Studies on IPM Policy in SE Asia

Two Centuries of Plant Protection in Indonesia, Malaysia and Thailand

Promotor: Prof. Dr. J.C. Zadoks, Emeritus hoogleraar in de ecologische fytopathologie

Jan H.M.Oudejans

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Proefschrift
ter verkrijging van de graad van doctor,
op gezag van de rector magnificus
van de Landbouwuniversiteit Wageningen,
Dr. C.M. Karssen,
in het openbaar te verdedigen
op vrijdag 26 februari 1999
des namiddags te vier uur in de aula
van de Landbouwuniversiteit te Wageningen

Coverphoto:
Farmers' drawings of natural enemies at Farmer Field School graduation day in S Cotabato, Mindanao, March 7th, 1995.
Photo by author

STUDIES ON IPM POLICY IN SE ASIA. TWO CENTURIES OF PLANT PROTECTION IN INDONESIA, MALAYSIA AND THAILAND.
Oudejans, J.H.M.

Thesis Landbouwuniversiteit Wageningen - With ref., with summary in Dutch.

Subject headings: Integrated Pest Management/pesticides/Southeast Asia

ISBN 90-5808-019-6 (thesis)
ISBN 90-5782-020-X
ISSN 0169 345 X

Distribution: Backhuys Publishers, P.O.Box 321, 2300 AH Leiden, the Netherlands.
Telephone: +31-71-5170208
Fax: +31=71-5171856
E-mail: backhuys@euronet.nl

Printed in the Netherlands by Ponsen & Looijen Wageningen

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Author's abstract

Integrated Pest Management (IPM) became a widely supported approach in the control of pests and diseases in crops. This study describes IPM policy and implementation, a.o. by the FAO Inter-Country Programme for the Development and Application of IPM in Rice in S and SE Asia, in Indonesia, Malaysia and Thailand. A brief description of agricultural development in the three countries serves to understand their priorities in crop production and protection, the origin of their institutions, their main pest and disease problems and their achievements in the public and private sectors. Examples demonstrate the ingenuity of colonial research in solving major obstacles in estate agriculture. A comparison of methods of pest management in pre-World War II agriculture without synthetic pesticides with modern IPM technology reveals some essential differences. In SE Asia in the 1960s, large scale intensification programs in rice production on the basis of Green Revolution technology led to serious outbreaks of secondary pests and virus epidemics. The Regional and National IPM programmes induced a political commitment to IPM in Indonesia and Malaysia. Large scale IPM training following the FFS extension method had reached about 1 million Indonesian farmers by 1996. The effect of the FAO IPM programmes on the pesticide markets of the three countries is evident in Indonesia, but not in Malaysia and Thailand.

Preface

This study evolved in the course of the past three years, a period of learning and reflection. It deals with the experiences which marked my career in developing countries and in Europe. Over the years, I met with many inspiring people who taught me new ideas and helped me to never lose my curiosity. I had an adventurous career that allowed me to see agricultural practices in all but one continent. The study might be seen as an end-of-career effort of sharing experience and as a token of gratitude to the people of SE Asia for the hospitality bestowed upon me.

Of great value for the research has been my supervisor at the Wageningen Agricultural University, Dr. J.C. Zadoks, emeritus professor of ecological phytopathology who, as an IPM expert and former member of the FAO/UNEP Panel for Integrated Pest Management, became personally acquainted with the environment and pest problems of SE Asia. Professor Zadoks showed me new perspectives of Pest Management and ways to lead my manifold impressions into effective grooves of thought. His detailed, accurate and demanding commentaries enabled me to write this dissertation.

My sincere thanks go to Mr. Ewoud Pierhagen (M.Sc.), director of the Division of International Affairs, Ministry of Agriculture, Nature Management and Fisheries, The Netherlands, for his generous encouragement since the time I left my position in his division to write this book. The facilities and support provided by Mr. Pierhagen were crucial for the successful completion of the study.

A grateful acknowledgement goes to Dr. Hans-Jürgen Schonlau and Annik Dollacker (M.Sc), Bayer AG, Business Group Crop Protection, Monheim, Germany, for providing a detailed analysis of the pesticide markets in three SE Asian countries covering 16 years. By confiding in me and giving professional advice, Dr. Schonlau and Mrs. Dollacker made a substantial contribution to this study.

I mention with respect the inspiring work of Dr. Peter E. Kenmore, at the time Chief Administrator of the FAO Inter-Country Programme for the Development and Application of Integrated Pest Control in Rice in S and SE Asia.

I thank Prof. Mohd. Yusof Hussein, Dean, Faculty of Agriculture, Universiti Pertanian Malaysia, for his hospitality in enabling my study in Malaysia.

A special word of thanks goes to Bram van Weeren for his invaluable help with computer technology and art work.

I also appreciated the support given by Liesbeth and Ab Lycklama-Oudejans, Ticia and Mauke van der Haer-Rueb during the final weeks.

Last but in no way least, I thank with all my heart my beloved wife, Ansje, for her ever lasting confidence and patience.

Contents

Abbreviations and Acronyms

AARD	Agency for Agricultural Research and Development (I)
AAETE	Agency for Agricultural Education, Training, Extension (I)
ADB	Asian Development Bank
a.i.	active ingredient (pesticide)
AIDAB	Australian International Development Assistance Bureau
AIM	Agricultural Institute of Malaysia
AIT	Asian Institute of Technology (Bangkok)
ANGOC	Asian NGO Coalition for Rural Development and Agrarian Reform
APPPC	Asia and Pacific Plant Protection Commission (FAO)
APL	*Algemeen Proefstation voor de Landbouw* (General Agricultural Research Institute) (I)
ARSAP	Agricultural Requisite Scheme for Asia and the Pacific
ASMEC	Agricultural Spraying Machinery Evaluation Centre (T)
ATA	Agricultural Technical Assistance (project)
AusAID	Australian Agency for International Development
AVRDC	Asian Vegetable Research and Development Center, Taiwan
AVNET	Asian Vegetable Research Network (coordinated by AVRDC)
AVROS	*Algemene Vereeniging van Rubber Planters ten Oostkust van Sumatra*, (General Association of Rubber Planters in E Sumatera) (I)
BAPPENAS	Indonesia National Planning Board
baht	Thai currency (1 US$ = 25,5 Baht 1996)
BIMAS	Mass Guidance (*Bimbingan Masal*) (I)
BND	National Improved BIMAS (*Bimbingan Nasional yang Disempurnakan*) (I)
BPH	Brown planthopper (*Nilaparvata lugens*)
BPM	Agricultural Bank of Malaysia (*Bank Pertanian Malaysia*)
BPTP	Food Crop Protection Centre (*Balai Perlindungan Tanaman Pangan*) (I)
brigade	specialized group (*e.g.* for monitoring or spraying)
BULOG	National Logistic Agency (*Badan Urusan Logistic*) (I)
Bt	*Bacillus thuringiensis*
CABI	International Centre for Agriculture and Biosciences (former Commonwealth Agricultural Bureaux International) (UK)
CB	Cabi Bioscience (former IIBC) (UK)
CGIAR	Consultative Group for International Agricultural Research
CIDSE	International Committee for Solidarity and Development in Indo-China
CIP	International Potato Center (Peru)
CIRAD	International Centre for Rural and Agricultural Development Research (France)

COPR	Centre for Overseas Pest Research (UK)
CPRO	*Centrum voor Plantenveredelings- en Reproductieonderzoek* (N)
CRIFC	Central Research Institute for Food Crops, Bogor (I)
CRIH	Central Research Institute for Horticulture, Jakarta (I)
CPB	Cacao pod borer (*Conopomorpha cramerella*)
CTA	Technical Centre for Agricultural and Rural Cooperation (Africa, Caribbean, Pacific countries - EEC)
DBM	Diamondback moth (*Plutella xylostella*)
DGIS	Directorate General for International Cooperation, Ministry of Foreign Affairs, The Netherlands
DEI	Dutch East Indies
DEMAS	Mass demonstration (*Demonstrasi Masal*) (I)
DEPTAN	Department of Food Crops (*Departemen Tanaman Pangan*) (I, M)
DITLIN	Directorate of Food Crops Protection (I)
DLO	*Dienst Landbouwkundig Onderzoek* (Service for Agricultural Research) (NL)
DoA	Department of Agriculture (*Jabatan Pertanian*) (I, M)
DOA	Department of Agriculture (T)
DOAE	Directorate of Agricultural Extension (T)
DoE	Department of the Environment (*Jabatan Alam Seketar*) (I, M)
DPV	*Deli Planters Vereeniging* (Deli Planters Association) (I)
ESCAP	Economic and Social Commission for Asia and the Pacific, an agency of the United Nations, Bangkok
ESM	Entomological Society of Malaysia (*Persatuan Entomologi Malaysia*)
ETL	Economic Threshold Level
ETZ	Swiss Agency for Technical Cooperation
EU	European Union (EEC)
FAO	Food and Agriculture Organisation of the United Nations
FAMA	Federal Agricultural Marketing Authority (M)
FELCRA	Federal Land Consolidation and Rehabilitation Authority (M)
FELDA	Federal Land Development Authority (M)
FFS	Farmers' Field School (agricultural extension)
f.p.	formulated product (pesticide)
GCPF	Global Crop Protection Federation (before GIFAP)
GDP	Gross Domestic Product
generic	Generic pesticides are off-patent compounds
GIFAP	International Group of National Associations of Manufacturers of Agrochemical Products (renamed GCPF)
GoI	Government of Indonesia
GoM	Government of Malaysia
GTZ	Deutsche Geselschaft für Technische Zusammenarbeit, German Agency for Technical Cooperation
ha	hectare (10.000 square metres)
HPR	Host-plant resistance

IBRDC	International Bank for Rural Development and Cooperation
ICP	Inter-Country Programme (*e.g.* FAO's ICP for Integrated Pest Control in Rice in S and SE Asia)
ICP	Integrated Crop Protection
IIBC	International Institute for Biological Control (UK) (renamed CB)
INMAS	Massive Intensification (*Intensificasi Masal*) (I)
INPRES	Presidential Instruction (*Instruksi Presiden*) (I)
INSUS	Special Intensification (*Intensifikasi Khusus*) (I)
IPHYTROP	Information in Tropical Phytopharmacy
IOBC	International Organisation for Biological Control of Noxious Animals and Plants
IOCU	International Organization of Consumer Unions
IOPRI	Indonesian Oil Palm Research Institute, Medan
IPB	*Institut Pertanian Bogor* (I)
IPC	Integrated Pest Control (see IPM)
IPM	Integrated Pest Management (*Pengandalian Hama Terpadu*) (see IPC)
IRRI	International Rice Research Institute (Philippines)
ISP	Incorporated Society of Planters (M)
JICA	Japanese International Cooperation Agency
KADA	Kemubu Agricultural Development Authority (M)
kiosk	Retail outlet of farmers cooperative
KUD	village unit cooperation (*Koperasi Unit Desa*) (I)
LEHRI	Lembang Horticultural Research Institute, W Java (I)
LEISA	Low External Input Sustainable Agriculture
LPN	National Padi and Rice Authority (*Lembaga Padi Negara*) (M)
M	million
MACA	Malaysian Agricultural Chemicals Association
MADA	Muda Agricultural Development Authority (M)
MAPA	Malaysian Agricultural Producers Association
MAPPS	Malaysian Plant Protection Society
MARDI	Malaysian Agricultural Research & Development Institute
MARIF	Malang Research Institute for Food Crops
MoA	Ministry of Agriculture (*Kementarian Pertanian*) (I, M)
MOAC	Ministry of Agriculture and Cooperatives (T)
NAEP	National Agricultural Extension Program (I)
NAP	National Agricultural Policy (M)
NARS	National Agricultural Research Systems
NESDP	Nucleus Estate and Smallholdings Development Program (I)
NGL	Netherlands Guilder (1 US$ = about 2 NGL, 1998)
NGO	Non-governmental Organization
NRI	National Resources Institute (UK)
ODA	Overseas Development Administration (UK)
OFCOR	On-Farm Client Oriented Research (I)
padi	rice (padi gabah = unhusked; padi beras = husked)

palawija	secondary food crops
PAN	Pesticide Action Network (London, Penang)
pers. comm.	personal communication
PIC	Prior Informed Consent
PMV	*Penyakit Merah* Virus (Tungro)
POJ	*Proefstation voor de Java Suiker Industrie, Oost Java,* (Sugar Research Station E Java), Pasuruan, E Java (I)
PORIM	Palm Oil Research Institute of Malaysia
PPL	village extension worker (*Penyuluh Pertanian* Lampangan) (I, M)
PROSEA	Plant Resources of South East Asia
RAPA	Regional Office for Asia and Pacific (FAO, Bangkok)
RENPAP	Regional Network for the Production, Marketing and Control of Pesticides in Asia and the Pacific (UNIDO)
RILET	Research Institute for Legumes and Tuber Crops (I)
RM	Ringgit, Malaysian currency (also Mal. dollar= M$) (1 US$ = 2.4 ringgit, 1998)
Rp	Rupiah, Indonesian currency (1 US$ = 2,500 Rps, 1995)
RRIM	Rubber Research Institute of Malaysia
RTG	Royal Thai Government
SARD	Sustainable Agriculture and Rural Development
SEARP	South and Southeast Asia Regional Program
SEWS	Surveillance and Early Warning
stimulants	Coffee, tobacco, tea, *sirih*
t	tonne(s) (metric ton = 1,000 kg)
TCDC	Technical Cooperation among Developing Countries (FAO)
TDRI	Thailand Development Research Instititute
T&V	Training and Visit (agricultural extension, World Bank)
treatable area	hectareage potentially treated if pesticides were to be applied conform dosage recommendations
ToT	Training of Trainers (agricultural extension)
ULV	Ultra-low Volume (application rate)
UN	United Nations
UNCED	United Nations Conference on Environment and Development, Rio de Janeiro, 1992
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Protection Agency
UNIDO	United Nations Industrial Development Organization
UPM	*Universiti Pertanian Malaysia* (Agricultural University of Malaysia)
USAID	United States Agency for International Development
WAU	Wageningen Agricultural University, The Netherlands
WB	World Bank/International Bank for Reconstruction and Development
WBPH	Whitebacked planthopper

Stellingen behorende bij het proefschrift van Jan H.M. Oudejans getiteld **"Studies on IPM Policy in SE Asia. Two Centuries of Plant Protection in Indonesia, Malaysia and Thailand"** te verdedigen op vrijdag 26 februari 1999 te vier uur.

Stelling 1.
In Indonesië ligt het cruciale probleem niet in het maken van IPM beleid, maar in het continueren van de uitvoering ervan.
(hoofdstuk 2 van dit proefschrift)

Stelling 2.
In Maleisië heeft IPM zijn duidelijkste uitingsvorm gekregen in de geïntegreerde bestrijding van onkruiden in rijst in de grote irrigatie-projecten.
(hoofdstuk 3 van dit proefschrift)

Stelling 3.
In Thailand komt het ontbreken van politieke aandacht voor IPM in rijst niet als een verrassing omdat in de 20ste eeuw de rijstproductie meer gericht was op de export dan op de nationale voedselvoorziening.
(hoofdstuk 4 van dit proefschrift)

Stelling 4.
Tijdens de koloniale periode van Indonesië leverde regelgeving een grotere bijdrage aan IPM dan in het heden.
(hoofdstuk 5 van dit proefschrift)

Stelling 5.
Generieke bestrijdingsmiddelen zijn de dood voor IPM.

Stelling 6.
Merkwaardig genoeg getuigt het massaal uitbreken van de wereng coclat (*Nilaparvata lugens* Ståhl.) op Java van de grote technische vooruitgang in het spuiten van insecticiden met vliegtuigen sedert het eind van de 1960-er jaren.

Stelling 7.
Het Directoraat-Generaal voor Internationale Samenwerking (DGIS) van het Ministerie van Buitenlandse Zaken pleegt kapitaalvernietiging wanneer het de grote investeringen in IPM voor rijst in ZO Azië niet onderhoudt. Dit IPM programma vormt een der weinige concrete invullingen van Agenda 21.
(Bron: Beleidsvoornemens in zake toepassing van criteria op het vlak van structurele bilaterale hulp. Brief van de Minister voor OS aan de Voorzitter van de Tweede Kamer der Staten-Generaal, 5 November 1998).

Stelling 8.
Met het relatief snel prijs geven van de eertijds befaamde Nederlandse expertise inzake tropische landbouw en plattelandsontwikkeling verliest het Ministerie van Landbouw, Natuurbeheer en Visserij de PR-waarde van zijn OS-geörienteerde instellingen voor het op de markt brengen van de Nederlandse landbouwkennis, diensten en produkten.
(Bronnen: "Schouders er onder: IAC en ILRI als versterking van Wageningen UR internationaal. Rapport van de Commissie Bukman, Kok en van der Lely, November 1998; Eindrapport strategische herorientatie LNV OS-beleid. Ministerie van Landbouw, Natuurbeheer en Visserij, November 1995).

Stelling 9.
Naarmate de verantwoordelijkheid voor beleid en uitvoering van technische ontwikkelingssamenwerking meer wordt toegewezen aan de sectordeskundigen op de ambassades, neemt de mogelijkheid voor Nederlandse ontwikkelingsdeskundigen af om kwalitatief en kwantitatief bij te dragen aan het ontwikkelingswerk.
(Bron: De Herijking van het Buitenlands Beleid. Nota van de Minister van Buitenlandse Zaken, 11 September 1995)

Stelling 10.
In de Directoraten-Generaal van de Europesche Commissie lijkt onvoldoende coördinatie en deskundigheid aanwezig om een zorgvuldig bestedingsbeleid te voeren in zaken die toewijzing en gebruik van pesticiden in ontwikkelingslanden betreffen. *(Bron: Verslagen van de European Workinggroup on IPM).*

Stelling 11.
In een tijd die van vluchtigheid aan elkaar hangt ontstaat vanzelf behoefte aan grondslagenonderzoek.
(Bron: Recensent Paul Scheffer in NRC van 26.02.1997 over de uitspraak van Rudiger Safranski's "Naar de grondslagen vragen betekent omkijken").

Stelling 12.
Het acronym SAIO (senior assistent in opleiding) is niet alleen een grapje. Juist oudere deskundigen, die hun in de praktijk opgedane ervaring willen analyseren en vastleggen, hebben wetenschappelijke en technische ondersteuning nodig om doeltreffend te kunnen werken.

Chapter 1

Introduction: From Paradise to Paradigm

1.1. Rationale

The title of this chapter refers to man's dream of an Arcadian agriculture (The idyll of the `sauvage noble', JJ Rousseau, 1712-78) and to the development of Integrated Pest Management (IPM) into a kind of paradigm (Kenmore 1996; Kuhn, 1970). The theme of this book, the development of crop protection in three countries of SE Asia, is inspired by a personal motive. My professional career as an agronomist confronted me with conflicting concepts and activities concerning ways and means to control pests and diseases of agricultural crops. For 30 years, I carried out my tasks dutifully under the given circumstances with the knowledge I had acquired at the time. Fortunately, the course of events enabled me to learn and to apply new insights in various professional positions. The present study is an effort to record and understand approaches and achievements in plant protection in the context of agricultural development in SE Asia. My interpretations and conclusions are based on research, experience in the field and over sixty hours of recorded interviews.

1.2. Serving two masters?

The author began his career with CIBA AG, Agro-chemical Division (which ultimately merged into Novartis, Basel, Switzerland), from 1966 to 1975. Five years of company representation and product trials in E Pakistan and Turkey and four years of world-wide research on aerial and ground application techniques brought valuable knowledge about company interests, product performance and spray droplet behaviour, but none about the ecological consequences of the work done so conscientiously. Doubts awoke during the following four years of service with a Dutch company, assisting in the management of some 4,000 ha of *Cinchona* (source of quinine), coffee, cardamom and other crops planted on the company's estates in Zaire, Rwanda and Guatemala. Outbreaks of *Helopeltis* bugs, coffee berry borer and caterpillars were treated by calender spraying with low efficacy and high incidence of intoxication of labourers. However, in the late 1970s, the validity of chemical control was not questioned in the world of industry. The pesticide oriented course was continued in the service of the Netherlands Directorate General for International Development Cooperation (DGIS), 1979-83. I was commissioned to the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), Bangkok, with the task of developing training capacity within the ARSAP Project. ARSAP, the Agricultural Requisite Scheme for Asia and the Pacific, was a long-term, Dutch financed, program to facilitate, increase and widen the domestic use in ESCAP countries of more productive agro-chemical inputs by small-scale producers of food and cash crops.

Duties in later years, with the Dutch Ministry of Agriculture, Nature Management and Fisheries, 1984-96, gave access to the world of biological control. Participation in various FAO/Netherlands missions dealing with Integrated Pest Management (IPM) in cotton (Sudan), rice (S and SE Asia), migratory locust control (Sahel) and FAO Code of Conduct implementation (C America) placed the questions of ecological balance and sustainability in the limelight.

The same Dutch Directorate General of International Development Cooperation, that once funded the pesticide use promoting ARSAP project, became the major donor of the FAO Inter-Country IPM Programmes for Rice and Vegetables in S and SE Asia and for the Development and Application of IPM in Cotton in the Sudan. The opportunity to participate on both sides, promotion of pesticides and promotion of IPM, raised the question: 'Did I serve two masters?' If so, what did I learn from it? SE Asia offered a good possibility, by availability of documentation and personal exposure, to search for an answer.

1.3. Crop protection: need and realisation in SE Asia

Before the 17th century, sufficient native crops could be grown in SE Asia to enable the settlement of numerous immigrants in the sparsely populated region of SE Asia. From the early 17th century on, trade in agricultural produce developed and foreign crops began to arrive. European trading companies exacted delivery of rice and sugar and imposed the cultivation of commodity crops by Indonesian and Malay farmers. In the 18th and early 19th century, enforced planting on a large scale, often as monocultures, under poor technical supervision of the colonial administration resulted in a low productivity. The shift to private plantation agriculture created a need for controlling the pests and diseases which threatened the huge investments. Scientific knowledge was not available. Public and private funding enabled the founding of endeavouring agricultural research, first in the Dutch East Indies and later in Malaya. In Thailand, there was little interest to improve productivity before the Second World War due to the absence of foreign investment in agriculture.

Through diligent research in the Dutch East Indies and Malaya, able scientists succeeded, among others, in developing methods for adequate pest and disease management. The solutions were sufficiently effective to enable an almost continuous growth of production in terms of quantity and quality and a high return on investment. Chemical means of pest control were limited to the application of only few botanical and chemical products. Pest management tools included breeding and selection for resistance, cultural control, employment of natural enemies, quarantine, sanitation and other elements of control. With these means certain sectors of plantation agriculture, in particular the sugar industry, in SE Asia attained a level of productivity unmatched after World War II. Pest and disease management had achieved a state of the art that continuation of scientific and financial support was never questioned by politicians or financiers.

Early in the 20th century, the dual character of agriculture, existing of a commercial export-oriented sector and an indigenous, almost self-sufficient production sector, was recognized. The build-up of knowledge concerning improvement of production, loss prevention and pest management had, in these two sectors, developed along separate lines and at a very different pace. The necessity to improve the productivity of indigenous agriculture and the income of the small farmers led to the establishment of Departments of Agriculture in the Dutch East Indies and Malaya in the same year, 1905.

The institutionalization of agriculture offered an opportunity to separate pest and disease management from crop husbandry and to shape it into a separate field of action. Protection of production and products became an independent subject of government attention. Hence, a Plant Protection Division was set up within the Departments of Agriculture. For the first time, public funds were allocated to the scientific improvement of production and protection methods for indigenous food crops. Agricultural Extension Services were created to test and demonstrate the findings of research in the farmers' fields.

In Thailand, where agriculture was regarded as a producer of export commodities only, scientific improvement of indigenous food crops only began after World War II.

1.4. The introduction of synthetic pesticides

The invention of DDT before and strategic research on synthetic organochlorine compounds during the Second World War gave agriculture access to biocides with a great potential for an almost instantaneous control of organisms noxious to crops. Between 1945 and 1960, research on chemical control of pests, diseases and weeds occupied the great majority of researchers and captured the bulk of funds, thereby leaving little resources for further development of non-chemical methods of control. Pesticide use was advertised and generally acknowledged as a reliable, cheap, easily applicable and possibly final solution to pest problems in agriculture. Due to the exodus of labourers from agriculture and rising labour costs, chemical control became the norm in agriculture in developed countries. Similarly, overseas companies promoted the use of chemical pesticides in plantation crops as a way to cut production costs and to reduce the need for labour. In contrast, pesticide use in indigenous agriculture remained limited till the 1960s.

The Green Revolution of the 1960s introduced high-yielding varieties, subsidized agro-chemicals, accelerated mechanization, and extended irrigation and credit facilities. International research agencies and international foundations, which financed the development of the Green Revolution technology, convinced politicians and national experts that pesticides were an essential ingredient. Donors offered ample financial and technical assistance, usually in support of food crop production, which almost routinely carried a substantial pesticide component. The pesticide message was passed on to the farmers through the agricultural extension services.

The chemical industry installed impressive sales networks and succeeded in transforming the rice sector into the biggest insecticide consumer in agriculture. Asian governments made pesticides available at village level through subsidies and logistic means. Two decades (1960s and 1970s) of intensive advertisement through private distributors, extension agents and politicians convinced a whole generation of farmers that they were likely to loose their crop if they did not apply insecticides.

Within a few years, population densities of pest organisms increased in major food and cash crops, and outbreaks and epidemics occurred more frequently than ever before. Since the causes of these phenomena were not understood, farmers in Asia and elsewhere were induced to increase the dosage of pesticides and the frequency of application.

1.5. The development of Integrated Pest Management (IPM)

In the 1950s, similar problems of increased pest outbreaks were encountered in N and C America in cotton, citrus, maize and alfalfa. In California, USA, fundamental entomological research on pest occurrence in alfalfa became a classic example of IPM technology. The alfalfa case inspired scientists, such as V.M. Stern, R.F. Smith and R. van den Bosch, to formulate definitions for IPM and Economic Threshold Level (ETL) (Flint & van den Bosch, 1981). A significant difference with pre-war colonial research was the pesticide-induced nature of the outbreaks in alfalfa. Initially minor pests, such as the spotted alfalfa aphid, became important when their natural enemies were killed. It was recognized that pest insect populations survived through a rapid build-up of pesticide resistance (van den Bosch *et al.*, 1959).

Novel was the experimentation with insecticide dosage levels and the search for target-specific insecticides with the objective to spare natural enemies if insecticide usage was deemed unavoidable. Monitoring for pests and natural enemies and the application of ETL values for taking chemical control decisions was not entirely new. Around 1920 in Indonesia, S. Leefmans developed ETL-values to decide on spraying, biological control or cutting of infested palm fronds for control of coconut moth outbreaks (Kalshoven, 1951). An important difference was that the Californian farmers had great interest in following the IPM recommendations, whereas the Indonesian smallholders at the time did not understand the measures. Innovative too in the Californian work was the fitting together of information, decision-making criteria, methods, and materials with naturally occurring pest mortality into effective pest-management systems aimed at the maintenance of the agro-ecological balance (Stern *et al.*, 1959). The capturing of a set of technicalities bearing great significance to sensitive issues such as food security, human health, environmental quality, and public reassurance simultaneously into a workable concept proved to be decisive. Politically minded scientists, such as R.F. Smith and P.E. Kenmore, transformed Integrated Pest Management from a mere technology into a pattern of thinking (paradigm) about the consequences of a growing dependency on chemicals in agriculture.

European researchers contributed particularly through the development of IPM technology for insect pest control in greenhouse crops (van Lenteren, 1995), and of guidelines for supervised or guided pest control in field crops and orchards on the basis of surveillance and ETL-values (de Fluiter, 1969b; Zadoks, 1986).

1.6. The appearance of donors

Throughout the second half of the 20th century, large funds became available for technical cooperation with developing countries. The motives of the donors consisted of a blend of cold-war strategy, feelings of colonial guilt, solidarity and trade opportunities. The so-called Overseas Development Administration (ODA) of individual donors called on their constituency for advice concerning targets and ways for dispensing the donor funds. Because of the prominent place of agriculture in the Third World economy and as a consequence of their accumulated experience in tropical agriculture, the United States of America and European countries, in particular the Netherlands, the United Kingdom, and France, offered governments of developing countries, through multilateral or bilateral channels, an array of agricultural development programs.

Many of these programs included a significant plant protection and pesticide supply component. Donors also contributed to agricultural development programs of United Nations Agencies, International Development Banks and Foundations. The founding of the International Agricultural Research Centres (IARCS) [*e.g.* for rice (IRRI) and for wheat and maize (CIMMYT)] under the aegis of the Consultative Group on International Agricultural Research (CGIAR) led to a break-through in food production and agricultural technology, the 'Green Revolution'. S and SE Asia were richly endowed with financial and technical assistance. The Netherlands, for instance, earmarked a relatively large part of its development funding for Indonesia.

In the 1960s, The United Nations Agencies for Food and Agriculture (FAO) and Environmental Protection (UNEP) set up a 'Panel of Experts on IPC' and launched the FAO/UNEP Global Programme for the Development and Application of Integrated Pest Control in Agriculture. Increasing pest problems in Green Revolution rice varieties led to the establishment of a FAO Inter-Country Programme for Development and Application of Integrated Pest Control in Rice in S and SE Asia, 1979-99, in which initially seven countries participated. Since the 1980s, the Inter-Country Programme succeeded in installing National IPM in Rice Programmes in the participating countries. The programs in Indonesia, Vietnam and India became particularly successful in the 1990s. FAO implemented similar regional IPM programs in vegetables and cotton in S and E Asia.

Australia (in line with the Australian-Asian alliance treaties) and the Netherlands contributed considerably, in terms of grants and expert assistance, to the FAO Inter-country IPM Programmes in S and SE Asia. In the Netherlands, ample availability of expertise in tropical agriculture and IPM technology and the historal relation with Indonesia were factors which influenced ODA-budget allocation to the FAO IPM programs. The Dutch modus of contributing through a FAO trust-fund enhanced the opportunity for direct involvement of Dutch experts in the FAO IPM Programmes in SE ASIA, Sudan and Nicaragua. In view of the ever increasing focus on environmental issues, the Dutch Government financed, in 1991, the joint 'FAO/Netherlands Conference on Agriculture and the Environment'. The resulting 'Den Bosch declaration', which reaffirmed the importance of IPM, served as major input for the United Nations Conference on the Environment and Development (UNCED, Rio de Janeiro, 1992) (IOCU, 1993).

1.7. Inter-Country and National IPM Programmes in SE Asia

The FAO Inter-Country Programme in Rice was launched at a time that brown planthopper outbreaks and virus epidemics threatened the hard-won self-sufficiency in rice production in S and SE Asia. In 1982, field studies of Kenmore *et al.* *(1984)* at IRRI in the Philippines established the pesticide-induced nature of brown planthopper outbreaks and the importance of natural enemy population dynamics in balancing insect pests in rice. These findings, pushed with persuasion by FAO Inter-Country Programme administrators, drew the attention of politicians and national scientists.

