waste and chlorinated organic solvents. Chemical waste which needs after-treatment, and/or which has to be stored in chemical waste depots are not suitable for incineration in a rotary kiln. The same rule applies to compounds which can only be incinerated when special safety precautions have been taken.

UTILITY OF THE ROTARY KILN

The conditions in the rotary kiln are similar to the conditions in a turbulence reactor of an incinerator. The temperatures in such a reactor are 1500°C–1600°C and the residence time is 0.3 seconds.

Table 1. Comparison of different regulations for combustions.

Standard regulations	EPA (United States Environmental Protection Agency	TA-Luft, 1983 West Germany (Regulations for the purity of air)	Commercial Incinerator/ turbulence reactor	Rotary kiln of a cement plant
Min. Temperature	1100°C	1200°C	1500°C - 1600°C	1850°C
Min. Air-supply	with air supply	11%	with air supply	30%
Min. residence time	1 sec.	0.3 sec.	0.3 sec	±1 h

According to air purity regulations (TA-Luft of 1974 of West Germany and the amendment of 1983), the requirements for the incineration of substances which contain PCB (Polychlorinated Biphenyls) are the following: minimum temperature 1200°C at a residence time of 0.3 seconds, minimum air supply 11%. A comparison of the regulations and criteria for combustion of pesticides is given in Table 1.

Polychlorinated Dibenzodioxins (PCDD) and related compounds are not formed due to the high temperature of 1850°C in a rotary kiln. Dioxins and the related compounds are split up into harmless fragments. The notorious 2,3,7,8-TCDD (Tetrachlordibenzodioxin) and its 22 isomers are known as the "Seveso-poison" (Appendix I). They and the related Polychlorinated Dibenzofurans (PCDF) are highly poisonous substances. These products are formed during a radical reaction, when hydrocarbons are incompletely decomposed in the presence of substances which contain chlorine at temperatures between 600°C and 800°C. These are the conditions in normal refuse incinerators. Dioxins have been found in the exhaust gas of such incinerators (Appendix II).

The group of PCDD can be decomposed completely by high temperatures. At temperatures over 1100°C and a residence time of 0.1 second, an annihilation of >99.9999% has been found (Kennedy et al. 1978).

Impurities such as chlorophenols are found in the herbicides 2,4,5-T; 2,4-D-ester, acid, amine, and in pentachlorophenole (PCP) and in many preparations such as wood preservatives. Under unfavorable conditions dioxins can be formed during combustion.

Other combustion studies included a US Air Force study (Hutzinger et al. 1982), in which a mixture of herbicides known as Agent-Orange was burnt with a minimum access of 30% air, and at combustion-wall temperature of 1400°C.

No detectable 2,3,7,8-TCDD was found at a detection limit of 300 ppb in the exhaust air.

Combustion studies made at the Midwest Research institute (Gould et al. 1978) showed that 99.9999% of organic pesticides are destroyed at high temperatures. A number of experiments have been carried out in the USA on the thermal degradation of fungicides and insecticides.

Appendix III shows the combustion products at 1275°C for methylparathion, captan and toxaphene.

In West Germany various cement plants started pilot projects to test the feasibility of this method. Used oils from generators were incinerated in the kilns of the cement plants. It is known that these oils contain PCB, which is the first step to dioxins. Since big amounts of these oils are available, the cement industry sees here a chance to save on expensive fuel (Bosdorf 1986).

One of the main problems of this kind of destruction of pesticides and chemical waste by means of a cement kiln is the contamination of the cement with chloride-ions. Chloride-ions and HCl, which could be formed, are decomposition products which could influence the quality of the cement. Routine quality control is done in the cement plant to determine the standard of daily production of the cement. The standard requirement for cement in Europe is that the chloride concentration should not exceed 0.1%. At temperatures between 600°C and 900°C, and in the presence of alkalines the corresponding chlorides are formed. For this reason, and according to safety standards for the cement, the chloride level in the cement should not exceed 0.03%.

According to a leading cement plant in West Germany, the contamination of cement with chloride-ions should not be a problem. In comparison with the capacity of the cement plant (which is 160 tons cement per hour) the amount of waste containing chlorinated substances which are incinerated is very small. Extremely high chloride concentrations are unlikely to be formed in the cement, because of the continuous production of the cement plant.

The technically simple and cheap method described in this paper meets all the requirements of environment protection of the EPA of the USA and the TA-Luft of West Germany, and is suitable for developing countries. Furthermore, cement plants are common in developing countries.

ACKNOWLEDGEMENT

The author is grateful to the Director General of the Department of Agriculture, Malaysia, for his support and permission to present this paper. The author would like to acknowledge the guidance and the encouragement of Dr. G. Vaagt, Leader of the Malaysian-German Pesticide Project and the counterpart staff.

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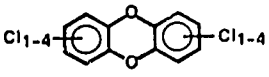
APPENDIX I

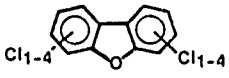
Polychlorinated dibenzo-P-dioxins and related compounds (Hutzinger et al. 1978).

POLYCHLORINATED DIBENZO-P-DIOXINS
AND RELATED COMPOUNDS



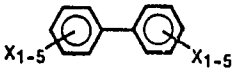
POLYCHLORINATED
DIBENZO-p-DIOXINS

PCDD



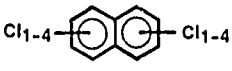
POLYCHLORINATED
DIBENZOFURANS

PCDF



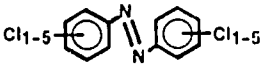
POLYCHLORINATED BIPHENYLS
(X = Cl)
POLYBROMINATED BIPHENYLS
(X = Br)

PBB PCB

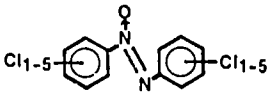


POLYCHLORINATED
NAPHTHALENES

PCN

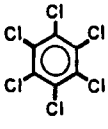


POLYCHLORINATED
AZOBENZENES



POLYCHLORINATED
AZOXYBENZENES

PAB

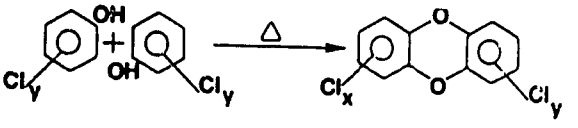


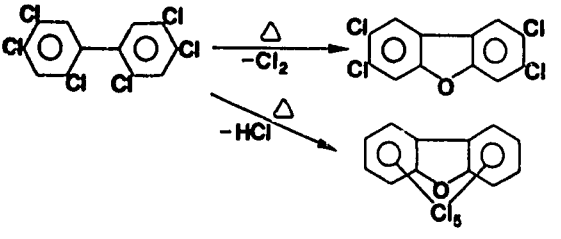
HEXACHLOROBENZENE

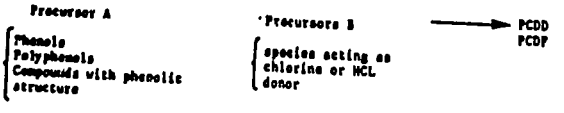
HCB

APPENDIX II

lorinated dioxins and related compounds (Hutzinger et al. 1982).







APPENDIX IIIa

Combustion products of chlorinated pesticides in air (Kennedy et al. 1978)

