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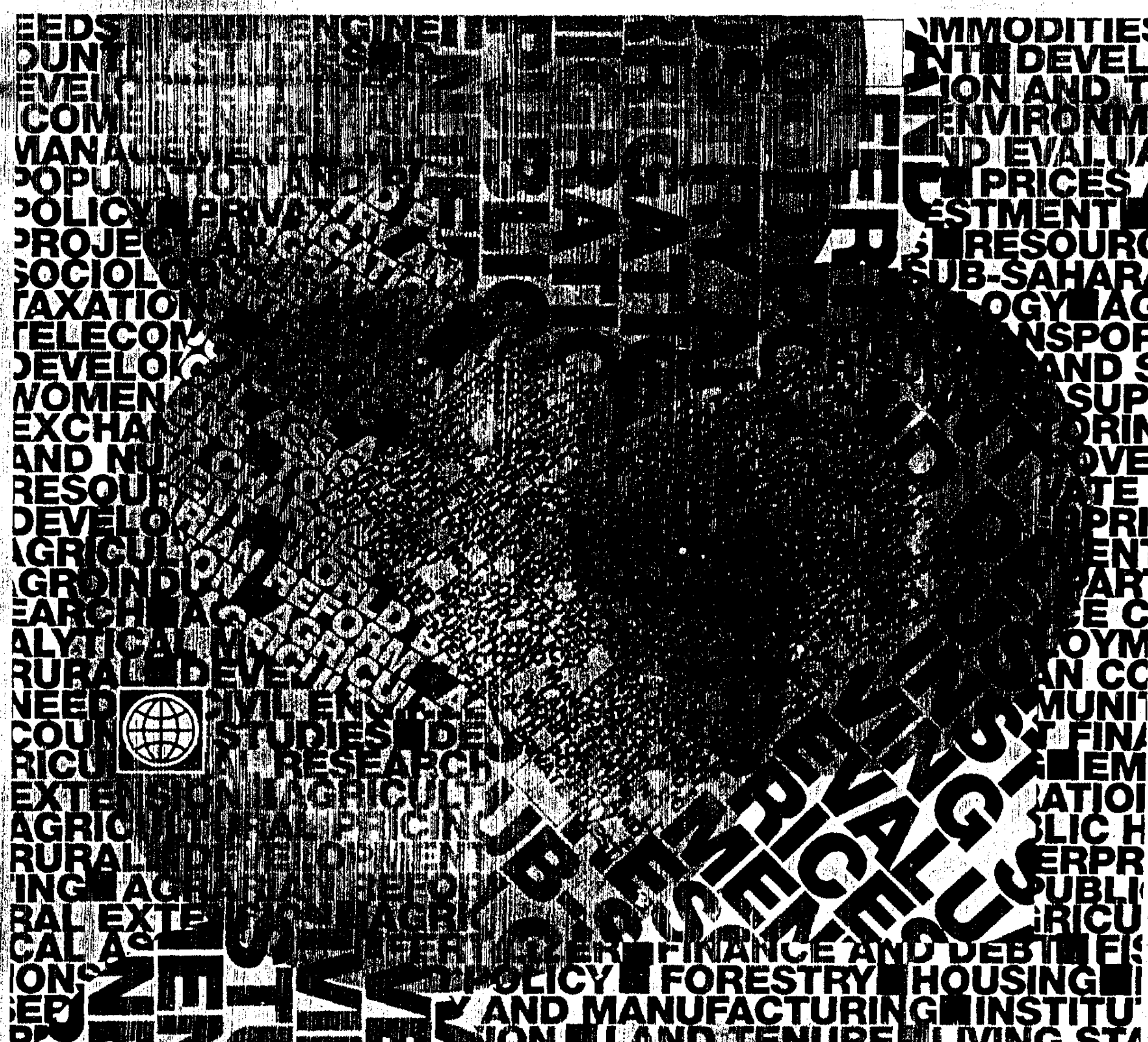
Integrated Pest Management and Pesticide Regulation in Developing Asia

Uwe-Carsten Wiebers



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Uwe-Carsten Wiebers

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FOREWORD

The Asia Technical Department has from time to time invited talented graduate students to prepare technical papers as part of their summer internship with the Bank. In this case, Uwe-Carsten Wiebers, a graduate from the University of California, has extended his wide knowledge of pesticide use and Integrated Pest Management (IPM) practices to a review of the current status in Asia of pesticide regulation and IPM practices. Pest control is one of the key areas that effect the profitability of farming. It is therefore an important topic to farmers, environmental planners and regulators, and this review should provide valuable information to policy makers and project designers in Asia and elsewhere. Mr. Wiebers' conclusions are both enlightening and practical. Importantly, he points out that IPM, to be successful, is a knowledge intensive technology which means that users involved in pest control require detailed training in the field, and that extension services may well have to change the way that they operate. There are some useful appendices that provide a valuable compendium of current IPM state of the art in Asian countries.

Daniel Ritchie
Director
Asia Technical Department

ABSTRACT

This paper describes the technical aspects of Integrated Pest Management in the regulatory, economic, and institutional context of developing Asian countries.

Following the introduction, the author explains Asia's plant protection policies and deficiencies and then turns the reader's attention to the regulation efforts for pesticides in Asia. The technical systems are then explored, as well as some of the economic and environmental aspects, and there is a discussion of pest management technology development and implementation. The author has attached a bibliography and glossary behind the conclusion.

The appendix section includes a discussion about how California's pesticide regulation affects the user. There is also a detailed chart showing pesticide markets and regulation for twelve Asian countries and another table which lists the techniques and effects (by crop) of IPM in Asia. The last appendix debates the question of whether the adoption of IPM always increases welfare or not.

The success and effectiveness of IPM depends on whether Asia growers expect that IPM practices will increase net benefits and if they are convinced of the advantages of implementing these practices. Developing and implementing training programs and specific management programs for different crops should then be high priorities. IPM programs will depend on chemical pesticides, but IPM technology will require a different approach to the application of them than the green revolution technology did.

ACRONYMS

BPH	Brown Planthopper
DBM	Diamondback Moth
ESCAP	Economic and Social Commission for Asia and the Pacific
FADINAP	Fertilizer Advisory, Development and Information Network for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
GIFAP	International Association of Pesticide Manufacturers
GLH	Green Leafhopper
GTZ	German Agency for Technical Cooperation (Gesellschaft für Technische Zusammenarbeit)
IOCU	International Organization of Consumer Unions
IPM	Integrated Pest Management
IRRI	International Rice Research Institute
kg	kilogram
PAN	Pesticide Action Network
Rp	Rupiah
UNEP	United Nations Environmental Program
USAID	U.S. Agency for International Development
USEPA	U.S. Environmental Protection Agency
WBPH	Whitebacked Planthopper

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I. INTRODUCTION

The "green revolution technology package" in developing Asia included pesticides as a standard, albeit minor, item. Rather than a tool to cure diseased or infested crops, pesticides often were viewed as an agricultural input designed to fully control the crop's insect environment. However, attempts to control the brown planthopper in Indonesian rice, in caterpillars in Malayan oil palm and in cotton in Andrah Pradesh, India, have shown that scheduled use of broad-spectrum insecticides fails to fully control and suppress insect populations in the field. In fact, the heavy use of insecticides has caused massive pest outbreaks and severe crop losses.

Agrochemical pesticides are a modern, nonrobust technology. Incorrect use may result not only in actual yield loss caused, for instance, by outbreaks of secondary pests, but also in health and environmental damages. On the other hand, pesticides are often necessary to protect crops from loss or damage by insects, and if properly used, modern pesticides may be less hazardous than other agricultural practices.

Two obstacles that limit the use of modern selective insecticides in Asia, particularly Southeast Asia, are the tropical and subtropical climatic conditions and the twelve-month cropping patterns. These factors make it possible for all insect life stages to appear simultaneously. Yield damages thus are substantial, ranging from 30% to 40% on average; total loss is not uncommon. However, although pests are considered a major, if not the main constraint to increased crop productivity, such severe yield damages are seldom a permanent threat requiring continued and scheduled use of pesticides as insurance against income loss.

Rather, the task is to design a cropping system or to create a productive ecosystem that minimizes growers' economic, health and environmental risks. This requires a good understanding of the agroecosystem--the interaction of climatic and other site conditions with the crop and its insect, fungi and other plant populations. Pesticides should function as an instrument of last resort--comparable to pharmaceuticals in human health care.

In the United States, California has legislated this idea, requiring an official recommendation for the application of an agrochemical pesticide and a report of each application (Appendix 1). This system actually goes beyond the system of prescription of pharmaceuticals, which does not follow up on use of medication.

Such strict regulatory measures may be difficult to enforce in developing countries. Nevertheless, regulation is an important instrument to limit unacceptable health and environmental risks. Within the limits of agricultural production and pest control given by regulation, training growers in farming and pest management practices, generally called "integrated pest management" (IPM), is aimed at decreasing economic and environmental risks.

Integrated pest management was developed in the 1960s but continues to face the criticism of being an immature innovation. This is due in part to differences of definition and in part to a question of the transparency of its results.

This paper describes the technical aspects of IPM in the regulatory, economic and institutional context of developing Asian countries.

II. PLANT PROTECTION POLICIES AND DEFICIENCIES IN ASIA

Plant Protection Policies

Agriculture is still the most important sector of most economies in Asia, and agricultural policies continue to focus on increasing productivity. National governments both regulate and invest their financial resources in the agricultural sector to maximize benefits to growers and consumers. Regulations can affect input and output markets as well as agricultural production itself; investments may be in research and development, education, training and extension in addition to agricultural markets, production and enforcement. Regulation of and investment in pest management take several forms.

(a) **Regulation of Pesticide Markets and Pesticide Use**

(i) Pesticide markets are controlled by pesticide production, import restrictions and registration procedures. Requirements for registration include information about product quality, toxicology, efficacy (based on trials of two to three years), residues in harvested products, environmental effects, labelling, packaging, advertising, handling and storage. Pesticide distribution and prices can be regulated and controlled through taxation or subsidization.

(ii) Pesticide use can be restricted by implementing registration procedures with restrictions governing pesticide application to specific crops and growth stages, type of application, dose rate, site, plant-back period and workers' reentry into the field. Use of a pesticide can be prohibited by cancelling its registration and withdrawing the product from the market or by prohibiting its import. Making decisions about pesticide use and application may be restricted to institutions other than those representing growers.

(b) **Investments in the Field of Pest Management**

(i) Investments are made in research and development of pest management techniques that can substitute for chemical pesticides or make their use safer to field workers, consumers and the environment while maintaining an optimal allocation of production inputs. Together, these methods are summarized referred to as *integrated pest management*.

(ii) Investments also are made in the education and interactive training of growers and pesticide applicators to generate and diffuse pest management technology improvements. Such investments may involve an agricultural school system, training programs, extension services and subsidizing private consulting firms.

(iii) Regulating pesticide markets and use also requires investments, but this aspect is not a focus of this paper.

To the grower, the concepts of (1) pesticide regulation and (2) investment in research, development and education in pest management have different characteristics and effects on agricultural production. On the other hand, pesticide regulation restricts growers' options of pest management practices without offering alternatives to protect the crop against pest damages. Thus, from the farmer's point of view regulation imposes costs by restricting the optimal choice of production inputs. On the other hand, investments in research, development and education supply the grower with pest management technologies and increase his or her choice of pest management inputs.

These two policies might seem to the grower to be opposite in character, but there are strong linkages between them because regulation can either foster or inhibit the development and adoption of pest management technology. For instance, restricting the registration of broad-spectrum insecticides like organochlorines may promote monitoring insect populations in the field for carefully timed pesticide application. Cancelling their registration may force the adoption of alternative control measures. Also, in highly regulated markets in developed countries, withdrawing the registration of certain pesticides--which might be essential to an effective IPM program--effectively stops development of that IPM program.

Economic policies also play a major role in adoption of IPM. For example, subsidized pesticide prices distort the opportunity costs of the various pest control measures and often make the use of agrochemicals preferable to nonchemical measures. In another instance, the grower's cost for scheduled chemical applications is lower than the opportunity cost of time spent on field monitoring that would permit chemical applications only at economic threshold levels.

Plant protection policy thus is about pesticide regulation on a macroeconomic scale and about development of integrated pest management on a microeconomic scale. In addition, it is important to consider the interaction of different policy strategies to efficiently develop an economically and environmentally sound pest management and production system. Figure 1 illustrates some of these relationships.

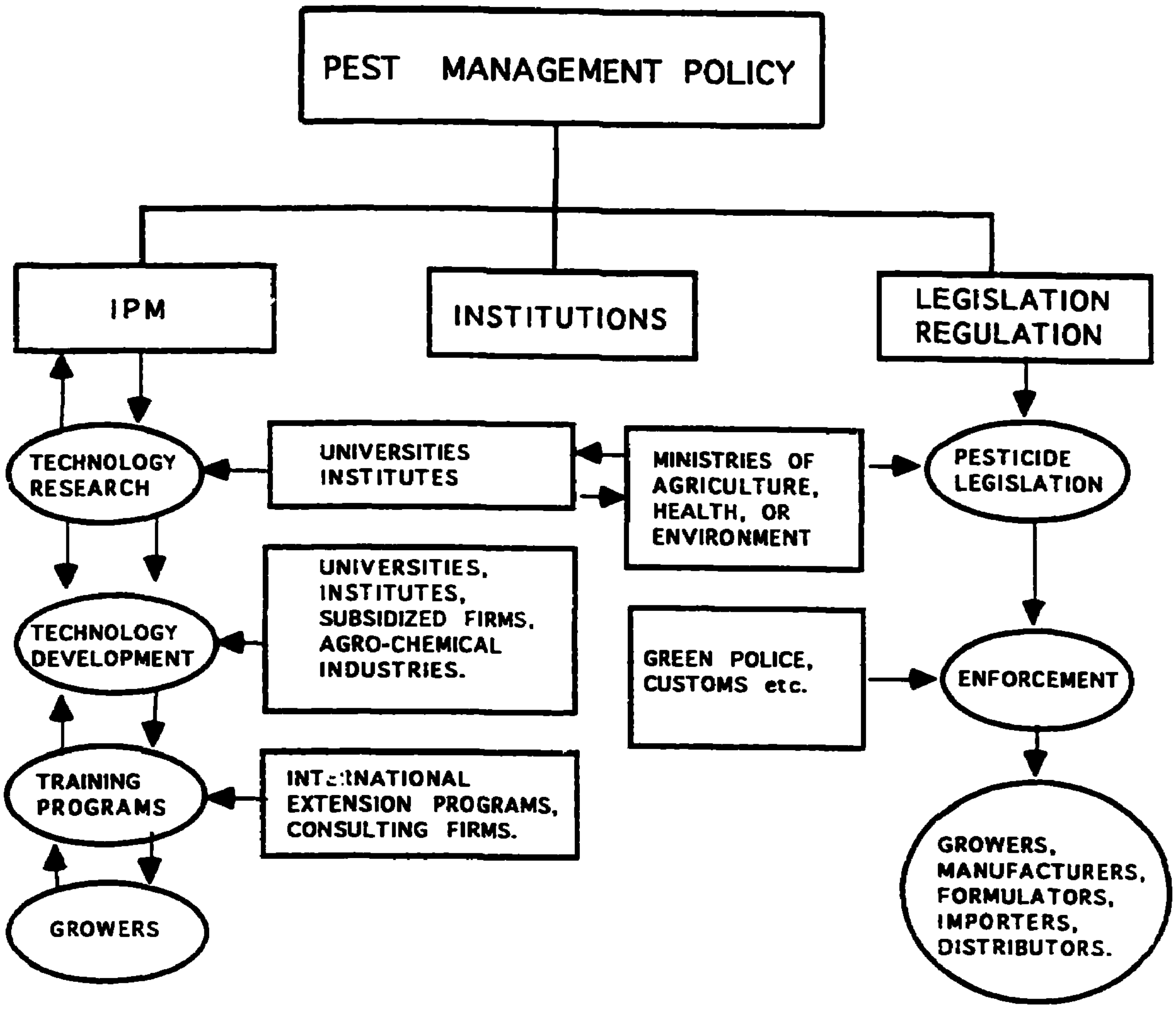
Deficiencies in Plant Protection in the Region

Problems of plant protection in the region can be summarized as follows (Amaritsut and others 1988):

(a) Knowledge of pests and natural enemies is generally poor with the exception of some common rice insect pests. Pest damage identification is commonly incorrect; many farmers are attempting to control beneficial insects.

(b) Chemical pesticides are usually the only means of commercial pest control. Availability and knowledge of nonchemical control agents is limited or unknown. In most countries, chemical pesticides are still subsidized, and control alternatives or training in the use of chemicals is much less promoted than sales of chemical products.

Figure 1: IPM and Pesticide Regulation



(c) Knowledge of pesticide groups and how to control pest resistance is lacking. Farmers often use only one type of chemical for all pests of all crops.

(d) Use of chronic toxicity pesticides (organochlorines) that are registered for agricultural use or that have "leaked in" from other uses such as malaria or termite control is not uncommon.

(e) Use of acute toxicity pesticides by untrained farmers or applicators leads inevitably to poisoning incidents.

(f) Pesticides are misused and/or overused causing excessive environmental damage, reduced effectiveness, excessive residues in harvested crops and resistance problems. Pesticides are often used at much higher or much lower rates than recommended by the manufacturer. Pesticide misuse also includes such practices as spraying without adequate protective clothing, infringement of harvest intervals and addition of pesticides to livestock rations for parasite control.

(g) Poor application technology and techniques lead to the same problems as overuse and misuse. Poor application equipment results in poor coverage and inadequate applicator safety.

(h) Toxicological laboratories to test harvested crops for pesticide residues are in short supply.

(i) False product labelling, unsafe packaging in bottles, product adulteration and storage and transportation of pesticides in with food products are common problems.

III. <u>REGULATORY EFFORTS CONCERNING PESTICIDES IN ASIA</u>

Several problems of plant protection listed above are closely related to the regulation of pesticides. It is not very difficult to link the poisoning of a rice grower in Thailand by a highly toxic imported pesticide with the extent to which OECD members, for instance, follow their agreements about exporting these products. The link between national price policies in the agricultural sector for input products such as pesticides and growers' willingness to use selective and less toxic pesticides is equally clear.

This section briefly describes the status and some trends of pesticide regulation in Asia. It draws on Oudejans' and Johnson's papers published in *News in Brief* 1990, both recommended for further reading.

The use of pesticides demands a well-developed social infrastructure that is able to respond adequately and efficiently to the problems and risks involved. That the interests of several groups in the production and distribution sector are at stake calls for a strongly developed sense of responsibility on the part of all parties concerned and for a strong government presence. It is the responsibility of national authorities and international organizations to create the conditions for rational and safe pesticide use as well as for the diffusion of IPM technology.

Countries in the Asia and Pacific region have introduced or are in the process of introducing the necessary legislation for regulating pesticides. Appendix 2 gives an overview of pesticide legislation, including regulation and its efficacy, for twelve Asian countries. Most countries adopted the international guidelines on the use of pesticides established by the Food and Agriculture Organization (FAO), the International Code of Conduct on the Distribution and Safe Use of Pesticides.

Although it is the responsibility of the government to set the standards of plant protection policies, effective implementation is only possible if all parties involved, especially the private sector, share this responsibility. The suppliers of pesticides are primarily responsible for developing appropriate pesticide products and application equipment, for distributing them effectively and for making available adequate advice on safe management and effective use of those products and apparatus. A second group sharing the responsibility is pesticide users, including producers of agricultural products, professional applicators, distributors of agricultural products (e.g., grain storage operations), farmers' organizations, processing industries and individual households. A third group of highly critical nongovernment organizations is of increasing importance in Asia. They are giving voice to growing public concern about the excessive use of pesticides.

FAO distributed a questionnaire to all member governments in the Asia and the Pacific region in December 1986 about the status of pesticide regulation. On the basis of their responses these countries can be considered importers of pesticides, although there is some local manufacturing and formulation. About 65% of the countries report that they observe the FAO code; about 15% reported that pesticide use is not regulated. However, this figure is misleading--a substantial percentage of countries also reported the absence of pesticide registration schemes and pesticide control legislation. Thus, more than 30%

reported that there were no limitations on availability and/or that they were unable to enforce restrictions on highly toxic pesticides. About 75% also reported inadequate resources for enforcement. Some reported that this situation could be improved by legislation focusing on funding decisions or by levying fees to support the program. More than 40% of the countries reported unsatisfactory conditions in a variety of areas such as (a) follow-up of products by traders to users, (b) review of pesticides marketed and feedback on them, and (c) banning of unsafe products by industry.

Although this shows that there is a need for the establishment of regulating authorities, it does not imply that all countries require the same level of regulation.

Of particular interest among the responses is the reported nonreceipt of expert notices (i.e., the principle of "prior informed consent," PIC[1]) for banned or severely restricted pesticides. Procedures for such notification were adopted by the OECD and UNEP in the early 1980s and in the FAO Code in 1985. A recent review by the OECD indicated that only a few OECD countries are actually implementing these procedures. It appears that exporting countries require to take significant steps in their implementation of the notification procedures of internationally agreed documents.