In 1985-86, the governments of Indonesia, the Philippines and India declared IPM as their national policy for rice production (Zadoks *et al.*, 1986). The primary impact of the IPM policy was the uncoupling of rice production intensification from pesticide procurement, the withdrawal of pesticide subsidies and a drastic reduction in the number of insecticide applications by rice farmers. The developments in Indonesia and Vietnam, where National IPM Programmes took the initiative, set the example. Through the adoption of the Farmer Field School method of extension (Röling & van de Fliert, 1994), impressive results were obtained in the training of plant protection and extension cadres, field trainers and farmers. Farmers, empowered by a season-long FFS training, reduced the number of insecticide treatments in rice. Next, they began to experiment with reducing treatments in non-rice crops, and selection in local varieties (van de Fliert *et al.*, 1995, 1996; van Huis & Buurma, 1998).

International development agencies, o.a. the United States Agency for International Development (USAID), the World Bank and Asian Development Bank (ADB) acknowledged the achievements of Indonesia in adopting IPM technology in rice-based cropping systems by accepting them as a valid collateral for agricultural loan embursement. The World Bank provided a 32 M US$ loan to Indonesia for IPM extension. (WorldBank, 1993a).

Contrary to Indonesia and Malaysia, the government of Thailand did not officially proclaim IPM as national agricultural policy. Malaysia and Thailand did not ban rice insecticides for ecological reasons. The implementation of the FAO-IPM Programme has as yet failed to get a strong foothold in either Malaysia or Thailand (Whitten, 1998).

1.8. Organisation of the book

This book reviews the development of agriculture and plant protection in Indonesia, Malaysia and Thailand. These three countries were chosen as a sample from SE Asia because they show comparable traits in historical and agricultural development, importance of rice as a staple food and of horticulture as a growth industry, the growth of the pesticide market, and participation in international IPM initiatives. A period of two centuries is described because the 19th century marks the beginning of agricultural development on the basis of scientific experimentation in botanical gardens and plantations in Indonesia and Malaya.

The book describes pest and disease problems and their control (Box 1.8) in rice, vegetables and fruits, and several major estate crops. The choice of these

Box 1.8

Definition of Crop Protection

For the purpose of this book `Crop Protection' is defined as the collective knowledge and expertise concerning the relationship between noxious organisms, crops and produce, mechanisms and means of control, the agro-ecosystem and the environment.

Crop protection is dealt with at two levels, the individual and the institutional. At the individual level, the farmer/entrepreneur manages pests and diseases with the methods of cultural, chemical or biological control known and available to him, with the objective to optimize the financial results of his cropping activities.

At the institutional level the following parties and issues play a role. *1.* The national government is responsible for regulation and inspection, product registration, quarantine, research and extension concerning pesticides, health of seeds and planting material and other relevant inputs, public health, environmental quality, and for financial instruments such as subsidies, tariffs and price controls. Responsibilities of national governments are increasingly shared or taken over by international bodies of government. *2.* The international pesticide industry is responsible for supply and distribution of pesticides and extension in compliance with the regulations. *3.* Certain non-governmental organisations (NGOs) represent the interests of consumers, producers or the environment and object against externalities resulting from pesticide use.

Relatively recent issues in the field of plant protection are mondial agreements concerning sustainable environment and agriculture, trade and tariffs among which the FAO International Code of Conduct with the Prior Informed Consent clause.

The above definition and its elaboration mean to include all aspects discussed in the book, not to supersede better-phrased definitions which emphasise particular interests, as in the case of the IPM definitions adopted by the FAO/UNEP Panel of Experts in 1966 (Brader, 1979).

crops was based on the following criteria: *a.* importance of the crop as a basic source of food for the population or as a commodity crop grown mainly on estates for export; *b.* origin of the crop as a native species or as an exotic species introduced from another region of the world; *c.* annual or perennial crop; *d.* providing illustrative examples of pest and disease problems and their management before and after World War II.

The chosen crops are listed in table 1.8. Rice and vegetables are target crops of IPM programs to be discussed. Two main approaches to pest control, biological and chemical, are presented in their historical sequence. Other crops are discussed when appropriate. The present dominance of chemical control in agriculture and the resistance against it by protagonists of a balanced agro-ecosystem is evaluated with the help of relevant records of the pesticide market.

Chapters 2, 3 and 4 describe and analyze the development of plant protection in respectively Indonesia, Malaysia and Thailand. They deal with the emergence of crop protection, departing from unstructured aggregated expertise obtained by research and practice to its institutionalized form, in the context of agricultural development. Answers are sought to questions such as `Where, when and how was crop protection recognized as an essential entity requiring political and financial attention?'; `To what extent did the differential pace of development in indigenous and industrial agriculture influence policy making and investment in plant protection?, and `What results were achieved by the various ways and means of controlling pests and diseases'. Chapter 5 probes for the origin and meaning of the concept `Integrated Pest Management'. How did the colonial agricultural industry manage to achieve profitable levels of production without the employment of synthetic chemical pesticides? How novel is today's knowledge and practice of biological control? The chapter describes the international and national initiatives for the development and implementation of integrated pest management (IPM) in rice and vegetables in S and SE Asia. What conditions might favour the sustainability of IPM in SE Asia? Chapter 6 highlights the development and problems of horticulture, since this sector shows a high dependence on pesticides. Chapter 7 analyses the pesticide markets in each of the three countries in an effort to measure the effect of international and national IPM programs on actual pesticide use between 1980 and 1996. What do sales figures reveal about political commitment, conflicting commercial interests and environmental concerns? Chapter 8 is an epilogue with a personal touch and chapter 9 gives a summary of conclusions.

Table 1.8. Selection of crops

Farming type	Origin	Annual	Perennial
Estate	**Native**	Sugarcane	-
	Introduced	Tobacco	Cacao, oil palm
Smallholder	**Native**	Rice	Coconut
	Introduced	Vegetables, fruits	Coffee

Chapter 2

Development of agriculture in Indonesia

2.1. Introduction

The Indonesian archipelago consists of more than 13.600 islands which bridge the distance between Asia and Australia over about 5,000 kilometres, from the north point of Sumatera to Irian Jaya. On these islands lives an ethnically diverse population estimated at 205 million in 1998 (FAO Yearbook, 1997). Since about 64% of the population resides on Java, Madura and Bali -which occupy about 7.2% of the country's total land area- the population density of these islands is among the highest in Asia. The islands of Sumatera, Sulawesi, Kalimantan, and Maluku are far more lightly settled. The archipelago is dominated by the Sunda mountain system, one of the largest coherent belts of mountains and submarine ridges. Along its entire range run two parallel belts of mountain arcs of which the inner range is volcanic whereas the outer is not. Java has many types of soils of which those of volcanic origin are generally very fertile. The lowlands of the Outer Islands consist mainly of alluvial and marshy plains.

The climate of Indonesia is characterized by high uniform temperatures, abundant rainfall, high humidity and light winds. This uniformity is largely due to the fact that virtually the entire area lies within the equatorial belt. The narrowness of the islands allows the tempering influence of the surrounding seas to penetrate deeply inland. However, the sharp changes in temperature and precipitation with altitude cause marked local differences. Average annual temperature at sea level is a little above 26°C for the whole archipelago and is fairly uniform throughout the year. Commonly, rainfall amounts to over 2,000 mm in the coastal plains and over 3,000 mm in mountain areas. Humidity is intense with two peaks occurring at the height of the monsoons in April and November. In eastern direction the seasonal distribution of rainfall between wet and dry seasons becomes progressively more apparent. The SE part of Indonesia has a very dry season and also Java may suffer in parts from occasional extreme droughts (Khan, 1974).

The high population densities now found in Inner Indonesia are a relatively recent phenomenon. The population of Java increased from 10.3 in 1815 (table 2.1) to 42 million in 1930, when the first reliable census was conducted in Indonesia. There are reasonably reliable data available for regions other than Java since 1930.

Until World War II, the outstanding feature of Indonesia's agriculture was its dual nature. Indigenous agriculture (*bevolkingslandbouw*), although of enormous importance, was inconspicuous and largely self-sufficient. The Dutch colonial administration imposed a policy of agricultural exploitation during most of the 18th and 19th century, whilst impeding private enterprise. In the 1860s, the system of forced cultivation was gradually withdrawn and replaced by estate agriculture financed by foreign capital. Indigenous agriculture remained underdeveloped and neglected until the beginning of the 20th century. Concerned with the general decline of the people's well-being, the government entrusted a new Department of

Agriculture with the task of improving indigenous agriculture in general and rice production in particular. About the same time, major irrigation works were undertaken to expand the area for wet rice cultivation.

In the 1920s and 1930s, scientifically managed European estate agriculture flourished and supplied 60% of total agricultural export value whilst utilizing only 7% of the cultivated area (Metcalf, 1952). The latest technical innovations were adopted, yields were high, and sizable profits were accumulated in good years. However, the system lacked flexibility, for it was highly dependent on the conjunctural cycles of world trade and general prosperity (Feuilleteau de Bruyn, 1941). Smallholders' agriculture, which came up in the wake of estate agriculture, lacked resources but could react more flexibly. At the time of low prices the smallholders moved away from their export crops, which they interplanted with food crops till conditions changed again.

The gross national income of the Dutch East Indies in 1939 was an estimated 1.6 billion US$[1]. Of this GDP 70% went to Indonesians, who constituted 97% of the population, and 30% was either earned by resident foreigners or by overseas stockholders. At that time, Indonesian per caput income was about 20 US$/y, which tallied with the prevailing pattern of subsistence farming and the concealed unemployment all over the islands. Pricing policies for rice and major food crops played an important role in the development of indigenous agriculture throughout the 20th century. However, food price policy and the rice market fall outside the scope of this study.

After World War II, agricultural policy focused entirely on rice production (Anonymous, 1991). Only after 1980, more emphasis was placed on production of secondary food crops. After Independence, Indonesia's research and extension suffered for decades from lack of skilled manpower, funding and facilities. After 1975 research was drastically reorganized and improved. Presently, the Indonesian government aims at an accelerated development of other sectors of the economy,

Table 2.1. Population and growth rates of Indonesia, 1880-1990 Sources: Booth, 1988; World Bank (1994); Central Bureau for Statistics, population census reports, 1961 and 1990.

Island	Population (million)			
	1815	**1930**	**1961**	**1990**
Java	10	42	63	108
Sumatera	-	8	16	37
Kalimantan	-	2	4	9
Sulawesi	-	4	7	13
Outer Islands	-	4	7	14
Indonesia	-	60	97	181

such as manufacturing, trade and public services, to solve the problem of rural poverty and under-employment. Agriculture's share in employment decreased from over 75% in 1900 to less to about 50% in 1990. Indonesia remains a low-income country and some 50 million people still live in absolute poverty, but it has great potential as most of the younger Indonesians received adequate education.

2.2. Early history

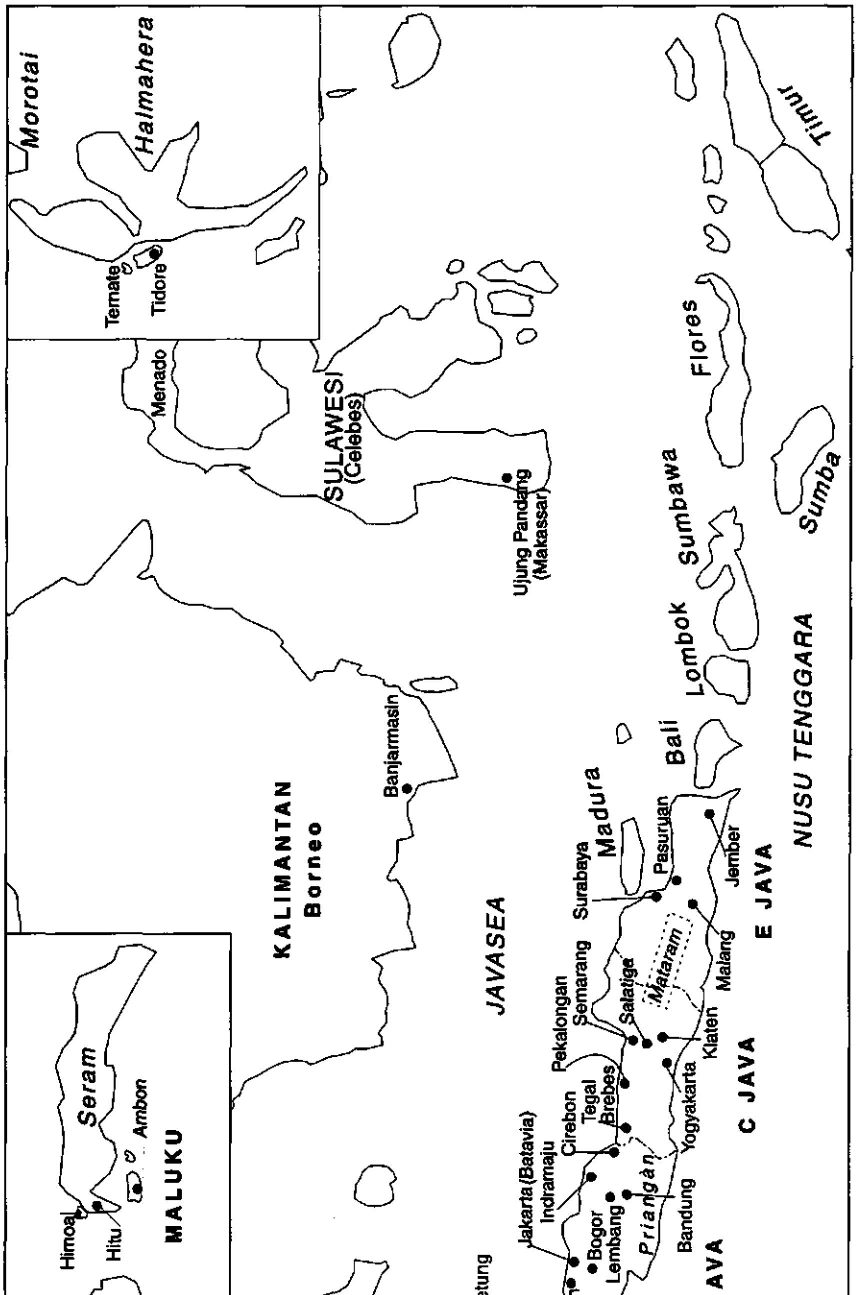
The early development of Indonesia can only be understood against the background of maritime trade and Indonesia's position along the ancient trade routes between the highly developed civilisations of India and China. Many early immigrants followed sea-lanes or passed ancient landbridges which once must have connected the Indonesian archipelago with the Asian continent. Possibly during the fourth millennium B.C. the ancestors of the Malays now inhabiting Java and Sumatera arrived. By the first millennium small communities had formed which engaged in food gathering or growing rice, bananas, leafy vegetables and root crops such *Diascorea* and *Colocasia* spp (taro).

In Indonesia with its complex geographical structure not all ethnical groups reached the same technical level at the same time. Many had developed their distinctive pattern of social and cultural life and early forms of government (Fonteyn, 1992). Early in the fourth century A.D., some Indonesian principalities came into contact with new ideas and techniques from the higher developed civilisations of India. Since the basis of an authentic culture had been developed, these principalities reacted with an astonishingly creative response to the Indian influence.

The first important Indonesian principality, Sriwijaya, had its centre in the area of today's Palembang, S Sumatera. Sriwijaya was governed by the powerful Sailendra dynasty which extended its influence over the Indo-Malay archipelago. During the eighth century, the Buddhist Sailendra dynasty ruled over Java where great architectural activity was developed over the next two centuries. Between 730 and 930 A.D., the Javanese built large temple complexes such as Candi Kalasan and Borobudur and hundreds of smaller temples. At about 860, the Sailendra lost control of Central Java to a dynasty from East Java called Mataram, which left its mark in the Hindu temple complex of Prambanan. The Sailendras withdrew to their maritime powerbase Sriwijaya in Sumatera (Map 2.2).

During the 13th century the last Hindu-Javanese kingdom of Majapahit gained overlordship over many of the archipelago's principalities but that kingdom lasted barely a century. The Majapahit's way of administration, which introduced a system of levies in produce and labour to be supplied by the villages to their lords instead of paying taxes, continued well into the 19th century (Palmier, 1965). Palmier distinguished two types of political power. Sriwijaya as a maritime power controlled shipping lanes and ports, whereas Majapahit as an agrarian power organized the labour force of a relatively compact population.

Probably in the 14th century, improved means of transportation brought an increasing number of traders from India and Persia to the Indonesian islands to buy pepper, spices, precious wood and other produce before going on to China. Merchants from Gujarat in NW India brought the Islam which may have been



Map 2.2. Indonesia (See also page 61: Malaysia and Sumatera)

adopted by certain coastal princes to counter the threat of the Portuguese who brought christianity. The first important Islamic state was Melaka in Peninsular Malaya. In the 15th century, Islam spread gradually over Sumatera and Java and finally reached the Maluku archipelago. Inner Indonesia (consisting of most of Java, Madura, S Bali and W Lombok) and Outer Indonesia (consisting of SW Java and the other islands) were characterized by different agro-ecosystems. In Inner Indonesia, lowland agriculture was predominant whilst swidden cultivation closely related to the tropical forest ecosystem characterized Outer Islands. Depending on soil fertility, village societies left the stage of subsistence farming and became involved in barter trading, first at local and later at regional level.

For instance, on the Maluku islands the staple food sago was gathered from surrounding islands such as Seram and Papua New Guinea. Spices, growing in the wild in N Moluku, were gathered for export. When traders introduced clove and nutmeg as barter goods to the Ambonese islands, the planting of clove trees there marked a transition to more permanent land use, improved purchasing power, and higher population growth. As clove cultivation competes with food crops in terms of arable land and labour, a need arose to import sago from Seram and rice from Java. Between 1450 and 1520, groups of immigrants arrived in Maluku from Java and Sulawesi as the trade network extended. A lively regional maritime trade evolved which attracted ever more merchants from far away.

2.3. Arrival of European contenders in Indonesia

2.3.1. The Portuguese and the English. Early in the sixteenth century a Portuguese fleet sailed to E Asia in search of the wealth of the spice lands. Vasco da Gama reached the coast of India in 1498. In 1509, the Portuguese conquered the important port of Goa in India and two years later the Muslim stronghold Melaka. From that port they directed their ships to the Moluku archipelago, the source of spices. In the second half of the sixteenth century the Spaniards had reached the Philippines sailing the Pacific from S America. From the Philippines, the Spaniards fought the Portuguese and the Maluku sultans to obtain a share of the spice trade.

Around 1580, an English squadron under Francis Drake passed through Indonesian waters on his westward circumnavigation of the world. Drake stopped at Ternate and took home a cargo of clove. Thereupon, the English, as the Dutch, wanted to be directly involved in the spice trade. In 1600, Queen Elizabeth I granted a charter to the English East India Company (EIC) and the English advance in Asia began. In 1604, the second EIC voyage under Commander H. Middleton reached Maluku. No contender could achieve the monopoly of the spice trade as too many strong parties had entered the scene (Palmier, 1965).

2.3.2. The Dutch. Towards the end of the 16h century, Dutch seamen who had sailed to the East on Portuguese vessels became acquainted with the sea routes and the lucrative trade opportunities. Enterprising merchants in Holland equipped fleets of which one squadron under the command of Cornelis de Houtman arrived in Lampung, S Sumatera, in June, 1596. The mission failed and the battered ships returned home after eight months without reaching the Maluku spice islands (Lubis, 1979). In 1598, another Dutch expedition reached Ambon and sailed home with a rich cargo of spices[2]. The success triggered a rage in Holland in establishing companies for the spice trade which soon created fierce competition. In 1602, the United Dutch East India Company (*Generale Vereenichde Geoctroyeerde Oost-Indische Compagnie, VOC*) was founded by a merger of the competing companies.

The first *VOC* foothold in Indonesia was the island of Ambon (Amboina), occupied in 1605 (Palmier, 1965). In 1609, the Board of Directors (*Heeren XVII*) of the *VOC* established the post of Governor-General[3] to direct the affairs in Asia. At that time, Java was largely governed by the powerful Muslim dynasty of Mataram in C Java. The only serious opponent of Mataram was the Muslim port-state of Banten which controlled the Sunda Strait of W Java. Continuous hostility of Banten in the west and Mataram in the east, inevitably drew the *VOC* under the Governor-General J.P. Coen into armed confrontation which disrupted agriculture and cut off the supply of rice to the *VOC* (Ricklefs, 1981). Without strong opposition on the seas and by alliance with the weaker parties in the continuous wars on Java, the *VOC* gradually succeeded in outmanoeuvering the European and local powers and controlling the network of sea routes with Batavia as the centre of power (Palmier, 1965). Throughout its operation in the Indonesian archipelago the *VOC* pursued the goal of establishing strategical strongholds and trading posts (factories, *faktorijen*) from where it could dominate the lucrative maritime trade between Europe and the Far East. By the middle of the 17th century, after Melaka fell to the Dutch, the *VOC* became master of the shipping lanes from India to Japan.

Initially, the *VOC* limited its interest in agriculture to safeguarding the supply of food to its personnel and ships, which was mainly achieved through the exaction of tribute in cash, produce and labour for public works from submitted or allied rulers. The Company's next objective was the acquisition of agricultural produce for export at the lowest possible price. According to an agreement concluded in 1678 between Mataram and the *VOC*, by which almost the entire Priangan was ceded to the Company, Javanese peasants were forced to sell their rice to the *VOC*. Ten years later, the *VOC* demanded exclusive loyalty from the Priangan heads who had to pay tribute in kind. When the *VOC* derived less profit from trade, it used its newly gained political power to dominate the spice trade and to exact levies *in natura* such as spices, coffee, sugar and rice.

2.3.3. Agricultural commodity trade under the VOC. Commodities which were particularly attractive for the *VOC* were cloves, coffee and cane sugar.

2.3.3.1. Cloves. The clove tree[4] (*Syzygium aromaticum*) was introduced to the Seramese Island of Himoal around 1510 and from there in the following twenty years to the Ambonese Islands. By 1560, the Islands of Maluku produced more than 74 tonnes of cloves (Deinum, 1948). From 1600 onwards, the *VOC* tried to obtain the monopoly of the clove and nutmeg trade by concluding contracts, but not at fixed prices, which led to strong competition with the English East India Company and with Asian traders[5].

A monopoly[6] was effectively enforced in 1656 and was terminated in 1864 only. Forced planting of clove trees on Ambon increased production rapidly, but after its highest level in the period 1700-05 the *VOC* ordered limitation of production. After 1800, when the Dutch East Indies government had taken over the monopoly from the Company, the government added directives on cultivation (*teeltvoorschriften*) to the planting orders and increased the price as an incentive for improving clove production (Taale, 1988).

2.3.3.2. Coffee. In the beginning of the eighteenth century the heads of the *Faktorijen* in their search for export commodities began to pay more attention to local production. In the area surrounding Batavia, the *VOC* encouraged agriculture by issuing land and draft cattle for ploughing and by granting freedom from taxation. In 1696, the Company brought the first seedlings of *Coffea arabica* from India to be planted in W Java. Production took off only when coffee was planted in Priangan, the mountainous region of SW Java. In the Priangan regencies, the local authorities, called regents (*bupati*), had enforced the planting so that they could meet the levies in kind demanded by the company. This separate arrangement[7] for taxation in coffee became known as the Priangan Scheme (*Preanger Stelsel*) (Mansvelt & Creuzberg, 1975). For a long time Priangan, and the higher parts of Cirebon and Pekalongan were by far the most important coffee producing regions of Indonesia.

Because of growing demand[8], the *VOC* in the 1720s began to enforce the planting of coffee on newly opened hillsides (growing coffee on `high authority') which caused an overproduction of some 6,000 tonnes by 1724 already. Through manipulation of the purchasing price for coffee[9], compulsory planting, extirpation orders and requiring tributes to be delivered in coffee, the *VOC* tried unsuccessfully to match supply and demand throughout the 18th century. Only in the later part of the 18th century, the *VOC* took steps to intensify the cultivation through the appointment of an Inspector of Cultivation and of European overseers to assist the regents in organizing the production and the maintenance of the coffee gardens (van Hall, 1939).

2.3.3.3. Sugar. Sugarcane was one of the earliest estate crops in Indonesia grown by Chinese and European farmers in the `private' lands S of Batavia and along the N coast of Java from the beginning of the 17th century. Some 50 years later, specialized cane sugar cultivation existed in several parts of W, C and E Java. *VOC* regulations mentioned the existence of 99 sugar mills by 1750 (Deinum, 1948). Sugar production for export remained small until the beginning of the 19th century as the product was too cheap in relation to its bulk to be paying for transportation overseas by sailing vessels (Mansvelt & Creuzberg, 1975).

2.3.4. Decline of the *VOC*. Under the *VOC* administration the Dutch had achieved control over coastal areas of Java and Maluku. They had penetrated into the interior of Java and succeeded in splitting the kingdom of Mataram into insignificant states, but their authority remained marginal. Meanwhile the Company's policy of forced levies was bringing steady impoverishment in Java and Maluku which ruined the economy and destabilized the native states. Outside Java, the Dutch barely controlled the important ports of Ternate, Menado, Makassar and Palembang. In Sumatera, Aceh's might had declined after the Company broke its control of the pepper trade around 1680.

Towards the end of the 18th century the political situation in Europe greatly influenced the balance of power in the Indonesian-Malayan archipelago. The Netherlands were drawn into their fourth maritime war with England (1780-84) so that the *VOC* in Batavia was isolated from its homeland. Following defeat in 1784, the Dutch were forced to cede the *VOC* possessions in India and Ceylon to England and to allow the English free trade on Ambon. During the 1790s, when the *VOC* had to request for financial support from the Netherlands, the government ordered an investigation of the Company's affairs. The investigation revealed scandal and mismanagement[10] in all quarters of the *VOC* and a state of acute bankruptcy. The Board of the *VOC* was dismissed in 1796 and the Company itself formally dissolved on 1 January 1800. The government of the Netherlands took possession of all the Company's[11] territories and rights. There was little immediate change in Indonesia, for the personnel remained in function and persued its old ways (Ricklefs, 1981).

2.3.5. Dutch and British administration between 1800 and 1816. In 1795, France invaded the Netherlands[12] and the Dutch stadtholder William V fled to England. From there he issued, in 1795, instructions (known as the 'Kew letters') to the Dutch colonial officials to surrender their territories in Indonesia to the English, to keep them out of French hands[13]. In the following years, the English used this authority as a pretext to attack *VOC* ships and to invade Java (Collins, 1966; Ricklefs, 1981).

In 1807, the French-dominated Dutch government under King Louis Napoleon appointed General H.W. Daendels, a Dutch aristocrat with a great interest in agriculture, as the Governor-General. In spite of British blockades, Deandels reached Batavia whereby the East Indies came under direct control of the Dutch government. Daendels put the entangled administration in order, began to build fortifications in Banten and constructed a 1,000 km post-road along the N coast. According to instructions received in 1808, Daendels continued the *VOC* policy of enforced cultivation of rice, sugar and coffee in W Java and of pepper in S Sumatera in a harsh way. Daendels new policy was not to treat the Javanese aristocracy as lords over their society, but as officials of the European administration with reduced power and income. Such exertion of sovereignty offended the Javanese kings and was the cause of many conflicts which sparked off the Java War (Ricklefs, 1981). Following the example set by the *VOC*, which sold land and even villages to Chinese merchants to remedy its budget deficit[14], Daendels sold large tracts of communal land to private European and Chinese entrepreneurs.

In 1810, a British fleet took the islands of Maluku, Banda and Ternate. In August, 1811, the Britsh conquered Jakarta and easily defeated the Dutch colonial forces defending Java. Soon, the Dutch colonial government capitulated and the English administered Indonesia for five years. Thomas S. Raffles succeeded

Daendels as Lieutenant-Governor from 1811-16 (Collins, 1966; Ricklefs, 1981). Raffles abandoned the system of enforced planting and product levies and replaced it by a system of land rent[15]. Factually, the English administration could not do without the income from product levies. When in 1816, the Dutch resumed power, little was maintained of the English reforms.

2.4. Agriculture in the Dutch East Indies between 1816 and 1870

2.4.1. Restoration of the Dutch administration. After the defeat of the French Emperor Napoleon[16], the Netherlands were liberated from French occupation and King William I ascended the throne. The Dutch resumed the administration over the colony which, till Independence in 1945, was referred to as the Dutch East Indies. The return of the Dutch was met with fierce resistance throughout the archipelago. The sultan pretender of Jogyakarta, Prince Dipa Negara, waged war on the Dutch after obtaining the support of many Javanese sultans and aristocrats and the people of Madura. The savage Java War[17] broke out in 1825 and ended in 1830 with the arrest of Dipa Nigara by the Dutch General de Kock during cease-fire negotiations.

On Sumatera, between 1818 and 1825, reinstatement of the Dutch administration required several military expeditions to Bangka and Palembang. The unrest was fuelled by Raffles who sought to maintain England's hold on Padang and Bangkulu. The defeat of the sultans by the Dutch forces signalled the end of the Sultanate of Palembang (Woelders, 1921). On the W coast, in the Minangkabau districts, Dutch expansionism clashed violently with the first major Islamic revival movement in 1819. The Padri war, which coincided with the Java war (1825-1830), lasted from 1821-38 due to strong support from Aceh to the Padris (Ricklefs, 1981).

2.4.2. The *Cultuurstelsel*. By 1830, the Dutch had achieved political dominance throughout Java. For the first time, they were in a position to exploit and control the whole island, and to try to make their involvement profitable. Profit from Java was essential because the state of public finance and private enterprise in the Netherlands East Indies had become desperate. A global economic depression, that began in 1819 in the aftermath of the Napoleonic Wars in Europe, caused a fall in prices of agricultural commodities, in particular of coffee. Not only had the colonial government to incur additional debts[18] in order to pay for the military expeditions on Sumatera and Java, but also the total value of the exports declined from 15.25 M NGL in 1825 to 6.4 M NGL in 1830. In the Netherlands, already impoverished by the French occupation, the economic situation further deteriorated when the Dutch-Belgian Union, created by the Congress of Vienna in 1815, collapsed in the Belgian revolt of 1830. In 1839, the Netherlands had to recognize the independence of Belgium, and thereby lost the more industrialized southern part of its territory (Ricklefs, 1981).

The Netherlands Government ordered L.P.J. (*burggraaf*) du Bus de Ghisignies, Commissioner-General from 1826 to 1830, to collect locally the means to pay for both inland expenses and contributions to the national income of the Netherlands (Reinsma, 1955). Various proposals[19] for Java were considered, all sharing a general aim of somehow procuring tropical produce at the right volume and price to make a profit. Cash crops such as `Java' coffee (*C. arabica*), tea, indigo, pepper, kapok, gambir, areca, sugar and tobacco showed promise but could not be collected in sufficient quantities[20]. The objectives were clear. The colonial government should meet its own expenses, repay debts to the Netherlands and, at the same time, create local purchasing power to increase the market for Dutch produce such as textiles (Mansvelt & Creuzberg, 1975).

To make the colony pay its way, Count J. van den Bosch, Counsellor to King William I, in 1829 designed a clever compulsory cultivation system, the so-called *cultuurstelsel* based on the following principle. The Javanese villages owed a land tax[21] (*landrente*) to the government, normally calculated as 40% of the villages' main crop, usually rice. As the land tax could not be collected from individual peasants, it was imposed on the villages and the local authorities were made responsible for the collection. Because of inadequate administrative resources and shortage of coins, the local administration, from the beginning, had to accept payment of taxes in kind. The supervision over the payment of the forced levies was entrusted to European civil administrators (Ricklefs, 1981).