COMBUSTION PRODUCTS *OF CHLORINATED PESTICIDES IN AIR

	Captan $C_9H_8Cl_3NO_2S$ MW 300,61		Toxaphene $C_{10}H_{10}Cl_8$ MW 414	
	Combustion and Exhaust Temp. (°C)		Combustion and Exhaust Temp. (°C)	
Product	1727°C	27°C	1727°C	27°C
Ar	8.40×10^{-3}	8.60×10^{-3}	8.07×10^{-3}	8.32×10^{-3}
CO	1.40×10^{-3}	0.00	1.56×10^{-3}	0.00
COCl	3.79×10^{-9}	0.00	1.78×10^{-8}	0.00
$COCl_2$	0.00	0.00	1.14×10^{-10}	2.73×10^{-29}
CO_2	1.47×10^{-1}	1.52×10^{-1}	1.56×10^{-1}	1.63×10^{-1}
Cl	5.58×10^{-3}	8.40×10^{-20}	2.35×10^{-2}	1.19×10^{-19}
ClO	1.14×10^{-5}	3.43×10^{-20}	4.59×10^{-5}	1.06×10^{-24}
ClO_2	2.08×10^{-10}	3.15×10^{-26}	7.98×10^{-10}	2.12×10^{-35}
Cl_2	5.60×10^{-5}	2.52×10^{-2}	9.92×10^{-4}	4.95×10^{-2}
Cl_2O	0.00	0.00	7.76×10^{-10}	1.09×10^{-26}
H	1.55×10^{-5}	0.00	3.50×10^{-6}	0.00
HCl	4.36×10^{-2}	1.02×10^{-4}	1.01×10^{-1}	3.11×10^{-2}
HNO	8.96×10^{-9}	0.00	4.18×10^{-9}	0.00
HO_2	1.56×10^{-7}	8.90×10^{-30}	7.82×10^{-8}	9.21×10^{-37}
H_2	9.14×10^{-5}	0.00	2.76×10^{-5}	1.25×10^{-35}
$H_2O(L)$	0.00	3.38×10^{-2}	0.00	1.55×10^{-2}
H_2O	4.34×10^{-2}	3.34×10^{-2}	1.25×10^{-2}	3.40×10^{-2}
H_2O_2	1.13×10^{-3}	2.40×10^{-25}	3.11×10^{-9}	5.33×10^{-30}
H_2S	1.09×10^{-10}	0.00	0.00	0.00
N	7.58×10^{-10}	0.00	7.39×10^{-10}	0.00
NH	1.26×10^{-10}	0.00	0.00	0.00
NO	2.31×10^{-3}	1.45×10^{-17}	2.15×10^{-3}	3.11×10^{-22}
NOCl	1.40×10^{-7}	8.25×10^{-15}	5.50×10^{-7}	2.47×10^{-19}
NO_2	1.12×10^{-6}	4.01×10^{-12}	9.92×10^{-7}	1.88×10^{-22}
N_2	7.12×10^{-1}	7.30×10^{-1}	6.76×10^{-1}	6.99×10^{-1}
N_2O	1.11×10^{-7}	1.03×10^{-20}	1.01×10^{-7}	2.15×10^{-25}
O	9.11×10^{-5}	0.00	8.70×10^{-5}	0.00
OH	7.22×10^{-4}	2.67×10^{-28}	3.79×10^{-4}	0.00
O_2	1.88×10^{-2}	4.04×10^{-4}	1.72×10^{-2}	1.95×10^{-3}
O_3	1.32×10^{-10}	3.09×10^{-34}	1.16×10^{-10}	0.00
SO_2	1.64×10^{-2}	3.99×10^{-13}	0.00	0.00
SO_3	1.27×10^{-5}	1.68×10^{-2}	0.00	0.00

APPENDIX IIIb

Combustion products of sulfur-containing pesticides in air (Kennedy et al. 1978).

COMBUSTION PRODUCTS OF SULFUR-CONTAINING PESTICIDES IN AIR

Methyl Parathion		
	$C_8H_{10}NO_5PS$ MW 263.21	
Combustion and Exhaust Temp. (°C)		
Product	1727°C	27°C
Ar	8.52×10^{-3}	8.72×10^{-3}
CO	8.15×10^{-4}	0.00
CO_2	1.13×10^{-1}	1.25×10^{-1}
H	1.71×10^{-5}	0.00
HNO	1.42×10^{-8}	0.00
HO_2	3.48×10^{-7}	2.16×10^{-28}
H_2	1.12×10^{-4}	0.00
$H_2O(L)$	0.00	4.53×10^{-2}
H_2O	7.56×10^{-2}	3.28×10^{-2}
H_2O_2	2.79×10^{-8}	2.00×10^{-24}
H_2S	0.00	0.00
N	7.63×10^{-10}	0.00
NH	1.40×10^{-10}	0.00
NO	3.31×10^{-3}	1.22×10^{-16}
NO_2	2.26×10^{-6}	2.87×10^{-11}
N_2	7.21×10^{-1}	7.40×10^{-1}
N_2O	1.60×10^{-7}	8.85×10^{-21}
O	1.29×10^{-4}	0.00
OH	1.14×10^{-3}	7.65×10^{-28}
O_2	3.80×10^{-2}	2.84×10^{-2}
O_3	3.80×10^{-10}	1.84×10^{-31}
S	2.85×10^{-9}	0.00
SH	5.06×10^{-10}	0.00
SO	1.16×10^{-5}	0.00
SO_2	1.52×10^{-2}	4.37×10^{-14}
SO_3	1.68×10^{-5}	1.56×10^{-2}
PN	1.93×10^{-8}	0.00
PO	9.38×10^{-6}	0.00
PO_2	1.41×10^{-2}	0.00
P_4O_6	3.01×10^{-4}	0.00
$P_4O_{10}(S)$	0.00	3.92×10^{-3}
P_4O_{10}	6.00×10^{-8}	2.71×10^{-8}

LOOKING FOR THAILAND'S "LOVE CANAL"

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The pleasant sounding words "Love Canal" provoke horror in most Americans. Thoughts that come to mind are chemicals oozing up through neatly trimmed grass where children play, birth defects and cancer. What was the cause of this horror?

Love Canal was a residential estate near Buffalo, New York, that was built over a chemical company's then-legal dump site for wastes associated with pesticide manufacture and formulation. This included old drums filled with toxic chemicals and solvents. The title of the land changed hands several times and was eventually sold for real estate development. The toxic waste dump site was covered over with dirt and homes were built on top of it. Twenty years later, the problems described above began.

Serious problems involving obsolete pesticide stocks exist in a number of developing countries in Asia and Africa. For example, it has been authoritatively reported (PAPA 1985) that 212 lots of pesticides have been identified in Punjab Province, Pakistan, and appear to be abandoned. Among these lots are reported to be 1.5 million kg of 5% endosulfan granules, 230,000 liters of Gusthion 20% EC, 250,000 liters of Phosvel 27% EC, and many more. The first two are examples of persistent chlorinated pesticides and toxic organophosphorus compounds. The third, Phosvel, has never been registered for use in the USA and was banned throughout the world due to its delayed effects on the central nervous system of mammals, causing temporary and sometimes permanent paralysis from high exposure. Until 1980, the government had distributed pesticides free of charge or highly subsidized them, resulting in excess stock far above the needs of farmers.

If large stocks of unattended, obsolete pesticides are left in the open or in temporary storage, especially in tropical climates, the containers may corrode and the contents may leak out, endangering man and the environment. An additional problem arises if a pesticide is broken down into more toxic degradation products.

The USAID Office of Foreign Disaster Assistance recognized that a "Love Canal" or a similar problem involving obsolete pesticides could occur in other African or Asian countries that are users of large quantities of pesticides, and hence funded a survey (Jensen & Zweig 1986) to determine whether such a problem is likely to occur in Thailand. The members of the survey team in Thailand were Yothin U. (Khon Kaen University, Khon Kaen 40260, Thailand), Paitoon P. (Department of Agriculture, Bangkok 9, Thailand), Usanee U.,

Rachanee K., and Sukanya B. (all of the National Environment Board, Rama VI Road, Bangkok 4, Thailand).

IDENTIFICATION AND LOCATION OF PESTICIDE WASTE SITES

In 1985, the pesticide market in Thailand was estimated to be about US$90 million (Gastor 1986). With the exception of paraquat, which is manufactured in a one-step reaction in two factories, all other pesticides are imported as technical materials or finished products to be formulated or repackaged in Thailand.

The distribution channels are mainly through the private sector, with less than 20% going directly to farmers through marketing organizations and the Thai Department of Agricultural Extension (DOAE).

During the preparatory phase of the survey, a brainstorming meeting was held in order to get ideas so that a systematic strategy could be formulated for finding large quantities of abandoned or obsolete pesticide stocks in Thailand. Representatives from the Thai Ministry of Industry, the National Environment Board, the Thailand Development Research Institute, the Ministry of Agriculture and Cooperatives, the Ministry of Public Health, the Bangkok Metropolitan Administration, and the United States Agency for International Development attended this meeting.

A rationale for the systematic search of possible sites was developed that was based on the inspection of the following points in the distribution chain for pesticide sales:

- Port of Bangkok;
- Formulation Plants;
- Repackaging Plants;
- Wholesale and Retail Outlets;
- DOAE Central Warehouse;
- Farmers' Warehouses; and
- Bangkok Dump.

Due to time and budgetary limitations, only a limited number of sites representing the above distribution points could be visited. They were all within two hours driving time from Bangkok. This strategy appeared reasonable because most of the pesticide formulating and repackaging plants are located in this area. Also, the central region around Bangkok consists mostly of agricultural land with the major crops being fruits, vegetables and ornamentals, all requiring frequent applications of pesticides year around.

RESULTS

No significant stocks of obsolete or abandoned pesticides or potential "Love Canal" toxic waste dumps were found in the farming or industrial areas around Bangkok. The explanation for this lies in the nature of the pesticide business in Thailand and ironically in the possible laxity of enforcement of environmental laws.

The Thai economy is based on private enterprise, with more than 80% of all pesticides sold through commercial channels. The profit motivation in private business tends to keep pesticide imports (and sales) in balance with, or even short of demand. Efficiency in forecasting import requirements and cost-reducing techniques for pesticides formulation are essential. Consequently, excessive stocks of pesticides are unlikely to exist in the private sector.

According to Thai law, stocks of banned pesticides may be sold until the stocks are used up, with no time limit. Further, there does not seem to be strict enforcement of laws regulating the quality of pesticide products in the marketplace, so that obsolete, substandard and even water-damaged products may be repackaged and sold. Due to these reasons, though they may be undesirable, "Love Canal"-like problems due to product obsolescence or substandard formulations have thus far not occurred around Bangkok.