Another interesting result of the FAO questionnaire is that despite the emphasis on IPM by international technical institutions, lending institutions and donor agencies for the recipients of such programs, IPM does not appear to be a major effort.

The reported problems in labelling, packaging and advertising also are indicative of the need for increased regulation of pesticides in the region. It appears from responses that the presence of regulatory programs do lead to more satisfactory labelling and packaging of pesticides, but even countries with developed regulatory programs do not seem to be more satisfied with advertising than are those with less sophisticated or even no pesticide legislation.

As shown in Appendix 2, most countries in the region are at some stage of establishing, changing or implementing legislation and registration procedures. Countries lacking basic laws and regulations are developing them, while those with more advanced pesticide regulation, such as the Philippines and Malaysia, are expanding programs into areas of worker protection and monitoring. It appears likely that all countries in the region will have basic regulatory structures in place in the next few years.

Legislation and regulation, however, is only as good as its enforcement, which is a major constraint in most of the countries of the region. Points of control are places of manufacture, formulation, importation, distribution and use of pesticides and markets of agricultural products. High levels of technical skills and decentralized regulating agencies and, thus, considerable financial resources are required. Developed countries like Germany, for

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1. PIC refers to those hazardous pesticides that are banned or severely restricted in exporting countries, and that may not be exported without first notifying importing countries of their health and environmental hazards, and seeking consent that export may take place. For a short review and discussion of PIC for Asia see also (News in Brief 1990, No. 2).

instance, formed special police forces (known as "green police" because of their green uniforms and motor bikes) to monitor the distribution, storage, use and disposal of pesticides and other environmentally hazardous products or activities. These highly mobile forces monitor the field, but also inform growers, distributors, and so forth about existing and new legislation and regulations. An example of such a highly regulated pesticide market is California; the key points of this legislation as it affects growers is summarized in Appendix 1.

Another principal problem the questionnaire identified is the lack of analytical capability to ensure the quality of pesticides marketed in the region. It is unlikely that most of these countries can easily establish and operate such laboratories.

It appears that countries in the region will be trying to reduce the use of pesticides that fall under the WHO Hazard Category 1A[2] and 1B (there are four categories for all pesticides). Mostly because there are significant resource requirements for training large numbers of growers, some countries are banning the use of very hazardous pesticides as and when less hazardous formulations become available. But the most significant force behind the change is that the countries themselves realize that pesticides need more regulation as use increases, as toxicity levels of products increases and as the patents of imported pesticides expire. Other stimuli come from international organizations including FAO, the Asian Development Bank, the World Bank, the International Association of Pesticide Manufacturers (GIFAP) and the Pesticide Action Network/International Organization of Consumer Unions (PAN/IOCU).

The FAO is conducting a multiyear program to implement the Code of Conduct in Asia and the Pacific. This project, which is funded by the government of Japan, offers technical assistance and training to individual countries, assisting them in drafting laws and regulations and upgrading registration and postregistration activities. Bilateral agencies such as the German Agency for Technical Cooperation (GTZ) and the United States Agency for International Development (USAID) provide assistance for activities that strengthen regulatory capability. An example is the Malaysian-German Pesticide Project that has helped develop regulatory procedures and has provided in-country and foreign training for Malaysian regulators.

Despite this progress, it is generally agreed by the countries in the region that much more needs to be done in the regulation of pesticides. However, implementing and enforcing regulations will remain a limiting factor. Thus, education of growers in the safe and effective use of pesticides and in alternative means of pest management should be given equally important emphasis.

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2. Examples of class 1A and 1B are aldicarb, captafol, fonophos, parathion, aldrin, carbofuran, methamidophos, methomyl, monocrotophos and nicotine. For the complete list of pesticides categorised by WHO, see CIRAD 1990.

IV. TECHNICAL SYSTEMS OF PEST MANAGEMENT IN ASIA

The Range of Pest Management Regimes

To discuss and design programs of improved pest management practices, it is necessary to understand the range of different pest management regimes. Otherwise what is meant by integrated pest management (Tait 1987) and how it differs from other pest control strategies may be unclear.

Pest management practices can be categorized as follows:
- Routine pest management or scheduled spraying;
- Monitoring systems;
- Integrated pest management;
- Pest management in organic farming; and
- Pest management in "philosophical agriculture."

(a) Routine Pest Management

Scheduled pesticide applications, or routine pest management, imply the use of pesticides as a prophylactic measure, regardless of pest incidence. It probably requires higher levels of pesticide use (Tait 1987) and a lower level of management than any other strategy in a given set of circumstances. Yield damage generally is low since scheduled pesticide applications attempt to fully suppress pest populations. However, incidences of pest resurgence[3/] and outbreaks of secondary pests[4/] have shown that yield damages can vary substantially.

(b) Monitoring Systems

Each pesticide application must be justified on technical and/or economic grounds--for example, an economic threshold--in monitoring systems. Pest observation using surveillance and sampling procedures determines infestation levels. When infestations reach previously determined thresholds, pesticides are applied. Monitoring systems are a common part of IPM programs, but are not IPM programs by themselves.

(c) Integrated Pest Management

Integrated pest management "considers any and all combinations of techniques for the management of weeds, insects, diseases, and animal pest problems within the context of the farming system" (McCarl 1981). This definition permits consideration of any pest management technique, including pesticides. It states the concept of IPM, not its objectives. All living organisms that can cause yield damage are included, in contrast to the narrow focus on insect pests of early IPM research. The definition involves neither eradication of pests nor living with pests, but these are alternatives. Systems of integrated pest management are monitoring systems, cultural control, biological control, and expert systems (Figure 2).

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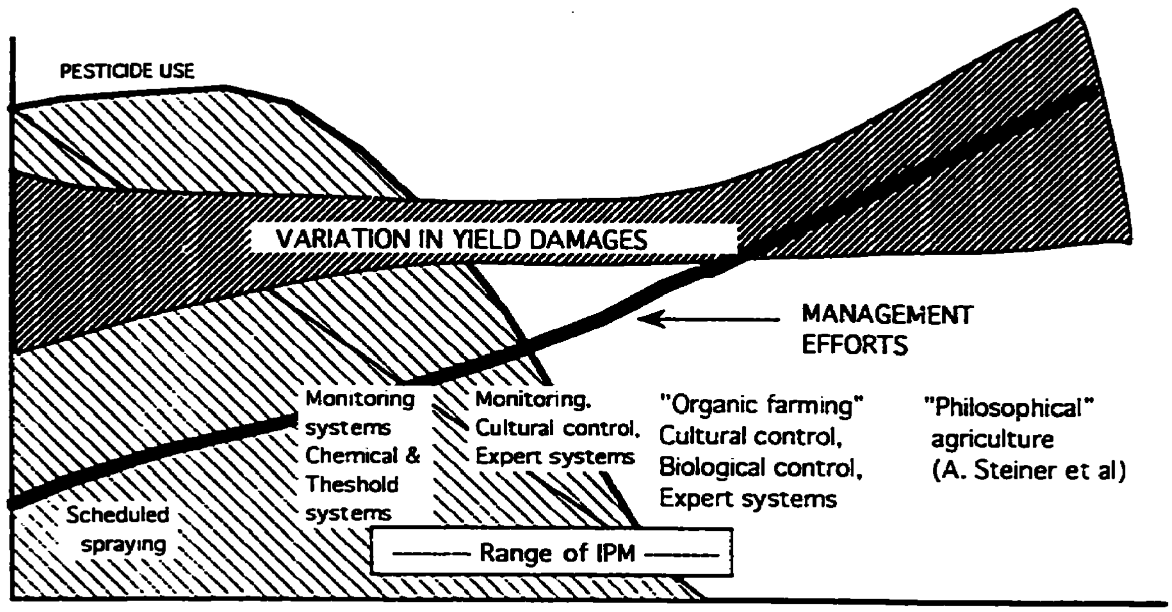
3. Pest resurgence occurs when an existing pest is susceptible to an insecticide, but its natural enemies are even more severely affected. Treatments may then give satisfactory initial control, but in the absence of biological control the pest population subsequently may increase to even higher levels than before treatment (Graham-Bryce 1987).

4. Secondary pest outbreaks are the transformation of a phytophagus species normally maintained at low levels by natural enemies into an economic pest by the use of (broad-spectrum) insecticides targeted at the primary pest (Graham-Bryce 1987).

Figure 2: Pest Management Systems and Effects



Many techniques of integrated pest management, such as weeding, crop rotation, mixed cropping and mixing varieties, are as old as farming itself. What is new is the scientific method used to understand the effects of management practices on the crop and its environment and the development of management guidelines based on this information.

While initial research objectives of IPM emphasized the economic improvement of pest management and production (profit maximization), recent efforts have been focused on finding "economical, long term solutions to pest problems while minimizing hazards to human health and the environment." (UC 1990a). Since it is methodologically not possible to maximize profits and minimize environmental risk simultaneously, preference must be given to one objective while the other is held constant. This choice is reflected in the conflicting interests of the agricultural sector and consumer and environmental groups.

(d) **Pest Management in "Organic Farming"**

This holistic approach, based on interactions of the agroecosystem, is similar to the concept of IPM. Synthetic pesticides and fertilizers, however, are not used as agricultural inputs. Rather, pest control is restricted to cultural control, biological control and use of nonsynthetic pesticides like sulfur and copper products. Minimizing environmental risks rather than maximizing profits is the emphasis. Organic farming is not an important consideration in developing Asia.

(e) **Pest Management in "Philosophical Agriculture"**

This method is mentioned here only to present the whole spectrum of pest management alternatives. Management decisions are based on philosophical teachings like those of the anthroposophic school of Steiner rather than on conventional agronomic science. Food products grown under these concepts are gaining identifiable market shares, especially in Switzerland and Germany.

Systems of Integrated Pest Management

Integrated pest management not only relies on the combining different crop protection measures but also requires a program integrating research, development and implementation. Prerequisites of an IPM program are the assessment of crop damages and yield losses and the analysis of commodity-pest interactions before actual techniques of IPM are developed.

(a) Crop Damage or Yield Loss Assessment

This should be the first step of plant protection at the farm and the national levels. Information about yield losses supports the grower's decision to manage the crop differently or to control a pest. On the macro level, yield loss assessment is needed to guide agricultural policy, particularly for the allocation of resources for research, development and implementation of cropping system technology and pest control practices. For a thorough discussion of the subject with extensive bibliography see Walker (1983).

(b) Analysis of Commodity-Pest Interaction

Research in this area focuses on quantifying when and how pests affect crop growth, quality and yield. Studies of this type are a necessary preliminary to developing sound management recommendations and monitoring programs for many pests (UC 1990b).

Research on pest-crop interactions has shown that most organisms are an economic problem only during certain times in the growing season and under specific growing conditions. This type of research, which appears fairly basic at first, provides the necessary background information for formulating recommendations on elimination of pesticide sprays and for developing alternative management practices. Such crops as cotton and for processing tomatoes often can tolerate much higher leaf loss or leaf spotting than previously thought, thus reducing the need for pesticide applications. Other research has indicated that certain pests become serious problems only under specific conditions of soil saturation, planting density or temperature-humidity relationships, or when plantings are early or late or harvest is delayed.

A better understanding of the life cycles of pests can help target chemical applications at a stage when the pest is most vulnerable. For instance, a better knowledge of the overwintering strategies of fungi allows more reliance on dormant sprays and a reduction of fungicide use later in the season--for example, *Uncinula necator* causing powdery mildew in California grapes (Flint 1989).

The most prominent result of research on pest-crop interactions are pest control guidelines that quantify economically intolerable levels of pest infestation. There are three main phases in the relationship between crop loss and development of pest attack: (1) the plant is able to tolerate or compensate for injury, (2) crop loss occurs but is insufficient to justify control, and (3) the reduction in yield or quality at least equals the cost of modifying the cropping system to lower pest pressure and/or the cost of control (Cammell and Way 1987). The "action threshold" is the level of pest infestation where action must be taken to prevent it from rising to an economically damaging level--that is, the "damage threshold" or "economic injury level" (Walker 1983)--that lies between phase 2 and 3. Once a damage threshold is reached, use of biological control may provide insufficient protection against infestation to reduce pest levels below the damage threshold.

(c) Management Systems

Practices of integrated pest management can be differentiated into two groups according to their objectives:

- Pest prophylaxis practices aim to avoid the build-up of pest populations above economically damaging levels.
- Pest control practices reduce yield-damaging pest activities below economically damaging levels.

(d) Pest Prophylaxis

Production of a crop requires many management decisions. One set of choices may promote the development of a pest while another set with equal or similar costs may prohibit and/or reduce the build-up of the pest population. These choices affect

- resistant varieties
- sanitation
- agronomic practices
- protection of natural enemies

These measures individually may not be sufficient to create a micro-environment unfavorable to pests; each of them may allow pest populations at damaging levels. But utilization of the interaction effects of these measures or their combined use and practice may protect the crop from significant yield loss or damage.

(e) Pest Control

A variety of control measures can control one pest or a pest complex. As with prophylactic practices the integrated use of control agents may be more effective in protecting the plant than the sum of the individual techniques. These control measures can be categorized as follows:

- manual and physical control
- biological control
- chemical behavioral insect control
- botanical or microbial pesticides
- selective use of chemical control

(a) Examples of manual control are weeding, weed cultivations, removing pest egg masses and pests at other live stages, manipulating temperature and steam sterilization of soil in greenhouses.

(b) Biological control[5] ranges from "the use or encouragement of 'beneficial' living organisms for the reduction of pest organism populations" (DeBach 1964) to the use of any nonchemical control method that is biology-based, such as host resistance, insect pheromones, crop rotations, and the like (Doutt 1972). Encouraging "beneficials" is achieved by cultural practices and has little in common with what growers understand as biological control. In any case, it is a preventive rather than a control method. However, autocidal control[6] may be considered a method of biological control. Thus, biological control may be defined as the use of beneficial organisms as well as sterile or genetically altered insects for the reduction of pest populations.

(c) Chemical behavioral insect control is the application of chemicals that alter such insect behavior as attraction, repellency, location of food, oviposition, mating, defense strategies, feeding behavior and social organization.

(d) Microbial pesticides are usually categorized under biological control. However, the types of application in the field and the requirements for registration are the same as for chemical pesticides. The biological mode of action therefore is comparatively irrelevant for categorizing these products. The most prominent botanical pesticide is based on extracts of parts of trees of the *Meliaceae* family, one representative of which is the neem tree. One neem-based pesticide received registration in the United States for use in ornamentals. Neem products are widely used, especially in India, for agricultural and other purposes. Use and limitations of botanical insecticides are discussed in the next section.

(e) Chemical pesticides can be chosen specifically for the pest and the area and time of application. The proper choice and application of

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5. Biological control agents can be classified as:

<u>Predators</u> - active organisms that seek their food and consume a number of prey, e.g. ladybird beetles, many species of bugs, lacewings, larvae of hover flies, etc.
<u>Parasitoids</u> - insects that develop parasitically in a single host that is eventually killed. They consume one prey during their lifetime.
<u>Parasites</u> - organisms that tend to weaken rather than kill their host. The exception is nematode parasites, which so far have not been very useful.
<u>Antagonists</u> - organisms that decrease pest populations by competitive exclusion but do not directly feed on them. They are important for the biological control of plant pathogens.
<u>Organisms or weed control</u> - plant-feeding insects that have high levels of host plant specificity--nematodes, microorganisms and fungi.

Ways to use biological control:

<u>Introduction</u> or <u>classical biological</u> control - introduction and permanent establishment of exotic beneficial organisms.
<u>Augmentation</u> - release of additional native natural enemies that are inadequate in numbers.
<u>Inoculation</u> - release of native natural enemies, which are absent from a particular area, at the beginning of the season or in a new crop.
<u>Inundation</u> - release of very large numbers of sterile insect pest males or genetically altered insect pests. The application of microbials, also applied inundatively, is similar in its requirements of the grower to the application of botanical or chemical pesticides. It is categorized separately.

6. "Autocidal insect control involves the rearing and release of insects that are sterile or altered genetically in order to suppress members of their own species that are causing the pest problem" (Bottrell 1979).

pesticides can help conserve natural enemies, improve control and lower pest management costs and environmental risk.

Pest Management in Asia

There are numerous crops in Asia, and the number of pests is vast. Pest management practices must be designed to fit each crop's characteristics given its specific cropping system, the climate, available farm resources, sociological issues, and so on. Because there are different techniques for different cropping and farming systems in different regions, it is impossible to list all information about pest management practices developed in Asia. Appendix 2 gives an overview of pesticide use in twelve Asian counties for the main crops treated, the percentages of insecticides, fungicides and herbicides used, and the main registered products. To the extent available information would permit, it summarizes various regulating agencies' regulatory efforts and their efficacy as well as the main problems of pesticide use and plant protection. Appendix 3 describes practices of pest management and new developments in Asia, focusing on integrated management techniques.

Special problems and prospects and limitations of individual pest management practices for important crops are briefly described here.

(a) Pesticide Use

The estimated value of pesticides used annually in agriculture in eight countries (China, India, Thailand, Malaysia, Philippines, Indonesia, Sri Lanka and Bangladesh) in the late 1980s is close to US$1500 million (prices at first distributor level). China and India account for about two-thirds of this amount. The Philippines, Malaysia and Thailand used pesticides valued between US$90 million and US$130 million a year. Pesticides for rice, costing around US$400 million a year in the eight countries, is the biggest single item. China alone spends US$218 million on rice pesticides (Jackson 1991).

The Asia and Pacific region is predominantly an insecticide market. Of the total estimated consumption of pesticides, about 75% of consumption is insecticides, 13% herbicides and 8% fungicides. Insecticides are used mainly for rice, cotton and vegetables; herbicides for rubber, oil palm, tea, coffee and cacao; and fungicides for tobacco, vegetables and bananas (Johnson 1990).

Although these figures are an indicator of pesticide use, they give little information about whether there is over- or underuse of pesticides in the agricultural sector. Most developing countries are characterized by an extremely skewed distribution of pesticide use. This results mainly from differences of agricultural development in different regions within each country and depends on the scale of production.

There are three stages of agriculture, each with a different demand for pest management: traditional agriculture, agriculture moving toward modernization and large-scale commercial agriculture.

In traditional agriculture, small-scale farmers grow grain or root crops as subsistence crops. The size of their plots is usually determined by the availability of family labor for land preparation and hand weeding. Diseases and pests generally are endemic, meaning that harmful organisms are present at all times but cause little damage because of their low population densities. They are effectively regulated by natural enemies, host plant resistance and weather conditions. Therefore, there is little need for insecticides and fungicides in traditional agriculture (Oudejans 1990). Labor-saving technology for weed control may substantially increase the productivity and household incomes of traditional farmers. Limiting factors for the use of herbicides include farmer illiteracy, cash requirements for herbicides and application equipment, and continuous market access. Better than herbicides might be manually operated mechanical weeders such as the International Rice Research Institute (IRRI) developed for rice. A single-row weeder developed by IRRI requires about 40 to 50 person-hours/ha and easily can be operated by women and children. The two-row weeder requires about 25 to 35 person-hours/ha as compared to conventional single-row rotary weeders that require 80 to 90 person-hours/ha and are difficult to operate. Manual weeding requires an average of 120 person-hours/ha (IRRI no date).

Growers who practice **agriculture in transition** have access to local markets and have cash incomes. They have gradually intensified their cultivation practices, decreased the number of crops grown in the rotation cycle, introduced new and more profitable crops, replaced traditional varieties with horizontal resistance with high-yielding and sometimes vertically resistant varieties, grow crops in monoculture instead of in varied cropping systems and manage water more efficiently through irrigation and drainage works. Examples of agriculture in transition are intercropping maize and soybeans, planting coffee, rubber or coconut trees as cash crops, and growing vegetables and fruit in addition to staple crops. Irrigation in rice-growing areas allowed year-round production. In effect, this doubled the rice-cropping area as rotations were intensified and rice yields increased by 25% compared to pre-green revolution levels. However, this also raised the pest carrying capacity of the environment by allowing year-round pest development (Litsinger 1989). Cash income made possible the purchase of pesticides, which became a necessary input to control pest outbreaks. The use of broad-spectrum insecticides disturbed the balance between insect pests and their natural enemies and caused pest resurgence and secondary pest outbreaks as described earlier.

Controlling rice insect pests through scheduled spraying is described for Sri Lanka by Jackson (1991):

> The common practice of insect control under a pesticide orientated regime is as follows. When paddy rice is broadcast-sown or to be transplanted, general practice is to spray an insecticide at 10 days (at present usually monocrotophos or dimethoate). However, in the case of transplanted paddy, if a granular insecticide treatment (carbofuran) is applied to the nursery the spray is not necessary. A second spray, usually of monocrotophos, is done 28-30 days after the first, i.e., closer to panicle initiation. A third spray, of BPMC, is applied between flowering and maturity if the population of brown planthopper (*N. lugens*) warrant it. Finally, insecticides are used against paddy bug, *L. varicornis*. Such a program can be implemented without much thought by the farmers, but provides far from optimal pest management.