Van den Bosch proposed that each village should set aside part of its land to produce export crops - especially coffee, sugar and indigo - for sale at fixed prices to the colonial government. Van den Bosch estimated that the produce of 1/5 of the sawah, calculated at a labour input of 66 days per ha per year (Fasseur, 1977), would suffice to cover the village's land tax commitment. For the village there should be a trade-off between payment of land tax based on rice production and acquiring a cash income from sales of export crops to the government. Instead of an uncertain land tax revenue the government would acquire tropical produce so cheaply that it could compete on the world market. The produce would be shipped to Europe by the Netherlands Trading Company (*NHM: Nederlandsche Handel-Maatschappij*). This company was set up in 1824 upon the King's initiative with the objective of breaking English and American dominance of shipping in the Malay-Indonesian area and bringing transportation revenues to the Netherlands. King William I accepted van den Bosch's proposal and appointed him as the Governor-General (1830-33).

In practice, there were wide variations in the application of van den Bosch's ideas from one area to another on Java. His concept of benefit for all turned into one of the more purely exploitative episodes of colonial history. Local officials, both Dutch and Indonesians, set both the land tax assessment and the level of crop production for each village, then compelled the village to produce. Crop payments substantially increased the amount of cash in circulation and the specialisation of labour. As the payment for the crop rose, officials used this as a justification to increase land tax assessment, so that much of the extra crop payment flowed back into the hands of the government. The *cultuurstelsel* developed into forced delivery (*dwangcultuur*) of export crops to the government, rather similar to the system which the *VOC* had imposed for coffee deliveries in Priangan in the 18th century. In 1826, the colonial government made a credit of 1 M NGL available to initiate sugar production on high authority[22] by large plantations (Mansvelt & Creuzberg, 1975).

The officials, both Dutch and Indonesian, who had to implement the new scheme, were paid percentages on crop deliveries. The aristocratic elite throughout Java made great profits through the percentage money, their position became more secure and hereditary succession to official posts became the norm. The percentage allowance made them, however, directly dependent upon Dutch rule for their position and income, and unloved by their subjects as they had to organize the coercion needed for the *cultuurstelsel* to function. The allowance became a source of corruption and abuse and a stimulus to extortionate demands upon the villages.

As a system of land exploitation the *cultuurstelsel* covered only a small percentage of total arable land on Java. Excluding areas for coffee grown on land not suitable for rice, only 6% of cultivated land was involved in 1840. There were major regional variations, but the highest official figures were for Bangelen and Pekalongan, where 15% of the land was committed to government crops in 1840. The investment of Javanese and Sundanese labour was massive. Fasseur (1977) calculated that in all of Java 57% of the labour force was involved in production of government crops in 1840 (Ricklefs, 1981). Van Niel (1968) concluded for the period of 1837-51 that over 70% of farmer families were producing export crops, over half of them coffee.

The results of the *cultuurstelsel* for the Dutch were obvious. The system led to a dramatic acceleration in the production of export crops on Java so that, at long last, steady and immense profitability was achieved. By 1831, the colonial budget was balanced, and thereafter the old debts of the *VOC* were paid off and enormous remittances were sent to the Netherlands. The impact of the *cultuurstelsel* on the welfare of the peasantry became visible during the 1840s. Signs of hardship among the Javanese and Sundanese began to appear, rice production showed a continuous decline while prices rose sharply. The situation worsened when the colonial government further increased the land tax and other impositions to meet financial crises occurring in the Netherlands Trading Company and the Java budget. An ensuing mass flight from villages led to even more rice land falling out of production. The expansion of the *cultuurstelsel* had reached its limits. Between 1845-50 exports of coffee, indigo and sugar decreased.

Opposition to the *cultuurstelsel* now grew in the Netherlands (Reinsma, 1955). The Dutch government began to doubt whether the system was still tenable, despite its renewed profitability. In 1848, a liberal constitution gave the Dutch Parliament (States-General) a position of influence in colonial affairs. Fasseur (1980) observed that the liberal criticism increased just at the time when the *cultuurstelsel* accumulated more revenue for the Dutch treasury than at any time before. This explains why the liquidation of the *cultuurstelsel* took so much political fighting.

The result of the debate in the Netherlands was the piecemeal dismantling of the *cultuurstelsel* throughout the Netherlands East Indies. The first to go were the least profitable crops, pepper in 1862, clove and nutmeg in 1864, indigo, tea and cinnamon in 1865, and tobacco in 1866. After 1850, profits from coffee and sugar[23] rose sharply as the world prices of these commodities went up. Coffee and sugar contributed 96 per cent of total profits of the *cultuurstelsel* between 1850 and 1860 (Fasseur, 1977) and they were the last to be abolished. The Sugar Law of 1870 decreed that the government withdraw from sugar cultivation over 12 years[24], beginning in 1878. Coffee cultivation on high authority, retained in a much less rigid form, was abolished slowly from the 1870s. It finally came to an end in Priangan - where it had begun a hundred years earlier - in 1917, and along the N coast of Java in 1919 (Ricklefs, 1981).

2.4.3. The rise of private estate agriculture. In the first decade of the 19th century, under Governor-General Deandels, large tracks of communal land had already been sold to Chinese and European planters. By 1811, it had become common practice for apanaged[25] persons in the Principalities of C Java to lease large complexes of their alloted land to Western entrepreneurs, and to supply them with labour: the so-called *Vorstenlandsche Huurlanden* or `Principality Leaseholds'. Apanaged persons saw the advantage of letting extensive sections of their land for the purpose of cultivating commercial crops on plantations (Mansvelt & Creuzberg, 1975). Thus around 1835, quite a number of coffee plantations were operated by private enterprise on rented and private lands. From 1856 onwards, lands outside the sultanates of C Java were rented out, 30,000 ha being let by 1870.

Several government imposed cultures could only exist through the collaboration of private enterprise. In the case of sugarcane, for example, after several failures with sugar factories under government control, the processing of cane was contracted to private entrepreneurs who built the installations to produce sugar. Usually, the government provided interest-free advances[26] for the construction and installation of sugar factories, which had to be repaid in the form of processed produce[27]. Aided in this way by public establishment and harvest credits the sugarcane contractors accumulated a great deal of experience in large-scale agriculture. When the Government regime began to loosen its hold in the 1850s and when after 1856 wasteland could be let to large agricultural enterprises, the sugar contractors endeavoured to develop new, non-sugar enterprises such as tobacco and tea (Koningsberger, 1948).

The year 1870, in which the `Agrarian Legislation' was enacted, marks the beginning of the plantation industry. The Act enabled to contract long leases[28] on uncultivated land for the purposes of estate agriculture. The upland estates planted coffee, tea, cinchona and cassava on land that had been newly opened up. The lowland plantations grew sugarcane, cocao and tobacco. According to the Sugar Act, the sugar industry was handed over to private contractors in steps from 1870 to 1891 (Reinsma, 1955).

In the 19th century it was mainly Java where the large agricultural enterprises grew up (Wormser, 1942). By 1860, private and government exports from all over the Netherlands East Indies were roughly equal in value, but by 1885 private exports were ten times those of the government. The number of European civilians in Java increased rapidly, from 17,285 in 1852 to 62,477 in 1900 (Ricklefs, 1981).

2.4.4. The state of indigenous agriculture (*bevolkingscultuur*). In the 1850s, the plight of the rice farmers in the irrigated areas under the *Cultuurstelsel* had become quite unbearable. Inspector of Cultures H. van der Poel (1864) noted that seed beds and *sawahs* were poorly irrigated and tilled and weeds little controlled. The seed was of inferior quality and seedlings were transplanted much too early and too close. The best rice lands were requisitioned for growing sugarcane, indigo and tobacco. The time required for maturation and harvesting of the sugarcane, and the competition for irrigation water, made it difficult to achieve a steady rotation with rice. Rice shortages appeared, and the price of rice fluctuated widely. The people were exposed to frequent natural disasters such as inundations, prolonged droughts and pests which made total crop failure a common phenomenon. Serious incidences of famine and epidemics diseases ravaged C Java, particularly in the residencies Cirebon and Semarang (regencies Grobogan and Demak[29]) (de Bruijn, 1869). Between 1847-64, the Department of Internal Affairs dispatched numerous directives[30] to the local administrators for the improvement of rice cultivation. Some socially-minded civil administrators[31] and planters advocated extension and technical assistance. The planter K.F. Holle[32] wrote various instructional leaflets on rice cultivation and edited a periodical 'The friend of the Javanese farmer'.

The colonial administration began to adjust its policy on indigenous agriculture (Löhnis, 1895). In 1866, the obligation of storing rice seed in communal stores was terminated in view of common corruption, theft and seed spoilage. Farmers stored and traded their own seed for better quality. In the 1870s, several commissions were installed for the improvement of rice production. In 1873, Chief Inspector of Cultures J.H.F. Sollewijn Gelpke (1874) was sent to Italy to study modern rice cultivation. From 1877 onwards, experiments were undertaken with introduced other crops such as groundnut, cassava, soybean and some European vegetables. Sollewijn Gelpke (1874) noted that the area planted to rice and non-rice food crops (*palawija*) was underestimated. In the uplands, *palawija* and garden production was more important than rice. In 1882, the number of inspectors was doubled to demonstrate single grain and row seeding of rice. In 1886, the colonial government sanctioned field demonstrations for farmers on account of the public budget.

2.5. Scientific development in agriculture between 1870 and 1945

2.5.1. The beginning of agricultural research. The founding, in 1817, of the government's Botanical Gardens (*'s Lands Plantentuin*) at Bogor[33] by C.G. Reinwardt[34] can be viewed as the beginning of agricultural research in Indonesia (Koningsberger, 1917). Although its objective was the collection[35] and study of useful and scientifically interesting plants, the scientists at the botanical garden initially had no eye for practical issues in farming. These were left to local civil administrators (*Binnenlandsch Bestuur*), who were explicitly given the task of supervising the cultivation of food crops in 1847[36]. During the years 1837-44, the garden's living collections were replanted and arranged in strict systematical order. In the 1850s, the collection was expanded with food and commercial crops. In 1868, under its second director, R.H.C. Scheffer, the *Plantentuin* became an independent institution. More scientists were employed and the laboratory and garden facilities were extended (Treub 1892; Koningsberger, 1917).

In 1876, as the oldest part of the Agricultural Research Institution at Bogor, the economic gardens (*cultuurtuin*) were established for testing of newly introduced species and varieties of rice, coffee, cocoa, rubber and shade trees (e.g. *Albizia* and *Eucalyptus*). In 1876, an Agricultural School was opened in the *Cultuurtuin*, which had separate divisions for Indonesian and European students (Treub, 1892, 1899).

After 1880, when Melchior Treub[37] was appointed Director of the *Plantentuin*, the application of science to crop production developed rapidly (Anonymus, 1954). When, in 1880, Treub started the search for the causal agent of *sereh*, a devastating disease of sugarcane, the emphasis of the research changed from taxonomical work to practical cultivation problems[38]. Treub never identified the causal agent, but his way of addressing the problem led to much development work in sugarcane and great results later on. In 1883, a zoologist began to study insects and an agronomist investigated the diseases of Deli tobacco (Koningsberger, 1895, 1898, 1903; Zehntner, 1903; Dammerman, 1918, 1919).

In 1884, the Foreigners' Laboratory of the *Plantentuin* was founded as the first botanical station in the tropics. Between 1883 and 1935 this Bogor station accommodated more than 250 visiting scientists. Initially, there were but few Dutch scientists[39] among them, because in the Netherlands research was not encouraged for lack of interest and doubt about its usefulness to society. It is Treub's foresight and merit to involve the *Plantentuin* in the development of biological science at large (Treub 1899).

In 1890, a Laboratory for Soil Research and a 'Botanical Laboratories' department were added to the *Plantentuin*, the latter for the study of the ecology and anatomy of tropical economic plants and their diseases. Since the emphasis was on plant diseases the botanical laboratory was often referred to as the Phytopathological Laboratory (Dammerman, 1919, Mededeelingen, 1915). In 1901, a new Zoological Museum was built and, in 1903, a Museum for Technical and Commercial Botany. About the same time an agro-chemical laboratory was erected, the Pharmacological (later Phytochemical) Laboratory. In 1910 a separate Department for Plant Pathology was instituted, so that the botanical laboratories could henceforth be used for general botanical studies (Mededeelingen 1-35, 1912-18). In 1914, a new foreigners' laboratory, named 'Treub Laboratory' in honour of the famous Dutch scientist, was funded by former visiting scientists (Koningsberger, 1917).

2.5.2. Private research stations. The institution of the Agrarian Law, and of the Long Lease Ordinance in particular, caused a rapid development of estates, mostly owner-operated. Regional planters' associations were created, the first in 1881. Apart from engaging in social activities, the associations discussed technical problems. Soon, the regional associations held annual or bi-annual meetings which, amongst others, invited scientists to give their views on important problems. Proceedings were printed and circulated and it was not long before certain associations pooled resources to employ one or more scientists. The estate owners frequently consulted the *Plantentuin* institutions, in particular the agro-chemical and botanical laboratories, for technical advice.

In 1881, the Java sugar industry was endangered by the *sereh* disease of cane, and by low sugar prices due to heavy competition from the European beet sugar industry. The sugarcane planters decided to finance research on the cause of *sereh* and on the improvement of sugar quality. They founded three private sugar research stations in Tegal, W Java (1885), Semarang, C Java, (1886) and Pasuruan, E Java (1987). The three stations collaborated ever more on solving disease and resistance problems. In 1925, two stations remained which were merged into the Central Association for Sugar Research with a chemical-technical department in Pekalongan, W Java, and a Cultivation department in Pasuruan, E Java. The latter became the Central Research Centre for the Java Sugar Industry at Pasuruan, E Java (Koningsberger, 1948; Hadiwigoeno, 1985; Handojo *et al.*, 1987).

In the 1890s, Treub became convinced that the other planters' associations should also establish private research centres. Treub wanted each commodity group to organize the funding needed to operate its own research station within the fold of a future Department of Agriculture[40]. Treub argued that a period of preparation would be needed to make the transition from a centralized research and extension capacity at Bogor to independent centres[41]. The colonial government authorized Treub to employ for the time being scientists who, although being paid by private organizations, would work under his supervision (Koningsberger, 1917).

The tea industry was the first to make an agreement with Bogor for chemical research. The tobacco planters from Deli, who struggled with a persistent seedling disease[42] in the nurseries, were second to found, in 1896, a private research station in cooperation with Treub. The *Plantentuin* pathologist J. van Breda de Haan was appointed director of the Tobacco Experiment Station of the Deli Planters' Association (*Deli Planters Vereeniging, DPV*) at Medan (Jochems *et al.*, 1931; Modderman *et al.*,1929). The third semi-private institution was the zoological research laboratory at Bogor, established in 1894, for which the funding was provided by banks and other institutions with interests in the sugar and coffee industries (Koningsberger, 1917).

Around the turn of the century an experimental station (*proefstation*) was set up for each export commodity crop, often as a result of cooperation with the Bogor institutions in the 1890s. Research stations for coffee and cacao at Salatiga (1901), tea in Bogor (1902), tobacco in Klaten (1907), coffee in Malang (1910), tobacco in Jember (1911), rubber in Bogor and Medan (1916). Apart from the internationally renown Deli Tobacco Research Station and the Rubber Research Station[43] at Medan, N Sumatera, the development of the private research institutes generally was a turbulent process. The main cause of the turbulence was that employed staff were usually scientists with little experience in the very practical issues plantation managers were interested in, such as land preparation, seeding, fertilising, combatting diseases, and processing. It took until the 1920s before the stations had established a balance between fundamental research and more practical extension-like activities. As long as it was unclear what members would get for their money, many of the smaller owner-operated plantations did not join the research associations (Van der Eng, 1993).

Each *proefstation* had its *Proefstation Vereeniging*, the association of estate owners providing the funds. Most private research stations remained very small, their staff not numbering more than ten senior scientists even in the 1920s. The Sugar Research Institute was the biggest with 35 European staff at Pasuruan, 15 more at regional centres and about 200 Indonesian staff in charge of the POJ field experiments (Handojo *et al.*, 1987; Pawirosemadi & Wirioatmodjo, 1986)

2.5.3. Establishment of the Department of Agriculture. At the end of the 19th century, over 75% of the labour force was entirely dependent on indigenous agriculture for its income. Indigenous agriculture was, in spite of its indispensable stabilizing influence on the Netherlands East Indies' society as the producer of major food crops, very much neglected. A comparable situation existed in the Netherlands, where the society became concerned about the standard of living of the farmers. During the 1890s, greater efforts on agricultural research, education and extension began to yield promising results for the Dutch farmers. This increased interest in the possibility of furthering peasant agriculture in the Dutch East Indies too through systematic research and through extension by means of demonstration fields. When Treub advanced his initiatives for a Department of Agriculture, there was a dearth of fundamental knowledge on many aspects of indigenous agriculture. There was a need for research in all directions, such as on pests, diseases, soil fertility, crop varieties and physiology. Treub was convinced that varietal selection and field experimentation could not be entrusted to farmers (Treub 1899, 1902). Farmers could neither bear the risk of crop failures nor could they sufficiently control the variables to obtain meaningful test results (Van der Eng, 1993).

On January 1st, 1905[44], the Department of Agriculture (DoA) was established and Melchior Treub was appointed as the first Director (Box 2.5.3). DoA's foremost task was the improvement of indigenous agriculture, animal husbandry and fisheries. Between 1905-10, the *Plantentuin* institutions[45], which before had worked primarily for the large estate crops, served as the core of the Department. In the following years, sections of other departments were transferred to DoA, such as agricultural education and the Veterinary Service from the Department of Education, and the sections for government coffee and cinchona plantations from the Department of Internal Affairs (Treub, 1902; Bernard, 1930).

New research institutes were founded, among which the Experiment Station for Rice and Second Food Crops (*Proefstation voor Rijst en Tweede Gewassen*) in 1907. Agricultural extension remained the responsibility of the local civil administration[46]. It was, however, Treub's conviction that the result of research should be brought to the farmers through a network of demonstration fields rather than directly via extension (Treub, 1910).

Treub stepped down as Director of Agriculture in 1909. His successor, H.J. Lovink[47], had more practical ideas about the working of DoA. He favoured direct contacts with farmers so that researchers and extension would gather field experience (Bernard, 1930). In 1910, Lovink upgraded DoA's section in charge of the demonstration fields to Agricultural Extension Service and expanded the tasks of the department. The *Plantentuin* institutions were re-assigned to fundamental research,

Box 2.5.3

Treub's initiatives for a Department of Agriculture

In 1899 Melchior Treub, director of the *Plantentuin* since 1880, pleaded for the establishment of a separate Department of Agriculture (DoA). The Departments of Agriculture, Industry and Trade and of Cultures had administrated the sector, but they had little technical expertise and had no voice in the planning of irrigation projects. Treub contended that the local civil administration (*Binnenlandsch Bestuur*) had no capacity to improve farm agriculture. Treub (1902) proposed an organisation modelled after the DoA of the United States of America. The American department was organized as a technical institute with a strong basis in agricultural research, and without much involvement in administrative work. In Germany and England, a DoA had predominantly an administrative task and, at the most, technical control over experimental stations and data collecting institutions. Scientific research was taken care of by universities. Treub's proposal was two-pronged: a. research on tropical agriculture should be undertaken *in situ* because its problems were location specific, and; b. in the Netherlands Indies fundamental research was mainly done by or in collaboration with the *Plantentuin* institutions. Similar to the U.S. DoA, the *Plantentuin* included divisions for botany, chemistry, vegetable physiology, phytopathology and entomology, soil science, and weather. Treub reminded that the *Plantentuin*, not in the least through its Foreigner's Laboratory, had acquired international fame and had contributed substantially to the rise of plantation agriculture. Henceforth, Treub recommended to establish DoA from within the *Plantentuin* at Bogor by expanding its infrastructure. His ideal was that the Department would become the nucleus of agricultural extension for the entire Netherlands East Indies, both for European plantation and for farm agriculture.

whilst other institutes were set up to solve the practical problems of peasant agriculture. When estate organisations gradually established their own research institutes (Roepke, 1920; Meijer, 1936), DoA terminated its work on coffee, tea and tobacco at the botanic garden laboratories. But it continued the research for minor estate and smallholder crops, such as kapok, sisal, citronella and coconut (van Gorkum, 1917).

DoA expanded rapidly and became involved in the preparation and implementation of Government policies. An example was DoA intervention in a financial crisis of the Experimental Stations for the *Bergcultures* due to failing contribution by estate companies. The problem was solved through the founding of the General Syndicate of Highland Crops (*Algemeen Syndicaat voor Bergcultures*) in 1925. DoA joined the Syndicate with all government-owned estates for cinchona, coffee, tea and rubber, and supported all measures taken in the interest of the *bergcul-*

tures[48] (Meijer, 1936; Toxopeus & Wessel, 1983). During World War I and immediately after, and especially during the 1930s, a range of economic policies occupied DoA's officials. Their activities soon extended beyond agriculture with the establishment of new services for trade and industry.

2.5.4. Development of peasant and smallholder agriculture. At the end of the 19th century the peasant farmers of Java, Madura and Bali grew rice as the main crop (van der Veer, 1948). The common system of production on their labour intensive, mini-sized farms was directed at self-sufficiency, but its massive scale provided a stable basis for further development of the export cultures and other economic expansion (Hasselman, 1914; Vink, 1941). Production for self-sufficiency made the farmers relatively independent of fluctuating market prices. Labour participation and yield sharing were socially integrated to an extent that capital and profit remained of minor prominence at village level. However, under influence of European-controlled agriculture and commerce, money had begun to play a greater role in the peasant society. The improvement of infrastructure and transport and payment of wages created markets and thereby the wish for more purchasing power. The change to market production required an adaptation of traditional farming methods (Hasselman, 1914; Scheltema, 1931; Bottema, 1995). Initially the farmers tried to compensate the shortage of cash money and credit by rationalisation in labour intensity, without engaging other production factors. Paying less care to soil tillage, weeding and planting caused the yields per hectare to decrease, but did not necessarily affect financial returns of farming. Demonstrations of the 'system Holle' (single grain seeding to reduce seed requirement, dry seed beds, row planting to allow use of weeding tools, and cultivar selection) in the 1880s and 1890s showed farmers ways of efficient cost reduction (Hasselman, 1914). Intensification, for instance through use of selected rice seed and fertilizer, came within their reach through the development of credit systems (Van der Stok, 1910, 1926; Bottema, 1995). A bank at Purwokerto was the first, in 1899, to offer credit to farmers. From 1901 onwards, a chain of agricultural credit banks was set up on Java and the Outer Islands. In 1903, the old system of village rice seed stores was reintroduced to guarantee seed supply to farmers in famine stricken areas such as the regencies Demak and Grobogan. In 1906, funds were released to intensify field demonstrations of non-rice food *(palawija)* crops in the same areas (Hasselman, 1914; Hirsch, 1929). Such concerted government efforts to improve farm agriculture made farmers more enterprising and receptive for technical advise.

Intensification became very evident in the changing character of farmers' home gardens (*erfkultuur*) on Java and Madura. Mixed home garden crops were grown with such skill that surplus production of fruits, native vegetables, spices, etherical oil grasses (citronella, vetiver and sereh) and herbs added substantially to farmers' income. Gradually, commercial fruit orchards and enterprises for European type vegetables and flowers with a highly specialized and localized character came into existence (ch 6.2). These new types of cultivation greatly increased trade turn over, especially at the local level, which does not appear in export statistics (Van der Stok, 1926).

On the Outer Islands, intensification became visible in the growth of indigenous rubber and coffee smallholdings, particularly on land formerly reserved for *ladang* cultivation. Smallholders tended to invest more in export crops so that their rubber, coffee and sugercane gardens produced yields comparable to those of the estates (Thee, 1969). Growing tobacco and oil palm was more difficult for smallholders and was moreover opposed by the planters' associations. Smallholding cultivation became the source of rapidly increasing purchasing power of the people on the Outer Islands. Acceptable data on smallholder agriculture are only available for the islands of Java and Madura (Scheltema, 1931).

2.5.5. Food production by farmers. Early in the 1920s, indigenous food production in Indonesia fell behind in comparison with population growth. In 1921, more than 475,000 t of milled rice and over 90,000 t of soybeans had to be imported by the Dutch East Indies. The annual import requirement for rice remained at the same high level during the whole decade 1926-35. When, moreover, the global economic crisis of the mid-1930s curtailed the market for Indonesia's traditional plantation exports, the colonial administration introduced a price policy in support of domestic food production. The setting of floor prices for rice assured the farmers a fair return and hence encouraged indigenous production. By subjecting imports to price-equalizing duties in 1934, the influx of cheap rice from Burma, Indochina (Vietnam) and Siam could gradually be stemmed. On Java, rice production increased and, by 1936, local supply exceeded demand, the surplus being shipped to the Outer Islands. In 1941, Indonesia as a whole became a net exporter of rice notwithstanding the mean annual population growth of 1.5% (Metcalf, 1952).

Self-sufficiency was achieved both through an expansion of the area harvested and an increase in production per hectare. In the period 1921-41, the area planted was extended by more than 1.5 M ha (Bolhuis, 1950). Since not much wild land was left, the greatest expansion was achieved from rotating non-rice food crops (*palawija*) with rice. The cropping rate on most of the irrigated land, in 1900 a little over 100%, increased to 140% around 1940. The cropping rate of dry soils increased only from 74% in 1928 to 87% in 1938. The most important food crops in order of hectareage were *sawah* rice, maize, cassava, soybean, dry rice, groundnut and sweet potato (Bolhuis, 1950).

Sawah rice production increased about 10% over the said period due to improved cultivars, better irrigation, chemical fertilizer, and crop protection. Farmers had learned to prefer high-yielding, more resistant rice cultivars over superior consumer quality. Row planting permitting a lower seed rate and improved weed control with hand tools was by now widely adopted (Kouters, 1992). The most important rice pests, rice stem borers and rats, were respectively controlled by regulation of the time of sowing[49] and by baiting (Gutteling, 1913; Dammerman, 1918; Van der Goot, 1925; Van der Stok, 1926).

2.5.6. Research for peasant and smallholder agriculture. In 1923, the Experiment Station for Rice and Other Food Crops and several other research institutes, among which the botanical garden laboratories and services at Bogor, were amalgamated into the General Agricultural Research Institute (*Algemeen Proefstation voor de Landbouw, APL*) (Meijer, 1936). This station consisted of four institutes dealing with botany, land management, soils, and phytopathology, respectively. As a division of the Agricultural Service of the DoA, the General Experiment Station aimed to solve the problems of peasant agriculture. It was involved with export crops only in as far as smallholders were concerned (Toxopeus & Wessels, 1983).

Research at the time was not targeted at the development and adoption of pest-resistant, fertiliser-responsive superior rice varieties. Rather, research was spread over a range of fields, which often did not benefit smallholder agriculture directly (Breman, 1983). There was simply not enough knowledge about indigenous agriculture to identify the major constraints to development, nor to decide on research priorities. Although there were no interdisciplinary research programs, personal contacts between senior staff, mostly graduates from Dutch Universities working in different sections at Bogor, and frequent publication of results enabled exchange of views and openmindedness (van Bijlert, 1921). Dialogue between researchers and extensionists was encouraged (Geerts, 1931; Kuijper, 1932).

The greatest increase in production per hectare was usually achieved in those crops for which intensive selection work at the General Agricultural Research Station of Bogor was supported by the agricultural extension service with field trials, demonstrations and publicity. The value of the surplus in production obtained through the collaboration of research and extension was such that it could easily pay for the operational costs of these services (Bolhuis, 1950).

Selection and breeding work was no longer restricted to the *Cultuurtuin* in Bogor because the *ex situ* results obtained there in earlier years had caused many disappointments in rice and other food crops. Selection trials on different locations and soil types (*in situ*) gave better practical information on growth duration, fertilizer demand, cultivar suitability and resistance to pests and diseases (Schwartz & Hartley, 1927). In 1942, the General Research Station maintained 31 experimental gardens throughout Java (Van der Eng, 1993). Early in the 1940s, tens of improved rice cultivars were available for testing of which several cultivars became popular (Bolhuis, 1950). DoA operated 57 seed farms on Java but their capacity was still too low to satisfy the demand for high quality seed. Inevitably, the amazingly large number of rice cultivars available in the villages throughout the archipelago disappeared in the process of modernization.

2.6. Rice production in Independent Indonesia, 1946-present

During the Japanese occupation, Dutch civil servants were imprisoned and most Indonesian personnel forced to seek other employment. The situation after August 1945 was chaotic and it took many months before the public and private sectors came back into operation. In the following years, the Indonesian demand for Independence led to a military confrontation with the Dutch army. The fighting inflicted more damage to agricultural installations and estates and foreign agricultural activities almost came to halt.

Indonesia obtained its Independence on December 27, 1949, but remained connected with the Netherlands in a Union relationship till 1956. The new nation established its authority over all islands which belonged to the former Dutch East Indies. New Republican Institutions were established, among which a Ministry of Agriculture (MoA). Finally, the rehabilitation of agriculture could begin.

2.6.1. Food production after World War II. Many problems facing Indonesian agriculture after Independence were similar to those existing during colonial days. Therefore, the new government's approach to their solution largely continued the policy and programs initiated under the Dutch colonial administration. Thus, the Indonesians continued with agricultural extension, technical research and experimentation along the same patterns of operation as before (Honig & Verdoorn, 1945; Verdoorn, 1945; Coolhaas, 1948).

Under the Japanese occupation, 1942-45, large numbers of draft animals for ploughing were slaughtered, the heavy military requisitions for rice reduced the farmers' willingness to work and the elaborate irrigation systems were not kept in good repair. Hence, in 1945 rice production on Java was 20% less than before the war. During 1946/47, a severe drought caused wide-spread crop failures which worsened the food shortage. After 1948, rice production improved again, but the need to import rice became bigger due to the growing population. Shortages rose to 425,000 t of milled rice *(beras)* in 1951. Rice was imported from Thailand, Burma and the United States of America under the Mutual Security Agency allocations (Metcalf, 1952).

Throughout the 1950s, the basic problem facing smallholder agriculture remained the production of sufficient food to keep up with the rapid population growth. In 1949, the Government of Indonesia (GoI) launched an Economic Urgency Plan, called the 'Special Welfare Plan for Smallholder Agriculture and Fisheries' which had as its main objective to improve rice cultivation in Indonesia. The recommended measures included rehabilitation of irrigation systems, use of improved seeds, fertilizers, crop protection and the conversion of estate lands to rice cultivation. Six research stations, 200 seed farms, 230 demonstration farms and over 1,000 farmer training centres would be set up. The pre-war practice of establishing transmigration schemes in the Outer Islands was brought up again (Metcalf, 1952).

Several pre-conditions had to be fulfilled before such a far-reaching Plan could implemented. The agricultural research apparatus should be strengthened, extension improved and the farmers' communities organized. To begin with, MoA revitalized the pre-war cooperative movement by providing credit and grants to existing and new agricultural cooperatives. By 1950, the cooperative movement counted more than 4,000 societies (Metcalf, 1952).

2.6.2. Agricultural research since Independence, 1949. The work at the Central Agricultural Research Station (*Algemeen Proefstation voor de Landbouw,* APL) at Bogor could be resumed in 1947 only. Many of the European and Indonesian experts had died or did not come back (Verdoorn, 1945; Honig & Verdoorn, 1945). A great deal of the research equipment, collections of plant species and germplasm, archives, herbaria and books had disappeared and parts of the gardens had been destroyed. Colonial agriculture, however, left Indonesia a class of highly experienced garden-, plantation- and factory attendants (*mandur*) who contributed enormously to the restauration of the public and private sectors. In 1948, the three experimental stations for highland crops (*bergcultures)* on Java were merged into one institute, the Central Association of Research Stations (*Centrale Proefstation Vereeniging, CPV*) in Bogor (Toxopeus & Wessel, 1983). It had experimental gardens[50] for testing of selected cultivars and the propagation of budwood and seed, and a strong extension service. The *CPV* stations served all highland crop estates in Indonesia, except in NE Sumatera which had its own Research Institute of the Sumatera Planters Association (*RISPA,* formerly *AVROS*).