Although there are environmental regulations (NEB 1986) requiring that obsolete pesticide stocks and used pesticide containers be destroyed by state-of-the-art technology, these regulations are rarely enforced. Drum refurbishing appears to be a thriving business. Therefore, the disposal of large steel pesticide drums may not be a serious problem from the potential waste site point of view. The lack of a program for the disposal of used plastic and glass containers, however, does pose a potential health problem which may be resolved by the imposition of cash container deposits.

At the present time, there is no designated hazardous waste site in Thailand, although there are plans underway for such a waste site to be established in Thonburi, outside Bangkok. Until this is established, along with stronger legislation and strict enforcement, a person or company wanting to get rid of obsolete pesticides will likely bury or dispose of them on private land. As a result, there may be many small potential "Love Canals" scattered throughout Thailand.

The small-scale farmer in Thailand usually purchases minimum quantities (100 ml to 1 liter) of the cheapest pesticide recommended by the dealer, and commonly will spray a mixture of several chemicals to achieve a quick pest "knockdown" (Jensen 1986). Monocrotophos, carbofuran and methyl parathion, considered highly hazardous by the World Health Organization (1984), are commonly used in Thailand. The on-farm storage of these chemicals is usually improper, often with pesticides within easy reach of young children, thus posing a potential health problem. Disposal of the glass, plastic and metal containers is usually done by selling them to a middleman, who in turn sells them for recycling.

CONCLUSIONS

Based on a systematic search of pesticide distribution points and discussions with Thai government and donor agencies, we concluded that large quantities of abandoned or obsolete pesticides thus far do not exist in the Bangkok metropolitan area, and are unlikely to exist in other parts of Thailand. Although the survey period was of short duration, we do not believe that we have failed to find such abandoned pesticide stocks if they did exist. We also concluded that the

existence of a pesticide dump site approaching the magnitude of "Love Canal" is improbable considering the strength of the private sector which dominates the pesticide business in Thailand and the slippage in enforcement of existing environmental laws.

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PESTICIDE PROBLEMS AND INDONESIAN NON-GOVERNMENTAL ORGANIZATION ACTIVITIES IN SOLVING THESE PROBLEMS

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The word "pesticide" actually has two meanings in agriculture: the first as a miracle to save people from hunger, and the second as a destroyer of human beings and the environment.

We will not discuss the advantages of pesticides here as the manufacturers have already promoted these commodities with very persuasive words, such as pesticides being instant insect killers, and being guarantees for a higher yield. Some people have claimed that the negative impact of using pesticides are the health and environmental risks associated with them. In my opinion, the following factors are important in considering pesticide use in Indonesia:

1. Lack of information in the community, especially about the dangers associated with pesticides. So far the community at large does not appreciate the threat to people and ecology from indiscriminate pesticide use.
2. Misleading pesticide advertisements which increase farmers' expectations of their capability, which often does not match reality. This leads to a lot of misunderstandings and false perceptions about the functions of pesticides.
3. There are too many trademarks and types of pesticides on the market, all of which have their own specifications. This gives the general community an impression that pesticides are similar to medicine. It also explains why many farmers use a mixture of two or three types of pesticides in one sprayer tank.
4. The attractive pesticide containers tempt farmers to use them as food containers or water cans.
5. Since the conditions under which pesticides are sold are not well defined, almost anybody can sell pesticides. Furthermore, the safety standards of pesticide storage and transportation are not properly observed, resulting in the contamination of other materials.
6. The sale of pesticides in smaller packages and at low prices in retail shops presents another set of problems. The repackaging commonly does not reach the same standards as the original and some are even sold without labels.
7. Farmers' knowledge of the techniques for the safe use of pesticides is generally low. It is also common that because of high temperatures in the tropics, simple protective materials are not used. Oftentimes, either farmers

cannot afford to buy protective clothing or they are not sold at the same shops that sell pesticides.

8. In spite of the general lack of knowledge of the safe use of pesticides, many farmers still want to apply the chemicals themselves. This is accentuated by the fact that trained applicators are few and expensive.
9. The farmers do not feel a great responsibility to produce safe and healthy crops for the consumers. We have found very high pesticide residues in vegetables and food due to excessive spraying.
10. The pesticide monitoring system in Indonesia is very poor. Knowledgeable treatment of pesticide poisoning is lacking, and antidotes such as vitamin K and Antrophine Sulphate are not readily available in every primary health center, making it difficult to treat any victim of accidental exposure.
11. The technology to reformulate pesticides is very poor in Indonesia. Often no due consideration is given for the security and safety of the worker and his working environment. We had a bad experience with a DDT factory in Bogor.
12. Last but not least, the controlled use of pesticides has been limited to only some areas which do not include a lot of small villages.

We have found that a serious negative effect of pesticide use is the poisoning of farmers and other people. It has been estimated that 2–12.5 million people in Indonesia are poisoned every cropping season.

It is a difficult task in Indonesia to overcome the problems associated with pesticide use due to the limited capabilities of public institutions and to the wide area involved. However, concern should not only be the responsibility of the Government but that of the people as well.

The Pesticide Action Network (PAN) of Indonesia, as a network among non-governmental organizations in Indonesia, also plays an important role in solving the problems of pesticide misuse. The network consists of the Environment Group, Consumer Group, Legal Aid Foundation, Community Development Group, and individual scientists, all of whom strive for safer use of pesticides.

Globally, PAN has the following ongoing activities:

1. A campaign launched against hazardous pesticides such as the "Dirty Dozen". This campaign aims to bring about farmer awareness as well as to influence decision makers through seminars, discussions, press conferences, and news releases on pesticide issues.
2. Activities to increase farmers' awareness of the danger of pesticide usage include educational programs such as talks/lectures, discussions/seminars with audiovisuals, publications, brochures, and articles in the media.
3. Study activities on pesticide legislation and implementation of laws controlling pesticides in trade and industry. We also monitor compliance with the Code of Conduct on Distribution and Use of Pesticides, together with PAN International.

4. Research and Development activities in using alternative pest control methods, comparative testing of some pesticides that are used in the home, such as mosquito coils, to detect active ingredients.

At the moment we are conducting a survey on 57 kinds of pesticides which have been restricted or banned by the Government from use in paddy fields. We hope to find out whether these pesticides are still being used by farmers.

In line with our program, the network functions as follows:

1. As a form of social control in government decisions on pesticide policy.
2. That with our awareness of pesticide issues, more social responsibility will be assumed by the producers of pesticides.
3. Assist the Government in dealing with pesticide problems, and encourage farmers and the general population to think twice before using pesticides.

In our attempts to conduct the above activities, we have been considered by the Government as troublemakers, and by the pesticide producers as people wanting to harm their business and trade. However, we firmly believe that urgent action needs to be taken to resolve problems associated with indiscriminate use of pesticides and we will continue to act to ensure a better quality of life for farmers and consumers.

A STUDY OF OCCUPATIONAL PESTICIDE EXPOSURE AMONG FILIPINO FARMERS IN SAN LEONARDO, NUEVA ECIJA

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The Philippines is a developing country with a population of about 52 million and an economy which is agriculture-based. Pesticides have become important agricultural inputs in this economy. Pesticide consumption based on sales statistics from the Agricultural Institute of the Philippines showed a steady growth of 15% from 1979 to 1981 (Gaston 1982). Organophosphorus and carbamate pesticides are the most widely available and frequently used pesticides in the market.

The transfer of agro-technology has not paralleled the transfer of knowledge on pesticide safety. There have been reports of occupational pesticide poisoning, both in the farm and in the formulating plants. In a study of pesticide problems in Bulacan and Metro Manila, Casanova et al. (1984) reported that on farms, farmers and spray applicators were not given proper education on the hazards of the chemicals and the manner of spraying. In the same study, it was found that no protective devices were usually worn; neither did farmers or applicators bathe and change their clothes after work. It was also noted that farmers were often exposed to more than one type of insecticide simultaneously or sequentially.

The study reported here was carried out among Filipino farmers to a) estimate the extent of the pesticide problem on farms, b) identify the risk factors for occupational pesticide exposure and c) determine the relationship of certain risk factors with the pulse rate, grip strength, and symptoms of pesticide absorption, and the relationship of certain risk factors with cholinesterase levels in the blood. Furthermore, a method of surveillance using grip strength was explored.

A cross-sectional survey of rice farmers occupationally exposed to pesticides was carried out by conducting two visits (before and after pesticide application) in selected villages (or "barangays") in San Leonardo, Nueva Ecija, which is located in the rice granary of the Central Plain of Luzon. 84% of the total land area in this study site is devoted to rice. Five barangays were chosen for the study, namely, San Anton, Poblacion, Adorable, Magpapalayok, and Tabuating. The barangays were chosen based on the farmers not having been exposed to pesticides for five months before the start of the study.

80% of the farmers completed the study. The reasons for dropouts were: (1) 5 did not farm due to health reasons, (2) 4 were not present at the time of follow-

up, (3) 3 transferred residence, (4) 2 did not farm due to financial reasons, (5) 1 was afraid of blood extraction, and (6) 5 hired spray applicators for their farms.

The farmers were generally in the age group of 21–60 years, of low educational background (55% had elementary while 35% had high school education), and with mean duration of pesticide use in the farm of 11.8 (S.D. 7.4) years.