Large-scale commercial agriculture generally is the biggest user of agrochemicals. Important commercial production systems include irrigated field crops such as cotton and sugarcane; estate crops such as bananas, oil palm and coffee; horticultural fruit and vegetables; and protected crops such as ornamental plants and flowers. Crops are grown in monoculture or with little rotation on estates or large farms. The efficacy of biological regulation of pests and pathogens is most drastically reduced if crops are genetically homogeneous, high-yielding cultivars with low natural host plant resistance, and when fertilizers and pesticides are used intensively. Pests get a chance to recover rapidly and to reinfest the crop if their natural enemies have been killed. Secondary pest problems are similar. Usually, estate companies and large-scale commercial farmers hire crop protection experts, or they themselves may have considerable experience in chemical plant protection. Economically attractive IPM methods can be introduced to this agricultural subsector on a commercial basis. Small-scale growers, who often produce commercial crops and use processing facilities and marketing channels of estate farms, may also benefit if they see IPM innovations adopted on the estates. Estates could both be targets for IPM programs of commercial crops and function as innovators.

(b) Developments in Biological Pest Control and Botanical and Microbial Pesticides

Integrated pest management's methods of monitoring, its cultural practices and biological control systems, and its botanical and microbial pesticides are listed for Asia in Appendix 3. Here, some limiting factors of the use of biological control and the use of botanical and microbial pesticides are discussed.

Classical biological control is one of the cheapest and, if successful, one of the most lasting methods of insect control. Attempts at classical biological control have been numerous in Southeast Asia, but they have mainly failed. Although the predators and parasites that were introduced into the treatment region often are very effective in their native habitats, in this case they have been ineffective--partly because of over-use and improper use of pesticides by Southeast Asian growers. Biological control workers in the region also feel that failures were due to lack of interest, support, and expertise in research and development of biological control (Napometh 1988). There have been some successes: the introduction of a predator mite for mite control in apples in China and a parasitic wasp for the hispine beetle in Western Samoa.

Other methods of biological control have been researched and used. The most widespread of these probably is associated with the parasitic wasp *Trichogramma* spp. The international newsletter, "*Trichogramma News*," reports research results from China, the Philippines, India and Burma with emphasis on the first two. China reports treating about 1 million ha a year.

There are two ways to apply *Trichogramma*. For release on the ground, insect eggs that have been parasitized by *Trichogramma* in an insectory and glued on cards can be hung in the crop. Wasps emerge from the eggs (anywhere from 10 to 260 wasps per egg) and parasitize freshly laid eggs of several insect pests. For aerial application, parasitized eggs are mixed with a material like corn cob grit to facilitate loading and dispersal. There is a large number of *Trichogramma* species, and selection is necessary to identify the one with the highest parasitization rate for the insect pest in the specific region. The fact that the wasp attacks only freshly laid pest eggs means that the frequency of release is more important than the number of released wasps. Release rates range from 40,000 to 250,000 eggs per season. Successful parasitization rates vary from around 50% to 75% of the insect pest eggs, but can be much lower. Besides the selection of the species and the timing of release, the parasitization rates depend also on the general ecological environment. According to Everett Dietrick of Rincon Vitova, Inc. (1990, personal communication), releases are most effective if the wasps occur naturally in the area. Depending on the crop, costs of *Trichogramma* releases can be less expensive than a pesticide program. The wasp, however, does not achieve full control of the pest and is thus not a feasible method where cosmetic appearance of the agricultural product is important.

Similarly, conservation and augmentation of lady beetles rarely provide complete control. They are usually seen as one component of an integrated system that may include other predators, parasitoids, horticultural and mechanical methods, and microbial and chemical pesticides (Olkowski, Zhang and Thiers 1991).

One of the most limiting factors of *Trichogramma* use is cost-effective production. In addition to the wasp, host eggs have to be produced. In China, eggs of the oak silkworm, eri silkworm and rice moth are used as hosts. Chinese researchers recently developed "semi-artificial" diets to raise *Trichogramma* without using live hosts, but these diets may be costs-effective only under Chinese conditions (Olkowski and Zhang 1991a, 1991b).

Botanicals offer another approach. Different parts of trees of the *Meliaceae* family have been used in Indian traditional agriculture for several purposes, one of them pest control. The most widely known of these trees is the neem. However, it has received little attention from researchers and is an undeveloped control option despite the registration of a neem-based pesticide in the United States. Neem-based pesticides have a broad insect pest spectrum but show low mammalian toxicity. They can be locally produced--the trees are common in India--and ground seeds need only to be diluted in water to produce an active solution. For a full description of the process see Radcliff and others (1991, p. 14). Factors limiting neem-based insecticides are that locally produced solutions deteriorate relatively quickly and must be produced for each application; collecting and grinding seeds is very labor intensive; and the percentage of active ingredients in the seeds varies substantially (0% to 10%, with an average of 3%), requiring relatively high rates of application. The following data on field trials in Niger illustrate the problem:

> Fifty grams of ground nuts per liter of water give 1.5 g of active ingredient (a.i.) per liter if 3% a.i. in the nuts is assumed. With an application rate of 400 l/ha of solution, 600 g a.i./ha are being applied. Thus one application requires 20 kg of seed, which is the average annual yield of a neem tree (based on data by E.B. Radcliff of the University of Minnesota, 1991, personal communication). Seeds can be stored for a year or longer; however, the development of highly toxic aflatoxin was observed in household storage.
>
> The recommended application rate for the U.S. Environmental Protection Agency's registered neem-based product is 20 g a.i./ha. If 3% a.i. in the seed again is assumed, 0.66 kg of seed are required for one application. A tree with an annual yield of 20 kg then supplies enough seed for one application on 30 ha compared to 1 ha in the Niger field trials. The low dosage rate recommended in the United States is possible

because the formulation of the neem product in the United States is consistent.

The current market price for neem seed in Niger is equivalent to US$12/100 kg, which gives an annual return of US$2.4/tree (based on data by D. Walter of W.R. Grace, personal communication).

The cost of US$2.4/ha is low compared to commercial pesticides. But the calculation does not include the opportunity costs of preparing the solution.

From this brief discussion, it appears that increasing the productivity of neem trees and developing locally manageable formulations would enhance the use of neem-based pesticides.

Microbial pesticides are unreliable because they sometimes work slowly and their mortality rates are low when used as the sole means of controlling their target pests. However, in combination with other control measures such as predator releases and cultural practices, they may be efficacious. The interaction effects between microbials and other control measures are worth studying.

Among the most developed microbial pesticides are products based on the *Bacillus thuringiensis (Bt)*. However, the success of *Bt* in Southeast Asia will depend more on reducing its cost through local production and on effective IPM programs than on the failure of petroleum-based insecticides. As with chemical pesticides, it is necessary that key pests be identified, thresholds for these pests established and simple sampling methods developed (Tryon and Litsinger 1988). The standardization of *Bt* products has not been successfully completed due to difficulties in dealing with such a diverse group of target pests. Several insects have been tried as standard insects for production purposes including the silkworm, the Asian corn borer and the cabbage worm, but problems remain. Application techniques need refinement, and availability has been poor, indicating the need for improved supply and marketing channels (Li and Pang 1991).

New viral insecticides have not been developed quickly, and large-scale disease outbreaks of most viruses are poorly understood. Multiplying viruses for insecticidal use has been limited by difficulties in mass-producing host-insects, due mainly to a lack of available artificial diets for the hosts. The production of viruses on insect tissue cultures has shown great progress, but costs are still too high for practical application. In addition, viral insecticides are highly selective in their control, particularly when two or more pest species break out at the same time, and thus are of limited use (Li and Pang 1991).

Fungal insecticides have been tested in China. Of the roughly 170 entomogenous fungi examined, about 10 have been produced for small- and large-scale field trials against various pests (see Appendix 3). The fungus with the widest use reported in China is *Beauveria bassiana (Bb)*. In addition to its main use in corn and forestry, it has been applied against 57 other pests, including 21 agricultural pests, 27 forest pests, 5 tea pests and 4 fruit pests. It also has been used in rice on a small scale (hundreds of hectares) against pests such as the causarina tussockmoth, *Lymantria xylina*, and the common rice leafhopper, *Neephotettix cincticeps*, a vector of rice viruses causing heavy rice loss. Hundreds of tons of *Beauveria bassiana* preparations have been produced in China, mainly by solid culture with simple equipment and cheap materials (primarily wheat bran). The principal problem with fungal insecticides has been their unstable and unpredictable field efficacy, which depends on the humidity of the environment. Strain breeding has achieved little (Li and Pang 1991). Also, only the widespread disease outbreaks caused by a few fungal insecticides have been studied.

Antagonists have characteristics unpleasant to pests. The roots of *Vetiver* grass (*Vetiveria* spp.) contain an oil that repeatedly has been reported to have insect repellant characteristics (Greenfield 1989). Although the production of insecticides using the vetiver root might not be cost-effective, there is some indication that planting the grass in sugarcane plantations (Levey 1940) or using it as mulch in orchards reduces pest attacks. The advantage of using antagonistic characteristics of plants like vetiver is that they do not create any selection pressure on insects. Since no insects are killed the selection of possibly resistant pest strains is reduced.

V. SOME ECONOMIC AND ENVIRONMENTAL ASPECTS OF PEST MANAGEMENT IN ASIA

The objective of pest management is to secure the quantity and quality of crop yields. It must be evaluated in the context of factors that negatively affect yield. Only then can resources of farmers, researchers and national and international institutions be efficiently allocated to increase agricultural production. Pest management and pesticide use has had substantial publicity, but other factors like loss of fertile topsoils, erosion of large areas (estimated at 6 million hectares a year) and soil salinity (affecting, for instance, 80% of crop acreage in Egypt) may reduce productivity to a greater extent and for a longer time than do pest attacks.

The benefits of pest management are not only productivity gains but also the beneficial environmental and health effects derived from pesticide use. Health hazards, however, are not caused by pesticides alone; they may be the result of other agricultural practices such as nitrogen fertilization. In Europe, for instance, the contamination of drinking water with nitrates originating primarily from natural fertilizers such as manure is a far greater problem than is contamination with pesticides. Again, policy efforts to decrease environmental and health hazards caused by pesticides should be seen in the broader context of the various sources of externalities in agriculture.

The following discussion of the costs and benefits of pest management looks at internal and external costs and issues at the farm and national levels. It is not meant to analyze the various effects but rather to describe the complexity of the system and the factors that must be taken into account when designing plant protection policies.

Costs and Benefits of Pest Management at the Farm Level

Considering that substantial yield losses are often assumed to be caused by pests, there is little quantitative data available about the actual scale of the problem. General estimates for agriculture range between 30% and 40%, but these figures obviously depend on the assumed yield potential and the circumstances of production that determined it (e.g., experiment stations or on-farm trials). For a single pest, high two-digit figures are often reported as yield loss estimates. Since it is unlikely that only one pest affects yield rather than a combination of insects, fungi and other disease agents, weeds and rodents, the averages sum up total loss from all causes. In addition, the interaction effects of infestation of several pests often result in greater damage than the sum of the individual pest infestations. Table 1 shows some yield loss estimates for pests in developing Asia.

(a) Benefits of Pesticide Use

The use of agrochemicals has substantially lowered the risk of yield losses and has contributed to the increasing agricultural productivity of the Asia and Pacific region. Despite the growing population, several countries have achieved self-sufficiency in important food products over the last 10 or 15 years. Rice production in Indonesia is one example. However, in recent years controversy has arisen over the contribution of insecticides to rice yields. Some research indicates that the heavy use of broad-spectrum insecticides leads to pest resurgence (especially of the brown planthopper)

TABLE 1: ESTIMATED YIELD LOSS OR YIELD PROTECTION BY PESTICIDE USE

Crop	Country	Pest	Yield Loss Estimates	Reference
Cocoa	Malaysia	mirids	can reach 85%	Ho 1988
		rodents	70-100% are common	Wood 1982
Coconut	Asia	Rhinoceros beetle	20% leaf reduction → 35% yield nut reduction	Zelazny 1979
	Thailand, South	rodents	3-13%	Kaske 1988
Oil Palm	Malaysia	caterpillars	12-38% after defoliation, occasional pest	Liau 1988
Rice	Rep. Korea	rice blast	8.4%	Staring 1984
Sugarcane	Thailand	borer Complex	6-40%	Prachuabmoh and others 1988
		stem boring grub	13-43% in infested areas	Prachuabmoh and others 1988
Vegetable	Asia	pests	30-40%	FAO 1990

and actually has a negative effect on yields. These findings about negative yield effects of current insecticide use on rice should not be generalized to agriculture at large.

Estimating yield protection from pesticides depends on the methods of analysis used, the variables explaining yield specified and the form of production functions chosen. Production functions often give unclear results about the productivity of pesticides or lead to overestimation of their effectiveness. They rarely show significant results for insecticides and fungicides when results are estimated from sample data (D. Zilberman, U.C. Berkeley, personal communication). The estimated productivity of pesticides also depends on the level of infestation, which is difficult to measure. High infestation may result in heavy use of pesticides, but yields still may be lower in these fields than in fields with lower infestation levels and thus lower pesticide use. In such a case, the heavy use of pesticides prevents further yield loss, but this is difficult to determine unless reliable infestation data is available. Where infestation of weeds is homogeneous within a cross section, measurement of infestation is less important, and thus the productivity of herbicides is easier to estimate.

A recent study in California showed herbicides contribute significantly to yields but insecticides and fungicides do not (Wiebers 1991). For many crops, weed control is a substantial share of the costs of production. In the Philippines, an average of 120 person-hours per hectare are spent for weeding rice (IRRI nd). Herbicide expenses, however, account for only 1.8% of all cash costs (Waibel and Meenakanit 1988). With increasing development of nonagricultural sectors and rising wage rates, the use of herbicides may also gain more importance in Asia, releasing a substantial amount of labor for other areas of agriculture or other sectors.

As agricultural systems develop and household income increases in Asia, the quality of food products, especially of vegetables and fruit, will become increasingly important. Insecticides today are often sprayed right up to harvest to preserve the cosmetic appearance of the product.

There may be other specific benefits of pesticide use as is the case with use of cotton defoliants, which allow mechanized harvest of the crop. A study in Egypt showed that defoliants shortened the growing period of cotton, which permitted obtaining an additional cutting of clover before the next cotton crop was planted. The use of cotton defoliants increased mainly the productivity of land (Wiebers 1987).

(b) Costs of Pesticides Use

Figure 3 gives an overview of the costs of pesticide use at the farm and national levels. The direct costs of pesticide use are expenses for the pesticide product, water and/or the transportation of water, labor for the application, application equipment and safety gear. The supply of safety gear is often inadequate and exacerbates growers' unwillingness to use protective clothing. In Kenya, for instance, growers complain that pesticide distributors do not offer protective gear such as masks (Wiebers 1989).

The indirect costs to the grower of pesticide use include:

- opportunity costs
- health problems
- environmental pollution
- pest resistance
- changes in the cropping pattern
- new pest strains

The opportunity costs of pesticide use involve time and money spent for pest control and time lost when entrance to a field is prohibited or when certain crops cannot be planted after an application of pesticide (plant-back period). Cash costs are incurred when growers--aware of the negative health effects--hire laborers to apply pesticides soon after earlier applications. In several countries in Asia, health damages are being transferred from those who can afford to hire labor or can delegate this work to those who cannot afford hired labor or who cannot reject the offered work.

Table 2 summarizes the results of four studies about pesticide poisoning. As the figures show, there is a large variation in the number of reported cases. It seems reasonable to assume that these differences come from different methods of collecting the data rather than from actual differences in the number of cases. The Indonesian figures, for instance, are cases where patients sought medication in health centers. The Malaysian figure is based on a survey of growers and estate workers, not on poisonings treated in health centers or hospitals. These levels of poisoning, which are intolerable from a human point of view, are a substantial cost to the grower if he or she is unable or less able to work and/or has to hire labor.

Figure 3: Costs of Pesticide Use.

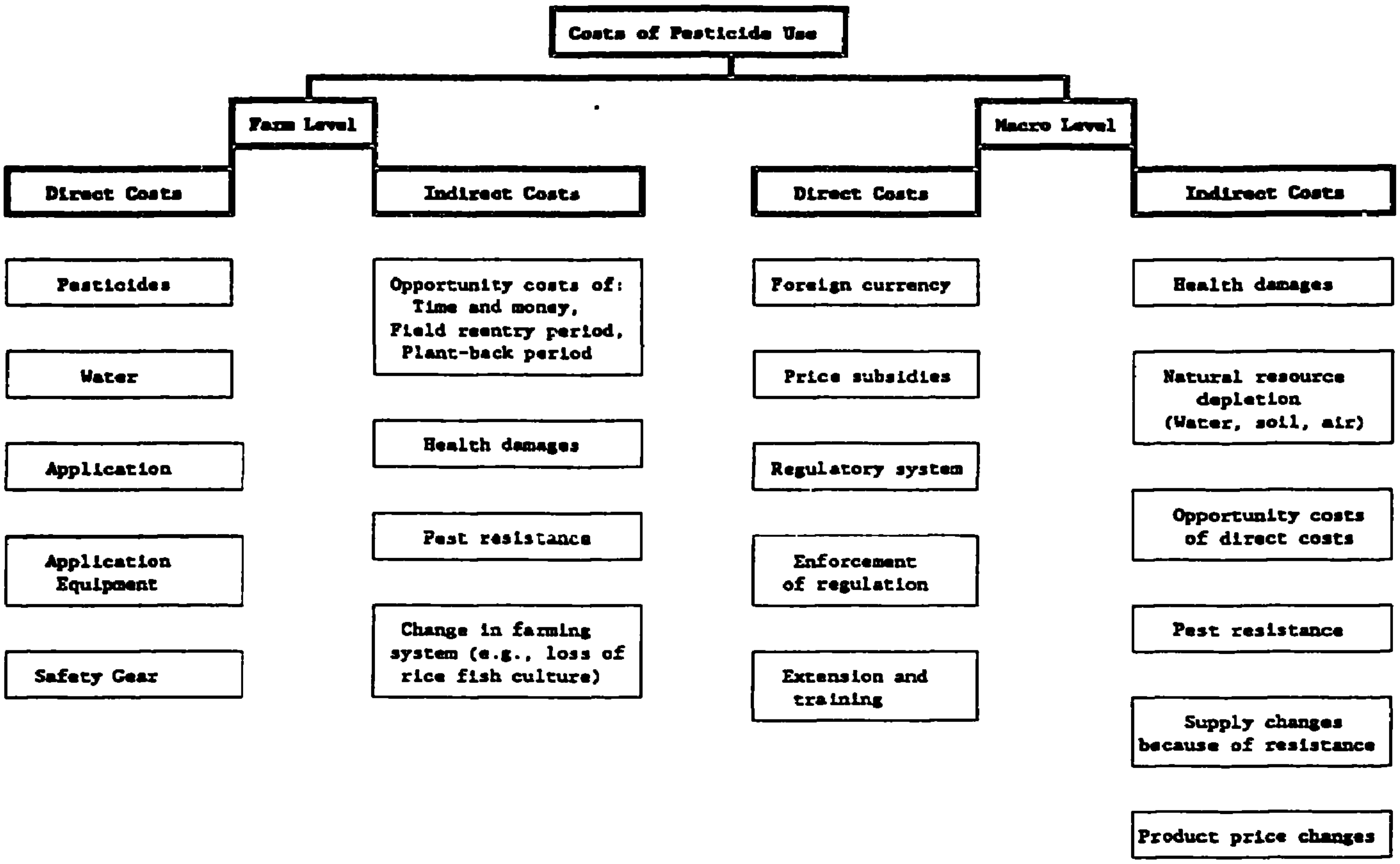

TABLE 2: PESTICIDE POISONING AND DEATHS IN ASIA

TYPE OF PESTICIDE	PHILIPPINES [1] (1982-85) cases of poisoning	deaths	THAILAND [2] (1985) cases of poisoning	deaths	MALAYSIA [3] (1985) cases of poisoning	INDONESIA [4] (1986) cases of poisoning	deaths
Insecticides	1,434	280	3,045	210			
Other Pesticides	102	6	1,001	79	54% of all agricultural workers		
No Information	268	36					
Total	2,804	322	4,046	289		404	32

Sources: 1. Castañeda 1988, 2. Kritalugsana 1988, 3. Aros 1988, 4. Mustamin 1988.

An excerpt (edited) from the *Bangkok Post* (3 February 1991) illustrates the problem:

> Farmers in rice growing areas have found that the use of chemicals has become less effective and is taking its toll on their health. Farmers try several ways to avoid exposure. Some hire laborers; those with large families take turns spraying. Others who can do neither continue until they come down with chemical-induced illness. "I have given up spraying for good; my body is unable to resist the effects anymore," said Chuam Harnphut of Ban Pongphlab. In 1977, he began to rely on heavy use of pesticides to increase productivity and it paid off. "It took a few years before it (spraying) took its toll on me. Early on I could do it all day long and still be fine. Later I felt sick in less than an hour." Since 1982 there have been pest outbreaks of different sorts of insects. As the problem worsened, he brought more kinds of pest control substances to kill the insects. Before, chemicals were sprayed every ten days, now every six to seven days. A brand of herbicide Chuam used on his farm was so poisonous that wading through the paddy fields made his feet burn and become numb, he said. If he felt dizzy while spraying, he would quit before poisoning became acute, but he never went to see a doctor about it. Some of his friends also suffered from acute contamination, vomiting and passing out. However, his sons seldom cover their nose and mouth. They quickly tired of masks. "One of my sons just sprays against the wind. He says it is too time-consuming to walk back every time, as one is supposed to." Farmers not only use formulas with greater toxicity, but also use twice the amount recommended on the labels because moderately poisonous chemicals are now less effective.