Research too was interrupted by the struggle for independence. The Central Agricultural Research Station (*APL*) lost four-fifth of its Dutch senior staff members and there were few qualified Indonesians to take their place. After Independence, some Dutch scientists returned to Bogor under FAO technical assistance projects, whilst the United States sponsored a few experts for fundamental research. Some Indonesians were sent to degree courses abroad, many others attended crash courses at the Agricultural College. This did not solve the problem since many of the agricultural graduates preferred employment by private research stations or agribusiness to lowly paid positions in the civil service. On the whole, there was a structural shortage of qualified manpower well into the 1970s. Research went into a state of general neglect because budgets were largely spent on salaries and institutional capacity, whilst personnel was scattered around in frequent reorganisations. Foreign assistance gave some relief but could not reverse the decline.

Matters began to improve in the late 1960s. The administrative fragmentation of research institutes was reversed with the re-establishment of the Central Research Institute for Agriculture (CRIA)[51] in Bogor and its sub-stations. In view of the importance of the agriculture for the economy of Indonesia, the budget for agricultural research was increased. Extra funds were made available for overseas eduction, local training and rehabilitation of research facilities (van der Eng, 1993).

2.6.3. Policy development, rice and other food crops

2.6.3.1. Rice production and the National Five-year Plans 1950-70. In the 1950s, the area on Java and Madura planted with rice amounted to some 3.5 M ha of which 90% *sawah* and 10% upland rice (*padi gogo*). At the time, only 17% of *sawah* land was double cropped because of lack of water. The total area of rice in the Outer Islands was estimated at about 2.4 M ha annually. The 1951 production of rough rice (*padi*) on Java and Madura was estimated at 6.5 M tonnes with an average yield of about 2.2 t/ha. Total *padi* production in Indonesia was estimated at 10 M tonnes, almost equal to the pre-war annual production level. Since the growth in production did not keep up with the growth in population, the per caput rice output declined from 200 kg in 1880 to 130 kg in 1965 (Booth, 1985).

During the 1950s and early 1960s, Indonesia went through a period of economic and political instability. Rural development stagnated and the GoI had to import up to 10% of the domestic rice consumption (Mears, 1981). By 1965/66, the high import requirements for food, fertilizer and other inputs had exhausted the treasury's foreign currency reserve. Rice imports dropped drastically causing severe food scarcity, rampant inflation and price increases of over 500%. The ensuing political turmoil brought a transition of political leadership. President Sukarno was ousted and President Suharto formed a new government (Palmier, 1965).

The 'New Order' government launched, in 1969, a series of National Five-year Development Plans[52] (*Pelitas*), intended to improve the living standard of the poor and to create an economically balanced development. Agriculture for food security and export commodity production became a priority sector. The first Five-year Plan (*Repelita I,* 1969-74) named the following research objectives: *a.* self-sufficiency in production of rice, corn and other *palawija* crops to be attained by 1979; *b.* increased production of agricultural export commodities and import substitution products; *c.* more effective use and conservation of land and water resources, and; *d.* improved social and economic well-being of the farmers through more equitable distribution of benefits.

Institutions for research and extension were almost continuously reorganized because responsibility for agricultural research and development in DoA had been divided over five Directorates General, i.e. Food Crops, Estate Crops, Forestry, Fisheries and Animal Husbandry. This resulted in bureaucracy and inefficiency. To improve research management a special Agency for Agricultural Research and Development (AARD) was established within the MoA by Presidential Decree in 1974 (AARD, 1981, 1986; Anonymous, 1986b).

AARD's mandate and organizational structure were specified in a Ministerial Decree of 1975. AARD's research programs reflected the priorities set out in the National Five-Year Development Plans. AARD was financed by the government and obtained additional funds from international and foreign national agencies through loans and grants. During the period 1981-86, the government allocation amounted to 230 M US$ and donor funding to 170 M US$ 170.

2.6.3.2. Intensification efforts in rice production. To implement the government's program not only the research institutions but also the Agricultural Extension Service had to be reorganized. Demonstrations to show the farmers innovations in cultivation technology, as done before World War II, had no effect. The Extension Service was understaffed and poorly trained, had a small budget and stuck to its old ineffective methods. To break the deadlock, the GoI undertook a series of intensification programs which were all based on the same principles but differed in implementation. These principles included *a.* improved extension to encourage farmers to grow improved varieties, use more fertilizers and pesticides, control pests, adopt better cultivation technology and make better use of water; *b.* provision and distribution of the needed input factors; *c.* organisation of a farmer credit system with repayment in harvested produce; and *d.* price stabilisation and improvement of marketing.

Three campaigns were initiated prior to 1965, the *Padi* Centres Program from

1959 to 1962; an Action Research project in 1963/64, and; a Demas (*Demonstrasi masal*, mass demonstration) campaign in 1964/65. However, these programs covered such limited hectareage that they had no effect on the national rice production. In 1965, the GoI launched two nation-wide intensification programs in rice, Bimas (*Bimbingan masal*, Mass guidance) and Inmas (*Intensifikasi masal*, Mass intensification). In 1968, the first real large scale program called *Bimas Gotong Royong* ('*Gotong royong*' = mutual cooperation) was implemented (Hadisapoetro, 1970).

A brief discussion of these programs is given below because they were the cause of later pest outbreaks and IPM programs in Indonesia. The *Padi* Centres Program commenced in 1959 with the installation of ten *padi* centres in C and E Java. The target was to establish 250 centres for coordination of all project activities by 1962 on an area of 1.5 M ha. Right from its start, the project lacked experienced manpower, logistic means and funds needed to run such a complicated input distribution, credit and repayment scheme. Repayment of loans by farmers, in the form of dry *padi*[53] collected after harvest, proved to be a bottleneck. Even after the terms of repayment and interest rates were revised, repayment stagnated, falling to 52% in W Java in 1960. The Ministry of Agriculture terminated the *Padi* Centres project in 1963 and transferred their task, in particular input distribution, to the state-owned enterprise P.N. Pertani[54]. Birowo (1975) drew attention to the low repayment capacity of the farmers and the need for a thorough pre-loan analysis in credit schemes.

During the wet season of 1963/64, the Institute of Agriculture in Bogor initiated an 'Action Research' experiment on 100 ha irrigated *sawah* in W Java. Twelve students, who were assigned in pairs to live in villages, should persuade farmers to apply the principles of rice intensification. The experiment yielded on average 50% more rice than the adjacent non-included farms. The success was primarily attributed to the continuous attendance of the students even though these were not experienced extension workers. The experiment was expanded in the wet season 1964/65 under the name Demas (*Demonstrasi masal*, Mass demonstration). This time, 440 students from 9 agricultural schools were stationed in 220 villages to oversee an area of 10,000 ha. Overall supervision was entrusted to the Departments of Agriculture and Education. Since the yields achieved in Demas project were said to be about three times higher than the national average of 2.3 t/ha, the GoI decided to transform the experiment into a national program under the name Bimas[55].

2.6.3.3. The Bimas-Inmas programs, 1965-67. The Bimas program was implemented during the wet and dry seasons of 1965-66 on an area of 332,617 ha of *sawah* in Java. Some 1,200 students were posted in villages with good irrigation and road facilities. DoA procured the seeds, fertilizers and pesticides and delegated their distribution to P.N. Pertani. An important feature of Bimas was that credit was offered to farmer groups through their village cooperatives (*Koperasi Unit Desa*, KUD) or village headmen. Any farmer living in a Bimas area could qualify for credit without collateral. In the first season, the loans were administered by the People's Credit Bank (*Bank Rakyat Indonesia*) (Birowo, 1975). The farmers received the credit partly in cash to cover living expenses and partly in the form of vouchers. Against these vouchers they could draw fertilizers, seed and pesticides from the village retail outlets (*kiosks*) of P.N. Pertani. During the first season, the farmers received the pesticides free of charge and the use of insecticides was actively promoted (Hadisapoetro, 1970; Birowo, 1975).

Since the average yield reaped by Bimas farmers was reported to be twice as high (4.9 t/ha of *padi*) as average yields elsewhere, the Bimas effort was extended to 0.55 M ha in 1966-67. In 1966, BULOG[56] participated in financing for the main provinces W and E Java and N Sumatera. Cash funds were routed through the provincial governor (*bupati*) to the village headmen for disbursement to farmers, whilst the farm inputs were supplied by P.N. Pertani as usual.

During 1967/68, serious problems began to appear. The Bimas loan packages were significantly increased in size, but the technical supervision became totally insufficient. Loan disbursement was poorly controlled since, at times, the People's Credit Bank, BULOG and P.N. Pertani were all issuing loans in cash or kind. Meanwhile the village cooperatives, which generally had a low standard of organization, education and financial management, had to collect the repayments (Birowo, 1975). Whilst distribution and supply of inputs stagnated, enforcement of repayments in kind invoked discontent and passive resistance. In the field, not enough students were available to attend to the farmers, whereas the agricultural officers were too busy with arranging deliveries, cutting yield samples, reporting and group meetings.

Meanwhile, Inmas (Mass intensification) was launched as a parallel program to Bimas for farmers who could pay in cash for subsidized seeds and agro-chemicals. The underlying idea was that Bimas farmers who had sufficiently raised their production and income would no longer need credit but only advice. The only criterion needed for sharing the Inmas benefits was that Inmas farmers would plant improved cultivars and use fertilizers and pesticides. The rate at which Inmas farmers adopted these technical improvements could, however, never be properly checked. Nor were special measures taken to strengthen the extension service in accordance with the Inmas program needs. Together, the Bimas and Inmas programs covered more than 1.6 m ha during the seasons of 1967/68. The considerable expansion of intensification areas did not cause an important increase of national rice production. Birowo (1975) suggested that the reports on the Inmas program may have merely served the purpose of filling the gap between target and accomplishment in Bimas.

2.6.3.4. The *Bimas Gotong Royong* Program, 1968-70. In the course of 1967, the GoI became disappointed and decided upon a new approach to intensification. It doubted the capability of P.N. Pertani to serve as the main distributor of farm inputs. The government solved various problems at one stroke by contracting seven chemical companies[57] on the basis of payment deferred one year. The foreign companies supplied and distributed fertilizers, insecticides and some equipment at a fixed price per hectare. The People's Credit Bank issued the credit[58] in cash and vouchers. Repayment in produce would be handled by BULOG.

Responsibility for program implementation was charged to the same authorities who directed Bimas and Inmas. The *bupati* was made coordinator and the provincial DoAs selected the areas, provided seeds and liaised with local staff. The multinationals were responsible for the distribution of inputs unto village level, but subcontracted Indonesian private firms for this huge task. The companies also provided technical advice to farmers, and supplied equipment such as sprayers, vehicles, and water pumps (Van Hees, pers. comm., 1996).

Farmers of the selected villages, which participated in this *Bimas Inmas Gotong-Royong* program, accepted the standard package[59] of input and credit (table 2.6.3.4.a). Growers of high yielding *Peta Baru* (=IR) cultivars received a higher loan package than farmers planting local varieties. The program covered about 4 M ha in the wet seasons of 1968/69 and 1969/70 (table 2.6.3.4.b.).

At the end of the two-year program, the GoI had spent 68 M US $ (22.4 billion Rp) on credit and additional costs of administration (Birowo, 1975)). The *Bimas Gotong Royong* program, probably the most expensive one ever executed in SE Asia, was considered a failure when compared to earlier program results and allocated means. Had the acceptance of deferred payment against hard loan terms been the proper solution? The year before *Bimas Gotong Royong* began, P.N. Pertani had imported the largest quantities of fertilizers and pesticides of the decade. According to Birowo (1975), the fear for lack of foreign currency, which prompted the decision to engage the foreign companies, proved to be unfounded. Afiff & Timmer (1971) summed up the major problems of the *Bimas Gotong Royong* pro-

Table 2.6.3.4.a. Composition and value of the Bimas (1968) and *Bimas Gotong-Royong* (1970) credit package per hectare planted to HY IR-rice cultivars. Source: *Badan Pembina BIMAS, Jakarta, Bank Rakyat Indonesia.*

	Bimas		*Bimas Gotong Royong*	
Composition	**Weight (kg)**	**Value (US$)**	**Weight (kg)**	**value (US$)**
Seeds	25	3.07	25	3.07
Urea	150	12.65	200	16.32
TSP	80	5.98	45	3.67
Insecticides	1	4.60	2	11.04
Rat poison+bait	-	-	1	0.43
Spraying cost	-	-	-	2,15
Techn. assistance	-	0.10	-	2.17
Cash allowance	-	3.22	-	n.a.
Total	-	29.62	-	38.85

TSP = Triple Sodium Phosphate; 1 US$ = 326 Rps (1968) gram. The program had a disruptive effect on the natural development of market structures and credit institutions, because it neglected existing trade links. P.N. Pertani was almost eased out of the picture. The normal growth of the extension service was interrupted. The lending activities of the People's Credit Bank were curtailed. Some village headmen and rice farmers sold a part of the subsidized fertilizers and pesticides to growers of non-subsidized crops. Repayment rates fell below acceptable standard and planned collection procedures were neglected (table 2.6.3.4.c). As foreign contractors were not involved in collection of repayment, low rates did not affect them. Farmers got used to non-repayment of loans[60]. The

Table 2.6.3.4.b. Indonesia, expansion of subsequent rice intensification programs and their effect on average yields on program farms, 1963-70. Sources: Hadisapoetro, 1970; Afiff & Timmer, 1971.

Year	Project	Season	Program area (ha)	Yield in rough rice in t/ha		
				Program	Non-program	Increase
1963/64	a.	wet	105	6.7	4.3	2.4
1964/65	b.	wet	9,985	7.3	3.4	3.9
1965/66	c.	wet	172,488	5.3	2.7	2.6
1966	c.	dry	160,129	4.5	2.5	2.0
1966/67	c.	wet	462,520	4.9	3.2	1.7
1967/68	d.	wet	1,596,200	4.0	1.9	2.1
1968/69	e.	wet	2,258,700	3.2	2.3	0.9
1969/70	e.	wet	1,748,600	4.3	2.3	2.0

Index: Rice intensification projects: a. Pady Centres Project; b. Demas Program; c. Bimas Program; d. Bimas/Inmas Program; e. *Bimas Gotong-Royong* Program.

Table 2.6.3.4.c. Indonesia. Contract values and credit released (M US$) and reported repayment rates of *Bimas Gotong Royong* loans in 1969 and 1970. Source: *Bank Rakyat Indonesia, Posisi Kredit Bimas Goting Royong* per 31 December, 1970.

Year/season		Contract value	Credit released	Repayment rate in %
1969	wet	12.1	13.5	30
	dry	28.1	23.5	20
1970	wet	20.0	21.4	12
	dry	8.0	5.6	7
Totals		68.2	64.0	17

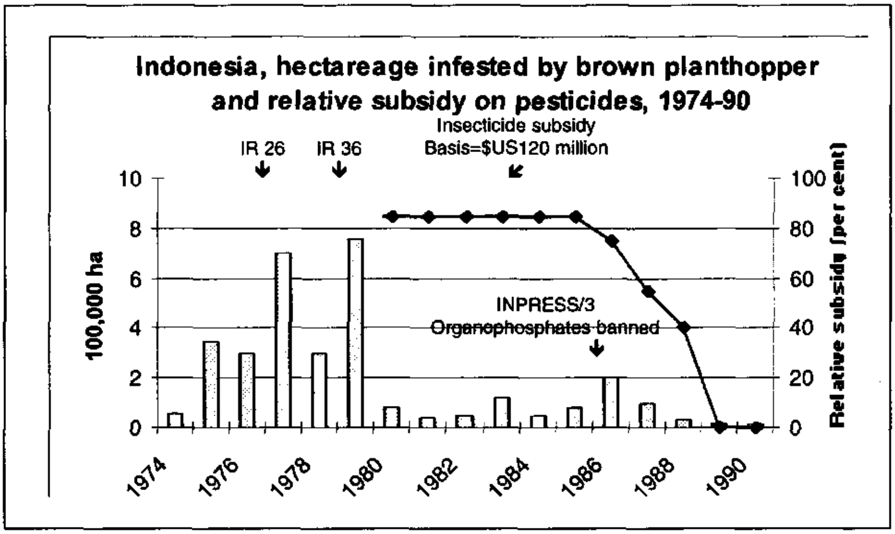


Figure 2.6.3.4.d. Indonesia, alleged relationship of rice hectareage damaged by BPH outbreaks and assiociated virus epidemics with the replacement of BPH sensitive rice cultivars by BPH biotypes 1 and 2 resistant cultivars and the withdrawal of pesticide subsidy, 1974-90. The FAO ICP-IPM in Rice Programme issued the illustration to promote adherence to implementation of the national IPM policy. INPRES/3 = Presidential Instruction 1986/3.

negative results brought about a change of government policy and a close to the *Bimas Gotong Royong* program at the end of 1970.

Notwithstanding its shortcomings, *Bimas Gotong Royong* had made significant contributions to agricultural development. For the first time, seeds and agro-chemicals were made widely available in the countryside. The wide publicity and the forceful extension methods accelerated the adoption of improved technology (Jatileksono, 1983; Prosterman & Riedinger, 1987). The autocratic style of government[61] and the dual function of the army in the society created the conditions to execute such massive campaigns. The replacement of the favourite traditional rice selections by less tasty HY-varieties was not readily accepted by the farmers.

But another observation also deserves to be made. Before the program started there were not more than 30,000 working knapsack and motor sprayers available in the country (James & Reddy, 1977a). The multinationals supplied thousands of sprayers, but never there was enough equipment to treat the millions of hectares under the program. Several companies, therefore, organized extensive aerial spraying operations[62]. Control of rice stemborers was the main objective, the need was established with light trap catches. Large rice areas were sprayed two to three times in both seasons of two successive years with accurately executed Ultra Low Volume (ULV) treatments (van Hees, projectleader W Java, pers. comm., 1998). Since the pilots usually achieved good coverage and fair to good deposit rates on continuous stretches of *sawah*, the environmental effect of this aerial spraying, although scarcely recognized at the time, must have been dramatic[63]. It is a striking coincidence that, since 1970, the brown planthopper (*Nilaparvata lugens*, BPH) developed from a minor rice pest to a real problem (fig. 2.6.3.4.d). Although by 1973 the yield losses in different BPH outbreak areas varied considerably, the average yield loss was estimated at 46%. The damages due to Grassy Stunt Virus (GSV) and Ragged Stunt Virus (RSV), both transmitted by BPH and leafhoppers, and `hopperburn' were included in this estimate.

2.6.3.5. Pest surveillance and emergency control operations. The Directorate of Food Crop Protection operated a Surveillance and Forecasting Service for rice since 1975. The work was delegated to the Crop Protection Divisions at the provincial and district level. In 1977, some 336 surveillance officers monitored blocks of 10,000 ha of rice each. The data were processed by the Directorate in Jakarta which reported on infestation and crop losses and decided whether control measures were needed. Brown planthopper and Grassy Stunt and Ragged Stunt Viruses, rice stemborers, rice case worm and rats caused the most problems. Average loss due to insects was estimated at about 18% in both seasons (James & Reddy, 1977a). Each province could mobilize three to five Units of the Crop Protection Brigade, equipped with power sprayers, pesticides and transportation, for emergency control in outbreak areas. If the pest outbreak covered a large area the DoA sent spray aircraft to do the job. The DoA managed a special outbreak budget to meet the personnel and material costs of the emergency control units.

AARD began research on alternative ways of pest control in rice in 1976. This included screening of insecticides, synchronized planting, crop rotation, sanitation, and biological control with natural enemies[64]. AARD collaborated with the `Pest surveillance and early warning' program of the Plant Protection Division. In late 1979, surveillance teams of the Plant Protection Service identified the whitebacked planthopper (*Sogatella furcifera*, WBPH) in N Sumatera for the first time.

2.6.3.6. Achievement of self-sufficiency in rice. When the GoI terminated *Bimas Gotong Royong*, it could not afford to stop intensification in food crop production altogether. In an attempt to find solutions primarily to the problem of credit, the agricultural agencies developed a National Improved Bimas (*Bimas Nasional yang Disempurnakan*, Bimas BND). Its main feature was the abolishment of the group approach to credit in favour of loans to individual farmer households. In 1969/70, a pilot project in Jogyakarta had been successful. Therefore, with the ending of the foreign companies' contracts, Bimas BND was immediately expanded on a nationwide scale. The People's Credit Bank provided the loans in cash and voucher through village units which covered up to 1,000 ha worked by 2,000 to 3,000 farmers from surrounding villages. The bank also organised marketing operations and built the needed stores for temporary storage of *padi* (Birowo, 1975).

In 1979, the GoI initiated once again a special rice intensification program called Insus (*Intensifikasi Khusus*, Intensification drive). It was similar to National Improved Bimas, but the farmers were grouped into production units based on irrigation blocks. The farmer groups decided what rice cultivars, fertilizers and pesticides suited them best, whilst DoA provided extension and credit facilities.

The growth in per hectare yield and total rice production was generally slow but steady (table 2.6.3.6). In 1980, Indonesia still faced an import requirement of

Table 2.6.3.6. Indonesia, rice area and rice production over period 1968-90. Sources: FAO Production Yearbooks; Central Bureau of Statistics, Indonesia; BULOG, 1984: Supplement to President's Report to Parliament, August 1985. (See also fig. 7.2.4.a).

Year	a	b	c	d	e	f
1968	8.02	1.60	17.16	11.67	34	2.14
1969	8.20	2.13	18.38	12.50	36	2.24
1970	8.20	-	19.32	13.14	38	2.36
1971	8.20	2.77	20.22	13.75	40	2.47
1972	8.30	-	19.38	13.18	38	2.33
1973	8.40	4.09	21.49	14.61	42	2.56
1974	8.51	-	22.46	15.27	44	2.64
1975	8.50	4.20	22.33	15.19	44	2.63
1976	8.37	-	23.30	15.84	46	2.78
1977	8.36	5.25	23.34	15.88	46	2.79
1978	8.93	-	25.77	17.53	50	2.88
1979	8.80	5.86	26.28	17.87	51	2.99
1980	9.10	-	29.65	20.16	58	3.29
1981	9.38	6.27	32.77	22.87	64	3.49
1982	9.02	-	34.10	23.19	67	3.78
1983	9.16	6.83	35.30	24.97	69	3.85
1984	9.76	-	38.14	25.93	75	3.91
1985	9.90	7.66	39.03	26.54	76	3.94
1986	9.99	-	39.73	27.01	78	3.98
1987	9.92	8.04	40.08	27.36	78	4.04
1988	10.14	-	41.67	28.34	82	4.10
1989	10.30	8.71	43.57	29.63	85	4.23
1990	10.50	-	45.18	30.72	88	4.30
1991	10.28	-	44.69	30.39	87	4.35
1992	11.10	-	48.24	32.80	94	4.34
1993	11.10	-	48.24	32.80	94	4.37
1994	10.73	-	46.64	31.72	91	4.35
1995	11.44	-	49.74	33.83	97	4.35
1996	11.33	-	51.16	34.79	100	4.51

Index: a. area harvested (M ha); b. area harvested Bimas/Insus (M ha); c. total production of rough rice (M tonnes); d. production in milled rice equivalent (M t); e. relative annual production (1996 = 100%); f. yield of rough rice (t/ha).
Conversion factor rough rice to milled rice C = 0.68 (BULOG, 1984).

2 M t of rice but by 1986 self-sufficiency in rice was achieved due to the large scale adoption of resistant high yielding cultivars and higher fertilizer use (Jatileksono, 1993). However, the mean yield in lowland rice yield stagnated at 2.5 t/ha of dry *padi,* although 4 t/ha were obtained on demonstration plots. Inadequate pest control was named as the main reason for the considerable yield gap.

Within 18 years, Indonesian rice production had risen from 11.7 M tonnes of milled rice in 1968, to about 27 M t in 1985. Meanwhile the harvested area had increased by 20% from about 8 M ha to 10 M ha. About 13 M rice farmers had holdings of less than one ha, but the per capita availability of rice had increased from 93 kg to 137 kg per year (AARD, 1981, 1986).

Such improvement was not only due to investments in rehabilitation and expansion of irrigation infra-structure and production of improved seeds by research and seed farms. The willingness of ten thousands of Indonesian rice farmers to adopt the Bimas package and improved technology for better crop management deserves much of the credit. Finally, the input and output pricing policies of the GoI created the conditions and incentives for implementation of the successive rice production intensification programs.

2.6.3.7. Developments since 1970. Research on rice remained focused on selection and breeding for resistance against pests in high yielding rice cultivar. IRRI began breeding for resistance to brown planthopper in 1968. From 1973 onwards, high yielding IR-cultivars with resistance to BPH biotype 1 became available for Indonesia[65] (Oka, unknown). Introduction was first made in the districts of N Sumatera, N, C and E Java, and Bali where rice fields were heavily damaged by the brown planthopper. Due to the enforced introduction of improved varieties in Indonesia, more than 0.4 M ha were planted with high yielding BPH1-resistant lines in the 1975/76 wet season already. The cultivars held their BPH-resistance for four consecutive seasons and achieved up to 70% of their yield potential even in heavily infested areas (Jatileksono, 1993). Early in 1977, however, a new biotype 2 of the brown planthopper was detected in N Sumatera which could break BPH1-resistance of the introduced IR-cultivars[66]. New BPH2 resistant rice cultivars, such as IR32, IR36 and IR38, were soon multiplied for early replacement of the widely planted IR26. Since the monogenic BPH2 resistance might fail again, an international testing program was started under coordination of IRRI in 1976. Indonesian breeders were able to release four cultivars with resistance against BPH biotypes 1 and 3 (Oka, unknown). Resistance against Tungro Virus disease had already been introduced in popular cultivars such as IR20 and C4-63.

Expansion of upland rice, which covered some 1,2 M ha, was hindered by drought and the diseases Bacterial Leaf Blight (*Pseudomonas oryzae*) and Rice Blast (*Pyricularia oryzae*). Six cultivars with resistance to blast were released since 1983, but their resistance collapsed after two to three growing seasons. Cultivar IR5 was better adjusted to Indonesian conditions than IR8, had moderate resistance to bacterial leaf blight and better consumer quality. Within five years, IR5 had spread to one fourth of the rice land in Indonesia and it remained the top variety until the mid-1970s (Prosterman & Riedinger, 1987).

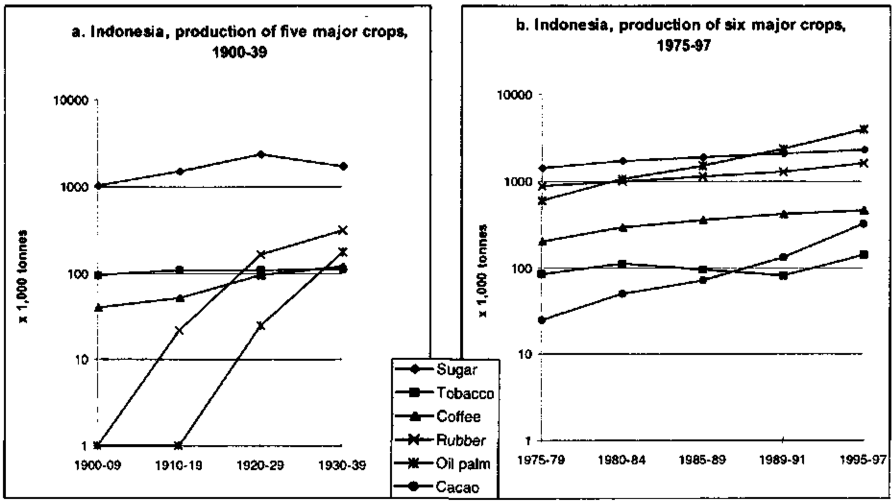


Figure 2.7.1. a,b. Indonesia, pre- and post World War II production of major estate and smallholder crops (x 1,000 tonnes), mean figures over indicatedperiods. Sources: Mansvelt & Creutzberg, 1975; supplement to President's Report, August 16, 1985; FAO Production Yearbooks, 1948-51).

1848 to 1868. Export of raw sugar increased from 63,400 t in 1840 to 161,800 t in 1868, whereas the hectareage planted increased from 22,400 ha in 1840 to 26,500 by 1865 (Hadiwigoeno, 1985; Handojo *et al.*, 1987; Koningsberger, 1948).

The upsurge of the Java sugar industry could only begin when two crucial laws were enacted. The Agrarian Law, passed in 1870, made the Javanese the proprietors of cultivated land whilst allotting to the state all other arable land, which was not acquired by third parties in accordance with existing regulations[70]. The Sugar Cultivation Law implied that sugar cultivation under the *Cultuurstelsel* should be replaced by a free Javanese sugar industry. The transition was to be implemented from 1878 onward over a period of 13 years[71] to prevent a sudden breakdown of the economically important sugar export.

The new laws offered effective protection of the rights of the people. To each sugar factory a concession was granted which gave ownership over up to 7 ha for construction and which specified the maximum area of farmers' land to be planted per year. To safeguard the production of indigenous food crops, the sugar companies were allowed to plant sugarcane on only one-fourth of the irrigated land within the allotted area. In order to prevent soil exhaustion and a resulting depreciation of farmers' land, only one crop of sugercane should be grown on the same soil in succession. Ratoon cropping over two or more years, the traditional practice on Java and elsewhere, was prohibited and each year the sugarcane had to be planted on another plot. Sugarcane was planted in a 3-year rotation with rice and *palawija* crops on large tracts of irrigated land obtained by voluntary short lease from farmers. The government determined the lease price according to soil fertility classification and controlled the labour contracts and wages.

The regulation to plant sugarcane sets (*bibit*) in yearly rotation, with all costs of labour and soil preparation, was only imposed in Java and unique in the world. Such a costly system of sugar cultivation necessitated a very intensive management of the crop in the field and the factory to make it profitable. Since the colonial government had changed its alliance, from shareholder and supplier of cheap production factors for the industry to defensor of the people's rights, the planters had to take care of all difficulties individually. Therefore, the planters soon began to organise themselves, though initially only in regional associations (Koningsberger, 1948).

In the early 1880s, the Java cane sugar industry was confronted with a double threat. First, stiff competition from the ever growing European beet sugar industry caused a financial crisis[72] in Java. Second, a devastating disease, called *sereh* and first observed in W Java in 1881, infected sugar estates all over Java within a few years. The planters' associations decided to search for scientific advice to control *sereh* and to improve sugar quality. They founded three regional experiment stations[73], i.e. Station W Java near Tegal in 1885, Station C Java at Semarang in 1886 and Station E Java at Pasuruan in 1887. By 1907, the Semarang station had been closed and the other two stations merged into the `Association of Research Stations for the Java Sugar Industry' (*Vereeniging het Proefstation voor de Java-Suikerindustrie*) which collected the cess funds for research. The Tegal station under H.C. Prinsen Geerligs contributed enormously to the improvement of sugar quality and established of the refinery proces on Java. Research on breeding, agronomy and pest management was concentrated at the Sugar Station Pasuruan, E Java, and its subdivisions at Jokyakarta, Cirebon and Banjumas (Koningsberger, 1948; Handojo *et al.*, 1987). After years of research the sereh problem was solved through the development of resistant hybrid cultivars such as the 2878 POJ lines.