Hematology tests showed eosinophilia in 76% and thrombocythemia in 13% of the farmers. A possible explanation for the eosinophilia is intestinal parasitism among farmers due to barefooted activities in the field. However, parasitism was not documented since no stool examination was performed. Thrombocythemia was noted among 18% of workers in formulating plants in a separate study by Maramba (1987). It is well known that secondary thrombocythemia occurs following repeated hemorrhage, acute trauma and hypoxia. Blood chemistry tests showed abnormal liver enzymes in 14% of farmers.

Cholinesterase depression was noted in 6.2% of the farmers at the end of the season. Copplestone et al. (1976) in their study among agricultural workers did not demonstrate a lowering of cholinesterase level.

There was a statistically significant difference in sweating at the end of the season. Jeyaratnam and Ponnambalam (1980) have also noted the highest incidence of sweating among public health workers exposed to fenthion.

96% of the farmers used liquid formulations of pesticides. Organophosphorus and carbamate pesticides were the most widely used by the farmers. A total of 45.44 kg of organophosphorus and 29.61 kg of carbamate pesticides were used during the season for 185.3 ha of land. The average amount of pesticide used was 0.245 kg/ha of organophosphorus pesticides and 0.16 kg/ha of carbamate pesticides. There was no standard measuring device used by farmers to mix pesticides. Anything on hand was used, such as covers of pesticide bottles or sprayers, kitchen spoons, measuring spoons in cans of baby milk powder, and matchboxes. 94% of the farmers studied were exposed to Category I-II organophosphorus and carbamate pesticides, with 55% being exposed for more than 15 hours. It would seem that, on the average, the farmers were using the pesticides within the recommended dosage as stated on the label. However, due to inaccurate measuring devices, the actual exposure of individual farmers was variable.

Exposure risk is further minimized by applying pesticides in the morning (84% of farmers). However, 58% did not consider wind direction during application. They complained that it was difficult to be coming back and forth to the field in response to wind direction.

The use of protective clothing was minimal if at all. All the farmers did not use boots and gloves, while 74% did not use masks. They found it inconvenient to be wearing boots, gloves and masks in the field. Boots were useless since they got stuck in the mud. Farmers were aware that wearing long sleeves and pants afforded some protection. 71% did wear long sleeves and long pants during application.

The farmers were conscious of personal hygiene. All farmers changed their clothes after pesticide application, 96% took showers either using the irrigation

canal or hand-pump water supply. It should be noted, however, that farmers clean their backpack sprayers in the same irrigation canal where they bathe. Regarding personal habits, 94% did not smoke and 97.5% did not eat during application.

The identified risk factors were correlated with the change in cholinesterase levels, grip strength and pulse rate. There were no statistically significant relationships in any of these parameters. It is noteworthy that the outcome variables such as cholinesterase levels, grip strength and pulse rate did not show statistically significant differences from baseline when compared at the end of the season. This could have affected the regression analysis.

The risk factors were also correlated with symptomatology of organophosphate and carbamate pesticide absorption. The only statistically significant correlations were found between the above two parameters and wind direction ($P = 0.04$) and alcohol intake ($P = 0.08$).

Cholinesterase levels was also correlated with grip strength in an endeavor to explore the possibility of making use of grip strength in surveillance of farmers. No statistically significant finding was noted. Thus, grip strength is not a good measuring method for surveillance of farmers.

It may be concluded from the study that because farmers in the study area were of low educational background, they did not know of the need to be adequately protected during spraying. The relationship between the risk factors (host, agricultural and personal habits, and practices) and the outcome variables (cholinesterase levels, grip strength and pulse rate) was not significant. There was, however, a significant correlation between symptomatology of pesticide absorption with wind direction and alcohol intake. Correlation between cholinesterase levels and grip strength was not significant. Thus, grip strength is not a good monitoring device for the surveillance of farmers.

Factors that may have contributed to the failure to show significant relationships between the risk factors and adverse pesticide effects were: (1) no significant changes in the outcome variables; (2) a significant number of dropouts; and (3) failure to re-evaluate the subjects at the prescribed time.

It is recommended that an occupational health program be undertaken for the under-served working population through an organized effort by three government agencies; namely, Ministry of Health, Ministry of Agriculture, and Ministry of Labor and Employment. Further investigations as to the causes of abnormal laboratory findings should be pursued. Studies on proper protective clothing and equipment, which would be acceptable, affordable and effective should be undertaken. Behavioral and cultural factors underlying farmers' habits and practices should be explored with the assistance of anthropologists and sociologists to plan for effective intervention schemes such as training and education of farmers on the proper use of pesticides. Field methodology for conducting biochemical analysis, including cholinesterase levels, need to be undertaken to answer the question of correlation between risk factors and the outcome variables.

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PESTICIDE SAFE USE TRAINING PROGRAM IN MALAYSIA

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The use of pesticides has become a necessary and accepted practice in current efforts to control insects and diseases, whether in agriculture, public health, forestry, veterinary or homes. Presently there are about 1,000 types of pesticides in various formulations, concentrations and trade names available in the Malaysian market. It is estimated that this country spends about M$250 million worth of pesticides annually for use in agriculture, forestry, public health, veterinary, and household sectors. Out of this, 50% are spent on herbicides, 32% on household pesticides, 10% on agricultural insecticides and rodenticides and 8% for other purposes.

Past surveys conducted in Malaysia show that, in general, the public (including farmers) give little attention to the proper use of pesticides and to the safety aspects of using pesticides. Few members of the public even realize the risks associated with handling pesticides without proper procedures. As a result there have been reports of users suffering from ill-effects due to the improper handling of pesticides.

With the recent increase in pesticide use, the need to have proper training on pesticide safe use has become even more important. As a result, the Department of Agriculture has taken a positive step by organizing a nation-wide campaign on the safe use of pesticides. This campaign, which was launched in August 1984 has three main objectives:-

i. To create awareness among the general public on the dangers of using pesticides,
ii. To expose the consumers or end-users to the safety procedures in handling pesticides, and
iii. To make the public aware of the Pesticides Act, 1974.

The most important strategy in this campaign was the training aspect followed by lectures/talks, exhibitions and publicity through mass media such as radio, television, and newspapers. Through these activities, we hope that end-users will eventually become more aware of the inherent dangers, and use pesticides judiciously. This report only covers the training aspects and other activities related to the pesticide safe use campaign being implemented in Malaysia.

TRAINING

Course Contents

Since the target group composed mostly of end-users such as farmers, plantation workers and smallholders, the topics covered were designed to be as simple as possible and to be completed within one day (short and intensive training). For each topic, the emphasis was on the "dos and don'ts" of using pesticides. The important topics covered in the training programs included toxicological aspects of pesticides (their modes of action, persistence, and residual characteristics; pesticide application techniques; the various formulations for specific application requirements; and the safety aspects of using pesticides); things to do before and after application; the importance of protective clothing; some aspects on the effect of pesticides on the environment; proper procedures in the storage and disposal of pesticides; and also some aspects of the Pesticides Act of 1974. The latter is to create awareness among end-users of the legal consequences of pesticide misuse.

Trainers

A special committee was set up with the Director of the Crop Protection Branch as Chairman to organize training programs for the trainers and also for the target groups. Members of this committee included Senior Agriculture Officers from the Pesticides Section and from the Extension Branch. The Extension Branch was responsible for selecting the relevant officers to be given the training so that they could, in turn, conduct similar training to the target groups within their states, districts, and extension areas.

The Crop Protection Branch of the Department of Agriculture was also responsible for providing the training materials such as films (documentaries), lecture notes, slides, etc. Other professional organizations, such as the Malaysian Agricultural Chemicals Association and the Malaysian Plant Protection Society, cooperated by providing guest lecturers and materials relevant for training members of the agrichemical companies and plantation workers.

TARGET GROUPS

The main target groups for the training were farmers, smallholders, plantation staff and workers, representatives of the agrichemical industry, and settlers of government land schemes.

OTHER SUPPORTING ACTIVITIES

Lectures/Talks

Lectures and talks were given periodically. The Pesticides Section of the Crop Protection Branch was responsible for providing the necessary notes, slides, reference materials, and equipment. These lectures/talks were given to the

general public such as school children, housewives, farmers, members of Consumer Associations, Government departments (for example, the Customs Department), and other agencies.

Most of the lectures/talks were given by the State Crop Protection Officers. Government agencies under the Ministry of Agriculture were given priority, e.g., the Rubber Industry Smallholders Development Authority (RISDA) and the Drainage and Irrigation Department (DID). Other agencies involved included the government land scheme agencies such as the Federal Land Development Authority (FELDA) and Federal Land Consolidation and Rehabilitation Authority (FELCRA). The number of training courses, lectures and talks given are shown in Table 1.

Exhibitions

We found that one of the best ways to attract the public was by holding exhibitions. To date 16 exhibitions have been held in the various states during Farmers' Day celebrations, convocations at universities, Pesticides Safe Use Campaign ceremonies, etc. (Table 1). Materials such as posters, various types of protective clothing, sprayers, and pesticides were displayed at the exhibitions.