These statistics and reports deal only with acute poisoning. Poisoning causing cancer, mutations, sterility and other chronic health problems are not considered. Organochlorine insecticides like DDT are known to cause chronic problems and are still widely used in Asia. The National Research Council (NRC 1987) states that since many commonly used pesticides in rice cultivation, such as cypermethrin, benomyl and captan, are known as potentially mutagenic and carcinogenic in lab animals, it is likely that human health problems result from excessive exposure.

An external cost of pesticide use--as environmental pollution --can be assumed considering the types of pesticides used in Asia. Besides negative effects on water, soils, air and wildlife, there are negative effects on populations of pest predators. The many attempts to introduce exotic natural enemies have probably failed because of the heavy use of broad-spectrum insecticides.

Another problem of pest management mentioned in the *Bangkok Post* article is the need for more toxic products, higher application rates and shorter intervals between applications due to pest resistance. Pest resistance as it affects vegetable production in Asia is probably worse in the case of the diamondback moth infestations.

> The diamondback moth (DBM) is perceived by farmers to be a very serious, if not the most important, insect pest of cruciferous vegetables. In Malaysia, at least 50% of the farmers apply insecticides two or three times per week. In all the countries the trend in pesticide use has been essentially the same - there has been a shift from the early botanicals to the organochlorines, then to the organophosphates, carbamates, pyrethroids, and now to the insect growth regulators. This shift is due largely due to the development of resistance by DBM to insecticides. (Lim 1988)

There can be indirect costs of pesticides caused by changes in the cropping system. Rice farmers in Northeast and Central Thailand have refused to use any recommended insecticides because of potential fish poisoning, but the reverse is true elsewhere: widespread use of insecticides in the Philippines has almost completely eliminated the rice-fish culture (Tryon and Litsinger 1988).

Scheduled insecticide applications in resistant varieties of rice accelerated the evolution of new strains of pests able to overcome the host plant resistance.

(c) Benefits of IPM

The benefits of IPM are usually evaluated in terms of pesticides applied on a calendar-scheduled basis. The benefits of IPM are hypothesized as:

- reducing pesticide expenses
- increasing yields through improved plant protection
- reducing external costs, that is, environmental and health hazards

Cost reduction from adopting IPM techniques depends on the pesticide price policy in the market. The California study mentioned above (Wiebers 1991) shows that cost reduction is more important for the adoption of IPM than improved yields. The same pesticide program in many developing countries is subsidized, making it far less costly to farmers. Thus, growers have less incentive to adopt IPM technology. An example from Bangladesh illustrates:

> Training farmers in IPM in six regions of Bangladesh resulted in pesticide cost savings of 60% while yields tended to increase. However, pesticide expenses accounted for only 4% of farmers' purchased inputs so that cost savings from IPM training were not substantial. Table 3 shows the cost shares of pesticide for other Asian countries. Increases in yield probably are associated with improved cultivation practices taught in training rather than with the substitution of IPM techniques for chemicals (Duloy and Nicholas 1991). This suggests that reducing external costs may be more important than reducing production costs.

Even in developed countries, the true costs of pesticide use are not charged to the user. If the external costs of environmental and health damages were "internalized" in the form of a pesticide tax, for instance, the

TABLE 3: FERTILIZER AND PESTICIDE COSTS AS PERCENTAGE OF TOTAL CASH COSTS OF RICE PRODUCTION IN SELECTED ASIAN COUNTRIES

	Thailand	Philippines	Sri Lanka	Taiwan
Fertilizer	27.1	18.2	9.9	54.5
Insecticides	2.4	6.1	3.1	28.4
Fungicides	2.2	0	0	0
Herbicides	0.4	1.8	3.1	5.8

Source: Waibel and Meenakanit 1988

adoption of new pest management technologies would be relatively more attractive. This problem will be addressed in the next section.

Since IPM is an improved pest management technology in comparison to scheduled spraying, it gives better prevention and control of pest infestations. Better crop protection results in higher yields on average and/or a reduced variation of yields on different fields or different years. The reduction of the expected variance of yield is synonymous with reduction in economic risk.

Table 4 presents the results of empirical improved pest management studies evaluating the economic effects of IPM on the farm in the United States. The researchers found that IPM generally decreases pesticide use and economic risk (see also Figure 1) and increases yield and net returns. The adoption of IPM may increase net benefits if analyzed on the farm level. The effects can be different on an aggregate level, however, if the whole industry adopts the technology. This is discussed in the next section.

The net benefits of applying the economic threshold concept to rice production in on-farm trials in Thailand and the Philippines is presented in Table 5. The threshold system is compared to prophylactic applications here called "farmers' practice."

IPM treatment at economic threshold levels increased net revenues according to all four studies. The last column shows the percentage of cases where an insect pest has been successfully controlled. Profits, however, did not significantly increase from yield increases (Rola and Kenmore 1986) but rather from reduced pesticide expenses. Several studies have shown that 95% of the increase in profits is due to a reduction in pesticide expenses (Waibel and Meenakanit 1988). Litsinger (1984) concluded that rice production in the Philippines could be maintained at current levels with half the amount of insecticides then being used. More recent estimates consider even 10% of current levels of insecticide use sufficient (H. Waibel, Universität Gottingen, Germany, personal communication). Since the benefits of IPM at the farm level come mainly from cost reduction, these benefits are limited to the cash spent for pesticides. These expenses are relatively small, so the incentive for the grower to adopt the threshold concept and take the time to obtain training and to monitor the fields might still be insufficient. (Appendix 4 briefly discusses the question of whether IPM, or any new technology, will increase farmers' welfare.)

TABLE 4: EMPIRICAL IPM EVALUATION STUDIES IN THE U.S., 1986-85

Effect of IPM on...	Pesticide Use and/or Cost of Production (no. of studies)	Yield (no. of studies)	Net Return (no. of studies)	Level of Risk (no. of studies)
Decreasing	35	2	0	7
No Impact	0	2	2	0
Increasing	0	13	24	2

Source: After VCES 1987.

Three other factors negatively influence the adoption of the threshold concept:

- Economic risk increases with the adoption of the threshold concept (Waibel and Meenakanit 1988).
- Threshold treatments result in fewer insecticide applications than is the farmers' general practice; but since farmers often use lower dosages than recommended, the cost-saving advantage of changing to the threshold system is reduced (Bandong and Litsinger 1988).
- Growers often overestimate the loss from one missed spraying (by 40% to 100%) and therefore overestimate the profitability of an application (Waibel and Meenakanit 1988).

More relevant than cost-effectiveness is IPM's potential for reducing environmental and health hazards; but these are not internalized to the user. Also, reduced insecticide use in rice will promote activities of pest predators and stabilize the agroecosystem. This reduces the incidence of pest resurgence and outbreaks of secondary pests as described earlier and adds to the benefits of IPM. Savings in pesticide costs are valued as a benefit, but the real question is how will the grower spend the extra cash? If he or she spends it on fertilizer, for example, the benefits of the threshold system become more significant (Waibel 1988).

(c) Costs of IPM

The costs of IPM depend on the set of possible techniques chosen. Monitoring systems (e.g., the economic threshold concept) require the time to monitor populations of pests and their predators, soil humidity, temperature, precipitation and the like. However, the time spent for monitoring is an insufficient measure of IPM under the hypothesis of decreased pesticide use. The California study mentioned above (Wiebers 1991) has shown that the quality of monitoring better explains pesticide use reduction and is a better measure of IPM than is the quantity of monitoring. Monitoring quality measures growers' ability to identify pest predators as well as the pests. The use of herbicides and insecticides actually increased with an increasing amount of time spent for monitoring--growers who searched more for pests found more and eventually sprayed more. However, if they also monitored insect predators, their use of insecticides decreased. Training in these skills is an another cost to the grower in addition to the time he or she has to spend for monitoring.

TABLE 5: INCREASES IN NET RETURN FROM THRESHOLD TREATMENTS IN RICE

Country/Source	Average increase of farmers' net return (%) based on			Percent of successful cases
	Untreated	Farmers' practice	Threshold	
Thailand	-	-	4.2	80
Philippines				
Litsinger 1984	-	-	-	52
Waibel 1988	-	-	3.3	61
Rola and Kenmore 1986	-	-	7.6	82
Bandong and Litsinger 1988	11.7	8.0	7.1	-

Sources: Waibel and Meenakanit 1988; Bandong and Litsinger 1988.

The costs of prophylactic IPM techniques are complex and cannot be listed here. Waibel and Meenakanit (1988) developed an interesting matrix that looks at possible negative effects of several agronomic IPM techniques on potential yield, crop prices, cash and labor resources. They conclude that the only IPM practice with no negative impact on economic factors is the use of economic thresholds, which is not an agronomic practice per se. Resistant rice varieties sometimes have a lower yield potential than highly susceptible ones--the highly susceptible rice variety RD1 with a yield potential of 750 kg/rai in Thailand is an example. More resistant varieties cannot match this yield. Also, highly resistant varieties do not always command as high a price as susceptible varieties. New, certified seed must be purchased for each planting instead of using seed from the previous harvest. Changing planting methods can severely affect labor and, consequently, cash resources. For instance, more transplanters may be required if growers change from direct seeding (a trend in Thailand) to transplanting or if synchronized planting is adopted.

The cost structures of an IPM program may be extremely complex and difficult to predict for researchers developing IPM methods. It is thus important to have a close interaction with growers on a local level and to develop these practices in close consultation with them.

Aspects of Pest Management Policies at the National Level

Some policy aspects were addressed above with regard to regulation of pesticide use and national costs of pesticide use (Figure 3). Additional policies to consider are price instruments and legal sanctions.

The government can indirectly affect pesticide demand through price policy and/or directly by severely restricting or banning a pesticide. The common policy still remains price subsidization; taxation, that is, the "internalization" of external costs of pesticides, is often discussed but has not been implemented. The low cost of pesticides is the dominant factor preventing growers from partially or fully substituting other pest management methods for chemical pesticides. Policies of subsidization and taxation are thus important parameters of an overall integrated pest management policy.

Types of pesticide subsidies may be categorized as obvious or hidden and direct or indirect (Waibel 1990). "Obvious" means the transfer of money or pesticides from the government to growers while "hidden" indicates growers' preferences for pesticides. "Direct" subsidies involve price reduction while "indirect" subsidies concern products and information. There are direct and obvious subsidies if the government sells pesticides, refunds pesticide companies' costs or provides pesticides on credit in a package of inputs. Direct but hidden subsidies may take the form of preferential rates for imports and local taxes, import credits or exchange rates. Or they may take the form of government tolerance of externalities. Indirect but obvious subsidies are the kind where governments supply pesticides to farmers under certain conditions, usually in relationship to the pest situation. Indirect and hidden subsidies are created by the information environment, which is believed to be strongly biased in favor of pesticides. Overestimation of crop losses in government surveys falls into this category, whether from an incorrect definition of loss and identification of pests by extension workers or from poor statistics.

These instruments have differing importance in the region's countries. In **Thailand**, for instance, the dominant subsidy is the provision of pesticides to farmers during pest outbreaks. In addition, although import duties are levied on pesticides, they are only one sixth of the duty on urea (Waibel 1990). Bangladesh and Indonesia eliminated their pesticide subsidies between 1974 and 1979 and between 1986 and 1988, respectively. When farmers in **Bangladesh** received a 100% subsidy on pesticides during 1971 and 1974, the annual area of rice sprayed was 3 to 5 million ha. In 1974, when subsidies were reduced by 50%, the treated area fell within two years to less than 1 million ha. After the elimination of the subsidy in 1979, treated area fluctuated around 0.5 million ha (Duloy and Nicholas 1991). In **Indonesia**, the government eliminated subsidies in stages and also banned the use on rice of 57 registered brands of broad-spectrum insecticides, about 20 of which had been widely used by farmers. The scheduled use of these products was considered responsible for the alarming outbreaks of brown planthoppers (BPH). Within three years, the number of applications per season decreased from 4.5 to 0.5, dramatically decreasing the volume of pesticide used. Farmers' expenditure on pesticides decreased from 7,000 rupiah/ha to 2,500 rupiah/ha, and the government's expense for pesticide subsidy dropped from 27,000 rupiah/ha to 500 rupiah/ha. The Indonesian government reallocated these funds to an extensive national IPM program. It also imported narrow-spectrum insecticide that affects the brown planthopper but not its predators. Fifteen hundred new pest observers were recruited, and senior pest observers were provided with motorcycles to improve surveillance and training of farmers (Oudejans 1990). Since the introduction of the new policy in Indonesia, rice yields have increased and the BPH infestation remains at low levels (FAO 1991a).

Pesticide subsidies must be evaluated in the larger economic context. Prices of agricultural commodities and thus farmers' income are often kept low to maintain low consumer prices. This forces farmers to intensify production to reach and maintain a certain level of income. Growers of such crops as cotton and vegetables can hardly afford the elimination of pesticide subsidies because pesticides are already a substantial part of their cost of production. Thus, the elimination of subsidies should coincide with implementation of IPM programs as in the Indonesian example. This strategy will ensure that growers are able to successfully control pest damage without substantially increasing growing costs.

Ideally, whether a pesticide product is subsidized or taxed should depend on the trade-offs between its contribution to the productivity of the crop and the sector and its actual or probable health and environmental effects. Not all pesticides are equally hazardous; not all have manageable alternatives. Therefore, a critical review of individual pesticides or groups of pesticides may result in price policies that cause very hazardous pesticides to be replaced by less hazardous ones and less selective pesticides by those that are more selective. This strategy requires a choice of pesticides in the short run, but not of chemical and nonchemical pest management techniques.

This discussion has looked at price instruments as they affect pesticide demand. In developed countries, however, the common strategy to reduce demand is to severely restrict use of certain pesticides or ban them entirely. This strategy may not be effective in Asia.

The government's capacity to implement bans or taxes is limited. Both require control over production facilities and the country's borders and, in the case of taxation over distribution points. Since this degree of control is unlikely, a ban or a tax would be only partially effective. The effect of each will be different, however. With a ban, a pesticide product becomes illegal which creates a strong incentive to mislabel the product. Technical assistance from governmental agencies is highly unlikely, and the premium charged above import parity is accrued by smugglers and illegal importers. With the tax, the product is still legal. There is thus less incentive to mislabel, technical assistance from the government remains possible and the collected tax adds to public revenues. All of these factors make taxation the preferred instrument in developing countries. When the capacity to enforce regulation increases, the ban is preferred, however, as it eliminates the environmental risks caused by highly toxic pesticides (Duloy and Nicholas 1991).

VI. DEVELOPMENT AND IMPLEMENTATION OF PEST MANAGEMENT TECHNOLOGY

Research in IPM has been conducted for many years in the Asia and Pacific region, and a great deal of IPM technology is already available. However, much of the technology has not yet reached the farmers of Southeast Asia (Heinrichs 1988). As just discussed, this is due in part to the complex cost structure of some IPM techniques, a factor that can be difficult for the researcher developing the technology to forecast. The solution may be greater interaction between researchers and growers.

In the tradition of the linear technology transfer as characterized by the training and visit system (T&V), pest management guidelines were distributed unidirectionally from extension workers to growers. IPM guidelines were given to growers in the form of quantitative economic thresholds that they were supposed to remember and apply in the field. These guidelines are usually developed in research centers or on-farm trails and then generalized for the area of the extension service. Indonesia followed this method during its early attempts to introduce IPM as a national agricultural policy (Röling and van de Fliert 1991):

> Following the declaration of IPM as a national policy in 1986 the government requested the World Bank to allow use of US$4.19 million of loan funds for a national agricultural extension IPM training program. 32 principal trainers and 198 master trainers were trained, mass media produced, travel money and other funds provided, etc. Although the project had presidential priority, training funds did not reach training centers in time. Training materials often arrived midway through courses. Only 25% of trainees visited rice fields. The goal was to train 125,000 farmers in the T&V system, but only 10,300 actually received training. Yet the entire US$4.19 million was spent in seven months. The leakages amounted to over 91.5% of the allocated resources. Only 8.5% could be delivered to the field to train less than 10% of the farmers targeted.

After these experiences, the Indonesian government with the support of the FAO IPM program for Southeast Asia changed its strategy. The program opted for a much more fundamental and penetrating approach consistent with the major turn-about in style and substance required for implementing IPM. It became obvious that considerable staff training is necessary to make an impact at the village level. The key elements of the new strategy were the same for training the trainers and the growers: individuals were motivated to ask questions rather than receive answers, and they were trained to make decisions on their own. The main training principle was, "A direct answer of a question is considered a wasted opportunity for learning." The key words of the educational process were:

- *discover* the elements of the crop's agroecosystem
- *distinguish* predators from pests
- *decide* whether there are enough predators to keep pest levels low
- *practice* and *learn* from experience
- gain *confidence* to conserve natural enemies
- *manage* the fields; do not simply consume inputs

It is probably fair to say that there were two objectives of the IPM program--making growers aware of IPM principles and training farmers so that they become "good" farmers. The management process listed above is applicable to the management of fertilization, irrigation and all other agricultural practices.

The Indonesian government proceeded with the new training program as follows: Extension workers were not suitable for training growers in IPM since they already had many tasks and pest control extension is a relatively minor one. The new program chose the pest observers of the Directorate for Plant Protection for the training program. The directorate operates food crop protection centers at the provincial level and pest control field laboratories at the local level. The pest observers report to the labs, but they are assigned to the rural extension centers. Initially, 30 people formed the core of the program. These trainers trained other pest observers in batches of 50, divided in work groups of five each. Each observer receives 14 months of training in several areas, each lasting three to four months: (1) induction training in rice IPM, (2) hands-on training of four groups of 25 farmers in the program's IPM farmer field schools, (3) training in dry season crops, and (4) a diploma course at the university (to allow them to reach a higher salary level). After training, the pest observers follow up with their four farmer groups and assist in the evaluation of the program. During this follow-up, they also train likely farmer candidates for farmer-to-farmer training. The pest observers maintain elaborate "insect zoos" and tend their own experimental fields. They carry out a set of experiments prescribed in the curriculum, working every morning like farmers in the field. Elaborate written manuals describe field and training methods.

The goal of this training is to make the pest observers into confident IPM experts; self-teaching experimenters; and effective trainers of farmers and extension workers. The two main principles of the training are (1) agroecosystem analysis based on careful field observation and (2) dialogue (and not lecturing). The pest observer training reflects the methods they are expected to use with farmers.

The central unit of the farmers' training is the IPM farmer field school, which consists of 25 farmers selected from farmers' groups and working in groups of five. The training lasts most of the crop season. The groups meet once a week for some ten weeks to work with each stage of the rice plant development. Each group has a training field where pesticides are not automatically applied and a field where the recommended chemical package is applied. There is hardly any lecturing during the training. Trainers are not to answer questions directly but to make farmers think themselves. Farmers are being trained to become the "experts." The main activity of the groups is observing sample rice hills. Notes are made about numbers of pests and natural enemies, stage of the plant and weather conditions. Farmers often keep an "insect zoo." Participants receive Rp 1000 for each day for their expenses of participation. Many groups or active members begin to train other groups (farmer-to-farmer dissemination).

The present national IPM program has a two-year budget of US$10.5 million. FAO (1990) estimates that training 1,000 pest observers, 2,000 extension workers and 100,000 farmers, which is the expected accomplishment of the program after two years, will cost about US$4 million with no frills and excluding start-up costs. So far, the IPM program in Indonesia has resulted in an increase of net benefits of US$18 per farmer (US$60 per hectare) and a return (dollar for dollar) on training investment ranging from 4.6 to 8.6 (FAO 1991b). It has a great motivating effect on growers and administrators. For those reasons, it may serve as a model for farmers' training in integrated crop management in the region.

There are questions about this system, however. Röling and van de Fliert (1991) discuss whether it can train 2.5 million farmers. Also needing answers are the following:

- Are there cheaper ways to train farmers on a large scale?
- Is the program sustainable in the Indonesian feudal society?
- Is it possible to train a farmer once and for all in IPM?
- Is rice IPM training transferrable to other crops, or is additional training necessary?
- Is face-to-face training necessary, or can mass media messages work as well?
- What are the criteria to select growers for the program?
- How can part-time farmers be trained in IPM?

VII. CONCLUSIONS

Various factors affect pest management. In Asia, the most important are:

- Increased transparency of information about pesticide markets, pesticide use, research results and programs in IPM.
- Notification to pesticide-importing countries of the hazards of severely restricted or banned pesticides.
- Appropriate packaging and labelling of pesticides, that is, text in the local language and scaled to the education of the end-user.
- Formation of pesticide price policy--elimination of various obvious and hidden subsidies and introduction of taxes on highly hazardous pesticides and on pesticides that will require greater and greater use to maintain pest control.
- Banning the use (i.e., importation and manufacture) of highly hazardous pesticides and pesticides that will require greater and greater use to maintain pest control.
- Introduction, improvement and enforcement of pesticide legislation and regulation. Establishment of the necessary infrastructure, for example, field inspection stations, and laboratories for pesticide and residue testing.
- Research and development of IPM techniques, for example, monitoring systems (thresholds), cultural practices (including resistant varieties, sanitation, protection of natural enemies, etc.), biological control, microbial and botanical pesticides and selective use of chemical pesticides.
- Innovative implementation of integrated pest management and integrated crop management principles in the field.