In the first half of the 20th century, export of sugar accounted for 25% of the total value of exports. In the peak years, 1928-31, sugar was grown on 200,000 ha, *i.e.* 1/18 of the irrigated *sawah* land on Java. The combined production of 179 sugar factories exceeded 3 M t/y of raw sugar and Indonesia became world's largest sugar exporter (Anonymous, 1979; Hadiwigoeno, 1985). Capital invested in the industry amounted to 318 M US$, or 40% of total investment in estate agriculture at the time (Metcalf, 1952). Local wages and land rentals paid by the industry constituted about 10% of the total income of the peasant households. During the great economic depression of the 1920-30s, the Java sugar industry, forced by overproduction and low prices, signed the International Sugar Restriction Agreement, Brussels, 1931. As a consequence, sugar planting was reduced to about 30,000 ha/y by 1936 (Koningsberger, 1948). Recovery was just getting under way when the Japanese invaded the Malay-Indonesian archipelago in 1941. After the Japanese had taken over the Philippines and Java and access to the world market had been cut off, Japan obtained more sugarcane than it needed. Production on Java was curtailed and the vacated land employed for the production of food and fibre.

Indonesia's struggle for independence, in the wake of Japan's capitulation in 1945, hampered a rapid recovery of the sugar industry and discouraged investors to put up the large funds needed for reconstruction. Increasing population pressure, a sharp rise in land rents and wage rates and political violence prevented the rehabilitation of the private sugar industry in its pre-war structure. By 1950, only about one-third of the pre-war estate hectareage was planted, 20 sugar factories back into operation and sugar production only one-fifth of the 1937-39 average annual output (Handojo *et al.*, 1987). Shortly thereafter, the largely Dutch owned sugar industry was nationalized. By 1964, the total area of estate and peasant sugar approached the pre-war total planted area but the production per ha of estate sugar had declined to just about one half as compared to 1938. Since production of peasant-grown sugar could not fill the gap, export of factory sugar almost stopped to meet the greater domestic consumption. By the end of the 1960s, Indonesia had become a large importer of sugar (Hadiwigoeno, 1985).

In 1996, sugar was grown on some 400,000 ha in Java, with some minor production centres in Sumatera, Kalimantan and Sulawesi. The production totalled 2.2 M t of raw sugar (FAO Production Yearbook, 1977) which was 0,7 M t below expected domestic demand. Hence, in 1980 the GoI launched a smallholder sugarcane intensification program. The GoI supported the growing of sugarcane, generally planted on high-quality land, by fixing the government procurement (floor) prices at trice the world market rate (Prosterman & Riedinger, 1987). The program was designed as a Nucleus Estate System (NES) and DoA advised growers through the Smallholders' Sugarcane Foundation and the Smallhollders' Cane Sugar Research Office. During the 1960s, damage by field rats was regarded as the most acute problem[74] (Handojo *et al.*, 1987).

2.7.2. Tobacco

2.7.2.1. 'Principalities' tobacco. The three principal areas of tobacco cultivation in the Dutch East Indies were the Principalities Jogyakarta and Surakarta in C Java, the regency Besuki in E Java and Deli on the E coast of Sumatera. The tobacco cultivation in the Besuki area is the oldest and began around 1855. The Principalities produced the so-called *'Vorstenlandsche tabak'* (Principalities' tobacco) and the Sumateran sultanates the 'Deli-tobacco'. Both types were used as wrapper-leaf and filling in cigar manufacturing.

In 1898, several tobacco companies in the Principalities established the Tobacco Experiment Station at Klaten, Besuki. In 1907, other companies established a second tobacco station which resorted under the Central Experimental Station at Salatiga. In 1912, the two stations were merged into the Experiment Station for Principalities' Tobacco (*Proefstation voor Vorstenlandsche Tabak*) at Klaten, E Java (Beets, 1949).

After 1913, the area planted to tobacco on Java decreased considerably, but this was compensated by a strong increase in production per hectare due to better fertilization and disease control (Beets, 1949). The most serious disease of Java tobacco was '*lanas*' caused by *Phytophthora solani*. Sanitary control of *lanas* through removal of all sources of infection and selection for resistance was effective (Beets, 1949).

2.7.2.2. Deli tobacco. Around 1860, tobacco from E Sumatera attracted the attention of the tobacco trade because of its superior quality. In 1863, a Dutch company, cultivating tobacco in Besuki, commissioned J.A. Nienhuis to undertake tobacco production in Deli. Not only the climate and soils appeared to be extraordinarily suited for tobacco, but also large tracks of land could be leased cheaply. The Sultan of Deli was very interested to attract investment for his underdeveloped state. The tobacco culture developed rapidly on the E coast[75]. In 1869, the first of the big companies, the Deli Company (*Deli Maatschappy*)[76], was established and by 1889 some 170 estates were in operation on the territory of the three sultanates, Deli, Langkat and Serdang (Jochems *et al.*, 1931; van der Laan, 1949). The tobacco industry brought great wealth to the E coast of Sumatera, Medan then being one of the most modern cities of E Asia. The success of the tobacco monoculture in Sumatera caused an over-supply of tobacco leaf and evoked import restrictions by the United States of America to protect the Virginia tobacco farmers. Decreasing prices drove a large number of estates, operating on marginal tobacco soils, from the market. Many planters changed to planting Liberica coffee during the 1890s and rubber after 1905. Around 1920, many of the surviving tobacco companies were amalgamated into four big companies[77], which completely dominated the scene up to Independence.

Pest pressure was extremely high in E Sumatera. Already in the 1880s, the Deli planters sought help from Treub in Bogor to find a solution for a devastating nursery disease.

2.7.3. Coffee. The Dutch introduced, in 1699, seeds of *Coffea arabica* into Java and enforced, within a few years, the growing of coffee by farmers. The productivity of the extensive coffee gardens grown under the *Priangan system* and the *Cultuurstelsel* remained so low because the conditions[78] were very disadvantageous for the farmers (de Bruijn, 1869). Since the colonial administration payed for the coffee far below its market value, revenues for the Dutch government were so high that the *cultuurstelsel* was continued for coffee longer than for any other commodity. The planting of government coffee was also enforced in several regions of Sumatera, such as Benkulu (till 1870), Sumatera's West Coast and Padang Highlands (till 1908) and Tapanuli (till 1902). On Sumatera too, productivity remained low because of its scarce population, limited infrastructure, backward agricultural development and, in particular, the people hated to maintain the crop. The dense, unweeded coffee gardens suffered badly from the Coffee Leaf Rust (*Hemileia vastatrix*) disease, which arrived in Sumatera and Java in the 1880s. After 1870, the *Cultuurstelsel* was gradually withdrawn from areas where coffee cultivation was less profitable and officially terminated by 1915 (Reinsma, 1955; Paerels, 1949).

In 1875, seeds of *Coffea liberica* were received via the Netherlands and the seedlings tested in the *Cultuurtuin*. Some private estates planted Liberica coffee but the production remained small because Liberica offspring was also susceptible to leaf rust.

Because of its importance as an export commodity, coffee was promoted as a free smallholder crop during the first quarter of the 20th century. To this aim, the government provided seeds and cheap credit, continued purchasing coffee, introduced protective terms[79] and encouraged smallholder cooperatives. In 1900, *Coffea canephora* or robusta coffee was introduced which, because of its strong growth and better resistance against Leaf Rust, soon replaced the other coffee types. Notwithstanding such government support, growing coffee as a free smallholder enterprise did not catch on in Java; it remained limited to some 10,400 ha only in E and M Java (Huitema, 1935; Paerels, 1949). For Sumateran smallholders growing robusta coffee in the lowlands and Arabica coffee in the highlands was financially attractive. The planting of robusta coffee as a cash crop under rubber or coconut became popular. Even during outbreaks of coffee berry borer (*Hypothenemus hampii*) in the 1920, which caused great losses in production, the planting of coffee continued.

Total Indonesian coffee production in 1932 amounted to 132,253 t of which 47% was produced by the estates, mainly on Java, and 53% by Sumateran smallholders. Robusta coffee covered more than 90% of the area under coffee. (Huitema, 1935).

In 1990/91, Indonesia produced 0.4 M t coffee on some 9 M ha, consisting of 93.5% robusta and 6.5% Arabica, and all under the name 'estate coffee' (ITC, 1992). The production came for 87% from smallholders, 8% from government estates and 5% from private estates (Wirjusuhardo, 1987).

2.7.4. Cacao. The Cacao tree (*Theobroma cacao*) was introduced into the Philippines from Latin America by the Spanish around 1665. From the Philippines, the cacao tree was spread throughout the Indonesian archipelago at the end of the 18th century. The *VOC* never appears to have traded in cacao, nor did it promote the crop as happened with coffee. During the 1850s, some 50 t of dry cacao beans were exported annually by European, Chinese and Indonesian farmers in the Minahassa, NE Sulawesi, for the Manila market. Then, the cacao production increasingly ran into problems, due to helopeltis bugs (*Helopeltis* spp.) and cacao pod borer (*Conopomorpha cramerella*, CPB), which could not be solved.

Experiments with cacao plantings in W and C Java resulted in an export of 10 t of dry beans in 1880 (Van Hall, 1939). A decade later many estates in E Java replanted their Arabica coffee, which had been devastated by Coffee Leaf Rust, with cacao seedlings. Soon, heavy infestations by *Helopeltis* bugs and the cacao pod borer, which was detected on Java in 1895, threatened the profitability of cacao as an export crop in Indonesia. In 1901, the Cacao Planters Association founded a Cacao Research Station[80] at Salatiga, C Java, primarily to find solutions to the insect problems (Levert, 1940; Bertrem, 1940; Oei-Dharma, 1969; Giesberger 1983). By 1905, the Salatiga station was enlarged and renamed to General Experimental Station (*Algemeen Proefstation*) at Salatiga. Its mandate was extended to include all highland cops (*bergcultures*) (Toxopeus & Wessel, 1983).

Around 1910, planters in E Java began to give up cacao because of excessive helopeltis and cacao pod borer damage to the predominant Java Red Criollo variety. During the 1920s, they replanted all cacao stands to *Hevea* rubber and robusta coffee, which were much easier to grow and more profitable than cacao. The planters of C Java, however, continued to grow cacao whilst gradually replacing the old Java Criollo by more vigorous Trinitario cacao. They successfully applied sanitary control by removing all fruits, *rampasan*[81], a method worked out at Salatiga[82] (Toxopeus & Wessel, 1983)(ch 5.6.4).

During the 1920s and 1930s, cacao was grown on large estates located in the Pekalongan and Semarang districts of C Java. Total exports of cacao beans from the estates during the period 1935-39 averaged 1,600 t/y. The major portion of this was *Edelcacao*, a premium grade hybrid cacao from the cross Forestero x Criollo. Smallholders' cacao production averaged only 26 t/y in that period. During World War II, about one-fifth of the cacao hectareage was lost through neglect and plant diseases. Production in 1950 was 866 tonnes, 54% of the pre-war average (Metcalf, 1952).

In 1995/96, cacao production in Indonesia totalled about 0.3 M t of dry beans with a value of 400 M US$, picked from 0.6 M ha, of which about half with mature fruit bearing trees. Following the expansion of cacao throughout Indonesia since the late 1980s (Wood, 1982), numerous outbreaks of cacao pod borer (CPB) have occurred. An Integrated Cacao Pod Borer Management Program was launched in 1996 for cacao smallholders in Sulawesi, where most cacao is grown. This IPM programme is currently being financed by Chocolate Manufacturers' Associations of the United States and the United Kingdom (Mumford, 1997).

2.7.5. Oil palm. The oil palm (*Elaeis guineensis*) was imported into the Dutch East Indies in 1848 and planted in the *Cultuurtuin*. In the following decades, the oil palm was spread throughout Java and the archipelago. In spite of many successful demonstrations by local civil administrators during the 1870s and 1880s, the Indonesian peasants were not interested in this new crop, because the familiar cocos palm supplied almost the same range of products without requiring mechanical processing. European planters were not eager to explore the possibilities of oil palm either, because world demand for vegetable oils was low and the crop was poorly studied. In 1911, the first commercial planting of oil palm was realized on the E coast of Sumatera (van Heurn, 1949). In 1919, palm oil was exported from Sumatera in 1919 for the first time and within two decades the region became the world's largest exporter of palm oil and palm kernel oil. In 1938, the total area with oil palm in E Sumatera and Aceh amounted to 74,500 ha and the export to about 220,000 t of palm oil and 47,500 t of palm kernel oil. In the 1990s the oil palm became the leading estate crop. The 1996 production yielded 5 M t of palm oil and 1.1 M t of kernel oil (FAO Production Yearbook, 1997).

The oil palm is little affected by diseases but some insect pests can cause serious damage. The most prominent pest is the rhinoceros beetle (*Oryctes rhinoceros*) which damages the apical bud of the oil palm. Considerable leaf damage can be caused caterpillars of the *Limacotidae* and *Psichidae* families. Tree rats (*Rattus tiomanicus*) can cause heavy damage too (Wood, 1982).

2.7.6. Development of the para-statal estate sector. After the surrender of the Japanese army in Indonesia, several foreign companies began to rehabilitate their agricultural estates and factories in Indonesia. Between 1947 and 1949, rebuilding was seriously hampered by the armed struggle for independence with additional damage to structures and plantations. In the early 1950s, business and investment could be resumed. Because of political disagreement between the Indonesian and Dutch governments concerning the territory of W Irian Jaya, the Dutch enterprises were nationalized by the Presidential Decree of 1957. Former Dutch plantations came under control of state-owned estate companies (*Perusahaan Perkebunan Negara*)[83]. The *Perkebunan* had a difficult start because of lack of expertise in management and research. As non-Dutch estate companies were allowed to continue independent operation, the estate sector counted numerous private enterprises. At the end of the 20th century, overseas investments are still considerable but Investment Laws require Indonesian majority shareholdership.

Plantation crop research, which also included pest control and efficacy testing of pesticides as required by the pesticide law, was handled by both the *Perkebunan* and private sector. Initially, the mandate for research on estate crops was entrusted to the former colonial Research Institutes for Highland Crops (*Berggcultures*) at Bogor (W Java), Djember (E Java) and Medan (E Sumatera), which operated under a central research management. A Bappanas study[84] showed that the state-owned *Perkebunan* and the private estate companies lost confidence in the poorly performing Bogor and Medan Institutes and established their own research centres[85]. Although in 1970, the GoI tried to mend the working relationship between the governmental Estate Crop Research Institutes and the private centres, it failed to achieve coordination and priorization of research objectives.

Over the years, the state-owned *Perkebunan* companies have developed into strong production units with ever expanding agricultural assets. Since 1975, *Perkebunan* enterprises assisted the government in the execution of Nucleus Estate and Smallholders projects (NES). The NES-program aimed at rehabilitating smallholders and accommodating migrant farmers in less developed areas with World Bank funding and government loans. The *Perkebunan* companies processed the smallholders' products, provided employment and arranged the supply of seeds, fertilizers and pesticides.

2.8. Discussion, Indonesia

The following discussion and conclusions reflect the author's perception of the situation and events in Indonesia. His perception is based on study, frequent visits to Indonesia, and on many hours of discussion with Indonesian experts.

The concern of the GoI about food security and the ever growing import requirements for rice and agro-chemicals formed the mould for agricultural policy making between 1950 and 1980. It explains Indonesia's readiness to accept the new rice technology which was advertised as the 'Green Revolution'. The intensity with which the GoI demanded the adoption of high yielding rice varieties, often literally forcing the Indonesian farmers to abandon the numerous favourite local varieties, is unmatched in SE Asia. The GoI, by means of National Five-years Development Plans, allocated huge resources to the rice production programs, subsidized increased use of fertilizers and pesticides in rice to the value of millions of

US dollars and even invited the international chemical industry to build fertilizer and pesticide plants in Indonesia and to take an active part in the execution of the *Bimas Gotong Royong* intensification program.

The GoI took, upon recognizing causes and consequences of injudicious pesticide use and BPH outbreaks in rice, the most drastic corrective measures. The 1986 Presidential Instruction to ban 57 brands of insecticides in rice changed the pesticide market in the rice sector deeply in terms of volume and choice of products (ch 7.2). Such a lasting impact of governmental policy on the pesticide market can only be demonstrated for Indonesia.

A similar fervour for accepting and incorporating beneficial innovations can been seen in the way Indonesia implemented its National IPM Programme in Rice (ch 5.7.4). In the decade of the 1990s, Indonesia expanded and intensified the extension of IPM in rice and vegetables. In SE Asia, only Indonesia and Vietnam continued to allocate ample national human and financial resources to IPM extension (Whitten, 1998). Indonesia abandoned the old top-down methods of extension in favour of participatory Farmer Field School approaches, which inevitably introduce the concept of social and economical empowerment of the farmers (van de Fliert, 1993, 1998).

Metcalf (1952) observed already that the cooperative movement in Indonesia had met with rapid success not only because of government sponsorship, but also because of the traditional communal character of the Indonesian rural society, which lends itself readily to the modern cooperative system of economic democracy and group participation. The eagerness with which Indonesian farmers participate in and contribute to season-long FFS training confirms the above observation.

One could wonder from where, in the autocratic Indonesian society, the class of knowledgeable and open-minded administrators and scientists originated that declared itself in favour of IPM and dared to stand up against considerable personal interest at high level positions in the society.

First, numerous Indonesian scientists and politicians have a great interest in agricultural and biological sciences and they are not alienated from the farmer class. Second, many of the agricultural high school graduates, who were program promoters in the villages and who witnessed the BPH and virus outbreaks during the 1970s, obtained influential positions in later years (Oka, Untung, pers. communications, 1994).

The GoI adhered consequently to its national IPM policy since it maintained a high level of budgeting throughout the 1980s and 1990 for the implementation of the National IPM in Rice Program. In line with the current decentralization policy national funds for IPM implementation are channelled through provincial budgets and used a.o. to cover personnel costs of extension and the costs of IPM training. It is crucial that this wide-spread support in federal and provincial administration and services is preserved for the future, particularly in the face of the economic recession of the late 1990s.

2.9. Conclusions, Indonesia

1. Colonial research succeeded in developing an efficient and profitable agriculture. Agriculture in colonial days provides an impressive example of commodity production without the resort to synthetic pesticides.
2. Research in the Dutch East Indies emerged from a scientific attitude of the gifted hortulani and researchers of the Botanical Gardens at Bogor (*'s Lands Plantentuin te Buitenzorg*) throughout the 19th century. In this way, Indonesia's research had an indigenous cradle attended to by dedicated foreign scientists.
3. Agricultural research dealt with a variety of indigenous and introduced crops, and with very diverse biotopes.
4. Colonial research was directed at practical problems in the field. The quiet pace of time and the open minded exchange of ideas and findings among researchers and planters provided a fertile setting for accurate observations and studies, and for finding economic solutions to pest problems.
5. The work on selection and breeding of improved cultivars and on developing techniques for grafting and making clonal progenies made a valuable contribution to global agriculture (ch 5).
6. Early studies in entomology and phytopathology made by scientists in Dutch East Indies are still regarded as standard works.
7. Colonial research results should be guarded as a treasure of information and inspiration for to-day's research, *e.g.* on biological and regulatory control of pests.
8. Colonial agriculture enriched Indonesia by the introduction and improvement of exotic crops.
9. It left Indonesia a class of highly experienced plantation and factory attendants (*mandur2*), who formed the backbone of Indonesia's agriculture after independence.
10. The Japanese occupation and the struggle for independence delayed agricultural development in the estate sector for decades.
11. The development in the food crop sector was probably accelerated after the departure of the Dutch administration. The enforced introduction of the Green Revolution needed a national government to deal effectively with the masses of discontented farmers.
12. After 1950, the spectre of national food security falling behind the population growth urged the GoI to direct most available resources at the improvement of national rice production.
13. The GoI adopted the improved high yielding rice varieties and the concomitant technology, offered by the International Agricultural Research Centres (IARCs), and enforced its adoption by the Indonesian farmers.
14. Due to the dual function of the army in the country's administration, the GoI had the power and means to enforce the replacement of favourite local cultivars by HY cultivars.
15. Since the early IRRI-varieties (*e.g.* IR5 and IR8) had none to low resistance to major rice insect pests, and fungal and virus diseases, the DoA services instructed the farmers to spray preventively and frequently. Insecticides were offered in village outlets against subsidized prices.
16. The administration of the credit and the collection of the repayments in kind

(*padi*) were major obstacles for the implementation of the intensification programs. In particular, the low repayment rates on credit forced the GoI to replace disappointing programs with improved, allegedly more efficient ones.
17. Since input distribution stagnated due to lack of infrastructure and expertise, the GoI requested multinational pesticide companies to assist in the implementation of the large scale programs. It also invited the industry to build pesticide formulation plants in Indonesia. This involvement gave the industry a strong bridgehead in Indonesia. Because of the huge amounts of money involved, personal interests occasionally influenced decisions.
18. Owing to the acute shortage of sprayers, some companies undertook large scale aerial spraying of insecticides two to three times in each rice seasons during two years. These blanket applications might have greatly contributed to the outbreaks of minor pests, such as BPH and leafhoppers, because the natural enemies were killed.
19. Shortage of sprayers were the direct reason to develop granular formulations. Although it added to the logistic problems, supply of granules led to increased use and to lower incidence of poisoning (ch 7.2).
20. The worsening outbreak situation endangered the gains in production made. The seriousness of the situation made the GoI receptive to scientific council concerning the pesticide-induced nature of the outbreaks. Once convinced, the GoI took the drastic step of banning many insecticides from use in rice and of eliminating pesticide subsidies.
21. The ban had an immediate and lasting effect on the size and composition of pesticide sales for use in the rice sector. It also changed the attitude of many agricultural officers in research and extension.
22. The GoI maintained its 1960s rice production intensification policy until the closure of the 20th century. It was consistent in allocating a major share of agricultural budget, initially for the procurement of inputs and provision of credit, later increasingly for extension.
23. When, early in the 1980s, self-sufficiency in rice came within reach, more funds were allocated to the development of non-rice crops.
24. The estate and smallholder sectors of agriculture showed a strong increase in production since 1975. In particular, the growing of sugarcane and rubber by farmers expanded due to sound investment of nucleus-estate type of processing industry. The growth of the palm oil industry is spectacular. Oil palm is mainly a crop of para-statal estates.
25. Indonesia has taken the lead in cacao production from Malaysia. The Chocolate Manufacturers' Associations of the United States and the United Kingdom are paying for extensive IPM programs in the main cacao production area, Sulawesi.

Notes

1. Calculated by J.J. Polak for the Council of the Netherlands East Indies (Metcalf, 1952).

2. A fleet of eight vessels under commander J.van Neck reached Ambon where they concluded a contract on the clove trade with the people of Hitu and established permanent trading posts (Ricklefs, 1981).

3. Under the first three Governors-General (1610-19) the *VOC* centre was at Ambon. Jan Pieterszoon Coen, twice appointed as Governor-General (1617-19, 1927-29), relocated the Company's seat in 1619 to Jakarta that had a good port. The principalities Banten and Mataram attacked the VOC fortress, 1616-19. On the site of the destroyed settlement of Jakarta the *VOC* erected a new stronghold and named it Batavia. Coen, who placed the *VOC* on a firm footing, is considered to be the founder of the Colonial Empire (Ricklefs, 1981).

4. The clove tree on Ambon came into production only after 10 years and grew till an age of up to 60 years. Flowering occurs irregularly between October and January. The flower buds (cloves) must be picked within a few days. The labour intensive harvest interfered with food production on Ambon. Forced clove production brought dependency on food imports and thus a need for purchasing power.

5. In 1621, the *VOC* destroyed the English factory on Ambon. As overproduction brought prices down, the *VOC* cut thousands of clove trees on Himoal. When, during the 1630s, Makassarese merchants obtained half of the export volume through their relations with the Himoalese, the Dutch fleet under Governor-General van Diemen came in action once more (Taale, 1988).

6. The *VOC* monopoly in the spice trade aimed at a limited clove production to keep prices stable and concentration of the production on the islands of Ambon. In 1656, all clove trees on the other islands were felled and compensation ('recognition money') payed to the N Moluku rulers (Taale, 1988). Global demand for cloves amounted to about 200 tonnes, but in 1680 production increased almost 400 t. The *VOC* ordered the cutting (extirpation) of clove trees to adjust supply to global demand throughout most of the *VOC* period. Thus, the number of clove trees on the Island of Lease deminished between 1770 and 1819 with 85%, and on Ambon with 65%. Regular military expeditions cut illegally planted clove trees and combatted smuggling of cloves by private traders (Taale, 1988).

7. The coffee growing on high authority under the Priangan Scheme was continued during the British Interregnum and thereafter by the Dutch colonial government until 1883 as a separate arrangement for taxation in coffee instead of the land rent (Mansvelt & Creuzberg, 1975).

8. The first auction in Amsterdam of Java-coffee in 1711 fetched high prices and demand grew within a few years to about 500 tonnes (van Hall, 1939).

9. The purchase price of 10 'stuiver' per pound would be paid in kind (cloth). The farmers lost interest and cut the coffee trees, which forced the *VOC* to increase prices. The priority of trade policy over farmers' interest during the following decades caused a vicious cycle of overproduction, price adjustment and cutting (extirpation) of trees by the *VOC*.

10. In the 18th century, corrupt *VOC* administrators began a black market in staying permits for the numerous Chinese immigrants and extradicted illegal immigrants. In 1740, this led to a heavy revolt which was suppressed at the cost of some 10,000 Chinese killed. Bands of Chinese who escaped overran several *VOC* outposts (Ricklefs, 1981).

11. The government of the Netherlands, called 'Batavian Republic' during the French occupation, took over all rights and duties of the *VOC*, including its debt of 134 M Dutch guilders.

12. General Napoleon Bonaparte, Emperor of France from 1804 to 1814, invaded Holland in 1795 and installed a French-dominated regime in the renamed 'Batavian Republic'. In the interest of centralisation of power, Emperor Napoleon made his brother Louis Napoleon king of the Netherlands in 1806. The independent-minded Louis made important decisions, with collaboration of Dutch patriots, regarding Dutch administration and agriculture in the Dutch East Indies.

13. Armed with the authority of Stadtholder William V (the 'Kew letters') and with more ships and firepower than the *VOC* in Indonesia, the British proceeded to conquest Dutch strongholds. From 1795, the English fleet commenced a blockade of Batavia thereby effectively prohibiting Dutch ships to sail

freely between 1795 and 1800. Immediately, English, American and Danish vessels took over the trade and transport of coffee and spices, which contributed to the bankruptcy of the *VOC* in 1798 (Ricklefs, 1981).

14. The endless succession of wars on Java, Sumatera and the Molukan islands caused a continuous drain on the financial resources of the *VOC* which from a trading company had developed into a sovereign state.

15. Land rent is a taxation on basis of available sawah land. Traditional taxation in pre-nineteenth century Java was not land-based, but population-based, reflecting the importance rulers gave to control over labour (Booth, 1988). Raffles replaced (at least on paper) tax obligations of the peasantry in the form of labour services and the enforced deliveries of produce by a taxation in money on the basis of agricultural land use (Reinsma, 1955).

16. The defeat of the French Napoleonic armies at Waterloo, Belgium, in 1814, and the ensuing Congress of Vienna (1914-15) installed the Kingdom of the Netherlands (including Belgium) as an independent monarchy and brought King William I on the throne. The Dutch possessions in Indonesia were given back, whilst the English withdrew to the Straits Settlements, Malaya, and to the British occupied Regencies Padang and Bengkulu on Sumatera (Ricklefs, 1981).

17. Prince Pangaran Dipa Negara and his able commanders fought a guerrilla war which forced the Dutch Governor-General to seek military and financial assistence from the Netherlands. The heavy loss of men (8,000 Europeans) and high cost of the Java War (over 20 M NGL) deeply changed the colonial policies of the Dutch government (Lubis, 1979).

18. On top of its public debt obligation of 20 M NGL, in 1825, the Dutch East Indies government had to contract additional loans to pay for the Java Wars. The annual interest due on these debts increased thereby to 2.5 M NGL. In 1830 not enough capital was available in the Dutch East Indies to make the required remission (Reinsma,1955).

19. Commissioner-General du Bus de Ghisignies recommended the establishment of large estates under European management on unreclaimed land which at that time still covered 7/9 of all territory under direct government control. This estate plan required long term investments which would aggravate the existing financial crisis of the colonial government (Reinsma, 1955).

20. One of the reasons for low production was that considerable areas of communal village-land had been rented out or sold to private Chinese and European merchants. As the lease contracts were usually short term ones, the planters hardly invested in growing export crops and yields remained low.

21. Land rent is also a measure of the sum demanded from the local rulers or desa headmen in the form of product consignments (levies) during the time of the culture system. Product consignments constituted an effective method of levying taxes in a society with a shortage of cash money (Reinsma, 1955).

22. The 'Government crops' mentioned in official statistics were export crops grown by peasant farmers on order of the government (on high authority) on communal village grounds for marginal planting wages. The yields were collected by the local administration (*Binnenlands Bestuur*) (Mansvelt & Creuzberg, 1975).

23. Over the periode 1851-70, the Netherlands treasury received twice the amount of remittances from *cultuurstelsel* profits it had received in 1831-50, whilst a deficit in the colonial budget due to military expenditure on the Bali War in the 1850s could be compensated (Ricklefs, 1981).

24. To avoid a sudden shortage of labour for the important sugar industry, the process of conversion to free enterprise plantations was spread out over a period of 12 year.

25. It was custom in the Principalities of C Java that, as a reward for services rendered, the control of smaller or larger districts or villages be conferred by the Court to deserving civil servants or relatives.

These allocations, called apanages, used to go with the right of apanage, i.a. taxation, disposal of villagers or communal land, commandeering labour and so on. The holders of apanages were also entitled to accomodate entrepreneurs with land and labour for large scale plantations (Mansvelt & Creuzberg, 1975).

26. By 1845, the government had advanced up to 10 M NGL on the basis of sugar, tea and coffee contracts. The sugar planting credits were continued to 1845 and the harvest credits to 1860 (Fasseur, 1980).

27. A prescribed quantity of sugar had to be delivered to government against fixed prices, whereas the remainder - usually a third - could be freely sold by the manufacturer.

28. The Agrarian Law of 1870 granted property rights on land only to Indonesians. Foreigners were allowed to lease land from the government for up to 75 years or from indigenous holders for periods from five to twenty years (Ricklefs, 1981). The Agrarian Law removed the difficulty under the old rules by which contracts could only be made for services and produce.

29. The Colonial Reports (*Koloniale Verslagen*) of 1849-1906 mentioned in particular the three Demak and Grobogan famines (respectively 1849, 1873 and 1901) when *padi* and *palawija* crops failed due to disastrous droughts (Hasselman, 1914).

30. Bijblad bij Staatsblad nos. 179 and 869; Circulars dated, 18 June 1846, 15 September 1848, no. 251 and 33 August 1863, no. 251.

31. The former Director of Public Works, H de Bruijn (1869), wrote that incessant overburdening of farmers' communities under the *Cultuurstelsel* had eroded the indigenous knowledge on rice cultivation, seed selection and even cultivar characteristics.