Mass Media

The main focus in this area was the production and distribution of pamphlets and posters on the safe use of pesticides. To date more than 50,000 posters have been produced in four main languages and distributed during the training courses, lectures and talks, exhibitions and visits to smallholdings plantations.

In 1985 and 1986, 18 radio programs were broadcast and one documentary film was shown on television. In future, there will be more programs since there has been a strong response from the public. More programs are currently being processed and will be broadcast or shown on TV this year.

A documentary film on pesticide safe use, which was dubbed in Bahasa Malaysia, has been produced for use by the extension officers in the states. The Department of Agriculture, specifically the Pesticide Section of the Crop Protection Branch, is currently preparing a guide book on pesticide safe and effective use, which will be published in four main languages. We are anticipating this book to be ready in June 1987.

DISCUSSION AND CONCLUSION

From random follow-up studies on the training program and on the campaign as a whole, we have found the response to be very encouraging. This is particularly true on the part of the farmers and smallholders, where the majority have given positive feedback through questionnaires given to them after the training courses. Although the survey is not yet completed, there were indications that the training courses were effective and useful. There were of course comments that the training courses were too short but this was inevitable

Table 1. Training program on the safe use of pesticides in Malaysia for 1985 and 1986.

Activity	Target Group	1985		1986		Total	
		No. of activities	No. of participants	No. of activities	No. of participants	No. of activities	No. of participants
Short course	Government staff	42	1085	18	697	60	1782
	Farmers	39	1379	36	1355	75	2734
	Estate workers	19	675	9	267	28	942
	Land schemes	2	65	11	330	13	395
	Others	7	701	2	50	9	751
	Total	109	3905	76	2599	185	6604
Lectures/ Talks	Government staff	17	311	9	331	26	642
	Farmers	40	1336	96	3605	136	4941
	Estate workers	11	229	8	164	19	393
	Land schemes	7	105	5	144	12	249
	Others	5	284	1	25	6	309
	Total	80	2265	119	4269	199	6534
Exhibition		16	-	-	-	16	-
Mass media	Radio	18	-	-	-	18	-
	TV	-	-	1	-	1	-
	Others	5	-	-	-	5	-

due to the shortage of trained officers to cover such large target groups. The only problem encountered was in conducting the training courses for the plantation workers due to the difficulty in arranging for a suitable time to hold the courses. However, we hope to overcome this problem by having a closer relation with the plantations' management, to convince the workers of the importance of pesticides safe use. The evaluation survey on the effectiveness of the training program and on the campaign as whole is expected to be completed by the end of 1987.

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PESTICIDE SAFE USE TRAINING PROGRAMS IN INDONESIA

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In Indonesia, as in many other countries, pesticides are indispensable to the economic development of the country, especially to the development of agriculture. Although many methods are used to control pests, use of pesticides is the main method of crop protection in many parts of the country. There are many reasons for this, one of which is that non-pesticide methods generally require more time, labor and higher cost. Thus, the supply and distribution of pesticides are important considerations in successful crop production. The Government has been very concerned about all problems associated with the supply and distribution of pesticides, and has acted to ensure that farmers can obtain pesticides anytime they need them, and that they use them safely and effectively.

Knowledge about pesticides is commonly limited among the general public, especially with respect to their utilization, distribution and storage. Very often, pesticides are improperly handled and even farmers do not understand the advice about safe use of pesticides. This becomes very important when about two-thirds of the Indonesian population are farmers who often use pesticides as part of their agricultural operations. Therefore, many farmers routinely face hazards associated with pesticide use.

The hazards resulting from pesticide use are known to be closely related to the level of education, knowledge and skill of their users. Generally, pesticide hazards are minimized if users are knowledgeable about methods for safe use. Therefore, in Indonesia, some training is carried out for pesticide retailers, and pesticide users like progressive farmers and others, to promote their knowledge and skills concerning handling and utilization of pesticides.

Since most pesticides are toxic to man and other living organisms, retail distribution of pesticides under certain conditions has brought about cases of accidental poisoning, contamination of foodstuffs and feed, and other undesirable side effects. It is very important that training for the safe use of pesticides be carried out in order to solve the problems associated with handling of pesticides.

SAFE USE TRAINING PROGRAMS

The Directorate of Food Crop Protection (DFCP) of the Ministry of Agriculture, has developed a training program on pesticide safe use. The objective of this program is to increase the level of knowledge among staff members of the Ministry of Agriculture, especially among the pesticide

inspectors. Pesticide retailers are also trained in the program. Ultimately, we hope that the program will benefit farmers by providing them proper advice on pesticide use.

The subject areas covered in the training program were pest and pesticide management of crop pests, pesticide formulation, toxicity and hazard, application methods, safe and effective use, labelling and packaging, safe storage of pesticides, regulations controlling pesticides, etc.

The training program has been implemented step by step, depending on the subject area, location and status of pesticide use. From 1981 to 1987, 2473 participants were trained, with each training activity having 20–60 participants. Depending on the problems and target groups, the titles of the training sessions have included the following: training of pest observer, training of pesticide retailers, training of integrated pest management, training and workshop on pesticide management, training of pesticide analysis, and training of pest control. In 1987, 565 classes for pesticide administrators and 2695 classes for farmers will be conducted.

The training was organized by the DFCP or the provincial Agricultural Extension Service (AES) following guidelines prepared by DFCP. Lecturers for technical subjects were officials from DFCP, Bogor Research Institute for Food Crops, Agency for Public Health Research and Development, and universities.

TRAINING OF PESTICIDE RETAILERS

Training of pesticide retailers was organized by the AES following guidelines and a syllabus prepared by DFCP. Each training session had 20-30 participants and lasted 3–5 days depended on locality and need. The participants were private pesticide retailers as well as representatives of farmer cooperatives. Priority was given to those distributing relatively large quantities of pesticides, and those with poor storage facilities. Instructors for the training sessions were members of the Crop Protection Division of AES, with additional lecturers from the provincial Public Health Service, and Agency for Labor Protection. This last group gave lectures on the safety aspects of pesticide use, including pesticide handling.

From 1979 to 1980 only a few training sessions were held in certain provinces, but in 1981 the program developed to cover 26 out of 27 provinces with 2–8 training sessions in each. A total budget of Rp50 million (US$30,000) was provided by the Government for implementing the program in 1981. Included in the training budget were costs for travel and lodging of the participants and their allowances.

In order to improve the implementation of the training program by AES, a workshop was organized jointly by DFCP and Agricultural Requisites Scheme for Asia and the Pacific (ARSAP), Economic and Social Commission for Asia and the Pacific (ESCAP) of the United Nations, at Cisarua, Bogor, from 24 August to 5 September 1981. The joint program was a combination of programs on training in pesticide management with special reference to pesticide

regulations and inspection, and a workshop on planning for pesticide retailer training. However, the program has not been continued due to budget reasons.

To increase the knowledge and ability of pesticide retailers, the Food and Agriculture Organization of the United Nations (FAO) has given funds for the FAO project on Fertilizer and Related Input Retailers Training for the period 1986–1989. These funds are managed by the Ministry of Commerce. In this program, emphasis has been given primarily to improving the expertise of instructors at the national level so that they can give further training in their provinces.

SUBJECT AREAS COVERED BY THE TRAINING

The main emphasis of the training is to impart knowledge on pest and pesticide management, in the hope that these will lead to improved and safer handling of pesticides. A sample syllabus used for training pesticide retailers is given in Appendix I.

During each training session, lessons on various subjects were given using visual aids such as white board, slide projector, overhead projector, etc. Additionally, insect and plant specimens, some pesticide samples and pesticide application equipment were also used. Lecture notes were also distributed to all participants on the subjects being discussed. Discussions were made on the technical subjects as well as on practical problems, with a view to solving those problems which the participants encountered in their work. A study trip was also arranged for the participants to visit rice fields and pesticide plants producing widely used pesticides.

Examinations were given after the training in order to evaluate the ability of participants. The successful candidates received certificates indicating their knowledge in pesticide safe use.

APPENDIX I

Syllabus for training of pesticide retailers.

1. Major pests and diseases of rice and other important food crops.

2. Pesticides and their properties.
   - 2.1 Formulation types (EC, WSC, WP, SP, etc) and composition.
   - 2.2 Appearance, physical state and properties of pesticide formulation pertinent to their quality (color, odor, viscosity, clearness, emulsifiability, suspensibility, compactness and shape of granules, particle size, etc.).
   - 2.3. Storage stability (effect of water, humidity, air, sunlight, heat, material of container, etc.).
   - 2.4. Mode of action (contact, stomach and inhalation poison, systemic, etc.) and spectrum of effectiveness.
   - 2.5. Pesticides recommended for use in the Bimas/Inmas (food crops production intensification programs), their efficacy and use.

3. Application techniques and equipment for different pesticide formulations (high volume, low volume and ultra low volume spraying, fogging, dusting, broadcast and soil incorporation of granules, seed/seedling treatment, etc.).