Pests are only one factor limiting agricultural development in Asia. Scarce resources for plant protection policies should be allocated according to how the following questions are answered:

(a) What are the "right" IPM strategies and in what regulatory environment can IPM develop?

(b) Which of the methods developed in (a) can be applied considering the status of the country, the region, the sector, the people, and the like?

(c) Which of the programs identified in (b) can be undertaken given scarce resources?

There is no single, regional plant protection policy. To answer each of the questions above, a considerable amount of additional data and information is necessary. The numerous examples of IPM research in China, for instance, have shown that information exists but is not readily available. The establishment of an international data base and information retrieval network for pesticides and IPM could enhance, coordinate and help avoid duplication of research efforts.

Despite the need for additional data and information, the following general conclusions can be made. The success of IPM and thus of safe and effective pest management depends on Asian growers and whether they expect IPM practices will increase their net benefits. Regulatory efforts can create a favorable environment for IPM, but in the end, growers must be convinced about the advantages of implementing concrete IPM practices. As pesticides often are a small share of the cost of production and regulation enforcement is insufficient in many countries, price policy, even taxation, and regulation will not do the job alone.

Many of the alternatives to chemical pest control need additional development to compete with the well-established markets of chemical pesticides. Chemical pesticides have large financial resources for research, development and promotion, smoothly functioning distribution channels and numerous field representatives. All of these factors remain to be established for nonchemical pest control.

The attempts of several national and international institutions to improve pest control by implementing monitoring systems and teaching economic thresholds have failed. There are no signs that Asian growers are applying economic thresholds. At the same time, pest problems in rice caused by outbreaks of planthoppers and in vegetables caused by pest resistance have increased dramatically.

Pesticide use is increasing in most countries of the region. With the wider use of modern rice varieties, for instance, this development will continue under today's conditions. Expenditure per hectare on pesticides in Bangladesh is more than five times higher for modern varieties than for traditional varieties. If the national consumption of pesticides is to decrease, IPM programs would have to offset this increase.

Whether a decrease of national consumption is desirable, however, cannot be answered with the data available. For many countries of the region, average use of pesticides per hectare is extremely low compared to developed countries. There may be regions and crops were there are no alternatives to pesticides.

IPM programs will depend on chemical pesticides in the near future. However, IPM technology demands a different approach to their application than that used under green revolution technology. Successful IPM application is very knowledge-intensive. Growers must change their production behavior, that is, they must be attentative to crop development in the field and not simply apply inputs mechanically. These behavioral changes are impossible to mandate. As the Indonesian example has shown, growers must become part of the process, participating in the development of their own IPM programs.

Further attention must be given to developing training programs for the majority of Asian growers and to developing specific management programs for different crops. Nonchemical pest management can then be integrated into these programs and will have a practical ground for development.

BIBLIOGRAPHY

Amaritsut, W. and others. 1988. Crop protection and IPM in rainfed cropping systems in Northeast Thailand. In P.S. Teng and K.L. Heong eds., Pesticide Management and Integrated Pest Management in Southeast Asia. pp. 135-44.

Aquino, G.B., and E.A. Henrichs. 1979. Brown planthopper populations on resistant varieties treated with a resurgence-causing insecticide. International Rice Research Newsletter 4(5):12.

Aros, N.M.T. 1988. Pesticide poisoning studies and data collection in Malaysia. In P.S. Teng and K.L. Heong,eds., Pesticide Management and Integrated Pest Management in Southeast Asia.

Bandong, J.P., and J.A. Litsinger. 1988. Development of action control thresholds for major rice pests. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia pp. 95-102.

BIRC, the Bio-Integral Resource Center. 1991. Least-Toxic Pest Management in China. Berkeley, California.

Bottrell, D.G. 1979. Integrated Pest Management. Council on Environmental Quality. Washington, D.C.

Browning, J.A. 1974. Relevance of knowledge about natural ecosystems to development of pest management programs for agro-ecosystems. Proc. Amer. Phytopathol. Soc. 1:191-99.

Burn, A.J., T.H. Coaker, and P.C. Jepson. 1987. Integrated Pest Management. London: Academic Press.

Cammell, M.E., and M.J. Way. 1987. Forecasting and monitoring. In Burn, A.J., T.H. Coaker, and P.C. Jepson, eds., Integrated Pest Management. pp. 1-23.

Castañeda, C.P. 1988. Pesticide poisoning data collection in the Philippines. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia.

CDFA, California Department of Agriculture. 1990. Food and Agriculture Code and Code of Regulation. Sacramento.

CIRAD, International Co-operation Centre of Agriculture Research for Development. 1990. Regional Agro-Pesticide Index. Vol.1. Bangkok, Thailand.

Clausen, C.P. 1978. Introduced parasites and predators of arthropod pests and weeds: A world review. USDA Handbook No. 480.

DeBach, P. 1964. Biological Control of Insects Pests and Weeds. Reinhold, New York. pp. 844.

Deng, Ziong and others. 1988. Methods of increasing the winter-survival of *Metaseiulus occidentalis* [Acari: Phytoseiidae] in North West China. Abstracted in Chinese J. Bio. Control 4(3):101.

Djamin, A. 1988. Crop protection and pest management of oil palm in Indonesia. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia. pp. 205-12.

Doutt, R.L. 1972. Biological control: Parasites and predators. In: Pest Control Strategies for the Future. National Academy of Sciences, Washington, D.C. pp. 288-97.

Duloy, J., and P. Nicholas. 1991. Controlling pesticide pollution: The choice between regulation and taxation. The World Bank. Washington, D.C. Discussion Draft.

Fadeev, I.N., and K.V. Novozhilov. 1987. Integrated Plant Protection. New Delhi.

Fan, Guanghua, and Jianfang Zhao. 1988. Effects of 12 commonly used pesticides on lady beetle *Coccinella septempuncta*. Journal of Plant Protection 14(6):20-21. (In Chinese.)

FAO, Food and Agriculture Organization of the United Nations. 1986. International Code of Conduct on the Distribution and Use of Pesticides. Rome.

_____. 1990. Status and management of major vegetable pests in the Asia Pacific region. RAPA Publ. No. 1990/3. Rome.

_____. 1991a. Rice IPM in Asia, Briefing Kit, April. Unpublished report. Rome.

_____. 1991b. Highlights in IPM implementation 1990-1991 in selected Asian national programs collaborating with the FAO Intercountry IPM Program. Prepared for the PPAB Meeting 22 May. Rome.

Flint, M.L. 1989. Annual Report, Statewide IPM Project. University of California.

Flint, M.L., and R. van den Bosch. 1977. A source book on integrated pest management. Univ. Calif. Int. Center for Integrated and Biol. Control.

Gaston, C.P. 1990. Promoting safe and efficient use of pesticides in the region. Agrochemical News in Brief 8(1):28-30.

Graham-Bryce, I.J. 1987. In A.J. Burn, T. H. Coaker, and P.C. Jepson, eds., Integrated Pest Management. pp. 113-59.

Granovsky, T.A. and others. 1985. Trainers Manual for Pesticide Users. Consortium for International Crop Protection, U.S. Agency for International Development, Washington, D.C.

Greathead, D.J., and J.D. Waage. 1983. Opportunities for biological control of agricultural pests in developing countries. Technical paper 11. The World Bank, Washington, D.C.

Greenfield, J.C. 1989. Vetiver Grass (*Vetiveria spp.*): The ideal plant for vegetative soil and moisture conservation. The World Bank, Washington, D.C.

Griliches, Zvi. 1958. Research costs and social returns: Hybrid corn and related innovations. J. Polit. Econ. 66(1958):419-31.

Grossman, Joel. 1991a. Biological control of weeds in China. In: Least-Toxic Pest Management in China. The Bio-Integral Resource Center, Berkeley, California.

_____. 1991b. Good potential for botanical molluscicides. In: Least-Toxic Pest Management in China. The Bio-Integral Resource Center, Berkeley, California.

Guangyu, Zhang. 1991. First commercial viral pesticide in China. In: Least-Toxic Pest Management in China. The Bio-Integral Resource Center, Berkeley, California.

Han, Jingsheng. 1990. Use of antitranspirant epidermal coatings for plant protection in China. Plant Disease 74(4):263-66. Beijing Agr. Univ., PRC.

Hasse, V., A. Drews, R. Corales, and A. Querubin. 1988. An approach to integrated pest management: Activities of the Philippine-German cotton project. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia.

Heinrichs, E.A. 1988. Role of insect-resistant varieties in rice in IPM systems. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia.

Heinrichs, E.A., and others. 1986a. Management of the brown planthopper, *Nilaparvata lugens*, with early maturing rice cultivars. Environmental Entomology, 15:93-95.

Heinrichs, E.A., H.R. Rapusas, G.B. Aquino, and Palis, F. 1986b. Integration of host plant resistance and insecticides in the control of *Nephotettix virescens* (Distant) (Homoptera: Cicadellidae), a vector of rice tungro virus. J. Economic Entomology 13:359-65.

Heul-Rolf and Vungsilabutr. 1988. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia.

Ho, C.T. 1988. Pest management on cocoa in Malaysia. In P.S. Teng and K.L. Heong, eds. Pesticide Management and Integrated Pest Management in Southeast Asia. pp. 193-203.

Ho, C.T., and K.L. Heong. 1984. Decision plans based on sequential counts for implementation of rat control programs in cocoa. Jour. of Pl. Prot. in the Tropics 1(1):9-18.

Huffaker, C.B., and P.S. Messenger. 1976. Theory and Practice of Biological Control. London: Academic Press.

IRRI, International Rice Research Institute. 1990. Workshop on the Environmental and Health Impacts of Pesticide Use in Rice Culture. Proceedings, March 1990, Los Banos, Philippines.

_____. No date. Rice machinery development. Los Banos, Philippines.

Jackson, G.I. 1991. Agrochemical usage in the Asia Region: A reference compendium. World Bank, Asia Technical Agriculture Division, Washington, D.C.

Johson, E.L. 1990. Pesticide regulation in developing countries of the Asia and Pacific Region. Agrochemicals News in Brief. Special Issue, November 1990. FADINAP/ARSAP/ESCAP. Bangkok, Thailand.

Kaske, R. 1988. IMP activities in coconut in Southeast Asia. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia. pp. 181-86.

Kritalugsana, S. 1988. Pesticide poisoning studies and data collection in Thailand. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia.

Levey, H.A. 1940. American vetiver and its production. The Drug and Cosmetic Industry Nov. 1940:47(3):334-38.

Li, T.S., and J.G. He. 1988. Polistes wasps control cotton and wheat pests. Kun-chong Zhishi 28(2):108-09. Abstracted in: The IPM Practitioner 10(8):14.

Li, Zengzhi, and Yi Pang. 1991. Microbial pest control in China. In: Least-Toxic Pest Management in China. Berkely, California: The Bio Integral Resource Center.

Liang, D.R. 1987. In: Insecticidal Microbes, Vol. I. Beijing: Agr. Press, pp. 76-80.

Liang, D.R. and others. 1986. In: Institute of Virology, Univ. Wuhan. Sci. Tech. ed. The Atlas of Insect Viruses in China. Changsha: Hunan Press.

Liau, S.S. 1988. Pest management on oil palm in Malaysia. In P.S. Teng and K.L. Heong, eds. Pesticide Management and Integrated Pest Management in Southeast Asia. pp. 187-92.

Lim, G.S. 1988. IPM of *Pluetella Xylostella* (L.) on vegetables in Southeast Asia: Rationale, need, and prospects. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia. pp. 123-29.

Lindner, R.K., and F.G. Jarrett. 1978. Supply shifts and the size of research benefits. Amer. J. Agric. Econ. 60(1):48-58.

Litsinger, J.A. 1984. Assessment of need-based insecticide applications for rice. Paper presented at MA-IRRI Technology Transfer Workshop March 15, 1984.

Litsinger, J.A. 1989. Second generation insect pest problems on high yielding rices. Tropical Pest Management 35(3):235-42.

Liu, Hechang, and Lanping Qin. 1987. Mass rearing of *Coccinella septempunctata* to control *Aphis gossypii* in Hebei Province. Chinese Journal of Biological Control 3(3):138. (In Chinese).

McCarl, B.A. 1981. Economics of integrated pest management. An interpretive review of the literature. Special Report 636. Oregon State Univ., Corvallis.

Mumford, J.D. 1986. Control of the cocoa pod borer (*Acrocercops cramerella*): A critical review. In E. Pushparajah and P.S. Chew, eds., Cocoa and Coconuts: Progress and Outlook. Incorporated Society of Planters. pp. 287-92.

Mustamin, M. 1988. Health hazards due to the use of pesticides in Indonesia: Data collection and surveys. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia. pp. 301-09.

Myint, M.M., H.R. Rapusas, and E.A. Heinrichs. 1986. Integration of varietal resistance and predation for the management of *Nephotettix virescens* (Homoptera:Cicadellidae) populations on rice. Crop Protection 5:259-65.

Nakasuji, F. and K. Kiritani. 1976. Epidemiology of rice dwarf virus in Japan. Paper presented at a seminar on The Rice Brown Planthopper, Oct. 4-10, Food and Fertilizer Technology Center for the Asian and Pacific Region. Tokyo.

Napometh, B. 1988. Status of biological control in non-rice crops in Southeast Asia. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia. pp. 123-29.

NAS, National Academy of Science. 1969. Principles of plant and animal pest control. Insect-pest Management and Control (Nat. Acad. of Sci. Pub.) 1695(3). 508 p.

News in Brief. 1990. Pesticides. PIC-Recent developments. Agrochemical News in Brief 8(2):23-25.

NRC, National Research Council. 1987. Regulating Pesticides in Food. National Academic Press, Washington, D.C.

Oka. 1988. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia.

Olkowski, H., and Z. Zhang. 1989. Masstrapping the poplar clearwing moth in China. The IPM Practitioner 11(8):15.

Olkowski, W. 1991. Alternatives to toxic pesticides: Learning from China. In: Least-Toxic Pest Management in China. The Bio-Integral Resource Center, Berkeley, California.

Olkowski, W., and S. Daar. 1989. Update: Chinese use insect-atticing nematodes against major pests. The IPM Practitioner 11(11/12):1-8.

Olkowski, W., and Anghe Zhang. 1991a. Ageratum cover crop aids citrus biocontrol in China. In: Least-Toxic Pest Management in China. The Bio-Integral Resource Center, Berkeley, California.

_____. 1991b. Trichogramma modern day frontier in biological control. In: Least-Toxic Pest Management in China. The Bio-Integral Resource Center, Berkeley, California.

Olkowski, W., Anghe Zhang, and Paul Thiers. 1991. Improved biocontrol techniques with lady beetles. In: Least-Toxic Pest Management in China. The Bio-Integral Resource Center, Berkeley, California.

Oudejans, J. 1990. Plant protection policies and regulatory infrastructure. Agrochemical News in Brief (Special Issue) November. FADINAP/ARSAP/ESCAP. Bangkok, Thailand.

Peng, Y.K. 1985. Field release of *Chrysopa sinica* as a strategy in the integrated control of *Panonychus citri*. Chinese J. of Bio. Control 1(1):2-7. Abstracted in The IPM Practitioner 10(11/12):17.

Prachuabmoh, O. and others. 1988. IPM activities in sugar cane in Thailand. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia. pp. 174-80.

Pu, Z.L., and Y. Pang. 1984. In Z.L. Pu, ed., Principles and Methods of Biological Control of Insect Pests. Beijing: Science Press, pp. 221-62.

Pu, Z.L., and others. 1980. In: Res. Inst. of Entomol. of Zhongshan Univ. Bulletin No. 1. pp. 1-34.

Radcliff, E.B., and others. 1991. Neem in Niger: A new context for a system of indigenous knowledge. Entomology Dept., University of Minnesota. Draft.

Rola, A.C., and P.E. Kenmore. 1986. Evaluating the integrated pest management technology in the Philippines: A case study of Calamba rice farmers (unpublished report.)

Röling and van de Fliert. 1991.

SAM, Sahabal Alam Malaysia. 1984. Pesticide Dilemma in the Third World: A Case Study of Malaysia. Penanag: SAM.

Soekarna, D. 1988. The role of insecticides in rice IPM systems. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia. pp. 67-72.

Staring, W.D.E. 1984. Pesticides: Data Collection Systems and Supply, Distribution and Use in Selected Countries of the Asia-Pacific Region. Bangkok, Thailand: ESCAP, U.N.O.

Tait, E.J. 1987. Planning an integrated pest management system. In A.J. Burns, T.H. Coaker, and P.C. Jepson, Integrated Pest Management.

Teng, P.S. and K.L. Heong, eds. 1988. Pesticide Management and Integrated Pest Management in Southeast Asia. Proceedings of the Southeast Asia Pesticide Management and Integrated Pest Management Workshop, February 23-27, 1987, Pattaya, Thailand. College Par, Md.: Consortium for International Crop Protection.

Tong, X.W. and others. 1988. Enhanced egg parasitization of *Dendrolimus punctatus* (lep.: Lasiocampidae) by supplementing host eggs in the forest. Chinese J. of Bio. Control 4(3):118-22. Abstracted in The IPM Practitioner 11(2):12.

Tran, L.C., R. Bustamante, and S.A. Hassan. 1988. Release and recovery of *Trichogramma evanescens* Westw. in corn fields in the Philippines. In INRA (Paris), ed., *Trichogramma* and Other Egg Parasites. Second International Symposium, Guangzhou (China), Nov. 10-15, 1986.

Tran-Gruber, L.C. 1988. Biocontrol of the corn stalk borer in the Philippines. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia. pp. 131-34.

Trichogramma News. Monthly newsletter by the Institute for Biological Pest Control of the Federal Biological Research Centre for Agriculture and Forestry, Heinrichstr. 243, D-6100 Darmstadt, Federal Republic of Germany.

Tryon, E.H., and J.A. Litsinger. 1988. Feasibility of using locally produced *Bacillus thuringiensis* to control tropical insect pests. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia. pp. 73-81.

University of California, Division of Agriculture and Natural Resources. 1984. Integrated pest management for cotton in the western region in the United States. Publication 3305. Oakland.

_____. 1990a. Integrated pest management for tomatoes. Oakland.

University of California, IPM Group. 1990b. Annual Report. Statewide IPM Project of the University of California.

VCES, Virginia Cooperative Extension Service. 1987. The national evaluation of extension's integrated pest management (IPM) programs. VCES Publication 491-010.

Waibel, H. 1988. Some new aspects on economic thresholds in rice. J. Pl. Prot. Tropics 5(1):31-37.

_____. 1990. Pesticide subsidies and the diffusion of IPM in rice in Southeast Asia: The case of Thailand. FAO Plant Prot. Bull. Vol. 38(2).

Waibel, H., and P. Meenakanit. 1988. Economics of integrated pest control in rice in Southeast Asia. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia. pp. 103-11.

Walker, P.T. 1983. Crop losses: The need to quantify the effects of pests, diseases and weeds on agricultural production. Agric., Ecosystems and Environ. 9(1983):119-58.

Wang, H.K. 1988. Field trials of spraying *Beauveria bassiana* against *Pyrrhalta aenescens* on elm trees. Chinese J. of Bio. Control 4(2):89. Abstracted in The IPM Practitioner 10(6/7):13.

WHO, World Health Organization. 1973. Technical Report Series No. 531. Geneva.

Wiebers, U.-C. 1987. Economic Evaluation of Cotton Defoliants in an Intensive Cropping System in Lower Egypt. Schering AG (internal publication), Berlin, Germany.

_____. 1989. Selected Pesticide Markets in Kenya. Schering AG, (internal publication), Berlin, Germany.

_____. 1991. Productivity, Demand, and Environmental Risk of Pesticides and Integrated Pest Management in Processing Tomatoes in California. USEPA Report. Berkeley, California. Forthcoming.

Wirjosuhardjo, S. 1988. Overview of IPM infrastructure and implementation on estate crops in Indonesia. In P.S. Teng and K.L. Heong, eds., Pesticide Management and Integrated Pest Management in Southeast Asia.

Wood, B.J. 1982. Progress in the control of tropical field rats. Proceedings of Int. Conf. Pl. Prot. in the Tropics, Kuala Lumpur. pp. 423-48.

Xu, Q.F. 1988. Some problems about the study of the application of *Beauveria bassiana* against agricultural and forest pests in China. Inyunwei Li and others, eds., Study and Application of Entomogenous Fungi in China. Vol. 1. Academic Periodicals Press, Beijing. pp. 1-10.