32. The self-styled extensionist K.F. Holle, with his friend the Chief *Pangulu* of Limbangan, published brochures on rice seeding, *palawija* cultivation, terrassing of hillsides, and pisciculture in *sawah*. Holle's *De vriend van den Javaanschen landman* and brochures were printed and distributed by the colonial government. In 1872, Holle was appointed as honorary councilor for indigenous agriculture (Hasselman, 1914).

33. The Dutch name of the well preserved botanical gardens at Bogor, at 60 km south of Jakarta, was *'s Lands Plantentuin te Buitenzorg* (referred to as *Plantentuin*). Its present name is *Kebun Raya Indonesia*.

34. C.G. Reinwardt, a professor of chemistry and pharmacology in Amsterdam, arrived in Jakarta as advisor to the Commissioner-General with the function of 'Director for Affairs of Agriculture, Arts and Sciences' (1815-22) (Treub, 1892).

35. In 1863, the *Plantentuin* contained an assortment of 10,000 plant species which were maintained and described by the illustrious hortulani J.K. Hasskarl, J.E. Teysmann, S. Binnendijk and R.H.C. Scheffer. Teysmann served from 1830-'69 and continued as travelling collector of plants for another twenty years. The Gardens' bulletin was named 'Teijsmannia' (1890-1922) in honour of his great contributions (Treub, 1892).

36. Bijblad bij het Staatsblad, No. 869 (18 June 1847).

37. Dr. Melchior Treub, 1851-1910, was an eminent botanist who became a member of the Netherlands Royal Academy of Science in 1879 already. In the tropics, Treub soon saw the importance of studying plants and cultivation problems *in situ*. Being appointed as Director of the *Plantentuin* at an age of 28 years he became an internationally reknown initiator of research in the Dutch East Indies and the founding father of the Department of Agriculture in 1905 (Koningssberger, 1917).

38. When in the 1880s the Sereh disease attacked the sugarcane and the Coffee Leaf Rust the coffee, the *Cultuurtuin* had already collected accessions of and experimental results on new crops to provide technical aid to the planters.

39. In order to enable Dutch botanists to work at the Foreigners' Laboratory and the other institutes at

Bogor, Treub managed to raise a '*Buitenzorg* Foundation' and obtained an annual subsidy from the Dutch Government (Koningsberger, 1917).

40. Treub contributed personally to the establishment of all research stations existing at the time. The Deli Research Station and the Stations for indigo, tobacco, coffee, tea, rubber and cinchona all had, during a certain period between 1905 and 1926, a mode of factual collaboration with the Department of Agriculture (Koningsberger, 1917).

41. Treub held the opinion that the independent research stations could not yet bear responsibility to develop their respective sector because *1.* communications in the Dutch East Indies were still underdeveloped; *2.* the planters' communities lacked the organisation required for continuity of organisation, and; *3.* scientists with experience in applied research and management were not yet available.

42. The scientist J. Van Breda de Haan identified *Phytophthora nicotianae* as the causal agent of wilting disease of tobacco seedlings and recommended removal of all infested seed beds and steaming of the soil of these beds.

43. The Rubber Research Station (Rubber Proefstation) at Medan was financed by the General Association of Rubber Planters in Sumatra (*Algemeene Vereeniging van Rubber Planters ten Oostkust van Sumatra, AVROS*).

44. Koninklijk Besluit, art. 2, dated July 28, 1904, no. 28 (Indisch Staatsblad No.380). Treub's initiative was supported by Secretary De Graaff, who later became Governor-General and a promotor of agriculture.

45. In 1905, the botanic gardens in Bogor, the *Plantentuin*, included the laboratories and experiment stations for rice, coffee, tea, indigo and tobacco, the herbarium, the Foreigners' Laboratory, the Mountain Garden at Cibodas, the Experimental Garden at Cikeumeuh and the Government's Cinchona Estate at Cinjiruan (Koningsberger, 1917).

46. During the parliamentary session on the proposed bill regarding the founding of DoA in the Dutch Indies, the Minister for the Colonies said that the Department of Internal Affairs would remain responsible for indigenous agriculture (*Bijlage op de Handelingen der Staten Generaal 1903/4*).

47. H.J.Lovink was an experienced agricultural administrator when he was appointed as Director of Agriculture in the Dutch East Indies from 1909 until 1918. As a newcomer to Indonesia, Lovink was more inclined to delegate power and to merge the numerous small laboratories and units into larger departmental divisions (Bernhard, 1930).

48. The Boards of the *Algemeen Syndicaat voor Bergcultures* and of the Sugar Syndicate advised the government on issues dealing with plantations on Java and S Sumatera (Toxopeus & Wessel, 1983). The combined Boards of AVROS (Rubber Planters' Association of E Sumatera) and the *DPV* (Deli Planters' Association) represented the interests of estates at the E coast of Sumatera.

49. P. van der Goot in the 1920's studied the biology of white and yellow rice stemborers. His recommendations on synchronous planting of rice in the centres of infestation -the regencies Kerawang, Cirebon and Pekalongan- met with remarkable success. In the district Pekalongan, the annual waiver of land rent, a form of compensation for yield losses, decreased from on average 20,000 NGL/y to 3,000 NGL/y (Mededeelingen IPZ, 1932).

50. There were eight experimental gardens, 600 ha in all, with about 285 ha rubber, 90 ha tea, 145 ha coffee, 40 ha cocoa and 10 ha Cinchona. The gardens were managed by a staff of about 600 employees of which 16 technical officers (Toxopeus & Wessel, 1983).

51. The Central Research Institute for Agriculture (CRIA *or Lembaga Pusat Penelithian Partanian, LP3*) in Bogor was supported by a network of 6 sub-stations and 23 experimental farms on Java, Sumatera, Kalimantan and Sulawesi.

52. The Five-Year Development Plans were indicated Repelita I, 1969/70-1973/74 to the current *Repe-*

lita VI, 1994/95-1999/2000 according the fiscal year (FY) which runs from April 1 to March 31. A Five-Year Plan consists of annual sub-plans which enable the adjustment of policy to the domestic and international economic situation through feed-back of annual evaluation results.

53. The rice trade in Indonesia uses various names to indicate degrees of treatments. These are *padi* for dried ears or unthreshed dried rice, (*padi*) *gabah* for unhusked rice, and *beras* for dehusked unpolished/polished rice.

54. P.N. Pertani (*Perusahaan Negara Pertanian*, Agricultural State Enterprise), which held a monopoly on fertilizer distribution, was charged with pesticide distribution for Bimas-Inmas till 1968. In 1969, the GOI took away the distribution task from P.N. Pertani for the *Bimas Gotong Rojong* program because of its failing management and poor price control. P.T. Pertani was then re-organized as an autonomous semi-government enterprise (*Perseroan Terbatas*, P.T.) (Afiff, 1979).

55. Bimas was defined as 'an intensive extension campaign supported by inputs and credit facilities delivered down to village level, stimulated by market prices favourable to the farmers. The pilot project was derived from the pilot activities by students in the period 1963-66 (Adjid, 1983; van de Fliert, 1993).

56. BULOG (*Badan Urusan Logistik*, National Logistics Agency) was the government agency in charge of padi procurement at the national and provincial level as a safeguard of supply and distribution to military and civil government institutions. BULOG played a decisive role in subsequent food price stabilization regulations.

57. The seven foreign companies included CIBA (Swiss), Mitsubishi (Japanese), COOPA (Italian), Hoechst (German) and Agrar und Hydrotechnik (German). BULOG opened letters of credit in the name of these multinationals to be drawn on the Central Bank of Indonesia.

58. The total volume of credit to be allocated during the program period was estimated at circa 29.5 M US $. The loan had to be repaid by the farmer to BULOG within one year.

59. The credit package of the *Bimas Inmas Gotong Rojong* program differed for farmers growing improved IR-cultivars and those growing local varieties. The former received 30% higher total loans for seed, fertilizer, pesticides and extension. The loan component for pesticides was the same for both categories (11 US$ = 4,440 rupiah). For farmers using improved cultivars the pesticide component amounted to 35% of the total loan.

60. The volume of *padi* turned in by the farmers as repayment on loans remained far below expectations. Lower than expected yields, cheating with yield declarations, low over-all rate of repayment (below 53% over four seasons), too easy terms of credit, and a score of other irregularities caused an unacceptable repayment deficit (Afiff & Timmer, 1971).

61. With support of the army, President Sukarno dissolved, in 1959, the Constituent Assembly and decreed the constitution which gave him, and not an elected cabinet, supreme powers in a 'guided' democracy. Under the autocratic governments of the Presidents Sukarno and Suharto, the army obtained an all pervading influence in Indonesia's society. The political function of the army was frequently utilized to impose unpopular measures upon the people (Palmier, 1965).

62. CIBA took a contract on 400,000 ha of rice in the wet season 1969/70 at 29,50 US$/ha (100,000 ha in each C and E Java, and 200,000 ha in W Java). The CIBA package included insecticides and two aerial applications per season. Fertilizer was not included but was supplied by P.T. Pertani (Sources: Pedoman 6.5.1969; Djakarta Antara 5.5.1969).

63. Oka (1996) cited the outbreak of rice gall midge in W Java in 1979 as an example of a secondary pest induced through aerial spraying of phosphamidon (Dimecron® ULV) to control rice stem borer.

64. Studies on natural enemies of BPH and whitebacked planthopper (WBPH) include amongst others *Cyrtorhinus lividipennis*, *Casnoidea* spp, *Paedurus* spp, *Coccinella* species, and the parasitoid *Haplo-*

gonatopus orientalis. During 1975, researchers identified several parasitoids of the rice gallmidge (*Orseolia oryzae*).

65. IRRI releases of rice cultivars possessing one dominant resistance gene (BPH1) for resistance to BPH biotype 1 began with IR26 in 1973, followed by IR28-IR34, IR36, IR38-IR54, IR64, and IMV2 cultivars since 1974/75. IR32, IR36, IR38 and later issues possessed gene BPH2 with resistance to biotype 2. These cultivars were introduced into or cross-bred in Indonesia and replaced gradually the high yielding but very susceptible cultivars IR5, IR8, C4-63 and the Indonesian IMV1 hybrids Pelita I/1, I/2 (both from IR5 x Syntha) (Oka, unknown; Jatileksono, 1993). Hybrid cultivars (from IMV1 x other HY-cultivars and called IMV2) comprised *i.a.* the popular cultivars Cisadane, Cimandiri, Citarum, Krueng Aceh and Semeru (Jatileksono, 1993).

66. The new biotype BPH2 could attack IR26, IR28, IR30 and IR34. Since untill 1977, BPH2 had only been found in N Sumatera, IR 26 was still widely planted on Java. IRRI released the rice cultivars IR32, IR36 and IR38 with resistance against BPH biotype 2 (Oka, unknown). Indonesia released the four HY-cultivars Asahan, Brantas, Serau and Citarum which possess BPH1 and BPH2 resistance.

67. For sawah conditions medium short cultivars with erect leaves are favoured to reduce lodging and disease. For rain-fed rice, which suffers from greater weed competition, breeding aims at taller cultivars with moderately erect leaves to shade out weeds.

68. Farmers prefer Cisadane because of its superior consumer quality, although it matures about 20 days later than IR36. Many farmers still grow IR36 because of its earlier maturity (110 days) and resistance to various pests and diseases.

69. The Bogor Research Institute for Food Crops, founded in 1905, and the Malang Institute (E Java) worked in particular on secondary food (*palawija*) crops. Rice research was primarely the responsibility of the Institutes at Sukamandi (W Java), Ujang Pandang (S Sulawesi) and Banjabaru (S Kalimantan). The Sukarami Institute (S Sumatera) was focussed on dryland rice and *palawija* crops.

70. Under the Agrarian Law of 1870, the indigenous landowner was authorized to lease his land for a certain period to non-indigenous parties. The unclaimed, so-called wild lands, could be leased out by the state initially for 20 to 40 years and, later, up to 75 years (hereditary long lease).

71. According to the Sugar Cultivation Law, each year 1/13 part of the enforced sugar culture should be transformed into free enterprise. Thus, by 1890 all enforced cession of land and labour by peasant farmers came to an end.

72. The Java sugar industry exported raw sugar of low quality to refineries in Europa and United States of America and lost thereby the added value. Improvement of sugar quality and processing technique became the main task of the Sugar Research Station W Java (Koningsberger, 1948).

73. For reasons of regional differences between cultivation conditions and poor communications at the time, the sugar planters' associations of W, C and E Java established three separate research stations, They declined collaboration with the *Plantentuin* institutions at Bogor and refused government interference.

74. An inquiry, held in 1963/64 at 28 sugar factories in district Madiun, E Java, with a total planted area 37,000 ha, revealed 40% damage from rats to the crop (Handojo *et al.*, 1987).

75. The first samples of Sumatera tobacco arrived in the Netherlands already in 1864 and shipments were auctioned regularly from 1865 onward. In 1884, the value of the Sumatera tobacco output had risen to 27.5 M NGL, thereby surpassing the production of Java tobacco which valued 7.8 M NGL.

76. The Chief-administrator of *Deli Maatschappy*, J.T. Cremer, who succeeded J.A. Nienhuis, founded the *Deli Planters Vereeniging DPV* (Deli Planters' Association) in Medan in 1871, and the Deli Railway Company in 1983. In later years, Cremer was appointed as Minister for the Colonies in the

Netherlands.

77. The four dominant tobacco companies were Delimy, Deli-Bamy, Senembah and Arendsburg. Their Chief-Administrators made up the Board of the *Deli Planters Vereeniging*. DVP established also a pathological laboratory for human medicin and an immigration service for Chinese labour in Medan.

78. The Government's coffee plantations in Priangan and elsewhere under the *Cultuurstelsel* were situated far away from the villages, wages for enforced service were low and supervision by European and local controllers entirely insufficient. Controller K.W. van Gorkom (1884) wrote that many square miles of coffee forests were unproductive since exclusion of light and aeration within the 'coffee jungle' prohibited fruit bearing.

79. The exploitation rights on former government coffee gardens were given to the people for a term of 10 years. Where growing coffee was less profitable, the lands were given out for growing food or turned in to forestry reserves. To protect smallholders against middlemen and money lenders the leasing of free coffee gardens to non-Indonesian was prohibited (Huitema, 1935).

80. The Cacao Proefstation at Salatiga was instituted in March 1901 and L. Zehntner was appointed Director. It was built amidst cacao estates, of which the managers (administrateurs) contributed on basis of area planted (cess fund). The Station's Bulletins (Mededeelingen) reported on results (Toxopeus & Wessel, 1983).

81. *Rampasan* implies that outside the fruit-bearing season all pods are removed from the trees, and buried in deep holes so that all larvae inside the pods are destroyed and female adults find no pods to deposit their eggs on. Zehntner (1903) concluded that only rampasan controlled cacao pod borer effectively.

82. At Salatiga between 1900-06, Zehntner studied the biological control of the cacao pod borer, because spraying of cacao pods was to expensive due to tree size and spray frequency (every 5 days) (Toxopeus & Wessel, 1983).

83. For example, Perkebunan XIII, established in 1971 by government decree no. 24, managed 19 estates in W Java. The main crop was tea, followed by rubber, cinchona, cacao, coconut and cloves. Since 1980, Perkebunan XIII opened nucleus estates in SW Java and W Kalimantan with World Bank loans.

84. 'Study on the improvement of plantation crop research in Indonesia', March 1971 (Bappenas Project ATA -4g)

85. The group of Perkebunan and private companies set up their own research centres which were to work independently from the public sector institutes. These included the Gambung Research Centre for Tea and Cinchona, a Rubber Centre at Getas, C Java, a Tobacco Centre at Djember, and an additional Centre at Medan, Sumatera, for rubber, oilpalm, Deli tobacco, tea and cacao.

Chapter 3

Development of agriculture in Malaysia

3.1. Introduction

The political entity 'Federation of Malaysia' came into being in 1963 and consists of West Malaysia, the Malay Peninsula, and East Malaysia, the States of Serawak and Saba. Singapore joined the Federation initially, but separated two years later. W Malaysia is part of a peninsula pointing southward from the Asian landmass. It shares borders with Thailand to the north and with Singapore to the south. E Malaysia is situated in NW Kalimantan and shares borders with Indonesia and Brunei. The agricultural situation in E Malaysia is of little relevance for this study and is, therefore, not reviewed.

From the rugged frontier area in the north of Peninsular Malaysia several mountain ranges run southward to form the central Malayan highlands. The heavily forested main range, rising steeply from flat coastal and riverine lowlands, forms a formidable obstacle to the east-west communication, but in the S State of Malaka its altitude deminishes to about 400 m.

Peninsular Malaysia has a hot equatorial climate with, in the lowlands, an average annual temperature varying between 25°C and 28.3°C. The rainfall determines the seasons, the NE monsoon prevailing between November and March, the SW monsoon from June to September. The rainfall pattern of Peninsular Malaysia is complicated. Most regions have more than 180 rain days per year. The driest periods are generally from December to March and in June and July (World Atlas of Agriculture, Vol.2:365).

The NW coastal lowland, with a marked dry season, is the chief rice producing part of the country. The CW lowlands of Krian and Tanjung Karang, and the SW lowlands of Melaka have deep peat soils, which are largely opened up for oil palm, pineapple, vegetable and rice planting. The lowlands on the E coast are generally less developed, but for the Kemubu Irrigation Scheme in Kelantan.

For centuries the peninsula was the target of Malay immigrants who arrived from the islands (*i.a.* Java and Sulawesi) of the Indonesian archipelago. Till the 19th century, the country had no more than a quarter million inhabitants. The first official census of 1911 reported the population of the peninsula as 2.3 million. The establishment of a colonial export economy invoked two successive waves of immigration of Chinese and Indians which not only augmented the population growth but also transformed the ethnologically homogenic social structure into a heterogenic structure. The population composition at Independence in 1957 was about 50% Malay, 37% Chinese, 11% Indians and 2% others. At the time, over two-third of the Chinese and Indians were born in Malaya (Kasch, 1984).

Agricultural development in Peninsular Malaysa was dominated by the European managed estate agriculture. After 1980, when control over the estate sector passed to Malaysian bussiness groups, the estates continued to prosper.

Indigenous agriculture received relatively litte attention from the colonial administration. After Independence, the Malaysian government invested heavily in improvement of rice cultivation for two reasons, *a.* to reduce the need for imports of rice, and, *b.* to improve the income of Malay farmers, equity of economic opportunity being a political issue. Another target group for government attention were the rubber and oil palm smallholders. Several Federal Authorities were established to open up new land and to organize the settlement of smallholders. The economic output of smallholder agriculture, however, remained a matter of great concern and many farmers migrated to towns. In consequence, the contribution of agriculture to the Gross Domestic Product decreased steadily during the 1990s. Development of other agricultural sectors, such as the production of vegetables and fruits, was by and large left to private initative.

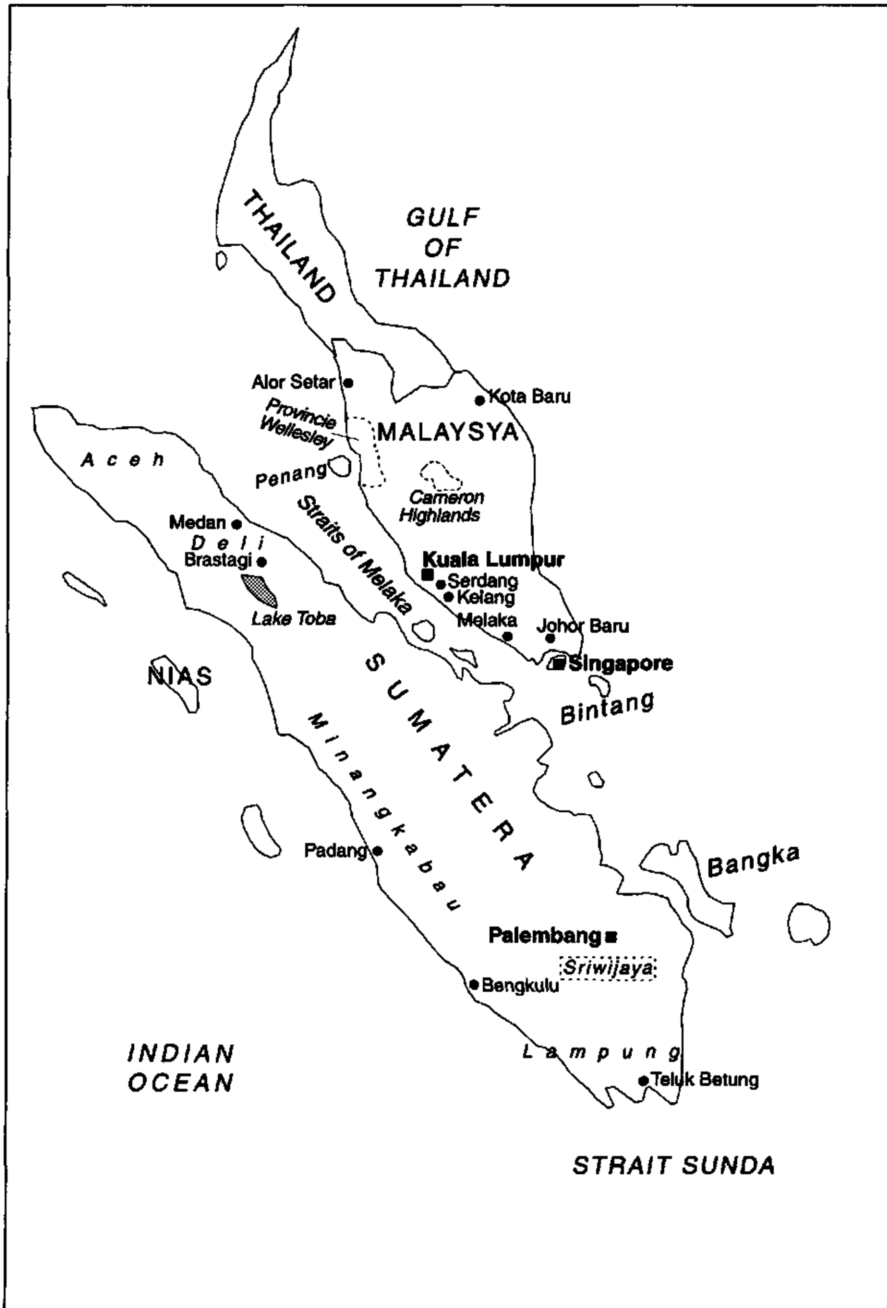
3.2. Early Malay history

Peninsular Malaya forms a natural bridge between the Asian continent and the Indonesian archipelago. As Malaya and Indonsia have similar climates and environments, their early history has much in common. Located at the convergence of two major sea routes and linked to the great markets of India and China, Malaya became integrated in the regional trading network which gradually developed from the third century A.D. Commerce attracted diverse groups of people from S India, Sri Lanka, S China and Sumatera which settled along Malaya's coasts and rivers (Ryan, 1976). The indigenous tribes, the 'orang asli', retreated into the jungle.

Hardly any written or sculptural documentation exists on the early history of the sparsely populated peninsula (Ryan, 1976). Malaya's development was probably set in motion by the rise of the maritime kingdom Sriwijaya in S Sumatera, in the seventh century A.D. (ch 2.2). Sriwijaya came to exercise suzerainty over the Melaka Straits with its typhoon safe harbours, and it controlled piracy in the area (Ryan, 1976). The ensuing period of peace favoured international trade to which Peninsular Malaya contributed its minerals and products[1] from the jungle and the seas, which were higly valued.

Sriwijaya's decline allowed the rise and glory of the Entrepôt State Melaka as the heart of the trade between the East (China) and the West (India, Arabia and Europe) in the 15th century[2]. Melaka's importance as entrepôt port stemmed from its efficient legislation and administration which guaranteed safety for traders and their ships, and honest and rapid handling of the cargo (Watson & Andaya, 1982). The foreign trading products included tea and manufacture from China, spices from Indonesia, cloth, pottery, copper and ironware from India, and rice from Siam and Indo-China.

Traditional food supply came from hunting, fishing, gathering and swidden agriculture. Indigenous crops included rice, banana, coconut, root crops such as sweet potato (*Ipomoea batatas*) and cocoyam (*Colocasia antiquorum*), probably sugercane, leafy vegetables and fruits. Immigrants from China and India introduced planting materials, tools, methods of permanent land use and wet rice growing. Expanding *sawah* in fertile plains during the 11th century gave the Sultanate of Kedah the commercial resources to free itself from its overlord Sriwijaya (Watson & Andaya, 1982).



Map of Peninsular Malaysia, Sumatera (Indonesia) and S Thailand. [Refer to map on p. 77 for names of Malay States and major granaries of Peninsular Malaysia].

3.3. Arrival of European contenders in Malaysia

3.3.1. The Portuguese, the Dutch and the English. In 1511, Melaka was attacked and captured by the Portuguese who sought direct control over the lucrative spice trade, in particular cloves and nutmegs from E Indonesia. In the late 16th century, Dutch ships began to arrive in Malay waters. In 1602, the Dutch East India Company (*VOC*) was founded for the promotion of the East Asia trade. In an effort to achieve monopoly over the lucrative spice trade, the *VOC* captured Melaka from the Portuguese in 1641 after a long siege, with the help of the Malay kingdom of Johor. (Map on page 61).

English influence on Malaya commenced in 1786 with the acquisition of the Island Penang from the Sultan of Perak by the English trader Francis Light. In 1800, the Englishmen wrested Province Wellesley[3] from the same ruler, who protested against the earlier deal (Ryan, 1976). At the time of the French invasion of Holland in 1795, all Dutch *VOC* possessions in Asia including Melaka were given in trust[4] to England to keep them out of French hands. In 1815, after Napoleon's defeat at Waterloo, the *VOC* settlements were returned to the Dutch. In 1819, the English acquired the island of Singapore from the Sultan of Johor. Several years later Melaka was ceeded definitely to England following the Anglo-Dutch treaties[5] of 1824 and 1826 (Watson & Andaya, 1982).

3.3.2. Agriculture before 1815. The indigenous hunting, fishing and gathering societies bartered the products from jungle and sea with inhabitants of river basins, who in turn sold them to entrepôt merchants. The increasingly busy maritime traffic and the growing population demanded a steady supply of food and fruits, which seems not to have created serious problems. In its high days, the population of Melaka, swelled by foreign traders, may have numbered as many as 100,000.

The Portuguese and the Dutch in Melaka appear to have contented themselves with maintaining an essential supply of food for their forces. With this objective, the occupying forces maintained a certain degree of suzerainty over the adjacent Malay territory Negeri Sembilan, and forced the inhabitants to pay them tribute in rice and other agricultural produce. In the territory of Melaka the successive governors established a system of land tenure and taxation that discouraged its agricultural development (Grist, 1935).

When the settlement of Penang was established in 1786, the British East India Company (EIC) soon ordered the growing of vegetables and fruits for its fleets and garrisons. With this objective it made grants of land on the island freely available to agricultural entrepreneurs. In the following years the EIC encouraged cultivation of rice in the Dependencies Penang, Province Wellisley and Melaka. The EIC also tried to bypass the Dutch monopoly on the spice trade through the cultivation of spice crops on Penang and Singapore Island. Records indicate that nutmegs, cloves, coffee and pepper were grown in both Settlements[6] since the end of the 18th century. With the intention of stimulating agricultural development Raffles inaugurated the botanical gardens in Singapore in 1822. These gardens were later abandoned, but they may have supported the introduction of spice cultivation.

3.4. Agriculture in Malaya between 1815 and 1914

3.4.1. British administration. From 1829, the four British possessions Penang, Province Wellisley, Singapore and Melaka constituted the Straits Settlements under a unified administration which, after 1832, had its seat at Singapore. The East India Company remained the controlling authority. In 1833, the EIC lost its monopoly of the China trade, which had hitherto alleviated the costs of maintaining the Straits Settlements as ports of call. Like the *VOC* one century before, the EIC found itself in the possession of strategically valuable ports that were not self-supporting and that left it with the financial burden of administration. When the EIC ceased to exist in 1858, the administrative responsibility over the Settlements was first transferred to the India Office and, in 1867, to the Colonial Office in London. Throughout the greater part of the 19th century, the British government did not expand its territorial control over Malaya. The EIC, and after its demise the British Government, was adamantly opposed to any involvement in Malay quarrels and considered vital to keep any Malay dispute a local matter under authority of the sultans.

From the late 18th century, Europeans in the Straits Settlements had experimented with plantation agriculture. Coffee, cotton, tea, tobacco and spices had all been planted but none had yielded the anticipated profits. Chinese agriculturists pioneered sugar planting in Province Wellisley and proved particularly successful in growing a combination of cassava, pepper and gambir[7]. They had already developed extensive pepper, spices and gambir estates in Singapore by the mid-1830s. A few European merchants also planted sugarcane and spices in the Settlements.

3.4.2. Development of Chinese enterprise. In the 19th century the Chinese came to dominate commercial agriculture and tin mining industry. The displacement of Malays in the local economy during this period may be attributed to inherent cultural attitudes. The Malay were noted as energetic traders, but seemed unwilling to work for wages on estates or in mines. The rigours of existence, the backbreaking work on the edge of the jungle and the depredations by tropical diseases caused a death rate of up to 50% in some rural areas. Chinese who survived demonstrated a competitive spirit and a determination to succeed which could not but affect the pace of change in the Malay world.

The pool of Chinese manpower increased rapidly and already by 1845 the Chinese became predominant in the population of Singapore and some Malay towns (Watson & Andaya, 1982; Kasch, 1984). Their immigration was actively encouraged by both the Straits Settlements and the Serawak governments, for Chinese energy and enterprise were widely acknowledged[8]. Unsettled conditions in S China, and especially the outbreak of the Taiping rebellion in 1851, stimulated emigration, mainly from the SE provinces of Kwantung, Fukien and Kwangsi.

What set the Chinese community apart from traditional Malay traders was their access to credit for investment in agriculture, either supplied from their own resources or from wealthy European merchant firms in the Straits Settlements.

Over the centuries the lack of liquid capital even among rich Malays was characteristic as available funds were usually quickly expended on an open display of wealth and on the maintainance of a large retinue, the cultural indices of a great man. The difficulty of most Malays to call on reserves for immediate investment hampered their competition with local Chinese, who could purchase modern equipment with lent money to process products such as sago and gambir.

The Chinese also had a concept of business organization which gave them further advantage over Malays. Their expertise is clearly seen in the *kongsi*, an association of individuals from the same dialect group and area of China who held shares in a co-operative venture. An added strength of the *kongsi* system were the ties to other major centres of SE Asia, a network that was unfettered by political boundaries.

With a ready pool of labour, access to capital and a business organization to absorb temporary losses, the Chinese position in the rapidly changing economy was secure (Kasch, 1984). Some perceptive Malays took advantage of the new opportunities presented by the Chinese and worked with them in true partnership. The best example of Malay co-operation with Chinese investors and labourers was undoubtly in Johor, where the sultan encouraged Chinese to plant pepper and gambir in a shifting cultivation system (Watson & Andaya, 1982). From the mid-1840s the Chinese began moving to Johor because of land scarcity and exhaustion of the estate soils on Singapore land. Controlling the system of land grants, Johor's ruler was able to maintain active Malay involvement in Chinese economic enterprise. A Chinese headman was placed in charge of each river basin where plantations were developed[9]. By the mid-nineteenth century the results of Johor's policy were evident in the expansion of plantation agriculture. In the 1860s, there were 1,200 gambir and pepper plantations in Johor, employing about 15,000 Chinese farmers.