4. Pesticide hazard.
   - 4.1 Acute and chronic toxicity and poisoning (skin contact and absorption, ingestion, inhalation, etc.)
   - 4.2 Persistence and accumulation of pesticides in body of living organisms and in soil, water and air.
   - 4.3 Hazards of pesticides on man (user, worker, consumer and other people), domestic animals and livestock, fish and other non-target organisms and the environment.
     - hazards resulting from pesticide spill/leakage at transportation and storage (contact with body of worker, contamination of food/feed, clothes and other material and of water supply, etc.)
     - hazards at weighing or pouring of pesticides and at preparation of spray solution, etc.
     - hazards at application (on operator and other people, fish, domestic animals, crops, etc.).
     - hazards arising from improper storage and misuse of pesticide containers.
     - consequences of environmental contamination.
     - other possible hazards.

5. Safe storage of pesticides.
   5.1 Requirements of storage room (floor, roof, wall, door, ventilation, air humidity and room temperature, exclusive use of storage room for pesticides, etc.).
   5.2 Storage (piling up, labelling and grouping by type and trade name of formulations, periodical inspection for leakage, etc.).
   5.3 Safe storage of empty containers.
   5.4 Protective clothing and devices.
   5.5 Washing facility (supply of water, soap, towel, etc.).
   5.6 Decontamination of pesticide spills and empty containers.

6. Pesticide poisoning and treatment.
   6.1 Early symptoms and signs of poisoning.
   6.2 First aid treatment.
   6.3 Information to be known by physician (name and type of pesticide which causes poisoning, pesticide label, patient's experience in working with pesticide, etc.).

7. General guidance for safe disposal of unused pesticides and empty containers.

8. Pesticide regulations.
   8.1 Government Decree No. 7 of 1973 (purposes and basic provisions laid down).
   8.2 Pesticide registration (purpose of registration, obligation of pesticide manufacturers/formulators to register their products, responsibility of pesticide registrant, etc.).
   8.3. Pesticide labelling (Agric. ministerial decree No. 429/Kpts/Um/9/1973, the importance and use of label, information to appear on label, characteristics of original/approved label, etc.
   8.4 Pesticide container and packing (Agric. ministerial decree No. 429/Kpts/Um/9/1973, container and packing requirements for safe transportation and storage, effects of container materials on pesticide quality, and safety during transport and storage, etc.).
   8.5 Commercial distribution of unregistered and/or adulterated pesticides,
      - pesticide retailers are requested not to distribute unregistered and/or adulterated pesticides.
      - attention should be given to the need that pesticide retailers have always to look carefully into the label, container and packing, appearance and properties of any pesticide they receive for distribution.
      - pesticide retailers should be well informed of the quality and characteristics of the approved label of registered pesticides which contains name and address of registrants, registration number, and other information as required by Agric. ministerial decree No. 429/Kpts/Um/9/1973.

- pesticide retailers are requested to accept only registered pesticides with labels and containers as used by the registered manufacturers or formulators.
- pesticide retailers should assist pesticide inspectors in preventing and eliminating pesticide adulteration by giving information on the origin of all pesticides they distribute (for that purpose pesticide retailers are requested to keep record of the name and address of anyone who asks them to distribute the pesticides).
- other information or guidance can be given to the pesticide retailers when it is felt necessary to eliminate pesticide adulteration.

9. Bookkeeping on pesticide distribution (records of the names and quantities of pesticides received and distributed monthly and annually, and other matters considered necessary for the purpose of collecting data on the types and quantities of pesticides distributed in the area and in tracing back cases of pesticide adulteration).

10. Other information on pesticides deemed necessary to be given to pesticide retailers to suit local conditions.

TRAINING THE TRAINER BY INDUSTRY

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Most Indonesian rice farmers own small-sized farms of about 0.5 ha, cultivating rice in rotation with root crops (cassava, sweet potato), pulses (soybean, peanut) and maize. Due to the marginal level of these farming enterprises, innovation is difficult. In the last decade the government has introduced high yielding rice varieties, fertilizers, and pesticides. These efforts are supported by subsidies on fertilizers and pesticides. Consequently, increases in rice yields have been recorded every year.

With the growth of the pesticide market, the pesticide industry has built up its field services to support its marketing activities. This paper reports on the extension activities by the pesticide industry in the bimas/food crops sector in Indonesia.

WHAT TYPE OF TRAINING IS NEEDED?

The topics to be covered in any training must be of practical value, and we have covered the following topics:

1. Identification of problem.
   Visual symptoms are shown to identify a specific plant health problem.
2. Product recommendation.
   A product/brand is recommended in detail such as:
   - dosage/concentration
   - time and frequency of application
   - method of application
   - precautions to be taken to prevent poisoning and pollution, and
   - cost per application/season.
3. Demonstration and Training.
   This is based on the principle of "learning by doing". The above-mentioned learning items have to be demonstrated and trained correctly and precisely.
4. Genuine products.
   To minimize the circulation of adulterated products, special attention is given to identifying the genuine product from the false ones.
5. Agronomic practices.
   In order to ensure a healthy crop, good agronomic practices are also demonstrated; this includes sanitation, soil preparation, manuring, etc. In the future good agronomic practices in the framework of integrated pest management (IPM) will be instructed.

WHO ARE THE TRAINERS TO BE TRAINED?

The key persons from whom the farmers seek advice are key farmers, extension workers, and retailers.

Key farmers and extension workers have received the attention of the government and the industry. In many cases retail shop owners and their assistants require training in the necessary product knowledge.

HOW TO DISSEMINATE KNOWLEDGE TO KEY PERSONS

The best training a trainer can receive is done under an environment simulating that in which he or she will have to train the farmer. We have provided in-depth explanations to trainers in order that they understand the material and can adjust the knowledge for local situations.

A dialogue is preferable during the training course because lively discussions could lead to more effective transfer of knowledge. Besides, dialogues provide feedback from the market to the industry, which needs it badly.

To support the training, different media are used, for example, exhibitions, TV, radio spots, posters leaflets, labels, etc.

In a big country like Indonesia, the pesticide industry has to take a systematic approach to the train-the-trainer activities in order to make them cost effective. Priority is given to:

1. Areas with a big market potential,
2. Important or urgent problem matters, and
3. Company preferences.

WHAT ARE THE LEGAL POINTS VALID FOR THE PESTICIDE INDUSTRY IN INDONESIA?

The legislation under which the pesticide industry operates in Indonesia are as listed:

1. Pesticide Committee:
   - Registration, 1973
   - Packing and labeling, 1973
   - Storage and distribution, 1973
   - Limitation of use of certain products on certain crops.
2. Government Policy:
   IPM on rice, Nov. 1986
   Supply and distribution for bimas program, and
3. The Code of Conduct, FAO 1986.

TRAIN-THE-TRAINER PROGRAMS IN THAILAND

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Thailand is in the course of accelerated development to achieve economic stability for the well-being of its people. The main occupation of the Thais is agriculture and in this respect farmers want to improve productivity through the application of advanced technology and keep up with technological changes. For example, fertilizers and pesticides are commonly used together for the prevention and extermination of pests.

Substantial losses are caused each year by pests during cultivation, harvesting, and transportation of products to the market. These pest-induced losses are the chief "variable" undermining agricultural production, leading to the lowering of both quality and quantity. The value of annual losses is thus sizeable. With the farmers' need to maintain quality and quantity, agropesticides have become common items among farmers in the control of plant pests. The reason is that these agropesticides have proved effective in putting a stop to the spread of pests to a wider area. Protection of crops from pests and maintenance of the normal condition of crops would be more difficult without help from agropesticides. However, the use of these agropesticides can produce numerous adverse effects. They are harmful to man and animals as well as to the environment. Other living things are also more or less affected by residues, depending on the extent of their evolution for survival. Thus we find in Thailand a situation where pesticides are posing a problem to the health of people, animals and other living things.

TARGET AUDIENCE OF TRAIN-THE-TRAINER PROGRAMS

Our target is to train five million farm families or 35 million people in the safe use of agropesticides and to instill in them knowledge about potential dangers from improper use of agrochemicals.

OBJECTIVES

1. To provide training to ensure correct, economical, and safe use of different types of agropesticides by farmers and to prevent harm to other living things and the environment.
2. To jointly seek measures for preventing harm from the use of agropesticides for agricultural purposes.

3. To publicize among farmers and consumers of agricultural products, information on the use of agropesticides for preventing and exterminating plant pests. We hope that through this publicity, farmers and consumers will become informed about the advantages and disadvantages of using agropesticides, and of the precautions that should be taken to avoid leaving residual agropesticides that can cause pollution.

WORK PLAN

1. To hold training for:
   - 1.1 123 officials of the Agricultural Extension Department.
   - 1.2 30 officials of the Agriculture Department.
   - 1.3 83 officials of the Ministry of Public Health.
   - 1.4 40 officials of companies producing agricultural chemicals.
   - 1.5 11,450 officials of regional government agencies.
2. Topics covered in the training:
   - 2.1 Policy and guidelines for safe use of agropesticides.
   - 2.2 Authority and responsibilities of government officials who are in charge of executing the Poisonous Act B.E. 2510.
   - 2.3 Coordination of work in prevention and extermination of plant pests among the Agriculture Department, the Agricultural Extension Department, and companies in the private sector; and guidelines for the use of agropesticides to control pests.
   - 2.4 Joint effort to publicize knowledge on correct and safe use of agropesticides.
3. Assessment of problems and obstacles.
   Officials of each group attending the seminar will, in turn, train other individuals concerned at different levels. After such training, problems and obstacles will be recorded so that further action may be taken to determine remedial measures.