Xu, Qinfeng and others. 1988. Experiments on the effect of *Beauveria bassiana* on some natural enemies. In Yunwei Li and others, eds., Study and Application of Entomogenous Fungi in China. Editors: Li, Yunwei et al. Vol 1. Academic Periodicals Press, Beijing. 255 pp. (in Chinese).

Yu, J.H. 1988. Locust-eating birds and their recruitment in prairies of Tianshan Mt. Chinese J. of Bio. Control 4(2):68-70. Abstracted in The IPM Practitioner 10(6/7):18.

Zelazny, B. 1979. Loss in coconut yield due to *Oryctes rhinoceros* damage. FAO Plant Protection Bulletin 27:65-70.

Zhang and others. 1981. Agricultural Science Hubei (7):25-27.

Zhang, L. and others. 1989. Biological control of a wood borer in China. The IPM Practitioner 11(5):5-7.

Zhang, Y.Q. and others. 1987. In: Insecticidal Microbes, Vol. I. Beijing: Agricultural Press, pp. 48-54.

Zhejiang Agricultural University, Entomology faculty, ed. 1982. Agricultural Entomology. 2nd edition, Vol. I. Shanghai: Shanghai Sci. and Tech. Publishing House. Also abstracted in The IPM Practitioner 10(10):14-15.

Zhou, Mingzang and others. 1986. Studies on the integrated control of cotton insects in north China. Acta Phytoghylacia Sinica 13(4):251-58 (in Chinese).

Zilberman, D., and J.B. Siebert (ed.). 1990. Economic Perspectives on Pesticide Use in California. Dept. of Agricultural and Resource Economics, University of California, Berkeley.

GLOSSARY

Active ingredient. The biologically active part of the pesticide present in a formulation.

Banned. A Substance for which all registered uses have been prohibited by final government regulatory action, or for which all requests for registration or equivalent action for all uses have, for health or environmental reasons, not been granted.

Carbamates. See Organophosphates.

Common name. The name assigned to a pesticide's active ingredient by the International Standards Organization or adopted by national standards authorities to be used as a generic or nonproprietary name for that particular active ingredient only.

Cross-protection. A method of protecting plants against damage from severe strains of a virus by infecting them with a mild strain of the same virus.

Formulation. The combination of various ingredients designed to render the product useful and effective for the purpose claimed: the form of the pesticide as purchased by users.

Hazard. The likelihood that a pesticide will cause an adverse effect (injury under the conditions in which it is used.

Insecticides. See Carbamates, Organochlorines, Organophosphates, Synthetic pyrethroids.

Integrated pest management. Where pest management is coordinated with production practices to achieve economical protection from pest injury while minimizing hazards to crops, human health, and the environment. The emphasis is on anticipating and preventing problems whenever possible.

Key pest. Regular pests under existing agricultural conditions at various growing stages. Key pests are best controlled by regular suppression of populations below economic levels by use of attrition methods (e.g., selective chemicals, sterile male techniques, biocontrol, cultural control, resistant strains).

Label. Written, printed or graphic matter on or attached to the pesticide or the immediate container thereof and to the outside container or retail package of the pesticide.

LD_{50}. A dose lethal to 50% of the test animals (rats or rabbits) measured as milligrams of active ingredient of pesticide per kilogram of the test animal (mg/kg). Generally two values are given: "LD_{50} oral" (ingestion) and "LD_{50} dermal" (absorption through the skin). These measures for acute toxicity provide guidelines for grower and worker safety.

LD_{50}	Categories	Probable Oral Lethal Dose for a 150 lb. woman
less than 50 mg/kg	I--Highly Toxic	A few drops to a teaspoon
50-500 mg/kg	II--Moderately Toxic	More than a teaspoon to an ounce
500-5000 mg/kg	III--Slightly Toxic	More than an ounce to one pint or one pound
more than 5000 mg/kg	IV--Relatively Non-Toxic	More than one pint or one pound

Source: Granovsky 1985.

Maximum residue limit (MRL). The maximum concentration of a residue that is legally permitted or recognized as acceptable in or on a food, agricultural commodity or animal feedstuff.

Occasional pests. Pests that are often found in small numbers under natural conditions, but that have the potential of outbreaks. It is possible to predict the necessity of intervention for control of outbreaks and often chemicals are the means of control.

Organochlorines. Tend to build up in fatty tissues of the body over a long period of time. They are commonly the cause of *chronic poisoning*. Common organochlorines include: aldrin, dieldrin, BHC, endrin, chlordane, heptachlor, DDT.

Organophosphates. With **Carbamates**, these chemicals are most commonly involved in *acute poisoning* cases. They are fast-acting and are considered more dangerous than organochlorines. Common examples of organophosphates are diazinon, malathion, and parathion; of carbamates, aldicarb, carbaryl, propoxur.

Pest resurgence. Occurs when an existing pest is susceptible to an insecticide but its natural enemies are even more severely affected. Treatments may then give satisfactory initial control, but in the absence of biological control the pest population may subsequently increase to even higher levels than before treatment (Graham-Bryce 1987).

Pesticide legislation. Any laws or regulations pertaining to the manufacture, marketing, storage, labelling, packaging, and use of pesticides in their qualitative, quantitative and environmental aspects.

Pesticide. Any substance or mixture of substances that can be used to prevent, destroy or control any pest--including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage, transport, or marketing of food, agricultural commodities, wood and wood products or animal feedstuffs--or that can be administered to animals for the control of insects, arachnids or other pests in or on their bodies. The term includes substances intended for use as a plant growth regulator, defoliant, desiccant, or agent for thinning fruit or preventing the premature fall of fruit, and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport.

Plant-back period. A specified time period after the application of a pesticide during which certain crops are not recommended to be planted.

Pesticide residues in the soil may contaminate the food crop or may damage the plant's productivity.

Potential pests. Those that occur through artificial disturbances and, in most cases, are naturally regulated once the disturbance lessens.

Registration. The process whereby the responsible national government authority approves the sale and use of a pesticide following the evaluation of comprehensive scientific data demonstrating that the product is effective for the purposes intended and not unduly hazardous to human or animal health or the environment.

Residue. Any specified substances in food, agricultural commodities, or animal feed resulting from the use of a pesticide, such as conversion products, metabolites, reaction products, and impurities considered to be of toxicological significance. The term *pesticide residue* includes residues from unknown or avoidable sources (e.g., environmental) as well as known uses of the chemical.

Risk. The expected frequency of undesirable effects of exposure to the pesticide.

Secondary pest outbreaks. The transformation of a phytophagus species normally maintained at low levels by natural enemies into an economic pest by the use of (broad-spectrum) insecticides targeted at the primary pest (Graham-Bryce 1987).

Severely restricted - a limited ban. A pesticide for which virtually all registered uses have been prohibited by final government regulatory action but for which certain specific registered use or uses remain authorized.

Synthetic pyrethroids. A relatively new group of pesticides that are fast-acting and of relatively low human toxicity. Pyrethroids have very low application rates (1/10 or 1/20 that of organophosphates). Common synthetic pyrethroids are: allethrin fenevalerate, cypermethrin, permethrin, decamethrin and resmethrin.

Toxicity. A physiological or biological property that determines the capacity of a chemical to do harm or produce injury to a living organism by other than a mechanical means.

APPENDIX 1

PESTICIDE USE REGULATION: SUMMARY OF PESTICIDE REGULATION AFFECTING THE GROWER IN CALIFORNIA

The legislation and regulation of pesticide use in California is extensive and is written in the Food and Agricultural Code and Code of Regulation (CDFA 1990). The most important parts directly concerning growers and new developments are summarized here.

Only registered pesticides (i.e., products approved by U.S. EPA) may be used for pest control. As a result of the registration process, use restrictions are developed and published on the product's label. Pesticides must be applied according to the label. The application is (or can be) restricted to specific crops, growth stages, type of application, dose rate, site, plant-back period and workers' reentry into the field. There are further possession and use limitations for restricted pesticides that include most pesticides except sulfur, lime, copper products and a few others. An official license is necessary to own or apply a restricted product. A permit system controls the use of restricted pesticides before the application. The operator of the property to be treated or an authorized representative (i.e., pest control advisor) must request permission. The application for permission includes the following information: location; areas that could be adversely affected by the use of pesticides such as schools, residential areas, lakes, and so on; crop; pesticide; pest; date of application or growth stage; and technical information about the application (CDFA 1990, § 6428).

The application for permission is evaluated and granted or rejected by the CDFA commissioner of the county. The criterion for the commissioner's evaluation is the environmental impact of the application (§ 6432). The commissioner must be notified at least 24 hours prior to using a pesticide requiring a permit (§ 6434). At least 5% of the sites identified in permits or notices of intent to apply a pesticide must be monitored by the commissioner (§ 6436). For the safety of the pesticide worker, age, employee training, emergency medical care, medical supervision, working alone, washing facilities, clothing, equipment, light field reentry after pesticide application for specific crops and pesticides and other aspects are regulated (§ 6700 - §6778). The regulation, in operation since January 1, 1990, requires that any person who uses pesticides for agricultural use or industrial post-harvest purposes must keep pesticide use records and submit monthly pesticide use reports to the commissioner (§ 6624 - § 6627).

In summary, the use of pesticides in California for agriculture is controlled by registering products, issuing permits to users, monitoring and reporting on their use.

APPENDIX 2

PESTICIDE MARKETS AND PESTICIDE REGULATION IN TWELVE ASIAN COUNTRIES

Country	Market in m$ 1988	Market in formulated product	Market in total active ingredients	Area treated	Main crops treated	Insecticide share of treated area	Fungicide share of treated area	Herbicide share of treated area	Main registered products	Market form	Pesticide price subsidy
China	530, in top 6 world-wide, 13% imported.		200,000 active ingredients	166 m ha	rice ($218 m) vegetables ($87 m) cotton ($57 m) wheat ($44 m)	72% $295 m	16% $89 m	12% $143 m	531	government controlled; import permits	
India	470		0.48 kg/ha	53 m ha	cotton ($240 m) vegetables ($42 m) almost all rice ($71 m)	77%	17%	6%	gamma-HCH, cypermethrin, monocrotophos, macozeb, butachlor, 125 active ingredients		
Thailand	90 (1985) 130 (1989)		18,500 (1990) 13,300 (1981)		plantation fruit crops: citrus, grapes, pineapples ($51 m), vegetables ($13 m) rice ($26 m) rubber ($11 m) cotton ($8 m) soya ($6+ m) sugarcane ($12.5 m)	56% rice (10% of the rice area, $12 m), fruits ($22 m)	11% fruits ($13 m)	33% rice ($16 m), fruits ($16 m), rubber ($11 m), cassava ($11 m)	parathion-methyl monocrotophos zineb methomyl captan. mancozeb propineb paraquat, 2,4 D atrazine, ametryne	free	
Malaysia	109				oil palm ($33.3 m, herbicides $31 m); rubber ($33 m, herbicides $28 m).	16%	6%	78%	247 active ingredients	free market, very diverse distribution channels	
Philippines	90			5 m ha	rice ($40+ m) bananas ($16 m) vegetables ($9.5 m) maize ($6 m)	62%	18%	20% rice ($14 m)			
Indonesia	non-rice: 51			non-rice: 9 m ha	rice vegetables ($18 m) oil palm ($12 m) soya ($8.5 m)	non-rice: 67%	non-rice: 18%	non-rice: 15%	monocrotophos, diazinon, carbaryl, propineb mancozeb, glyphosate, 2,4 D	abolishment of government distributor Pertani, free market.	abolishment of all subsidies January '89
Bangladesh	13	5,000	200 active ingredients	0.5 m ha (rice, 1985)	rice 90%, sugarcane, cotton, vegetables, jute	96% $12.4 m	2% $0.16 m	2% $0.23 m	157 formulations		reduction by 50% in 1973, removed in 1978
Sri Lanka	21 annual growth of 5.8%				rice ($10.7 m) vegetables, especially chilies ($3.3 m) tea/rubber ($2.5 m)	50% (of $ value) rice ($5.1 m), vegetables ($4 m)	7% (of $ value)	43% (of $ value) rice ($5.6 m) tea/rubber ($2.2 m)	gamma-HCH monocrotophos macozeb propanil, paraquat		
Viet Nam			0.3-0.4 kg a.i./ha, low, increasing							total control of importation, distribution, etc.	

<u>Source</u>: Jackson 1991; Gaston 1990.

Country	Market in m$ 1988	Market in formulated product	Market in total active ingredients	Area treated	Main crops treated	Insecticide share of treated area	Fungicide share of treated area	Herbicide share of treated area	Main registered products	Market form	Pesticide price subsidy
Myanmar		0.042 kg/ha very low, low infestation			rice 40% cotton 30% groundnuts 20%				aldrin (soil insects), DDT diazinon, EPN fenitrothion		
Papua New Guinea	estimated: 1.5-2.				plantains	10%	60%	30%	paraquat, ametryne, 2,4 D, DDT		
Western Samoa	estimated: 0.3										price subsidies: paraquat (33%); tridemorph (50%)

Source: Jackson 1991; Gaston 1990.

Country	Regulation	Efficacy of Regulation	Regulating Agency	Pesticide Resistance	Environmental Problems	Other Pesticide related Problems
China	Environmental Protection Act (1982) provisional guidelines. Registration after 2-year trials. Standards do not conform with FAO guidelines for packaging and labeling.	Limited, looking into "basic law of pesticide control." No regulation enforcement on domestic manufactures. No residue limits.	ICAMA MoA			Product quality, poisoning due to misuse, phytotoxicity, lack of paper for publications, translation of papers at NAS, high residue in vegetables, shortage of toxicological laboratories, distribution of pesticides, "second or third best choice" of chemical.
India	Insecticide Act (1968, '71). Registration (1979) not in harmony with FAO Code.		Central Insecticide Board (CIB)	On brassicae Plutella xylostella, on peppers, pulses, and tobacco Spodoptera litura to organochlorines, OP's, carbaryls and pyrethroids. On cotton Heliothis armigera to pyrethroids in Andra Pradesh.	Unknown, but organochlorines likely to have impact.	Residues on vegetables despite pre-harvest-interval information on labels.
Thailand	Poisonous Article Act (1967). Registration developed in '85. Phased registration end of '87. Registration of all products in '89. Quality control since Nov. '90.	Shortage of scientists, technicians, funds, and laboratories to operate and police the regulatory system.		Heliothis in cotton to pyrethroids, Plutella in the cabbage family to insect growth regulators, OP's, carbamates, pyrethroids. Indications of resistance to Bt.	Poisoning, residues on food crops. Use of organochlorines (dieldrin, DDT), although importation banned).	Low farmer comprehension of different pesticide groups and their relevance to control resistance. Shortage of farm labor. Insufficient education and training of farmers. Use of rel. highly toxic products. Use of products with chronic health effects. 4,000 distribution points complicate enforcement of the regulation. Quality and packaging (glass bottles) of locally produced pesticides.
Malaysia	Pesticides Act (1974). Registration of imported products ('78), Labeling ('84). Licensing for sale ('88). No regulation of municipal pest control operators.	Implementation only in Peninsular Malaysia, effective Sept. 1988. Importation of illegal pesticides.	Pesticides Board, MoA	High levels of resistance to OP's, carbamates, pyrethroids and insect growth regulators. No resistance to Bt.	Aldrin and dieldrin still used. More than 1000 occurrences of poisoning a year, mainly suicides.	False labeling and product adulteration. Residues in vegetables.
Philippines	Presidential Decree (1977). Registration after 3 years, following FAO guidelines. Data requirements: toxicology, residues, environmental effects, efficacy data, etc. Enforcement by Provincial Coordinators.	Generally products registered before current regulation are still on the market (more toxic OP's). FPA has no analytical laboratories. Inadequate coordination among bodies enforcing regulation. Adulteration and false labeling of products.	Fertilizer and Pesticide Authority (FPA)	Plutella on cabbage and thrips on vegetables to OP's, carbamates and pyrethroids. Stored grain weevil resistant to chlorinated hydrocarbons, OP's and carbamates.		
Indonesia	Government Decree No. 7 (1973). Government Decree No. 944 (84). Inpres 33 (1986) banned 57 products, e.g., OP's in rice, and increased import duty on pesticides 6-fold (to 30%).	Sound framework, but problems in practical implementation. Gaps in scientific expertise on the specialist committees, coordination among agencies and enforcement. Shortage of trained extension workers.	MoA	BPH in rice to carbamates and OP's. Several insects in vegetables to OP's, carbamates, pyrethroids. Dosage of Bt is increasing to control Plutella.	Fish killed by endosulfan.	Residues in vegetables. Misuse of pesticides (endosulfans for killing fish). Geographical diversity causes problems in training farmers and enforcing regulation. Use of DDT in rice vegetables and fruit. False labeling, product adulteration.

Sources: Jackson 1991, Gaston 1990

Country	Regulation	Efficacy of Regulation	Regulating Agency	Pesticide Resistance	Environmental Problems	Other Pesticide-related Problems
Bangladesh	Pesticide Ordinance 1971. Pesticide Rules 1985. Adoption of FAO Code. Registration and license system for importers, manufacturers, etc. Registration based on overseas literature and trials of 2-3 years.	Requested assistance for enforcement system. There are no facilities for pesticide testing of material in distribution. Therefore: adulteration, dilution and mislabeling. One-fifth of pesticides are smuggled from India.	Pesticide Advisory Technical Community, Plant Protection Wing, Ag. Extension, MoA		Fish poisoning	Pesticide laboratories not sufficiently equipped, shortages of spare parts, chemicals and servicing facilities. Quality control at end-user level. Lack of application equipment, use of expensive and poor-quality granulars.
Sri Lanka	Control of Pesticides Act (1980). 2-year field testing for registration. Implementing FAO Code of Conduct. Restricted Import of pyrethroids to 1,000 litre maximum (control of BPH resurgence and resistance).	Registrar of Pesticides lacks the staff and facilities for proper enforcement. Shortage of toxicological laboratories and trained staff, which inhibits proper monitoring of residues.	Registrar of Pesticides and 8 other independent members.	Import restrictions on pyrethroids to avoid resistance. Insect growth regulators still effective and popular.	The Central Environment Authority is not yet geared to monitor environmental problems. No data.	Pre-harvest intervals are not kept, e.g., in vegetables. Comparatively high awareness, but indiscriminate use and overuse of pesticides still common. Use of highly toxic and/or hazardous products (aldrin, captafol, dichloropropene, organo-mercurial compounds).
Viet Nam	None		Dept. of Plant Production and Protection of MoA		Poisoning.	Illiteracy, packaging, imported labels in original language.
Myanmar	FAO Code	Sales in original containers, labels, extension monitoring, residue monitoring.	Import: Myanmar Agric. Service			
Papua New Guinea	Recent implementation of Code registration, labeling ads, training	Paraquat applications by licensed operators. Distribution of pesticides only at threshold levels.			Poisoning due to paraquat.	
Western Samoa	Poisons Act (1968) no control on pesticide use, labels	Ag. Dept. requested FAO assistance in drafting legislation.	Health Dept.		High incidence of poisoning.	Excessive use of pesticides on vegetables, pest resistance.

Sources: Jackson 1991, Gaston 1990

Sources: Jackson 1991, Gaston 1990

APPENDIX 3

TECHNIQUES AND EFFECTS OF IPM IN ASIA

This list is not intended as a "handbook for Asia IPM" but a cross section of practices that fall into the range of integrated pest management. Practices are listed alphabetically by crop. In addition, the target pest or pests and the type of the technique (biological, cultural, chemical and microbial pesticide) are specified. The results, stage of development and scale of use are described if known. If the scale of use is not specified, use in field trials should be assumed. The last column of the table gives the reference for further reading.