3.4.3. Beginning of civil turmoil. Johor's control over the Chinese was exceptional, since its Malay rulers were content to let the Chinese community exist outside centralized control as long as the revenue due to the local authority was paid. Although an estimated 100,000 Chinese lived in Johor, frictions with the Malay authorities remained rare for several decades. However, Chinese investors of the Straits soon found it more efficient simply to advance money for business operations in mining and agriculture directly, bypassing the local Malay chief.

This trend had far-reaching effects. First, it hastened the rate at which the Chinese tightened their grasp on resources. Second, the independence of the Chinese settlements undermined the authority of the Malay chiefs and hence their ability to maintain order. Rivalries and hostilities between clan and dialect groups within the local Chinese society made the situation more complicated. The absorption of the Chinese by the existing Malay political and social system was hindered by the so-called 'secret societies' rooting in China which had a reputation of fomenting dissent. The potential threat of the secret societies to established government was evident in street fights between rival groups in Penang and Singapore and in the riots which often erupted when some unpopular law was promulgated. Strong leadership was a decisive factor in maintaining stability of the society, but at least in the British view it was precisely this element which was lacking most in several Malay states (Watson & Andaya, 1982).

In the second half of the 19th century, immigrants from India settled in the Straits Settlements. The Indians worked as labourers in road construction or as traders and remained outside agriculture. The migration of large groups of Tamils for the estate industry was organized, around 1900, by the United Planting Association, a society of planters (Kasch, 1984).

3.4.4. The British take-over. In the third quarter of the 19th century civil war among rival sultans had become endemic. Malays and Chinese were often in conflict, and there were bitter faction fights among the Chinese themselves. As the fighting became more widespread through the early 1870s, several sultans, Chinese merchants who did bussiness in the native states, and merchant houses urged the government to intervene. Till 1872, London insisted that there was to be no further British involvement at an official level in the troubles of the states. Finally, the need to establish law and order became a major rationale for British involvement in the peninsula[10].

During the 1870's, on varying pretexts[11] and through occasional military action the British quickly established control over the states Perak, Selangor, Negeri Sembilan and Pahang, where British residents were posted (Map page 61). Hence, the four above states were referred to as Protected States. Despite many initial, often serious mistakes the British thus consistently expanded their rule from 1875 onwards by what came to be called the residential system[12].

To lessen economic disparity and differences in development between Pahang on the east coast and tin-mining states Perak and Selangor on the west coast, the four Protected States were grouped into a Federation in 1896. The Federated Malay States (FMS) were brought under a unified administration, civil service and common treasury seated at Kuala Lumpur. This move towards centralization strengthened British control over Malaya.

The northern Malay States remained under Siam's suzerainty until the beginning of the 20th century. In 1909, King Chulalongkorn of Siam ceeded control over the states of Kedah, Perlis, Kelantan and Terengganu to the British by treaty. In the following years the northern states were included under the unified administration as the Unfederated Malay States (UMS). In 1914, the British were finally able to extend control to the southern state of Johor, despite the strong relationship its rulers had maintained with Singapore. Thereby, Johor was able to preserve more privileges than the other states.

3.4.5. Establishment of export oriented agriculture. When the British Government abandoned its policy of non-intervention in 1873, the Protected Malay Sates began to benefit from the systematic development of agriculture as initiated by the British administration in the four Strait Settlements. New Botanic Gardens were founded, in Singapore in 1858 and on Penang around 1887, to experiment with new crops and to provide technical services. Although the Gardens were primarily intended to serve the Settlements and were maintained entirely from colonial funds, the services of the Botanic Gardens Department of the Straits Settlements were later extended to the entire peninsula. Thus, the Botanic Gardens became the predecessor of the Department of Agriculture of the Federated Malay States.

Late in the 19th century, Chinese interest in gambir, tapioca and pepper declined as prices fell. By then, the colonial government considered traditional Chinese plantings inimical to the larger interests of Malaya as their shifting cultivation led to soil exhaustion and to depletion of firewood, needed for the numerous small factories. Consequently, it moved to suppress this type of agriculture and promoted permanent land-use through investments in experimental European plantations of coffee, tea and rubber as already established in Ceylon[13] and the Dutch East Indies. For this purpose, the colonial office supplied planting stock of pepper, clove, nutmeg and coffee.

European entrepreneurs were eager to develop plantations because of the lucrative market for agricultural exports. The European planters had access to much greater capital and better expertise than the Chinese and could employ the most skilled labour force. In Europe, the industrial capital sought to effectively invest its merchant capital in the colonies (Loganathan, 1990). Western merchant firms and management agencies, of which about a dozen had real importance[14], linked the agricultural and mining activities on the peninsula with commerce in Singapore, and with technical expertise and finance of the UK.

In view of the chaotic land tenure situation existing at the time, the firms wanted legal titles to the land to justify their long-term investments. The colonial government, henceforth, enacted an adequate land legislation, the Selangor Land Code of 1891, which was based on the Torrens[15] system of registration of title (Grist, 1935).

3.4.5.1. Sugarcane. As earlier Chinese efforts in growing sugarcane had been successful, a few European merchants began planting cane in the Settlements with the help of experienced sugar planters from Mauritius and Ceylon. In the 1840s, the Malacca Sugar Co. and other enterprises had been formed which operated with Chinese contract growers. Malayan sugar became a higly capitalized European-controlled industry and appeared to have a bright future. But from the beginning the planters were hampered by a shortage of labour, although Tamil labourers were brought in from India, under indentures, during the 1880s. When indentured labour was abolished in 1913, the last sugar factory closed (Allen & Donnithorne, 1956). No evidence was found that the *sereh* disease impeded sugarcane cultivation in Malaysia as it did in Indonesia.

3.4.5.2. Coffee. The cultivation of coffee began in the 1880s with the arrival of coffee planters from Ceylon, whence they had been driven by the outbreak of Coffee Leaf Rust Disease, caused by *Hemileia vastatrix*, which destroyed their *Coffea arabica* plantations (Allen & Donnithorne, 1956). The Coffee Leaf Rust Disease spread from Ceylon throughout SE Asia and reached Singapore Island in 1879. As *C. arabica* was the most widely grown species the search for resistant coffee was commenced without delay (Sivaram, 1980). In 1875, coffee planters tried a supposedly resistant species, *C. liberica*, which was introduced from Africa.

The government wholeheartedly supported the coffee planters with generous land terms, planting loans, technical advice and a favourable labour situation[16]. Consequently, proprietary[17] estates were rapidly taken over by companies. Between 1891 and 1896, the Brazilian coffee industry slumped due to the abolition of slavery. This caused a price hike on the world coffee market and a boom for the young coffee industry in Malaya. Coffee planting was greatly expanded in Selangor and extended to Negeri Sembilan, Perak and Johor. However, by 1899, when new supplies of Brazilian coffee came on the market, the coffee price fell to one-third of its peak value at a time when most of the newly planted estates came into bearing. The situation aggravated by the outbreak of the hawk moth (*Cephanodes hylas*)[18] which induced the European planters to replace or inter-plant coffee with rubber or to abandon their plantation. When *C. liberica* proved to be susceptible to the Leaf Rust Disease coffee growing almost disappeared. To date, the remaining coffee gardens in Selangor and Johor consist predominantly of a mixture of *C. liberica* cultivars (Sivaram, 1980).

3.4.5.3. Rubber. Towards the end of the 19th century, interest arose in the commercial use of rubber. Since it was known that *Hevea* trees from the Amazone Basin provided the best source of natural rubber, the British Colonial Office in 1876 commissioned the scientist Henry Wickham to Brazil to collect seeds of *H. brasiliensis*. Wickham succeeded in smuggling some 70.000 seeds out of Brazil, which were germinated in quarantine at Kew Gardens, England. Some 2,700 seedlings were sent to the East of which 21 were received at the Singapore Botanic Garden[19] in June, 1877 (Polhamus, 1962). After several years of experimentation, young rubber trees were given out to the coffee planters struggling with the Leaf Rust epidemic. Early in the 20th century interplanting coffee with rubber became common, and forest land was cleared for rubber planting. Rubber seemed the ideal crop to fulfil the government's aim of long-term land use by Europeans. In 1897, special land regulations were introduced in the Federated Malay States to encourage rubber cultivation. As rubber gave the highest return on investment and was less prone to pests, other crops such as spices, cassava, sugar, and coffee disappeared gradually from estates.

The expansion of the motorcar industry caused the first boom in rubber planting in 1905. By 1908 rubber was planted in every state of Malaya. Numerous small rubber companies obtained funding through British agencies[20] established in the Straits Settlements. Another rubber boom, in 1909-1912, encouraged European companies to spent large sums to buy up Malay lands and old Chinese sugar, gambir, and cassava plantations. Many Malay and Chinese smallholders began to plant rubber with the hope of eventually selling the land to Europeans. Thus between 1910 and 1913 the area under estate rubber more than doubled to 322,000 ha. By 1916 rubber passed tin as Malaya's chief export earner, a position it held till 1980.

3.4.5.4. Oil palm. The oil palm, *Elaeis guineensis,* was introduced from West Africa into the peninsula through the Singapore Botanic Garden in 1870. At first it was mainly cultivated as an ornamental plant. Only in 1917, the first plantation was set up as a commercial venture. Although palm oil was used in the manufacture of soap, candles and margarine, there was little progress in the industry until the slump in rubber prices after World War I forced planters to look for an alternative crop.

3.4.6. The state of indigenous agriculture. Whilst the colonial government was actively encouraging European investment in estate agriculture, it adopted a general *laissez-faire* attitude towards the economic development of Malay farmers. A large percentage of Malays were subsistence rice farmers in the coastal plains and river deltas. Many Malay and Chinese farmers planted also some pepper, gambir, coconut and fruits for cash income. In the early 1880's, over 90% of the coconut plantings were managed by Malay, Indian and Chinese smallholders (Ahmad, 1980). Between 1910 and 1925, European and Asian estate companies planted the coconut to export copra[21].

As the tin mining and estate industries absorbed increasing numbers of migrant labourers, the authorities began to actively encourage greater Malay rice production to feed the growing population. There was even an attempt to import Chinese and Indian padi farmers, but with little success. Rice growing was centered in the northwest and northeast[22] because these areas had usually adquate supply of water, good drainage and some manure. Beginning in the 1880s, the Kedah aristocracy was in the forefront to encourage the expansion of rice growing. While the colonial government constructed a big irrigation scheme for Kerian and other smaller projects in the 1890s, Malay initiative was mainly responsible for the increase in rice production[23].

Malay farmers soon regarded rubber as an ideal cash crop because it is hardy, little affected by pests and diseases, and it thrives almost anywhere in Malaya. The older rubber cultivars could be tapped from the seventh year and remained productive for about thirty years. The smallholder was, thus, assured a steady income from his rubber trees which require little care and minimal cost in the production of latex. The colonial government, minding its rice production strategy, actively discouraged the Malay from planting other commercial crops, especially rubber. A 'no rubber' condition was imposed on certain land to prevent Malay farmers from growing this increasingly profitable and convenient crop (Grist, 1935).

3.4.7. Establishment of a Department of Agriculture. Before 1900, the services of the Botanic Gardens Department of the Straits Settlements were invoked by planters in the Federated Malay States (FMS), particularly for advice on coffee and rubber cultivation. In 1903, the government of the FMS realized that the existing institutions could not cope with the pace of agricultural expansion. In 1904, it commissioned Dr J.C. Willis, then Director of the Botanic Gardens in Ceylon, to report on agricultural conditions in FMS and to make recommendations on future policy. Willis formulated an operational scheme for the organization of a

Department of Agriculture (DoA) and stressed the need for close collaboration between all departments of government concerned with agricultural questions (Grist, 1935; Ahmad, 1980). The recommendations were accepted and the Department of Agriculture of the FMS was inaugurated in 1905.

The first major task of DoA was to implement the new agricultural policy issued by the government to accelerate agricultural development and preservation of land rights. Plant protection officers prepared the first legislation[24] on prevention of the entry of noxious organisms and on quarantine for the Federated Malay States. DoA also assisted in drafting other important enactments. The passed enactments included: *1.* the Labour Code, 1912, securing the rights of contract labourers from China and Indonesia, *2.* the Malay Reservations Enactment, 1913, Federated Malay States, empowering State Governments to declare any area within that State to be a Malay Reservation, in which land cannot be sold to a non-Malay. It ensured that a sufficiently large area of fertile land would be reserved for native smallholders, and *3.* the Country Lands Enactment, 1914, granting plots of up to 4 ha to farmers for cultivation.

3.5. Advancement in agriculture between 1914 and 1957

3.5.1. Impact of World War I. The First World War, 1914-18, considerably affected agriculture in Malaya. Owing to the increased demand for rubber, the rubber industry claimed priority at a time when a large number of administrative and scientific officers were called into the services. The war impeded the import of rice thereby causing a precarious food situation. The FMS government issued a policy to increase the production of secondary food crops, such as bananas, cassava, vegetables, sugarcane, groundnut and maize, and to intensify ongoing research on rice, coconut and oil palm. The policy was supported by new legislation. In 1917, a Rice Lands Enactment and a Coconut Preservation Enactment were introduced to prevent these crops from being replaced by rubber. In addition, the Food Production Enactment of 1918 set aside specific land for food crops only. Other inducements and subtle coercions urged the Malay farmer to remain on the land to produce food and, above all, rice. A regional shortage of rice occurred due to crop failure in India and Siam which gave these measures special urgency.

Yet there were major shortcomings in the government's efforts to encourage Malay rice farming. It neglected the need for rural credit at reasonable terms. The farmer always faced the threat of losing his land to his creditor or of eviction by his landlord. Instead, the available credit facilities were channelled primarily to European plantations. It also let research on rice lag far behind that devoted to export crops. Throughout British rule the Malay farmer was viewed as a needed producer of rice with no real place in export crop production.

In 1917, the government of the FMS appointed an Advisory Committee to increase the production of rice and other food crops. The work of the Committee resulted in the establishment in the Krian District of the first government rice mill and a Rice Research Station to stimulate rice breeding. The improvement of the irrigation system in Krian and other districts was speeded up (Grist, 1935). The government took control over the production of all food crops and enforced planting of food crops by all employers of labour. Rapid agricultural development dated from this time and was, to a large extent, rendered possible by the rich revenues coming in from the tin-mining industry of the FMS.

3.5.2. Development of the Agricultural Services

3.5.2.1. Privately funded research. DoA was responsible for the development of all economically viable crops, but rubber was always given most attention. In tackling the technical problems of rubber cultivation, DoA was assisted by scientists employed by the larger rubber estates[25] and by the 'Rubber Growers Association' (Ahmad, 1980). Shortly after World War I, however, the rubber industry demanded more intensive research on rubber in the form of a scientific organization over which the industry would have control. The FMS government concurred with this desire and, in 1918, commissioned E.J. Butler[26], Director of the Imperial Agricultural Research Institute at Pusa, India, to evaluate the agricultural services and conditions in the FMS. Butler recommended to separate rubber research from that on other crops and to strengthen the technical staff of DoA (Grist, 1935). Accordingly, in 1921 began the development of a large Experiment Station at Serdang, Selangor, for crops other than rubber, coconut and rice.

The year 1922 brought a serious agricultural depression due to the fall of the rubber price. To meet this crisis, the Colonial Office, London, introduced the Stevenson Scheme of Rubber Restriction throughout Malaya, Ceylon and India -the Dutch East Indies abstained- which remained operational until 1928. Owing to the economic depression, primarily, the establishment of a private rubber research institute was delayed for six years. Finally in 1926, the Rubber Research Institute of Malaya (RRIM) was founded. RRIM became a leading centre for improvement of rubber clones, tapping technique and latex processing throughout the 20th century.

When DoA handed its mandate[27] for research on plantation rubber to RRIM, it meant the first break in policy which rendered it both possible and necessary to reorganize the Department. DoA remained responsible for all research and extension concerning smallholder rubber, and for the administration of all legislative measures connected with the national control of rubber diseases.

3.5.2.2. Publicly funded research. DoA's Crop Protection Branch took over certain research projets of the Botanical Gardens on pest and diseases in estate crops. Among these, the Branch continued data collection on the infestation and damage inflicted on coffee by the hawk moth caterpillar[28], on its life cycle and host plants. Besides making recommendations on sanitary and chemical control, the government entomologists described three natural enemies[29] of the hawk moth. They also studied the next important pest, the coffee berry borer, *Stephanoderes hampei*, but did not detect its natural enemies.

The DoA collected resistant planting material of all commercial crops for observation in the government experiment stations. In 1925, for example, 14 coffee cultivars were obtained from the Experimental Coffee Plantation, Bangala, East Java (Sivaram, 1980). Grist (1935) noted collaboration with the Dutch East Indies on the exchange of high-yielding rubber clones. The technique of bud-grafting rubber clones was learned from researchers in Medan around 1915. Research on rubber kept its priority status with DoA. The program included experimenting with different tapping techniques, testing of new clones under different soil conditions, and fertilizer trials. DoA's Field Branch, responsible for advising rubber smallholders, established clonal nurseries and supplied millions of clonal seedlings and large quantities of budwood for grafting. In 1952, DoA and RRIM jointly set up the Rubber Industry Smallholders' Planting Material Scheme for the supply to land development schemes (Ahmad, 1980).

The Division of Plant Breeding began, in 1915, to make pure line selections in rice. In 1927, the breeders tried to cross local rice cultivars but failed to obtain new cultivars. Line selection yielded some high yielding strains which by 1936 had largely replaced local rice cultivars in Krian District (Van, 1963). The average small farm size of about 1 ha was a limitation to raising rice production.

In 1927, the Experiment Station at Serdang was reorganized and its name changed to that of Central Experiment Station. Additionally, a considerable number of subsidiary experiment stations and demonstration plots was established under the supervision of the State and Circle Agricultural Officers throughout the FMS and the Straits Settlements. Serdang, Selangor, remained the centre of agricultural research throughout the 20th century.

3.5.2.3. Strengthening of the agricultural services. Early in the 1920s, DoA realized that smallholders needed more assistance. Consequently, the Extension Service of DoA's Field Division recruited Malay personnel to work as field staff in the districts. This development necessitated an adequate training of the Asian staff, for which purpose an Agricultural Training Centre was established at Serdang in 1923. In 1929, DoA was reorganized into separate branches for research, extension, and support services (box 3.5.2.3). In 1931, DoA and RRIM jointly put the Rural Lecture Caravan on the road, a van equipped with instructional films, lantern slides and exhibits which toured the rural areas (Ahmad, 1980).

From 1930, the governments of the Unfederated Malay States (UMS) began to organize their agricultural extension services on the lines adopted in the FMS. Committees were established for the promotion of food crops. The Rice Committee, installed in 1930, led to the establishment of a Drainage and Irrigation Department in the Ministry of Agriculture. This department collaborated with DoA for the improvement of existing rice growing areas and the expansion of irrigation systems. A Tobacco Committee was installed in 1932, and a Vegetable Oil Committee in 1934.

In 1931, the School of Agriculture, Malaya, was opened at Serdang, with the objective of training Asians for appointment in the Department and for the estates. Recommendations made to this effect came from officers of the Education Department who visited the Philippines and Java, and from the agricultural instructor who visited Ceylon. Elementary agriculture was taught at the Training College for Malay Teachers for primary schools.

By 1935, agricultural services had been made available to all states except Perlis, and specialist officers from the DoA headquarters could be called on by the UMS. The closer collaboration between all Federated and Unfederated States of Malaya in the agricultural sector necessitated amendment of existing legislation.

Box 3.5.2.3

The Department of Agriculture of Malaya

The founding of a Department of Agriculture for the Federal Malay States (FMS) resembled the course of events in the Dutch East Indies. In both countries, around 1900, the colonial administration became hard pressed to maintain an effective balance between the capitalist plantation agriculture and the need to improve the income generating capacity of indigenous agriculture. The services of the Botanical Gardens Departments were overcharged and there was no adequate extension. The institutional organization was in both cases conceived by a Chief Scientist, M. Treub on Java and I.C. Willis from Ceylon for Malaya.

In 1905, J.B. Carruthers was appointed as the first Director of Agriculture of the FMS. The newly recruited staff of DoA included an entomologist, a mycologist and a chemist. Agronomists of the Botanical Gardens, such as the Coconut Inspector and the Superintendent of Plantations, were also placed under the jurisdiction of DoA. Through such arrangements, DoA took over the research and advisory tasks on crop improvement in the FMS from the Botanic Gardens Department of the Straits Settlements. In 1919, the mandate of DoA was extended to include the Straits Settlements.

In 1923, the government appointed a Malay Civil Service Officer to head DoA with the title of Secretary of Agriculture and changed the post of Director of Agriculture to that of a Scientific Advisor. In 1928, the post of Director of Agriculture was reinstated with the appointment of the scientist H.A. Tempany. The latter reorganized DoA fundamentally by establishing separate Branches for Research, Field (extension) , Agricultural Economics and Publication, and Education (Tempany, 1930). The duties of officers in the Field Branch were clearly defined to secure close collaboration with the Research Branch. In the same year 1929, a Department of Statistics was established in the Ministry of Finance to organize Agricultural Census and to perform surveys on the estates and agro-industry. DoA collected most of the data on smallholders' agriculture.

3.5.3. The fateful decades, 1930-1950

3.5.3.1. The great economic depression. In 1928, the Stevenson Scheme of Rubber Restriction was terminated. Thereafter rubber production both in Malaya and Dutch East Indies rapidly increased and outstripped consumption[31]. This increase, combined with the great world depression which commenced in 1929, led to a decline of rubber prices to an unprecedented level. Concurrently, prices of all other agricultural commodities declined, in many cases sinking to below cost price. The Malayan industries most affected were the coconut and oil palm industries. The situation was exacerbated by a corresponding depression in the tin mining industry, due to overproduction. These developments caused great financial stringency both in public finance and in commerce[32]. Between 1931 and 1947, the government adhered to a restrictive policy on immigration of alien labour while encouraging their repatriation[33].

3.5.3.2. Second World War and the reconstruction. The Malayan economy was badly affected by the Japanese occupation, 1942-45. Most Europeans and many Malayan citizens were imprisoned or deported. Agricultural and industrial stocks and much infrastructural equipment were confiscated by the Japanese army. When a situation of acute food shortage arose, the Japanese administration sent the urban dwellers into the countryside to grow large quantities of food crops (Ahmad, 1980). After the war, the pre-war agricultural policy of crop diversification was maintained, in particular concerning food crops. Thus, in 1946, the government instituted 'The Agricultural Food Crop Proclamation' which required major proprietors to plant at least 2% of their total cultivated area with food crops. As a result of this proclamation, approximately 14,000 ha were planted in 1946. By the end of 1955, this area had increased to about 39,000 ha.

Research institutions and plantation industries suffered the loss of records and equipment during the war. Most of the pure lines and crosses of rice and other annual crops remaining in the experimental stations were lost too. Improved cultivars, which had been widely adopted, had become mixtures. It was necessary, therefore, to begin all selection and breeding work from scratch (Van, 1963). Work on food crops was resumed inmediately and self-sufficiency in rice became an important goal. By 1960 at least seven improved cultivars were available for large scale release in various states (Van, 1963).

Utilizing the earlier testing work at the Serdang Experiment Station on Trinitario cacao in 1934, the DoA performed a feasibility study on establishing a cacao industry in 1947 and commenced nurseries with Trinitario seeds obtained from Ceylon. Soon, about 15,000 seedlings were given out for trials after scrutiny by the Plant Protection Division of the DoA (Ahmad, 1980).

By the outbreak of the War in 1941, the rubber industry was in a strong position due to new high yielding clones, and progress in mechanization and processing. The perennial crops on experimental stations and estates were less damaged than annual crops and could thus provide the backbone for a rapid agricultural recovery. By 1946, Malaya's rubber production was almost back to pre-war level and by 1948 a record production of 708,000 tonnes was reached. The palm oil industry recovered rapidly too although much machinery had been removed from the factories. By 1950, over half of the national output and employment was again generated in the agricultural sector. Rubber alone contributed nearly one third of Gross Domestic Product (GDP). In the last years of colonial government, a First Five-year Malaya Plan, 1956-60, for economic development was issued and implemented.

3.6. Agriculture in independent Malaysia, 1957-present

3.6.1. The arrival of Independence in Malaysia. On February 1st, 1948, the Federation of Malaya was formed by joining the Federated and Unfederated Malay States including Johor, Penang and Melaka. Singapore remained outside the Federation[34].

In 1957, the Federation of Malaya gained its independence from Britain. Several years later, in 1963, the Federation of Malaysia was formed by almalgamation of Malaya, Singapore and the northern Borneo territories of Serawak and Sabah. In 1964 Singapore left the Federation, but the rest of it survived the severe confrontation with Indonesia and the Philippines over the Borneo territories.

When the Federation of Malaysia became independent in 1957, the primary objective of government changed from maintaining law and order to national development. The economic policies of the independent Federation were no longer determined by the concerns of overseas investors or foreign governments. Instead, the government tried to create opportunities for an equitable development of estate and smallholder agriculture.

3.6.2. Agricultural policy since 1957. The government prepared a First Five-Year Plan for independent Malaysia, designated Second Malaya Plan, 1961-65. The series of five-year plans since the formation of the Federation of Malaysia in 1963, which cover the period 1966-2000, were named First to Seventh Malaysia Plan. These national plans cover all sectors of the economy including agriculture and form the basis for allocation of the budget (Anonymous, various).

The main objectives of the First and Second Malaya Plan, 1956-65, were economic growth and the elimination of economic disparity among the ethnic groups. A third objective, creating more employment opportunities, would be achieved with greater economic growth.

The government had only limited success in reforming rural land tenure, credit and marketing, which were the major factors contributing to rural poverty. In 1955 and 1967, the Padi Cultivators (Control of Rent and Security of Tenure) Ordinances[35] were passed in order to protect the farmers (Watson & Andaya, 1982). In an effort to give farmers access to land, the government set up the Federal Land Development Authority (FELDA) in 1956. Between 1956 and 1966, this body opened up large areas of land in Pahang and Johor, each constituting 1,600 to 2,000 ha, for rubber and oil palm smallholders. The DoA supplied budwood, fertilizers and herbicides under the Rubber Smallholders Planting Material Scheme (Ahmad, 1980).

The agricultural sector was a major earner of foreign exchange, averaging about 55% of the commodity export earnings between 1965 and 1985. This impressive performance was a major reason why Malaysia did not suffer any lengthy or pronounced balance of payment crisis. Over the decades since 1957, the agricultural sector was characterized by *1.* the predominance of a small number of perennial crops, producing export commodities such as rubber, palm oil and cacao, *2.* an efficient, well-organized plantation-scale agriculture and a less developed smallholder sector, *3.* dependence on export of agricultural commodities and sizeable imports of food and feed and, *4.* high incidence of poverty and under-employment in the Malay smallholder sector.

When economic growth began to level off by a decrease in tin production and a growing competition to natural rubber by synthetic rubber, the early planning for diversification of the economy paid off. The palm oil industry boomed, aided by a large influx of capital after World War II, an adequate research program and a buoyant overseas market. By 1966, Malaysia had become the world's largest producer of palm oil. The exploitation of timber and iron ores, and an increase of manufacture also contributed to total export earnings.

Ethnic disturbances in May, 1969, forced the government to reassess the entire question of economic growth in relation to the now vociferous Malay demand for a greater share in the country's wealth[36] (Mahathir, 1970). The government designed a National Economic Policy (NEP), 1971-90, in an effort to reconcile the vexed question of ensuring economic growth and eliminating economic disparity[37], which in Malaysia unfortunately tended to reflect ethnic divisions (Rehman Rashid, 1993).

The Second Malaysia Plan, 1971-75, contained guidelines for poverty alleviation through facilitating the access of the poor to land, capital, training and public services. More equity of income and opportunities should be brought about by reducing the dependence of Malay and other indigenous groups on subsistence agriculture. The Third and Fourth Malaysia Plans, 1976/85, continued the same policy lines by allocating 38% of the development budget to poverty eradication and to the development of backward rural areas by building towns and industries. However, the NEP's goal of poverty eradication remained elusive and large numbers of Malay farmers migrated to the towns. By 1981, Malay constituted one-third of all urban dwellers. The Malay held a privileged position over other ethnic groups in terms of job opportunity with the result that the rate of poverty elimination has been faster for them than for Indian and Chinese rural and urban poor (Yusof Hussein, pers. comm., 1996)

3.6.3. Agricultural research since 1960. The Federal and State Departments of Agriculture and the universities developed jointly the first research programs for independent Malaysia during the Second Malaya Plan, 1961-65. Since there were few researchers at the time, the government set research priorities for double cropping of wet rice, soil fertility, crop diversification, cultivar improvement, control of diseases and pests, post harvest technology and marketing (AADPC, 1984a). A Division of Food Technology was established in the Ministry of Agriculture in 1966. Two years later, the Malaysia Agricultural Research and Development

Institute (MARDI) was founded (Yusof Hashim, 1990). Its mandate included all crops except rubber, livestock, poultry and fisheries. DoA established seed multiplication farms to supply improved rice varieties. The research budget was increased from 10 M US$ for the First Malasia Plan to 40 M$ for the Fourth Plan. Actual expenditure remained usually below the budget ceilings.

In 1975, the Agricultural University of Malaysia (UPM) was founded which provides education both at degree level and diploma level. Under the Malaysia Plans the Ministry of Education is responsible for funding agricultural education. For this reason the university's agricultural teaching and research programs are rather theoretical (Oudejans, 1996).

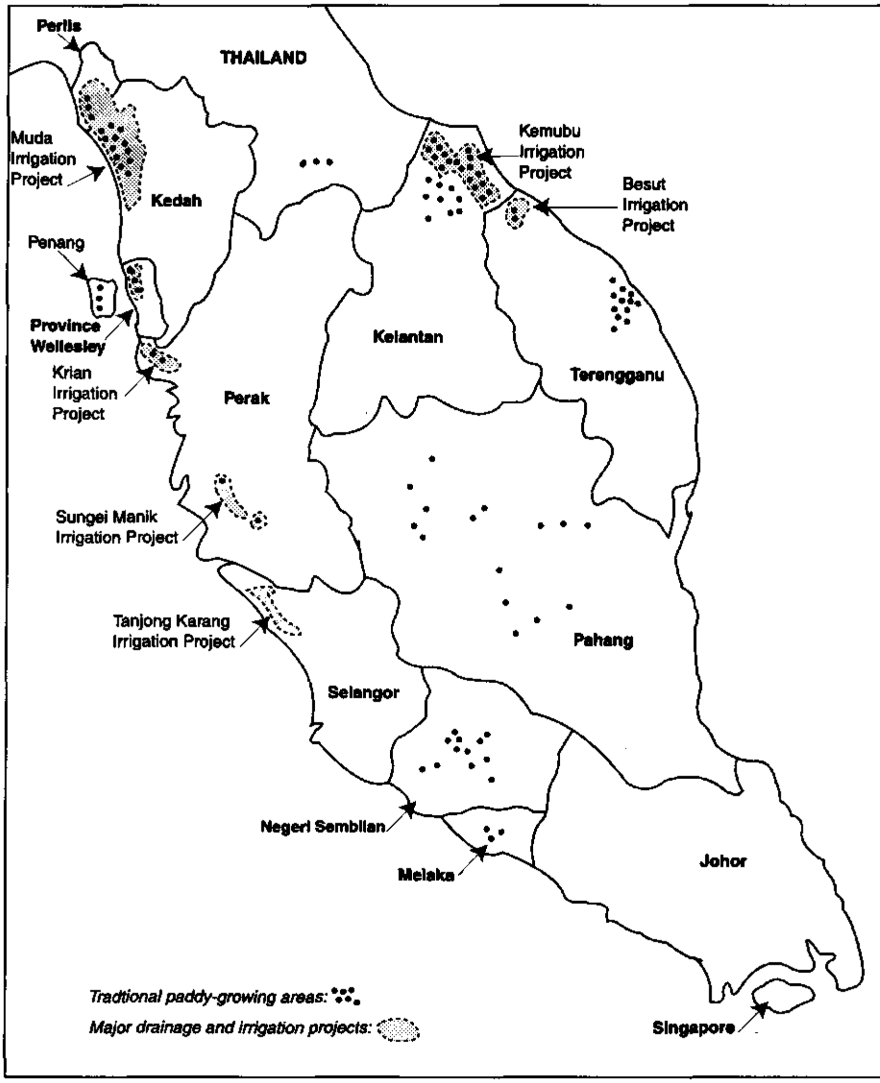
The Federal and State Departments of Agriculture were responsible for the extension of research findings. Since 1971, the extension service was strengthened through the establishment of training centres for farm mechanization and crop production technology. Most of DoA's extension efforts were carried out through Farmers' Associations. Although the budget allocations for extension were increased for each Five-Year Plan period, the extension service reached only few farmers (AADPC, 1984a).