METHOD OF OPERATION

1. To require agencies and organizations concerned to prepare training courses,
2. To provide training for officials concerned at different levels, and
3. To cooperate in giving training to five million farm families or 35 million farmers in accordance with the set target.

THE AGENCIES CONCERNED

1. The Ministry of Agriculture and Cooperatives
2. The Ministry of Public Health
3. The Office of the National Environment Board
4. The Pesticide Association of Thailand
5. The Office of University Affairs

PERIOD OF IMPLEMENTATION AND SCHEDULE OF WORK

1. Complete training of instruction officials of the 1st level within 1 year (see Appendix I for example of training syllabus).
2. Complete training of instruction officials of the 2nd level in 1 1/2 years.
3. Complete training for farmer leaders in 2 years.

EVALUATION

It is expected that the training will contribute to increased cooperation and coordination of efforts to solve problems associated with careless and irresponsible use of pesticides. Further, the training will help make all the parties concerned – government agencies, manufacturers, and users or farmers – conscious of their responsibilities and feel the need to work jointly to reduce problems associated with pesticide misuse. In addition, such training will lead to increased coordination and cooperation among the above groups in research work. It will also promote the understanding needed to find an effective and speedy solution to the pollution problem, especially the dangers generated by the use of agropesticides in pest control.

APPENDIX I

Training course syllabus for instruction officials of the first level.

Course topics	Responsible agencies
1. General knowledge concerning pests	Agriculture Department and Agricultural Extension Departmen
2. Basic knowledge of agropesticides used in pest control	Agriculture Department and Pesticide Association of Thailand
3. Principles of effective use of agropesticides	Dr. Banpot Napompeth
4. Tools required in the use of agropesticides	Agriculture Department and demonstration of tools by TJC Company
5. Principles of safe use of agropesticides	Pesticide Association of Thailand
6. Poisoning and methods of treatment	Faculty of Medicine, Mahidol University
7. Poisoning and danger levels of agropesticides	Department of Forensics, Siriraj Hospital
8. Diffusion of agrochemicals to human beings and to environment	Office of National Environment Board
9. Poisonous Act	Agriculture Department
10. The techniques of teaching people	TMA
11. Observation tour	Pesticide Association of Thailand

PESTICIDE SAFETY TRAINING PROGRAMS IN THE PHILIPPINES

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The Fertilizer and Pesticide Authority (FPA) of the Philippines was created under Presidential Decree 1144 on 30 May 1977 as an attached agency to the Department of Agriculture and Food. The immediate objectives of FPA were to assure the agricultural sector of adequate supplies of fertilizers and pesticides, to protect the public from the risks inherent in the use of pesticides, and to educate the agricultural sector in the benefits as well as the hazards of pesticide use.

Given the mandate of the law to provide the general public with maximum protection from adverse hazards of pesticides, while not denying them access to benefit from its use, the FPA in 1978 launched the National Pesticide Safety Program. Its training component is geared towards a multi-faceted audience, namely, the medical/paramedical practitioners, farm technicians, dealers, pesticide applicators, and fumigators. Different training modules were then designed with these specific sectors in mind to instill awareness on the proper use and safe handling of pesticides as well as management of poisoning cases.

THE AGROMEDICAL PROGRAM

The agromedical program is designed to educate the medical and paramedical practitioners in rural health hospitals and centers throughout the country, on the recognition and management of pesticide poisoning cases. The training program is a one-day activity with resource persons/trainers from FPA and the University of the Philippines (UP), College of Medicine. It concentrates on the major topics outlined in Appendix I. An integral part of the program is the monitoring of pesticide poisoning cases by the rural health centers and hospitals participating in the training course. Likewise, the program includes distribution to these centers and hospitals pesticide poison-control kits consisting of supplies and antidotes.

The program has been conducted in coordination with the Department of Health and the UP-College of Medicine. As of 31 December 1986, 3705 medical and paramedical practitioners in rural health centers and hospitals throughout the country have been trained.

THE AGROPESTICIDE DEALERS TRAINING PROGRAM

Realizing the critical role of the dealers in advising farmers and pesticide users on the hazards and safe use of pesticides and the limited knowledge that the

dealers generally have on these subjects, FPA came up with the Agropesticide Dealers Training Program. This is a one-day activity with resource persons and trainers from FPA and the Core of National Instructors who had previously undergone training in a course entitled "Training Course Development for Agropesticide Dealers" held during 9–20 June 1980. Here, emphasis is on the efficient use and safe handling, storage, transport and disposal of pesticides (Appendix II). FPA requires attendance of this training before a dealership license is issued. To date, 5897 persons have been trained for dealership.

TRAINING OF FARM TECHNICIANS

The objective of this training program is to instill awareness in technicians of the hazards posed by pesticide use and to promote consciousness in the efficient use and safe handling of pesticides. The technicians, in turn, have direct responsibilities for training farmers on the subject as part of their extension work. So far 11,497 farm technicians have been trained.

TRAINING PROGRAM FOR CERTIFIED PESTICIDE APPLICATORS AND FUMIGATORS

The program was instituted to generate awareness of the inherent risks associated with misuse of pesticides. It was designed to update technical knowledge and professional standards in pest extermination and fumigation. As of October 1986, FPA has accredited 932 pesticide applicators and fumigators.

The importance of training handlers on the proper use and safe handling of pesticides cannot be overemphasized. One may view the magnitude of the problems associated with the formulation and implementation of training programs by taking note of the following factors or situations prevalent under Philippines conditions:

- the quantity of pesticides used to control pests in the major economic crops (rice, corn, vegetables) and the important export crops (bananas, mangoes, pineapples) has increased over the years (Appendix III),
- of the 402 registered products, the top 28 products representing 95% of the insecticides used in 1984 are classified under Toxicity Categories I and II of the World Health Organization Classification,
- training by private industry is confined to launching new products or selling the benefits of existing products. Training of applicators at the farm level is almost nonexistent, and
- shortage of budget and adequately trained staff, and reorganization problems have reduced to the minimum the capabilities of government agencies concerned in terms of applicator training and safe use on a mass scale.

These are but a few of the factors which FPA and other concerned government agencies have to address to effectively formulate and implement training programs on the safe use of pesticides in an effort to be responsive to the critical challenges of ensuring the health and safety of pesticide handlers as well as the protection of the environment.

APPENDIX I

Course program for agromedical safety training.

DURATION	TOPIC
	WELCOME ADDRESS
45–60 min.	I. FPA OVERVIEW A. FPA Rules, Regulations and Programs Objective: To know and understand FPA Rules, Regulations and Programs and their implications.
	BREAK
60–90 min.	II. PESTICIDE INFORMATION Objectives: To review basic pesticide classification. To be aware of the hazards and toxic effects of pesticides with emphasis on restricted pesticides.
	LUNCH BREAK
	III. PESTICIDE SAFETY
120 min.	A. Recognition and Management of Pesticide Poisoning
60 min.	B. Epidemiology of Pesticide Poisoning Objectives: To recognize signs and symptoms of pesticide poisoning. To acquire skills on management of pesticide poisoning.
	BREAK
45–60 min.	IV. OPEN FORUM
30 min.	V. EVALUATION
	VI. AWARDING OF CERTIFICATES

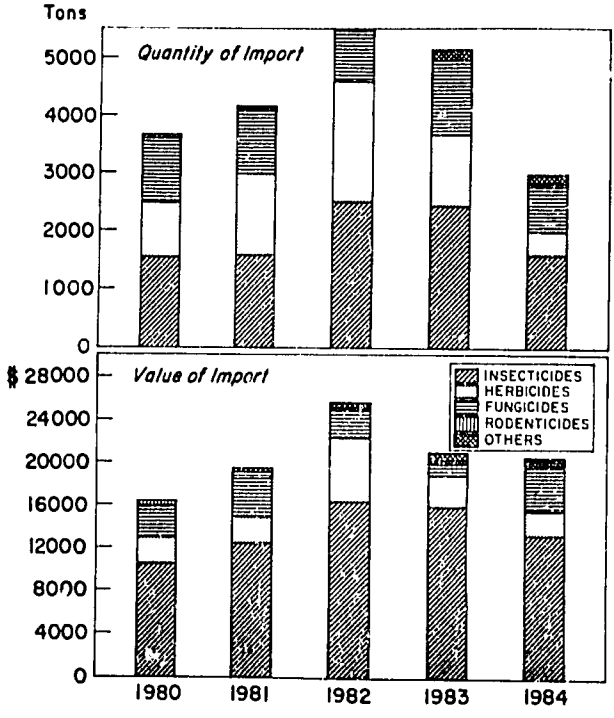
APPENDIX II

Course program for agropesticide dealers training.