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Apple	Alligatorweed, Alternanthera philoxerroides	China	Biological, Classical	Introduction of the weed-eating beetle, Agasicles hygrophila. The beetle is protected by a cage over the plants for early spring releases.	Beetle was introduced in southern China and showed some success in controlling the weed.	Grossman 1991a,b
Apple	Bitter rot, Glomerella cingulata	China	Chemical	Application of GZM at 5g/l, a stable water emulsion with dodecyl alcohol as the main component. It forms a film or membrane on the plant's surface that allows passage of oxygen or carbon dioxide but not water.	The product was recently developed and was tested in field trials. Reduction of bitter rot was 84% compared with controls. Testing so far has not shown any environmental toxicity at recommended concentrations.	Han 1990
Apple	Mites	China	Biological, Classical	Introduction of predatory mite (Metaseiulus occidentalis) from California. To ensure overwintering, waste cotton and wheat husks covered with plastic bandages were wrapped around trunks.	In experiments of 1983-86 in northwest China, the predator mite failed to overwinter. The trunk covering resulted in overwintering and effective control of Eotetranychus pruni.	Deng et al. 1988
Apple	Mites	China	Cultural	Covering tree trunks with waste cotton and wheat husks held against the bark with plastic bandages; piling leaf and grass debris under the tree canopy.	The survival of predator mites during periods of severe cold (i.e., -7.3°C) increased and mite infestation decreased.	Deng et al. 1988
Apple	Peach fruit borer	China	Biological	Properly timed application of entomogenous nematode Sterernema carpocapsae as aqueous suspension sprayed on the soil under apple trees.	Control was equaled and in some cases exceeded control by synthetic chemicals.	Olkowski and Daar 1989
Bamboo	Scales, Kesticoccus transversus	China, southern Jiangsu	Cultural	Intercropping with rape (rape:bamboo=1:10) to attract lady beetles, rape harvest timed to initiate move of beetles into the bamboo plantation.	Field tests from 1984 to 1986. The resulting reduction in pesticide use enabled the reestablishment of another scale parasitoid, Anagyrus dactylopii.	Olkowski, Zhang and Thiers 1991
Citrus	Alligatorweed	China	Biological, Classical	See apple, alligatorweed, China.	No information.	
Citrus	Mites	China	Cultural	Planting of tropical ageratum, Ageratum conycoides, among the citrus trees helps control pest mites by enhancing the effectiveness of predator mite species.	Intercropping alone results in better control than chemical control alone, while best results are achieved by intercropping and chemical control at the economic threshold.	Olkowski and Zhang 1991a

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Citrus	Red citrus mite	China	Biological	Collection of lacewing cocoons in wheat fields and release at early instar stage on citrus.	Mites were reduced by 90% in 5 days, and lacewing production costs were reduced by 31%. Farmers found this an easy program to follow.	Peng 1985
Citrus	Red citrus mite	China, Sichuan Province	Biological and Chemical	Use of *Chrysopa sinica* egg releases combined with one early spring insecticide application when mites are hatching, plus spot treatment of minor pests around May.	This program gives good results, with a reduction in insecticide usage of 62 to 83%, and an 8.5 times reduction in pest mite numbers compared with orchards using chemical insecticides only.	Peng 1985
Cocoa	Cocoa pod borer	Indonesia, Malaysia	Cultural	Use of plastic sleeves as pod-covering just before they become attractive to female moths.	1. Practiced in the primary cocoa-growing regions in the country. 2. Highly labor-intensive.	1. Wirjosuhardjo 1988 2. Mumford 1986
Cocoa	Cocoa pod borer	Malaysia	Biological	Mass-breeding and release of the naturally occurring egg parasite *Trichogramma bactrae fumata*.	Releases on an experimental scale showed encouraging results but cost-effectiveness is still to be fully gauged.	Mumford 1986
Cocoa	Cocoa pod borer	Malaysia	Biological	Use of synthetic female pheromones for monitoring, mass-trapping and mating disruption.	Practice on an experimental basis. Mass trapping has shown promising results but is not cost-effective yet.	Mumford 1986
Cocoa	Cocoa pod borer	Malaysia	Chemical	Spraying of the undersides of roughly horizontal, lower canopy branches with pyrethroids or carbamates 4-5 times at 10-14 day intervals during low crop periods.	Lower branches are the daytime resting place of the moth. Technique is effective to protect subsequent high crop, and ecological and pollinator risks are minimal. Besides frequent harvesting, this is the most cost-effective alternative.	Mumford 1986
Cocoa	Cocoa pod borer	Malaysia	Cultural	Frequent harvesting, rapid breaking, and subsequent destruction of the husks by bagging, burning, drying, etc.	This practice reduces the successful emergence of caterpillars in the field and contributes to lowering of moth populations. Besides selective spraying this is the most cost-effective alternative.	Mumford 1986

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Cocoa	Cocoa pod borer	Malaysia	Cultural	"Rampasan," the complete stripping of immature and mature pods for a short period during the cropping cycle to break the life cycle of the moth.	Although neat in theory, this practice is, especially in plantations, extremely difficult, with no guarantee of success for the considerable effort expended.	Mumford 1986
Cocoa	Cocoa pod borer	Malaysia	Cultural	Use of hard-shelled and thus mildly resistant varieties.	Hard-shelled varieties have been observed in Sabah, but a breeding program will be time-consuming.	Mumford 1986
Cocoa	Mirids, *Helopeltis theobromae, H. clavifer*	Malaysia	Biological and Chemical	Industry standard is application of gamma HCH. The predator cocoa black ant, *Dolichoderus thoracicus*, is a prospective biocontrol agent.	The ineffectiveness of enemies might be due to use of broad-spectrum insecticides. No effective cultural control has been developed.	Ho 1988
Cocoa	Rodents	Malaysia	Chemical	Wax block baiting with anticoagulants at 60-80 pieces per hecatare at 4-7 day baiting rounds. Detect-and-treat system based on sequential sampling.	Sequential sampling proved high accuracy in prediction plus reduction in labor requirements. Resistance, already a problem, might be delayed.	Ho and Heong 1984
Cocoa	Stem and trunk borers, *Zeuzera* sp.	Malaysia	Cultural and Chemical	Early detection (census) and pruning of light branches with borers. Parasitized larvae (e.g., by *Spinaria sp.*) are left in the field. Pumping of dieldrin into bores of trunks and thick branches.	If early detection and treatment is achieved, considerable damage (up to loss of trees) can be avoided. Census and program have been successful in Malaysia.	Ho 1988
Coconut	Coconut hispid, *Brontispa longissima* G.	Indonesia	Biological, Classical	Introduction of *Tetrastichus brontispae* F. from West Java to South Sulawesi.	Complete control of the pest was achieved.	Napometh 1988
Coconut	Coconut rhinoceros beetle	Malaysia	Biological, Classical, Cultural and Chemical	Introduction of *Scolia ruficornis* F. from Zanzibar in 1960.	The insect got established but no control is reported.	Napometh 1988
Coconut	Hispine beetle, *Brontispa longissima* G.	Western Samoa	Biological, Classical, Cultural and Chemical	Introduction of the parasitic wasp *Tetrastichus brontispae*. Evaluation of infestation levels and percentage of parasitization. Proper weeding.	The national IPM program started in early 1980s and prevented an estimated yield loss of 10%. Farmer's benefits are US$50/ha with no input at the farm level.	Kaske 1988

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Coconut	Rhinoceros beetle	Asia	Biological, Cultural and Fungal insecticides	Sanitation, removal of old logs and stumps. Artificial introduction of a baculovirus of the beetle (Western Samoa in 1967). Cultivation and application of the fungus *Metarhizium antisopliae* against larval stages. Leguminous cover crops (**Pueraria** spp., **Centosoma** spp., **Calopogonium** spp.).	The program (since 1964) has been successful in Western Samoa, and damage has remained at low levels. In the Philippines the beetle is the most important coco insect pest but virus infestation is low. Virus transmission to control the beetle is impaired by dry conditions in this area for several months of the year.	Kaske 1988
Corn	Asian corn borer, **Astrinia furnacalis**	China, north	Fungal insecticides	Application of the fungal insecticide **Beauveria bassiana** (Bb).	Research on Bb started in the 1950s; it has been mass-produced since the 1970s and used on a tremendous scale in agriculture, horticulture and tea. Against the corn borer the accumulated treated area from 1978-1987 in Jilin Province alone is 1 m hectare.	Li and Pang 1991; Wang 1988; Xu 1988
Corn	Corn stalk borer	Philippines	Biological	Release of **Trichogramma evanescens** Westw. at 200,000 eggs per release. Distance between release points was 7-10 m and 50-100 m between plots. 2-5 releases per cropping season.	Parasitism varied from 32%-78% depending on year and site and control is considered effective. The corn borer is persistent through alternate hosts and therefore T. is persistent as well.	Tran-Gruber 1988
Corn	European corn borer	China, Jilin Province	Chemical	Choice of pesticide. Application of the pesticide 'phoxim' reduces predator population up to 93%, while the microbial insecticide **Beauveria** bassiana shows no significant reduction.	Results are from field inspections. Selective pesticides utilize the pest-decreasing effect of predator and parasite populations and reduce pesticide use and/or crop damage.	Xu et al 1988
Corn	Oriental corn borer	China, Miyun County, north of Beijing	Biological	Release of 10,000 **Trichogramma ostriniae** per mu (0.066 ha) per year.	The **Trichogramma** production unit supplies 13,300 ha three times a year. Savings from corn losses are estimated at 40 m kg ($3.2 m) over the last 14 years and reduced pesticide use by 255 tons.	BIRC 1991

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Cotton	Aphids	China, southern Hebei Province	Cultural	Intercropping of cotton, rape and corn with wheat in adjacent fields. Corn is planted twice during the year in two or three seedling bunches every 2 meters.	Local farmer's practice. In tests, the intercropping showed predator levels three to six times that of monocropped fields. Pesticide applications were reduced by three to four sprays annually.	Zhou et al. 1986
Cotton	Aphids; Mites; Cotton bollworm	China	Biological	Release of the predator **Coccinella septempuncta**, which is collected at the end of the season from vegetable fields and released in the next season.	**C. septempuncta** is mass-reared on aphids or male pupae of honey bee, and recently on artificial diets, which allows cost-effective mass production.	BIRC 1991
Cotton	Cotton aphids	China	Biological	Utilization of small "greenhouses" (bamboo and plastic) constructed in cotton fields for rearing the seven-spotted lady beetle.	This technique is utilized on 6,000 ha of cotton and effectively reduces aphid numbers, generating savings of $6/ha/yr.	Liu and Qin 1987; Olkowski, Zhang and Thiers 1991
Cotton	Cotton aphids	China, Henan Province, Anyang County	Biological	Field collection and release of the C7 lady beetle, **Coccinella septempuncta**.	Well-established practice in Henan Province. In Anyang County in 1974, 93.3% of all cotton fields (22,000 ha) utilized C7 beetles. Savings of about $309,000 in pesticide costs.	Olkowski, Zhang and Thiers 1991
Cotton	Cotton bollworm	China	Viral insecticides	Application of nucleopolyhedrosis viruses (NPV).	NPV for cotton has been mass-produced as "78-3" and has been applied to about 100,000 ha, usually yielding 90% mortality after 11 days.	Zhang et al. 1981
Cotton	Cotton bollworm	Philippines	Biological	Locally produced **Trichogramma australicum** released preventatively at 40,000/ha twice a week.	The costs of one application of a synthetic pyrethroid equals the costs of **Trichogramma** releases for six or seven weeks.	Hasse et al 1988
Cotton	Cotton bollworm	Philippines	Chemical	Peg-board for farmers' use. Simplified surveillance system.	Reduction of pesticide use.	Hasse et al. 1988
Cotton	Cotton bollworm	Philippines	Chemical	Surveillance system for technicians. Threshold of 17-18 infested plants out of 20 plants considering predator population densities.	Reduced insecticide applications.	Hasse et al 1988

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Cotton	Cotton bollworm	Philippines	Cultural	Intercropping of 15-20 rows of cotton with 1 row of maize or tobacco as trap crop (pest trap) with synchronized reproductive phase.	Reduced sprays from 6.5 to 2.5 per season.	Hasse et al. 1988
Cotton	Cotton bollworm; Cotton aphid	China	Biological	Release of the predator lacewing Chrysopa spp.	The predator has been mass-reared and released since 1979. Chrysopa larvae are reared in eggs of rice moth, Corcyra cephalonica, and in artificial eggs encapsulated by low-melting-point parafin.	BIRC 1991
Cotton	Cotton flower weevil	Philippines	Cultural	Cessation of irrigation for up to four weeks after the onset of flowering.	Forced boll maturation, increased pupal mortality (100% at 9% soil moisture), favorable environment for predator ant.	Hasse et al. 1988
Cotton	Cotton flower weevil	Philippines	Cultural	Increase of planting density from 60,000 to 130,000 plants/ha.	Increased yield security.	Hasse et al. 1988
Cotton	Cotton flower weevil	Philippines	Cultural	Planting of all fields within the shortest time.	Infestation remains below threshold if no migration from older fields occurs.	Hasse et al. 1988
Cotton	Cotton flower weevil	Philippines	Cultural	Planting a trap crop of okra (Hibiscus esculentus L.) so cotton and okra flower at the same time.	Reduced early infestation with flower weevil.	Hasse et al. 1988
Cotton	Cotton leafhopper	Philippines	Chemical	Chemical application at the threshold of 50% defoliation.	Yield increase is reported.	Hasse et al. 1988
Cotton	Cotton leafhopper	Philippines	Cultural	Introduction of a hairy variety from Paraguay.	Reduction of early insecticide applications.	Hasse et al. 1988
Cotton	Cotton pink bollworm	China	Biological	Release of the braconid parasitoid Bracon nigrorufium.	Field parasitism rates are highest (90%) for the first generation bollworms. 2nd and 3rd generation parasitism reaches 60%.	BIRC 1991

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Cotton	**Heliothis armigera** and **H. assulta**	China	Viral insecticide	Application of the nuclear polyhedrosis virus (Ha SNPU) at 4.8 x 10^{11} PIB/ac by ground or air application.	Research started in 1975. It is now the first commercially available viral insecticide in China. Sales volume increased from 600 ha ('86) to 2800 ha ('87) to 5700 ha ('88) and an estimated 10,000 ha in 1989. The price is equivalent to chemical insecticides ($5/ha).	Guangyu 1991
Cotton	**Hypomeces**	Indonesia	Cultural	Early planting to prevent infestation.	No information.	Wirjosuhardjo, 1988
Cotton	Mealybug	China	Biological	Release of **Cryptolaemus montrouzieri**.	**C. montrouzieri** was introduced to China in 1955 and is mass produced on **Aleurites molluccana** trees.	BIRC 1991
Cotton	Old World bollworm, Small cotton measuring worm	China	Biological	Moving of overwintering queens of the predator wasp **Polistes hebraeus** into nests within controlled temperature and humidity greenhouses.	Increased infestation of bollworm and measuring worm by 61% and 57% respectively. Suppression of the wheat armyworm and the wheat sawfly.	Li and He 1988
Cotton	Spodoptera	Indonesia	Mechanical	Handpicking of Spodoptera eggs	No information.	Hasse et al. 1988
Cotton, storage	Cotton pink bollworm	China, more than 10 provinces	Biological	Local production and release of the pteromalid ectoparasitoid **Dibrachys cavus**. Release in stored cotton to control overwintering larvae.	Mass production and release in more than 10 provinces since 1960. Parasitism of cocoons reaches as high as 100%.	BIRC 1991
Forest	Caterpillars, **Dendrolimus punctata; D. tabulaeformis**	China, Guandong and Shadong provinces	Viral insecticides	Application of cytoplasmic polyhydrosis viruses (CPV's) of the caterpillars.	CPV's of the caterpillars have been used extensively in the two provinces. **D. spectabilis** has been introduced from Japan where it has been registered and applied on a large scale.	Li and Pang 1991
Forest	Gypsy moth, **Lymatria dispar**	China	Viral insecticides	Aerial application of nucleopolyhedrosis viruses (NPV) of the gypsy moth at 6x10^{6} PIBs/ml.	The NPV has been used successfully in forests, producing 92% mortality of the pest.	Liang et al 1986
Forest	Masson pine caterpillar, D. punctata	China, south	Fungal insecticides	Application of the fungal insecticide **Beauveria bassiana** (Bb).	Bb has been used on 70,000 59 200,000 ha in each of 4 southern provinces during the 1980's. see also Corn, China, Corn borer.	Li and Pang 1991, Wang 1988; Xu 1988

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Forest	Pine caterpillar	China	Biological	Supply of oak silkworm eggs on cards three times per month throughout the year. The eggs are an alternative host for many parasites of the pine caterpillar.	In host-supplemented forests, population density of parasitoids increased by 68%-140%. Caterpillar egg parasitization was increased by 6%-24%.	Tong et al 1988
Forest, Chinese fir	Wood borer, Semanotus sinoauster	China	Biological	Release of Scleroderma quani.	Field test on 100 ha showed reduction of infestation from 33% to 2.9% 7 months after treatment. Wasps were released in the center of the plot.	Zhang et al. 1989
Forest, Chinese fir	Borer Semanotus snouster	China	Biological	Release of the external parasitoid Scleroderma quani (homopteran family Bethylidae).	Parasitism rate of 40%-70% in the first generation of the wasp. It will produce multiple generations and suppress the pest below economic injury level.	Zhang et al. 1989
Forest, pine	Pine aphids	China, northeast	Biological	Field collection and augmentation of lady beetles, Harmania axyridids, at a rate of 36,000 to 60,000 beetles/ha.	19 ha have been treated in Jilin Province. Pest reduction ranges from 83% to 92% depending on release rates.	Olkowski, Zhang and Thiers 1991
Forest, poplar	Poplar bores clearwing moth, Specia siningensis	China, north	Biological	Mass-trapping using a synthesized pheromone of the sex pheromone (Z,Z)-3,13-octadecadein-1-Ol.	A three-year program of mass trapping on about 10,000 ha reduced pest damage below the economic threshold. Pest populations are reduced by 40%-60% compared with untreated areas. More than 26,000 ha are damaged by the moth.	BIRC 1991
Forest, poplar	Clearwing borer, Specia siningensis	China	Biological	Trapping of insects using pheromone-baited traps.	After 2-3 years of mass-trapping, infestation was reduced by 40%-60% (below threshold).	Olkowski and Zhang 1989
Forest, pine	Bark beetles	China, Hebei Province	Biological	Release of Cryptolestes turcicus, a secondary insect pest in grain, in plantations.	The insect has been mass-produced since 1983 in Hebei Province on moist and moldy wheat flour.	BIRC 1991
Forest, pine seedlings	Schlerotinia; Pythium; Armilareilla tabescens	China	Fungal pesticides	Application of biological fungicide (Trichoderma harzianum strains).	Common availability reported	Olkowski 1991
Fruit trees	Schlerotinia; Pythium; Armilareilla tabescens	China	Fungal pesticides	Application of biological fungicide (Trichoderma harzianum strains).	Common availability reported.	Olkowski 1991

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Grassland	Grasshopper	China, northwest	Biological	Augmentation of birds (rosy starling Sturnus roseus) by building artificial bird houses and habitats (i.e., building rock piles, planting shrubs, etc.).	Project was applied to 8200 acres. Infestation was reduced by the birds, from 38.5 hoppers/m^2 to 1.3/m^2.	Yu 1988
Horses	Croton weed, Ageratina adenophorum	China	Biological	Release of the gall fly, Procecidochares utilis.	Release in Hunan Province resulted in a parasitization rate of 70%-75%. The fly has been less successful in Australia.	Grossman 1991a
Lac	Eublemma amabiblis	China, south and southwest	Biological	Release of the ectoparasitoid Bracon greeni.	The parasitoid has been released in the Guangdong Province since 1975. Field parasitism is up to 100%, pest densities have decreased fivefold, and lac harvest has increased by 40%-100%.	BIRC 1991
Mulberry	Bark beetles	China, Hebei Province	Biological	Release of Cryptolestes turcicus, a secondary insect pest in grain, in plantations.	The insect has been mass-produced since 1983 in Hebei Province on moist and moldy wheat flour.	BIRC 1991
Neem related botanical chemicals	Worms, other insects	Asia	Botanical chemicals	Application of extracts of trees of the Meliaceae family (same family as neem).	The tree is widely spread in much of East Asia. Extracts are used against a variety of insects on a trial basis.	Olkowski 1991
Oil Palm	Bagworm, Mahasena corbetti	Malaysia	Cultural	Handpicking of the pest.	This has proved to be useful and economical and has reduced pesticide use.	Liau 1988
Oil Palm	Leaf-eating caterpillars	Indonesia	Chemical, Biological and Cultural	Conservation and augmentation of several natural enemies (insects, fungi). Early warning system, population census system. Spot spraying of selective insecticides (trichlorfon). Trunk injection of monocrotophos. Cover crops as enemy habitat.	Pesticide consumption was reduced by 29% from 1978 to 1982. Heavy use in the 1960s destroyed the pest-enemy balance and led to increased spraying and severe outbreaks.	Djamin 1988
Oil Palm	Rhinoceros beetle	Malaysia	Cultural	1. Planting of leguminous cover crops as a vegetative barrier to reduce breeding of the beetle. 2. Shredding and burning of stumps.	1. Common practice where rotting trunks and stumps cannot be removed. Also improves natural enemy habitat. 2. Stumps and trunks are the main breeding site of the beetle.	Liau 1988

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Oil Palm	Rodents	Malaysia	Biological	Augmentation of the barn owl, *Tyto alba*, as predator.	Augmentation has not been successful in the past but industry is interested. Rodenticides may cause secondary poisoning.	Liau 1988
Oil Palm	Rodents	Malaysia	Cultural	Periodic removal of nests from plants and of waste materials from crown. Destruction of burrows. Building of barriers such as wire guards around young plants. Trapping. Removal of ground cover.	Although adopted by various estates, these techniques have not been proven to be very effective overall.	Liau 1988
Papaya	Papaya ringspot virus	Thailand	Biological	Cross-protection (artificial infection) with mild-strain ringspot viruses.	Effectiveness of the cross-protection depends on the inoculum pressure. Cross-protection should be integrated with eradication programs and breeding programs for resistance.	Amaritsut et al. 1988
Peach	Bark beetles	China, Hebei Province	Biological	Release of *Cryptolestes turcicus*, a secondary insect pest in grain, in plantations.	The insect has been mass-produced since 1983 in Hebei Province on moist and moldy wheat flour.	BIRC 1991
Pepper, Cayenne	*Heliothis armigera* and *H. assulta*	China	Viral insecticide	Application of the nuclear polyhedrosis virus (Ha SNPU) at 4.8 x 10" PIB/ac by ground or air application.	It is the first commercial viral insecticide in China with rapidly increasing sales volume as worms are resistant to chemicals. See Cotton, China, *H. armigera*.	Guangyu 1991
Rice	Paddy weeds	1. China 2. Thailand	Cultural	1. Seasonal rotation of rice production with fish ponds. Nine species of fish are used, mostly grass carp. 2. Raising fish in paddies.	1. This rotation increases overall fish and rice yields. Rice paddy yield increased by 7%-15% in one province. 2. Increase in rice yields.	1. Grossman 1991a 2 Amaritsut et al. 1988
Rice	Army worms	Indonesia	Chemical	Application of fenitrothion, methamidophos or deltamethrin when most larvae are at the first to third instar stage. Scouting.	Pest mortality of 100%, lower if applied at later stage.	Soekarna 1989
Rice	Brown planthopper, Green leafhopper, Whitebacked planthopper	Indonesia	Cultural	Rotation with short maturity non-rice crop between wet-season and dry-season rice.	Rice pests cannot develop and they are gradually brought under control. Synchronized planting necessary.	Oka 1988

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Rice	Brown planthopper, Green leafhopper, Whitebacked planthopper	Indonesia	Cultural	Synchronized planting of rice.	1. Serious outbreaks of hoppers are avoided and resistant varieties remain resistant for a longer period. Negative labor and price effects. 2. *Reduction of BPH population by 25%.*	1. Oka 1988 2. Heinrichs 1988
Rice	Brown planthopper, Green leafhopper, Whitebacked planthopper	Philippines	Chemical	Chemical application based on monitoring of 0.5 older nymphs/tiller.	With this approach, natural enemies were given time to exert their effect. Sequential sampling and the threshold is "quite effective."	Bandong and Litsinger 1988
Rice	Brown planthopper (BPH), Green leafhopper (GLH), Whitebacked planthopper (WBPH)	Asia	Cultural	Wider spacing of rice plants, so sunshine can penetrate into the basal portions of the rice plant.	Close spacing creates microenvironment that is less favorable for natural enemies of BPH. Ultraviolet radiation restrains BPH increase.	Oka 1988
Rice	Brown planthopper (BPH)	China	Chemical	Using selective insecticides. Application of MTMC 12.5% diluted 1000 times. Or use of *cartap 50% at 0.1 kg/mu instead* of BHC 6% at 1 kg/mu.	MTCM achieved a pest mortality of 88% against BPH but only 5.8% against spiders. Control by BHC *and cartap was equal, but BHC* reduced spider populations by 48% while cartap showed no decrease.	Zhejiang Agricultural University 1982
Rice	Brown planthopper (BPH)	Malaysia	Cultural	Draining the fields for about two days.	*BPH outbreaks are suppressed.*	*Oka 1988*
Rice	Brown planthopper (BPH)	Philippines	Cultural	Withhold irrigation in BPH-infested fields when the rice crop is almost mature and plants are spread out every few rows to dry out the fields.	BPH outbreaks are suppressed.	Oka 1988
Rice	Brown planthopper	Indonesia	Cultural	Use of early maturing rice lines.	Rice plant becomes unsuitable before insect reaches the damaging third generation.	Heinrichs et al 1986a
Rice	Brown planthopper	Indonesia	Chemical	Selection of pesticides: combination of fenitrothion and BPMC.	Two applications resulted in lowest hopperburn. Next most effective mix was diazinon and BPMC. Other pesticides showed higher BPH populations.	Soekarna 1988

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Rice	Brown planthopper, other insects and diseases	Asia	Cultural	Use of resistant varieties.	More than 29 resistant varieties are developed and planted on large areas in Southeast Asia. In China more than 3 m ha are being planted with BPH-resistant varieties.	Heinrichs 1988
Rice	Defoliating caterpillars	Philippines	Chemical	Chemical application based on monitoring of damaged leaves and presence of live larvae or of larvae per hill.	Control in both cases unsatisfactory (16%). Consideration of parasitization will be necessary.	Bandong and Litsinger 1988
Rice	Gall midge	Philippines	Chemical	Application at the threshold of 0.8 galls/hill. Detailed sequential sampling plan. Maximum sample size is 30 hills/site.	The sampling plan is based on an estimated model. No field results are given.	Heul-Rolf and Vungsilabutr 1988
Rice	Green leafhopper, Rice dwarf virus	Indonesia	Cultural	Gene rotation, i.e., use of variety with one gene for resistance in wet season and use of another resistant variety in dry season.	Used to slow green leafhopper biotype selection.	Heinrichs 1988
Rice	Green leafhopper, Rice dwarf virus	Philippines	Biological	Plant resistance and thus less insecticides and thus higher predation have cumulative effect, e.g., variety IR29 and predation by **Cyrtorhinus lividipennis** Reu.	In green house trials, leafhopper mortality on IR29 was 66% due to resistance alone but increased to 92% with the addition of the predator.	Myint et al. 1986
Rice	Green leafhopper, Rice dwarf virus	Philippines	Cultural and Chemical	Use of host plant resistant varieties and low toxic insecticides.	Increased effectiveness of insecticide and resistance. Treated and moderately resistant varieties (IR36) show low tungro virus infestation compared to untreated fields.	Heinrichs et al 1986b
Rice	Green leafhopper, Rice dwarf virus	Japan	Cultural	Winter plowing to control weeds such as **Alopecturus aequalis**, and alternate host of the green leafhopper.	Epidemics were almost completely subdued within two years.	Nakasuji and Kiritani 1976
Rice	Leaffolder	Philippines	Chemical	Application based on a sequential sampling plan.	The sampling plan is based on an estimated model. No field results are given.	Heul-Rolf and Vungsilabutr 1988
Rice	Leaffolder	Philippines	Chemical	Chemical application based on monitoring of 0.5-1 larva per hill.	The control of 42% at this threshold can be improved with experience.	Bardong and Litsinger 1988

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Rice	Leaffolder Brown planthopper resurgence	Philippines	Chemical and Cultural	Application of insecticides to control leaffolder and use of BPH-resistant variety to control BPH resurgence.	Minimization of BPH resurgence. BPH-resistant variety had 10 BPHs per hill, susceptible variety 1100 per hill.	Aquino and Heinrichs 1979
Rice	Lepidoptera pests (key pests)	Philippines	Microbial pesticides	Weekly application of locally isolated Bacillus thuringiensis (Bt).	Significant yield increase (5.94 t/ha) compared with Bt plus chemical applications (4.62 t/ha) and the chemical-based IPM program (4.07 t/ha).	Tryon and Litsinger 1988
Rice	Planthoppers, Leafhoppers	India, Cuttack	Cultural	Planting by the end of July.	Crops planted later were severely damaged.	Oka 1988
Rice	Rice pests	China, Guangdong Province, Dasha township	Biological, Bacterial and fungal insecticides, Cultural	Combined use of Trichogramma spp., Bt, Bb, cultural measures and other management agents.	The concept was applied from 1973 to 1982 on up to 4,000 ha. Chemical insecticide use was reduced by 80%, predators and parasites rose in species and in numbers.	Pu et al. 1980; Pu and Pang 1984
Rice	Rice pests, Green leafhopper, Planthoppers etc.	China	Cultural	Placement of rice straw bundles in paddies during times of flooding or harvest to provide refuge for spiders, i.e., natural enemies.	Reported as common practice in China.	Zhejiang Univ. 1982.
Rice	Rice pests, Stemborer, Brown planthopper, Green leafhopper	Asia	Cultural	Burning or plowing under of ratoons, stubble and straw.	It disrupts the life circles of the insects. Burning is often not possible in intensive cultivation or wet climate. It may destroy plant-decomposing anthropods, resulting in higher nutrient loss by leaching.	Oka 1988
Rice	Rice pests, Stemborer, Gall midge, Brown planthopper, Sheath blight, Bacterial blight	Asia	Cultural	Avoiding overfertilization with nitrogen. Lower rates than recommended are not advisable. Resistant varieties allow higher nitrogen levels and control BPH.	Insects and diseases were significantly more abundant in fields with increased nitrogen levels. Exact relationship of nitrogen level and BPH is not known (Oka 1988).	Oka 1988
Rice	Stemborer	Asia	Cultural	In areas where synchronized planting is difficult, late planting minimizes infestation.	No information.	Oka 1988

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Rice	Stemborer	Philippines	Chemical	1. Based on monitoring, chemical is applied if less than 50% of the 0.5-1 egg masses/m^2 are parasitized. 2. Sequential sampling system is developed based on the economic threshold of 68% infested hills (deadhearts).	1. Control of this system is insufficient (32%) even with light traps. Pheromone traps might be needed to determine the threshold. 2. The threshold is based on a model and requires around 20 sample units (hills) depending on infestation levels.	1. Bandong and Litsinger 1988 2. Heul-Rolf and Vungsilabutr 1988
Rice	Stink bug, Green leafhopper	Asia	Cultural	Cutting grasses short or removing grasses on dykes and surrounding areas.	This disrupts the life cycles of the insects.	Oka 1988
Rice	Water weevil	Asia	Cultural	Draining of fields at "proper" time and stopping irrigation for a predetermined period.	Outbreaks of rice water weevil are suppressed.	Oka 1988
Rice	Whitebacked planthopper	Philippines	Cultural and Chemical	Use of pest-resistant varieties and low toxic insecticides.	Increased effectiveness of insecticide. The LD_{50} of the planthopper treated with ethylan was 9.4 on susceptible TN1 and only 2.8 when reared on moderately resistant N22.	Heinrichs 1988
Rice, seedlings	Maggot, whorl	Philippines	Chemical	Soaking of roots of seedlings with diazinon at the threshold of 0.5-1 egg/hill depending on the site. Monitoring is twice per week.	This threshold provides a control of 40% and is considered "reasonable." Monitoring of damaged leaves was ineffective.	Bandong and Litsinger 1988
Rice, upland and dry seeded	Maggot, seedling	Indonesia	Chemical	Seed treatment with carbofuran, carbosulfan and thiocarb just before planting.	Reduced damage by 20%-40%. Seed treatment is more practical and economical than spraying or dusting.	Soenarka 1988
Several (bacterial pesticides as control agent)	Mosquitoes	China	Bacterial pesticides	Application of *Bacillus sphaericus* (Bs).	So far 300 tons have been produced. Bs has a long-lasting pathogenicity of one to five weeks and is therefore preferred to Bt.	Zhang et al. 1987
Several (botanical pesticides as control agent)	Snails	China	Botanical, Chemical	Several authors report that the Chinese have screened 1100 plant species for molluscicidal activity since the 1930s.	Little is known in the West beyond the fact that Chinese farmers are successfully using botanicals on a regular basis in national snail control programs.	Grossman 1991b

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Several (lady beetle as control agent)	Several	China	Biological	Utilization of the lady beetle in rubber against fungi, in citrus against whiteflies, in pine against scales, in pear and apple against psyllids, in poplar and elm against leafbeetle, in cotton against mites, in wheat against aphids, in vegetables against leafhoppers, in corn, millet and sugarcane against pyralids, in rice against planthoppers.	This list describes the important predator-host relationships of the lady beetle in China. The augmentation of the beetles is often accomplished via collection in one area and release in another area. Target pests successfully controlled under these systems include aphids, scales and spider mites.	Olkowski, Zhang and Thiers 1991
Several (Trichogramma as control agent)	Several	China, provinces throughout the country	Biological	Local production and release of the parasitoid Trichogramma spp. Use in citrus against swallowtail, in poplar willow against notodontidmoth, in pine against caterpillars, in cotton against bollworm, in cabbages against armyworm, in corn against corn borer, in rice against case borer.	Trichogramma is locally produced and released on about 1 m ha/yr in China, second only to the USSR (release on 15 m ha/yr). Mechanized production lines for Trichogramma throughout the country. First production in 1952. Current production is about 500 t/yr.	Olkowski and Zhang 1991b
Several, not specified	Worms, other insects	Asia	Botanical, Chemical	Application of extracts of the neem tree.	Extracts of the fruits of the neem tree were recently introduced as botanical insecticide, marketed as Margosan-O™.	Olkowski 1991
Soybeans	Dodder	China	Fungal pesticides	Application of the fungus Colletotrichum gleosporides.	Common practice during the 1960s until late 1970s in 20 provinces. Application on about 670,000 ha reduced yield losses by an estimated 30%-50%.	Grossman 1991a
Sugarcane	Sugarcane borer	Indonesia	Biological	Release of Trichogramma spp. and Diatraeophaga striatalis.	No information.	Wirjosuhardjo 1988
Sugarcane	Sugarcane borer	Thailand	Biological	Release of Trichogramma spp.	T. releases in China to control Chilo sp. showed good results; however, in Thailand Sesamia inference is the predominant borer, which cannot be controlled by T.	Prachuabmoh et al. 1988

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Sugarcane	Sugarcane pest complex	Thailand	Chemical, Biological and Cultural	Use of moderately resistant varieties, sequential sampling, economic thresholds, hand removal of pests, disease sanitation, etc.	In one region, IPM yielded profits compared with a loss of profit using farmer's practice. In another region, IPM reduced profit loss by 30% in another region.	Prachuabmoh et al. 1988
Tea	Tussock moth, **Eurproctis pseudoconspersa**; Tung oil tree geometrid, **Buzura suppressaria**	China	Viral insecticides	Application of nucleopolyhedrosis viruses of the tussock moth and the tung oil tree geometrid.	From 46 tea plant pests, 58 strains of viruses have been found. Eight of them have been tried for mass-production and field application. The viruses listed here are the two most widely used, with applications of 10,000 and 20,000 ha respectively.	Liang 1987
Tobacco	Green peach aphid	China, Fujien an Yunan provinces	Biological	Release of the parasitoid **Aphidius gifuensis**.	The parasitoid has recently been mass-reared.	BIRC 1991
Tobacco	**Heliothis armigera** and **H. assulta**	China	Viral insecticide	Application of the nuclear polyhedrosis virus (Ha SNPU) at 4.8 x 1011 PIB/ac by ground or air application.	This is the first commercial viral insecticide in China; sales are increasing rapidly because worms are resistant to chemicals. See Cotton, China, H. amiogera.	Guangyu 1991
Tomato	Early blight, **Alternaria solani**; Septoria leaf spot, **Septoria lycopersici**	China	Chemical	Application of GZM at 5g/l, a stable water emulsion with dodecyl alcohol as the main component. See also Apples, China, Bitter rot.	Yield increased by 111% in field trials.	Han 1990
Tomato	**Heliothis armigera** and **H. assulta**	China	Viral insecticide	Application of the nuclear polyhedrosis virus (Ha SNPU) at 4.8 x 1011 PIB/ac by ground or air application.	This is the first commercial viral insecticide in China; sales are increasing rapidly because worms are resistant to chemicals. See Cotton, China, H. amiogera.	Guangyu 1991
Vegetables, Cabbage	Cabbageworm, Pieris rapae	China	Viral insecticide	Application of the nucleopoly-hedrosis virus "PrGV(W1-78) Insecticide." Mix with Bt also in use.	Since 1978 more than 100,000 ha have been treated with the virus, yielding a mortality rate of about 85%.	Liang et al. 1986

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Vegetables	Diamondback moth	Indonesia	Biological, Classical	1. **Diadegma cerophagus** Grav. introduced from the Netherlands in 1928. 2. **D. cerophagus** introduced from New Zealand in 1950.	1. Failed to establish. 2. The insect fully established in Java and Sumatra and gave 72%-82% parasitization.	Napometh 1988
Vegetables	Diamondback moth	China	Viral insecticides	Application of the nucleopolyhedrosis viruses of the diamondback moth	Viruses have been mass-produced and applied over large areas with good results.	Li and Pang 1991
Vegetables	Diamondback moth	Thailand	Microbial pesticides	Application of Bt at 3 kg/ha ($45/ha) every three days.	Common practice in central Thailand since moth is resistant to all chemical insecticides.	Tryon and Litsinger 1988
Vegetables	Green peach aphid	China, Fujien an Yunan provinces	Biological	Release of the parasitoid **Aphidius gifuensis**.	The parasitoid has recently been mass-reared.	BIRC 1991
Vegetables	**Schlerotinia; Pythium; Armilareilla tabescens**	China	Fungal pesticides	Application of biological fungicide (**Trichoderma harzianum** strains).	Common availability reported.	Olkowski 1991
Vegetables, Cucumber	Downy mildew, **Pseudoperonospera cubensis**	China	Chemical	Application of GZM at 5g/l, a stable water emulsion with dodecyl alcohol as the main component. See also Apples, China, Bitter rot.	Reduction of the incidence of infestation by about 70%. Yield increased by 24% in field trials.	Han 1990
Vegetables, Pea	Pea aphid; Red mite; Whitefly	China	Biological	See cotton, cotton bollworm, biological. Release of the predator lacewing, **Chrysopa** spp.		
Watermelon	Anthracnose, **Colletotrichum lagenarium**	China	Chemical	Application of GZM at 5g/l, a stable water emulsion with dodecyl alcohol as the main component. See also Apples, China, Bitter rot.	Reduction of the incidence of infestation by about 57%. Yield increased by 49% in field trials.	Han 1990
Wheat	Aphid	China	Biological	See cotton, cotton bollworm, biological. Release of the predator lacewing, **Chrysopa** spp.		

Crop	Pest	Country	IPM Type	IPM Method	Results	Reference
Wheat	Aphid	China	Biological	Release of the predator **Coccinella septempuncta**, which is collected at the end of the season from vegetable fields and released in the next season.	**C. septempuncta** is mass-reared on aphids or male pupae of honey bee, and recently on artificial diets, which allows cost-effective mass production.	BIRC 1991
Vegetables, Bean storage	Bean weevil	Bean storage containers	Mechanical	Shaking of bean storage containers twice a day until consumption.	The weevil needs to brace itself against a hard surface to get sufficient leverage to bore into the bean's coat. Reduction of weevils by 97% after 2 weeks.	Washington Post, 8/19/1991, page A2

APPENDIX 4

DOES THE ADOPTION OF IPM ALWAYS INCREASE WELFARE?

Litsinger (1989) states that rice growers now earn less than at an earlier stage of the green revolution despite the fact that they now produce more rice than ever before due to such technical innovations modern varieties, improved irrigation, pesticides, and the like. The following brief discussion looks at the conditions leading to this development using economic theory based on a paper by Lindner and Jarrett (1978). The terminology is purposely kept simple.

"When more farmers adopt a new technology, prices adjust to the new general level of productivity. At the bottom end of the distribution, those who cannot afford to adopt the new technology see their incomes fall, even though they do exactly what they have always done" (Röling and van de Fliert 1991, p. 24). This, however, depends on the nature of the supply change (shift of the supply function) resulting from the adoption of the technology (IPM) and how consumers of the agricultural product respond to price changes (demand elasticity).

Based on Lindner and Jarrett, growers' benefits increase in aggregate if for both "low-average-cost" producers and "high-average-cost" producers the adoption of technology results in the same absolute reduction in average costs (parallel supply shift). Growers lose only if (a) total costs of "low-average-cost" producers and "high-average-cost" producers are relatively unaffected by the adoption of the innovation (cost structures for all producers are reduced and the supply shift is pivotal) and (b) consumers demand similar quantities even if prices increase (demand is inelastic). Growers also gain if the supply shift is pivotal and demand is elastic. Thus, the question of the quality of the innovation's effect on the producer can be reduced to whether demand for the product is inelastic and if so, whether the supply shift is also pivotal. The nature of the supply shift depends on the type of innovation; the demand elasticity depends mainly on the commodity.

Agricultural products that have a low rate of substitutability and are basic products of consumption are likely to have a lower demand elasticity than products with the reverse characteristics. Rice is likely to have an inelastic demand curve. Exported goods like oil palm products, on the other hand, can be assumed to have highly elastic demand curves as they are easily substituted with other oil products on world markets.

The type of supply shift must be determined for every innovation, and no generalization for pest management improvements can be made. Griliches (1958) found a pivotal shift following the introduction of hybrid corn in the U.S. Lindner and Jarrett conclude that biological innovations in general tend to result in proportional rather than parallel supply shifts. Classical biological control, for instance, is costless to the individual grower. Under the assumption that low-cost producers who grow traditional rice varieties with a fallow in the dry season have a lower incidence of pest infestation than high-cost producers with modern varieties and double cropping, biological control programs would also result in a proportional supply shift. Low-cost producers at the bottom end of the supply function will gain less in terms of absolute cost reduction than high-cost producers. This is also a likely case for pesticides.

On an aggregate level there is thus a reasonable probability that some pest management-related innovations reduce growers' benefits as observed by Litsinger and Röling and van de Fliert.

So far the discussion has assumed that the innovation is adopted equally by all producers. Adoption theory, however, shows us that there is often substantial variation in the adoption of innovations. Innovators and early adopters may actually increase their benefits even in the scenario described above, while late adopters and laggards may be forced to adopt productivity—increasing innovations because they receive a decreased price for the agricultural commodity.

In contrast to biological and chemical innovations, organizational innovations are considered by Lindner and Jarrett to result in a parallel (or even convergent) shift as they are likely to be scale-dependent. Integrated pest management, with its high organizational requirements, might result in at least a parallel supply shift and be beneficial to growers independent of demand elasticities.

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