DURATION	TOPIC
	WELCOME ADDRESS
45–60 min.	I. FPA-DEALER RELATIONSHIP FPA Rules, Regulations and Programs Objective: To know and understand FPA Rules, Regulations and Programs and their implications.
	BREAK
60–90 min.	II. PESTICIDE INFORMATION Objectives: To review basic pesticide classification. To be aware of the hazards and toxic effects of pesticides, with emphasis on restricted pesticides. To know and understand labels and labelling guidelines.
	LUNCH BREAK
90–120 min.	III. PESTICIDE SAFETY A. Signs and Symptoms of Pesticide Poisoning and First Aid Treatment of Pesticide Poisoning Objectives: To recognize signs and symptoms of pesticide poisoning. To acquire skills on first aid treatment of pesticide poisoning.
	BREAK
45–60 min.	B. Safe Handling of Pesticides Objective: To know and acquire skills in proper handling of pesticides.
	IV. OPEN FORUM
	V. EVALUATION
	VI. AWARDING OF CERTIFICATES

APPENDIX III

Quantity and value of pesticides imported into the Philippines, 1980–1984.



PESTICIDE SAFETY CAMPAIGN IN THE PHILIPPINES

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While it is recognized that pesticides are essential inputs for crop production, especially in a country like the Philippines where there is mounting pressure to increase food production, it is also acknowledged that they present hazards to man in particular, and to the environment in general. It is therefore necessary that certain actions be taken by the pesticide industry, in cooperation with the government and all those involved in the pesticide trade, including users, to reduce to a minimum and, if possible, eliminate the risks involved in the manufacture, distribution, and use of pesticides. It is, after all, reasonably possible to safeguard all operating exposures which may result in poisoning or injuries. It is for this reason that the local pesticide industry, individually and collectively, has adopted the Food and Agriculture Organization (FAO) International Code of Conduct on the distribution and use of pesticides.

In the past, the industry had adopted safety campaigns like the use of informative posters and the training of government extension staff and farmer leaders, but these have not been done in a unified and sustained manner. In fact, many of the pesticide companies have, in their own way, conducted safety campaigns. But much more remains to be done. We, in the industry, are convinced that for a safety campaign such as this to be really effective, it must be done as a collective effort and on a continuing basis with total commitment from all those concerned.

APIP SAFETY COMMITTEE

To address the issue at hand, a safety committee was organized within the Agricultural Pesticide Institute of the Philippines (APIP). The immediate objective of this committee was to draw up a comprehensive program of safety which would encompass all aspects of the physical distribution and use of pesticides, namely,

1) manufacturing and formulation,
2) transport, storage and distribution,
3) end-users (plantations and small farmers),
4) pesticide applicators, and
5) medical/occupational health.

ACTION PLAN AND PROGRESS OF THE CAMPAIGN

End-Users

In view of the broad scope of use of pesticides and the number of people in this segment, end-users are being given the highest priority in the safety campaign. The activities for each group of end-users are outlined below.

SMALL FARMERS A two-phase program was adopted for this particular group.

Phase I - Safety Information Drive

The proper dissemination of information among small farmers is the key to an effective information drive. We have produced a series consisting of six 30-second radio spots (safety tips). These spots are now being aired free of charge as a joint public service project of APIP, the Fertilizer and Pesticide Authority (FPA), and the Association of Radio Broadcasters in the Philippines – over 80 radio stations in the country. In addition, the spots are also being aired through the Ministry of Agriculture Farm programs over 90 radio stations throughout the country. A poster and a leaflet have also been produced and disseminated in identified areas, while billboards are being installed in the North and South Expressway areas of Luzon.

Phase II - Training the Trainers

A local training syllabus/module has been developed for this purpose. A schedule of training is being drawn up in coordination with FPA. The areas are prioritized based on intensity of pesticide use. This training involves company representatives, FPA coordinators and agricultural extension agents. All of these groups will, individually and in coordination with each other, handle the training and information drive for farmers.

PLANTATIONS Normally, each pesticide company would have its own Material Safety Data Sheet (MSDS). However, the implementation of safety precautions are often wanting and there is a need for a more serious effort at observing acceptable safety standards. The ultimate objectives of training are:

a) To be able to assist in the training of pesticide handlers, from receivers to field applicators. The training should be conducted by a joint team from APIP, FPA, and plantations,
b) Establishment of a poison control center in each plantation, and
c) Advice to plantation management on suitable personnel protective clothing and equipment.

In line with the above, we have started a series of meetings with plantation groups (starting with the pineapple group), to discuss problems related to pesticides and agree on action items.

RESEARCH PERSONNEL Our objectives with regards to researchers are to furnish appropriate data and other relevant information regarding handling and use of pesticide products being evaluated.

Transport, Storage and Distribution

DISTRIBUTORS AND DEALERS We are working closely with the FPA to provide training to this group on a provincial and regional basis. The training will be done using the same geographic regions as in the train-the-trainer programs.

CARRIERS (Forwarders/Brokers, Truckers, and Shipping Lines) A safety manual adapted for carriers, distributors, and dealers is being produced and will be distributed among carriers first. Posters and stickers will also be produced and pasted on carriers, premises, and on trucks. To disseminate these, we will:

a) Organize meetings with shipping lines, particularly members of the Conference of Inter-island Ship Owners and Operators (CISO), and some "batil" operators,
b) Organize meetings with truckers and forwarders or brokers. Each chemical company prepares a list of forwarders, brokers, and truckers that it uses. Likewise, distributors and dealers, particularly in Visayas and Mindanao, who use truckers will also be asked to submit their lists. Thereafter, the meetings will be scheduled.

Pest Control Operators (PCOs)

Training courses are held under the auspices of FPA for "new" PCOs or applicators before they are duly licensed. We tie in with these courses with special emphasis on "Safe Use & Handling". Only duly licensed pesticide applicators can do actual applications. The following guidelines are designed to ensure that pest control establishments and their staff are made fully aware of the importance of "safety" in their operations:

1) Licenses will continue to be issued only to those who have undergone the FPA-required training and have passed the tests for pest control operators. The training should be extended to all the field staff doing pest control for the FPA-registered PCOs. Other requirements before a license is issued should include proof that the applicant has standard equipment, i.e., proper sprayers, spray protectors, proper clothing, etc.
2) Campaign for all pest control outfits to become members of at least one Pest Control Association, either Pest Control Association of the Philippines (PCAP) or Pest Exterminators Association of the Philippines (PEAP). With this campaign, it would become easier to monitor the activities of PCOs and to maintain contact with them.
3) Primary responsibility for training of Certified Pesticide Applicators should lie with both PCAP and PEAP. In view of the high turnover of staff, regular training sessions should be held in coordination with FPA and

APIP. Topics to be reviewed and discussed during such in-service training should include:

a) Proper procedure in the preparation of the solution,
b) Pesticide calculations,
c) Disposal of waste/containers,
d) Protective clothing/safe handling,
e) Briefing the occupants of the house to be treated, and
f) Disciplinary action for not observing rules, etc.

Medical/Occupational Health

The APIP works closely with FPA to coordinate and achieve common objectives under this segment. The following actions are proposed:

1) Identify and establish in coordination with the Ministry of Health regional Poison Control Centers. Satellite Poison Control Centers should also be established wherever necessary within a region. A training course should be conducted in the Poison Control Centers once a year, and these centers should be utilized as information centers to provide necessary instruction in the procedures for handling and management of pesticide poisoning cases.
2) Form Medical Training Team(s) composed of representatives from FPA, Ministry of Health and APIP. Doctors and other hospital staff will be properly trained on the management of pesticide poisoning.
3) Publish a booklet and other relevant material dealing with pesticide information and recognition, diagnosis, and treatment of pesticide poisoning. A poster on the same subject will also be prepared.
4) Identify suitable antidotes and equipment and make sure that these are available at all times in the poison control centers.
5) Monitor all cases of pesticide intoxication and its causes, institute remedial measures, and report these to FPA.
6) APIP should work closely with FPA in the implementation of health monitoring programs.

Manufacturing and Formulation

The localized nature of this segment makes it the easiest to address. The action plan is simple and two-pronged. The first step is to call a meeting of all plant and independent entities. Each plant's safety program is to be presented and assessed during the meeting. As an offshoot of the meeting, a so-called Advisory Plant Safety Inspection Team is to be formed. This team will have the following functions:

a) schedule plant visits for plant safety evaluation,
b) give recommendations for improved plant safety,
c) set up timetable for implementation of recommendations,
d) follow up for compliance of recommendations, and
e) institute periodic audits, perhaps twice a year.

In addition to the above action, the APIP has to ensure the quality of pesticide products manufactured. A strict quality control must be instituted,

including packaging, and the use of a "Good Housekeeping" seal should be considered.

PRIORITY AREAS

On the basis of the level of pesticide usage and problems previously identified, the following areas will be given the highest priority, particularly action plans involving end-users such as farmers and the medical/occupational health campaign: 1) Baguio/Benguet area, 2) Central Luzon, 3) Davao, 4) Cagayan Valley, and 5) Panay.