3.6.4. Rice cultivation in Peninsular Malaysia

3.6.4.1. Irrigation schemes and Green Revolution. In the coastal flood plain of the Muda river in NW Peninsular Malaya, large scale rice growing was introduced during the 15th century from Siam (Taylor, 1980). In the following centuries, rice was grown as rain-fed *padi* in the low-lying river basins and estuaries of Malaya which were irregularly flooded during the monsoon seasons. Seeds were broadcast when the first rains enabled tillage of the soil. Owing to the erratic rainfall patterns, serious weed competition always resulted in low rice yields. The method of transplanting, which replaced direct seeding, was probably adopted to overcome weed problems. Pre-germinated seeds were sown on nursery beds and the seedlings transplanted after 30-40 days into the fields which remained flooded until about two weeks before harvesting.

The major indigenous varieties planted in Malaya before World War II were of the photoperiod sensitive indica type which were only suited for the main season[38]. In 1942, the Japanese introduced three early maturing, photoperiod insensitive rice varieties[39] from Taiwan. These introductions were suitable for off-season planting and marked the beginning of double cropping in independent Malaysia (Ho, 1993).

Before the Green Revolution of the 1960s, almost all rice farms were small and single-cropped[40]. Only a negligible percentage of land was double cropped. Early in the 1960s, the government of Malaysia commissioned the development of large scale irrigation facilities with loan-funding by the World Bank. The Tanjung Kareng Scheme, measuring 20,000 ha, in Selangor was the first one to be completed in 1961. In 1966 began the construction of the Muda River Irrigation Scheme in the northern states of Kedah and Perlis. The Muda and Pelu dams and canal system enabled a transformation from single cropped *padi* land to Malaysia's largest double cropping scheme, which encompasses an area of 97,000 ha and pro-



Map 3.6.4.1 Malaysia, location of the major Rice Irrigation Schemes

vides employment for 63,000 farm families (Syed & Ho, 1985). The Muda Scheme was completed in 1968-69, the Kemubu Scheme in Kelantan in 1972, the Besut Scheme in Terengganu in 1975, and the Kerian/Sungai Manik Scheme in 1976 (map 3.6.4.1) (Taylor, 1980). Thereafter, expansion of irrigated double cropping area was slow because the remaining padi growing areas were small and scattered (Taylor, 1980).

During the 1960s, the Green Revolution was adopted in Malaysia, where the Irrigation Schemes became the main beneficiaries of its technology package of high yielding rice varieties, fertilisers, pesticides, and credit. Because of the profound effect of the Green Revolution on total rice production (table 3.6.4.1), Malaysia's rate of self-sufficiency in rice increased from 56% in 1955 to about 90% in 1990. The large scale adoption of modern varieties and technology also changed traditional forms of land use because they made rice farming profitable at last. A sizeable number of tenants were evicted between 1966 and 1975, when owners either took back their land or hired more land to increase the size of their farms. Owner-farmers could manage larger farm units because mechanization of ploughing, soil levelling and harvesting operations solved labour constraints.

3.6.4.2. Rice cultivation in the Muda Irrigation Scheme. In 1967, the Kedah Department of Agriculture began experimenting with double cropping[41] to explore its feasibility for the Muda Scheme. Pilot projects, using rice variety IR8, in the following years served to adjust traditional cultivation practices and to show the farmers the importance of synchronizing planting activities. When irrigation became available in the Muda Scheme in 1970, double cropping was ready for area- wide introduction (Syed & Ho, 1985). By 1974, about 92% of Muda Irrigation Scheme was doubled cropped (Ho, 1993). During the 1970s, rice production increased steadily through *a.* improvement of the irrigation and drainage infrastructure[42], *b.* adoption of early maturing, high yielding varieties[43], *c.* mechanization of tillage and harvesting, and *d.* sharply increased use of fertilisers and pesticides through provision of institutional rice production credit and fertiliser subsidies[44] (table 3.6.4.2).

A major limitation to rice production in the Muda Scheme was a chronic water deficit[45] since irrigation demand always exceeded available supply. When water was let into the main channels, only the farmers (less than 10%) adjacent to secondary supply canals could obtain water directly. Farmers with fields further away and especially those near the drainage end of the blocks had to wait up to forty days before water reached their fields. Poor pre-saturation of the soil hampered the synchronization of planting activities, such as flooding, ploughing, transplanting, and weed control, to prevent pests. Due to the unevenness of the soil surface and lack

Table 3.6.4.1. Effect of irrigation and Green Revolution technology on total off-season rice production in Peninsular Malaysia. Hectareage planted with improved varieties and imput expressed as percentage of total rice area. Source: Ho, 1994a.

Period	Total production (x 1.000 t)	Hectareage planted (x 1.000 ha)	(%)
season 1/56	443	43	1
season 1/76	1,075	222	44

of water for submersion of the fields, weeds created big problems. Shortage of labour was another reason for delays in tillage and transplanting[46] of rice seedlings.

3.6.4.3. Transition from transplanting to direct seeding. In the seasons 1970/1 and 2, the performance of six rice varieties was compared in transplanting, line sowing and broadcast experiments[47]. Although suitable varieties were found for direct seeding, farmers hesitated to adopt this practice. Uneven soils, deficient water management and erratic monsoon rainfall, and resulting heavy weed infestation, were high risk factors in direct seeded fields. Escalating transplanting costs due to lack of labour and cancellation of all irrigation in season 1978/1 due to severe drought prompted some farmers to try direct seeding. Studies on land preparation[48], mechanization and soil characteristics in the Muda area, enabled a shift from wet to dry tillage (rotavation) in first-season land preparation.

The actual change to large scale dry rotavation and direct seeding was attributable to disease and pest control recommendations. The wide-spread planting of a few, non-resistant IR-varieties contributed to an outbreak of green leafhopper (*Nephotettix virescens*), vector of a tungro virus, between 1981 and 1984. The ensuing tungro virus epidemic in the Muda area was controlled through the intro-

Table 3.6.4.2. Malaysia. Rice production between 1980 and 1996. Source: Various FAO Production Yearbooks. Index: a. area harvested (M ha); b. production of rough rice (M t); c. annual production in relative values (1995 = 100%); d. yield of rough rice (t/ha). (See also fig. 7.3.3.b).

Year	a	b	c	d
1980	0.72	2.07	93	2.9
1981	0.72	2.10	95	2.9
1982	0.72	1.83	83	2.9
1983	0.68	1.81	82	2.7
1984	0.66	1.76	79	2.7
1985	0.66	1.95	88	3.0
1986	0.63	1.75	79	2.8
1987	0.64	1.70	77	2.7
1988	0.67	1.78	80	2.7
1989	0.65	1.74	79	2.7
1990	0.68	2.03	91	3.0
1991	0.69	2.14	97	3.1
1992	0.67	2.07	93	3.1
1993	0.68	2.08	94	3.1
1994	0.71	2.16	97	3.0
1995	0.68	2.22	100	3.1
1996	0.66	2.07	93	3.1

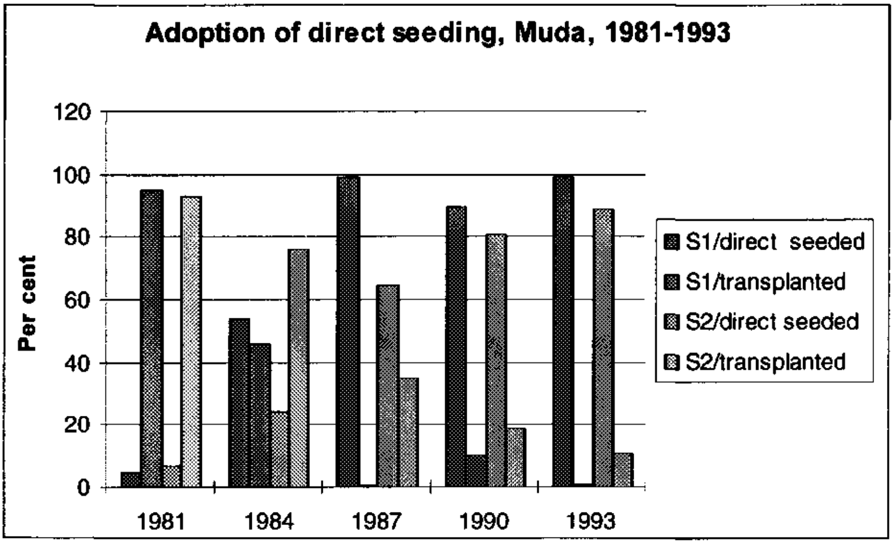


Figure 3.6.4.3. Transition from transplanting to direct seeding in rice, Muda Irrigation Scheme, 1981-33. Source: Ho, 1993.

duction of variety IR42[49] and sanitation (Ho, 1993). The burning and ploughing of the fields after harvesting to destroy the tungro virus inoculum in the stubble and ratoon crop, readied the field for direct seeding. Further, the Muda Agricultural Development Authority (MADA) terminated all first season supply of irrigation water in January, beginning 1984, and imposed a complete fallow during the month of February every year. The severe measures were necessitated by chronic water deficit and staggered planting problems which, among others, interfered with adequate pest and disease management (Ho, 1993). The result was that the direct seeding technique increased from 5% of the planted area in season 1984/1 to 90% in season 1990/1 and to almost 100% in the 1990s (fig. 3.6.4.3).

Table 3.6.4.3. Hectareage under direct seeding in season 1993/1 in the major irrigation schemes of Peninsular Malaysia. Source: Ho, 1993, 1994a.

Irrigation scheme	Total planted (x 1,000 ha)	Direct seeded (x1,000 ha)	Direct seeded (%)
Muda	92.7	91.8	99
Kemubu	35.9	26.0	72
Kerian/Sungai Manik	31.0	3.7	12
PBLS	19.0	18.1	96
Seberang Perau Utara	13.0	9.1	70
Tanjung Karang	20.0	?	?

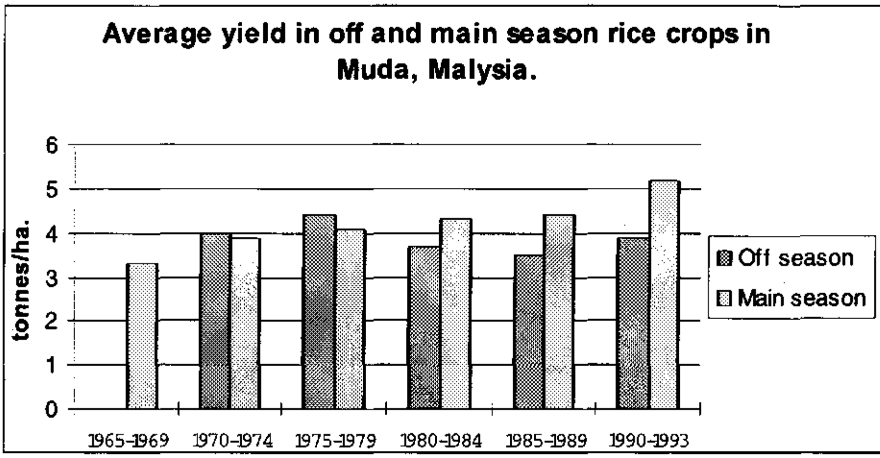


Figure 3.6.4.4. Average yield in first and second season rice crops in Muda Irrigation Scheme , Malaysia, 1965-1993.

The other major irrigation schemes of Peninsular Malaysia followed the developments initiated by MADA regarding research on and extension of the direct seeding technique. By season 1993/1, over 70% of the total hectareage of irrigated rice was direct seeded (table 3.6.4.3).

In the Muda area three types of direct seeding technique can be distinguished: *a*. wet seeding with pre-germinated seeds, *b*. dry seeding with non pre-germinated seeds, and *c*. utilisation of shattered seed[50] with minimum or zero tillage. Each dry seeding technique has its own requirements concerning field preparation, supply of irrigation water, recommended seed rates and labour input. Each technique results in a typical pattern of weed growth.(Ahmed & Moody, 1980)

In wet seeding, the field is puddled, levelled and drained before broadcasting pre-germinated seeds. Adequate tillage and water management before seeding can suppress weed emergence to a great extent. With dry direct seeding, the field is ploughed to incorporate the broadcast ungerminated seeds into the ground without any flooding. As the rice seeds germinate at the onset of rainfall in late March or early April in the first season, water is let into the field in stages. Meanwhile, uninhibited aeration of the soil (aerobic condition) stimulates the germination of grass weeds. In the case of self-sown seed the rice straw and stubbles are burnt and the fields usually dry rotavated. With minimal or no tillage, paraquat might be applied to dessicate left-over vegetation.

3.6.4.4. Change in weed ecology under dry seeding practice. According to Ho (1991), the scenario of weed infestation and distribution changed dramatically since the adoption of double cropping in 1970. The MARDI station at Bumbong Lima, Penang, began to study weed ecology in rice in 1976. MADA conducted the earliest detailed weed study in the Muda area in season 2/79, when still over 99%

of the rice fields were transplanted. Twenty-one species were recorded with broadleaved weeds accounting for more than 80% of the infestation in transplanted fields. Grasses and sedges were found growing sporadically along the edges of direct seeded fields (Ho, 1991).

In the season 1980/1, farmers, practising wet direct seeding for three consecutive seasons, reported heavy infestation of the grasses *Echinochloa crus-galli* and *E. colona*. In 1982, a MARDI weed survey of all major rice schemes in Peninsular Malaysia, reported 34 weed species in the Muda area, sedges (*Cyperaceae*) and grasses (*Poaceae*) being dominant. *Echinochloa* spp. increased in the other schemes too. The age similarities and morphological resemblance of grassweeds and rice seedlings often lead to delayed weeding (De Datta & Bernasor, 1973). In the season 1984/1, when 53% of the Muda area was direct seeded, of which three-quarter by self-sown seedlings, 42 weed species were recorded by MADA. In season 1987/1, when 99% of the scheme was dry seeded due to acute water shortage, surveyors counted 50 species in dry seeded fields against 32 species in transplanted rice.

3.6.4.5. Chemical weed control in Muda area. Before double cropping was introduced, hand weeding with a sickle was the common practice. In season 1973/1, weeding took 70 h/ha. Chemical weeding reduced labour input to 10 h/ha by 1981, although weed density had increased under direct seeding. In the 1970s, the majority of the farmers used herbicides to control broadleaves and sedges. They applied mainly chlorphenoxy (2,4-D) compounds[51], but usually less than the recommended dosage rate (Ho, 1983, 1985).

When pre-emergence herbicides[52] became available in the Muda area in the early 1980s and post-emergence herbicides in 1986, these largely replaced 2,4-D to control grasses. By 1988, an estimated 11% of the Muda area were treated with 11 commercial herbicide formulations (Ho, 1991). Chemical weeding became an important cost factor in rice production (table 3.6.4.5).

Table 3.6.4.5. Comparison of expenditures (US$/ha) on production activities between transplanting and wet-seeding technique in the main season rice crop of 1991, Muda Irrigation Scheme, Malaysia. Sources: Wong, 1993; Ho, 1994a.

Production factor	Transplanting	Wet-seeding
Land preparation	89	94
Seeding/transplanting	111	12
Fertiliser application	7	8
Insecticide application	5	5
Herbicide/weeding	7	22
Harvesting/transport	145	153
Total production costs	364	294

Lack of soil moisture and improper land preparation in direct seeded rice are the efficiency limiting factors of pre- and post-emergence herbicides (Ho, 1994a). Continuous use of the same herbicides caused the problem of selective suppression of grass weeds. For instance, repeated application of molinate (at 3 kg a.i./ha) controlled *Echinochloa* spp but worsened infestation by *Leptochloa chinensis* and *Ischaemum rugosum*. Subsequent application of pretilachlor (at 500 g a.i./ha) and fenoxaprop-p-ethyl (at 60 g a.i./ha) controlled *L. chinensis* and *I. rugosum*. Research by MARDI and MADA focussed on reduction in herbicide usage, and on integrated weed management (IWM) in order to solve the increased weed problems in direct seeded rice and in the irrigation canals system (Ho, 1994b). MADA's extension department developed IWM training packages on the basis of farmers' knowledge, attitudes and practices (KAP) studies. Since 1989, MADA organized several IWM extension campaigns which included training on water management, soil preparation and herbicide selection, spray equipment and application technique (Ho, 1994b). To encourage the use of relatively more expensive herbicides for grassweed control, MADA negotiated with the Bank Pertanian Malaysia to include selective herbicides in the credit package. The herbicide credit doubled the use of molinate whilst reducing use of 2,4-D compound by more than two-third (Ho *et al.*, 1990).

3.6.4.6. Trend in rice yields in the Muda Irrigation Scheme. Prior to 1970, *padi* yields under rainfed conditions were about 3.2 t/ha. After the introduction of double cropping, the *padi* yield remained relatively stable at 4 t/ha from 1969-1977. The off- (first) season yields in the 1970s exceeded those of the main (second) season due to higher solar radiation and lower pest and disease incidence. With the introduction of a fertiliser scheme in 1978/2 yields rose above 4.5 t/ha. Between

Table 3.6.4.6 Production trends and productivity in off-season and main-season rice crops in the Muda Irrigation area over the period 1982-1992. Sources: Ho, 1993, 1994a.

Item/Seasons	Unit	1982	1984	1986	1988	1990	1992
Off (first) season							
Planted area	1,000 ha	89.5	83.1	91.0	92.2	92.6	92.2
Transplanted	%	79	47	35	9	10	1
Direct seeded	%	21	53	65	91	90	99
Average yield	t/ha	3.3	3.2	3.8	3.2	4.1	3.6
Main (second) season							
Planted area	1,000 ha	95.2	95.5	96.0	97.0	97.1	97.2
Transplanted	%	77	76	50	40	19	13
Wet seeding	%	23	24	50	60	81	87
Average yield	t/ha	4.3	4.6	4.4	4.2	5.2	5.1

1982 and 1984 *padi* yields declined to 3.2 t/ha due to the tungro virus epidemic in the Muda area. Throughout the 1980s, overall rice yields fluctuated strongly, whilst off-season yields were lower than main season yields due to water stress, lodging and severe weed infestation (Ho, 1994a).

Crop cutting surveys over five main-seasons (1987-91) showed that the direct seeding technique could raise the yield potential of irrigated rice. The average yield in 1979/2 was 4.8 t/ha. Since 1990, the average main season *padi* yields were above 5 t/ha when more than 80% of Muda was direct seeded (table 3.6.4.6). Pilot projet studies in seasons 1991/1 and 1992/1 indicated that, if farmers carefully followed integrated weed management recommendations, the yields of dry seeded crop were up to 9% higher[53] than in those of the wet seeded crops (Ho, 1993).

Direct seeding using self-sown seed with minimal or zero tillage became popular during the years 1985-88 but was then discontinued because of worsening weed problems and low yield.

3.6.4.7. Insect pest control in major irrigation schemes. In Malaysia before 1977 insect pests in rice did not cause major damage. Generally, farmers followed a standard recommendation for spraying at 30 and 60 days after transplanting (DAT) to control rice insects, in particular rice stemborers (Heong *et al.*, 1985). In the Tanjung Karang Irrigation Scheme, insect pests such as the rice stemborers were relatively unimportant in the 1960s (Ooi, 1976; Khoo & Lee, 1978). An increase in preventive spraying by Tanjung Karang farmers, however, triggered a massive outbreak of the brown planthopper (*Nilaparvata lugens*, BPH) in 1977 (Lim *et al.*, 1978). Chemical control efforts against BPH also caused an increase of the white-backed planthopper (*Sogatella furcifera*, WBPH), striped rice stemborer (*Chilo polychrysus*), white rice stemborer (*Scirpophaga incertulas*), other rice insect pest and the tungro virus (*penyakit merah*) disease (Lim *et al.*, 1978; Ooi & Heong, 1988). In the main season 1979/1, a major combined outbreak of BPH and WBPH was recorded in the Muda Scheme (Ho, 1993).

As a response to the BPH outbreak in Tanjung Karang and the combined BPH-WBPH outbreaks in Muda, a Pest Surveillance and Forecasting System (PSFS) was established for Peninsular Malaysia in 1979, with computerized data processing in Muda and Tanjung Karang (Heong, 1977). The government allotted 8.1 M US$ to the project and entrusted DoA with its implementation in all major rice growing areas (Ooi, 1982). The system involved field scouting to determine the size of pest and predator populations and to record data on crop development, water management and farm practices. Catches from light traps and aerial net traps were collected for verification. The Malaysian Agricultural Research and Development Institute (MARDI) helped to determine the economic threshold levels (ETLs) for BPH and WBPH[54] (Ooi, 1992; Ooi & Heong, 1988).

At the time, pest surveillance and regular monitoring were regarded as prerequisites to IPM implementation among farmers (Lowe 1980; Lim *et al.*, 1980; Heinrichs & Mochida, 1984). In 1979, Malaysia presented the PSFS network as the backbone of integrated pest control in rice (Yusof Hashim, 1992) and its functioning as main reason that major outbreaks stopped (Chen, pers. comm., 1996). But in the 1990s, surveillance and monitoring were neglected and farmers in many places[55] went on spraying in rice. Only in the northern part of the Muda area, a few teams of children scouts continued to monitor pests and diseases weekly and to report to the district plant protection officers (Zadoks *et al.*, 1986; Chen, personal communications, 1996). No recent survey reports on insecticide use in rice, intoxication and development of resistance against pesticide in rice pests were found Malaysia (Oudejans, 1996).

3.6.4.8. Implementation of IPM in rice and other crops. In 1980, Malaysia became a member of the newly launched 'FAO Inter-Country Programme for the Development and Implementatio of IPM in Rice in S and SE Asia. Details on the FAO ICP-IPM Rice Programme and its achievements are dealt with in ch 5. IPM in horticulture, in particular Malaysia's great contribution to IPM research, are described in ch 6. Information about efforts to implement IPM and IWM in dry land rice outside the irrigation schemes were not found.

The history of increased incidence of insect pests, the occurrence of pesticide induced outbreaks of brown planthopper, leafhoppers and virus diseases resembles the events in Indonesia though on a smaller scale. The isolated position of the irrigation schemes and their central administration made integrated management of economic pests and diseases feasible. The effective management of chronic water shortages and increasing weed competition in rice in the Muda and Kumubu Schemes resulted to the highest yields obtained in Malaysia.

Through training programs on integrated weed management (IWM), KADA and MADA techniciens skilfully guided the farmers in the transition from transplanting to direct seeding methodology in rice crop establishment. They also issued recommendations on tillage, choice of varieties, fertilisation, pest control, and water use on the basis of carefully conducted surveys. Such close guidance can be appreciated as an efficient extension approach to relatively rich farmers already working together in farmers' associations and irrigation bloc units.

Studies on extension strategies and farmer participation, pertaining more to IWM than to IPM, were only seen for the Muda Irrigation Project (Ho, 1977; Syed, *et al.*, 1985; Ho, 1994b) and Tanjung Karang area (Heong, 1984). In a large scale rat control campaign in Penang, 1985, the National IPM Committee emphasized the importance of farmer participation (Asna, pers comm., 1986; Zadoks *et al.*,1986). In 1986, DoA's Extension Service had not adopted the FFS extension model and did not intend to organize Training of IPM Trainers (various, personal communications, 1996). A major concern for the near future will be the recruitment of agricultural staff at all levels of the agricultural institutions and services. There are few students of agriculture[56] and they prefer to be employed by estate agencies (Oudejans, 1996).

In the scatttered dry land areas where farmers grow one crop of rice per year in rotation with other food and root crops, extension is less secured. The Agricultural Extension Service still relied on the T&V method because the Service held the opinion that the FFS method does not suit the Malay rice farmers, the majority of whom are middle-aged. It is questionable if the FFS routine, as practised in the

Indonesian National IPM Program (ch 5), would add to the empowerment of the farmers in the Irrigation Schemes. There was no project proposed for the strengthening of extension in plant protection outside the schemes (various personal communications, 1996).

The public and private agricultural research institutions of Malaysia have good expertise on the economically important crops. But the findings of public research, *e.g.* MARDI's recommendations for the biological control of pests of vegetables, are not adequately extended to the farmers. Recommendations for integrated management of pests and diseases in vulnerable crops such as cacao and vegetables are hardly put into practice by the farmers.

3.6.5. Estate and smallholder agriculture. After 1958, the government decided to develop more land and adequate crops for the smallholder sector and demanded the help from the private sector for this aim. Smallholders could obtain subsidies under the Agricultural Input Diversification Program for growing rice, and secondary food crops such as maize, fruits, coconut and coffee. The Farmers' Organization Authority provided fertilizers, pesticides and planting material for food crops. At the end of 1980 more than half-a-million farmers had benefited from the subsized programs. The largest amount was spent on the rice subsidy scheme which was introduced in 1979. The rice subsidy increased from 40 M US$/y in 1979/80 to 144 M US$/y in 1990/91. The government spent a further amount of 160 M$ on fertilizer subsidies for rice during 1991-95.

3.6.5.1. Rubber. Since 1961, governmental subsidies to replant old estate and smallholder rubber has been adopted as a national policy in Malaysia, supported by export taxes (cess funds) on rubber. The subsidy is paid yearly as a grant and credit, and each year's subsidy is based on the progress made in replanting (Polhamus, 1962). In Peninsular Malaysia, by 1970, replanting on estate land amounted to 89,000 ha of rubber and 26,300 ha of oil palm, whilst on smallholding land 121,400 ha were replanted and 20,200 ha newly planted with rubber. The area under high yielding rubber increased thereby from 78% to 89% on estate lands, and from 50% to 65% on smallholdings. New plantings of rubber in Saba and Serawak totalled about 60,000 ha (AADPC, 1984a).

3.6.5.2. Oil palm. Similar subsidies were extended to oil palm and coconut replanting programmes in Peninsular Malaysia and E Malaysia. In response to the heavy demand from the oil palm industry for more detailed breeding and selection[57] work a special Oil Palm Unit was established within the Research Branch of the DoA in 1967. This unit also performed research on pests and diseases in oil palm. When oil palm cultivation continued to expand, the government decided to create an semi-autonomous Palm Oil Research Institute for Malaysia (PORIM). In 1979, PORIM commenced operation by taking over the mandate for palm oil research from the DoA (Basri, 1995).

3.6.5.3. Cacao. Through the 1950s, selection and breeding work on cacao was carried out using not only the Trinitario clones imported from all parts of the world, but also the newly introduced Criollo and Amelonado clones (Ang & Shephard, 1978). In 1953, the first commercial cacao planting was established in the State of Terengganu, Peninsular Malaysia. Initial enthousiasm for developing cacao as an estate crop was soon dampened when the 'Vascular Streak Die-back' (VSD) disease, caused by the fungus *Oncobasidium theobromae*), became a serious problem (Turner & Shephard, 1978). Estate planting was reduced and breeding work was curtailed as a result of this disease. By the end of 1965, the hectareage under cacao had dwindled to only 720 ha.

The introduction of the cacao hybrid Upper Amazone enabled a revival of the cacao cultivation as this hybrid proved to be more vigorous, high-yielding and less suseptible to VSD than the Trinitario and Criollo clones. By 1975, the hectareage under cacao had expanded to some 2,00 ha of which half on smallholdings under coconut. In Sabah DoA advised since 1961 to stop spraying contact insecticides in cacao plantings to enable biological control (Conway & Tay, 1967). Cultural control through pruning, removal of unripe pods outside the main season, and treatment with pyrethroids was recommended.

By 1995, total area under cacao had increased to 452,000 ha, making Malaysia the world's fourth cacao producer with an exported value of 180 M US$. Cacao is seriously emperiled by pests of which the cacao podborer (*Conomorpha cramerella*), the cacao myrid (*Helopelthis theivora*) and VSD cause economic damage. High labour costs for pest control caused a stagnation of cacao planting in Malaysia.

3.6.6. Pesticide regulation. The growing dependency on pesticides called for regulatory oversight of pesticides. In 1974, DoA's Plant Protection Division prepared the first pesticide law for the Federation of Malaysia, enacted as Pesticide Act 149. Under the Pesticide Act of 1974, the Pesticide Board was installed and, in 1976, a Pesticide Registration Rule issued (ADB, 1987). DOA was equipped with a pesticide quality and residue laboratory to enable inspections[58] (Anonymous, 1994, 1994a; Puteh, 1994).

During the same period, the Plant Quarantine Branch of the DoA prepared a new 'Plant Quarantine Act 167', enacted in 1976. This law furthered the collaboration between Peninsular Malaysia, Serawak and Sabah in restricting the entry of plant pests. This was no luxury in the early years of the Federation when relations between federal and state officers in W and E Malaysia were often strained (Mumford, pers. comm., 1997). Daily air and sea trafic between the component regions of Malaysia make it imperative to enforce the Quarantine Act uniformely (Singh, 1977). The Plant Quarantine Regulations were amended in 1981 and 1991 to enable the issuance of phytosanitairy certificates and export licenses in compliance with stricter international trade requirements[59].

3.6.7. Agricultural trends at the end of the 20th century. Although agriculture held its central place in the development of Malaysia for a long time, other sectors began to gradually overtake agriculture. Thus, by 1980 the relative share of agriculture had regressed to 22% of GDP, to about 30% of exports earnings and to about 40% of employment opportunity. In 1981, the Malaysian government moved to gain greater control over the economy to improve Malay participation in the modern estate economy. In September 1981, the National Equity Corporation[60] took control of those estate agencies, which had their financial basis in London. Thus, the government obtained control over the estate sector and its agricultural export crops, and could cash the added value through expansion of local processing and marketing.

Concurrent with the series of Five-year Malaysia Plans, since 1986, a special First Five-year National Agricultural Policy Plan (NAP) 1984/92 was implemented. A Second NAP, 1992/-2000 is currently being implemented. Since 1990, the government sought the solution for alleviating rural poverty outside the agricultural sector. The Prime Minister declared that under the Second NAP the government would be satisfied with 65% self-sufficiency in domestic rice production (Business Times, February 2, 1993). An accelerated industrial development and the service sectors offered more hope for reducing rural unemployment.

The effect of the changing official attitude can been seen in the rice sector. In the early 1990s, rice cultivation occupied about 0.5 M ha in W Malaysia and 0.2 M ha in E Malaysia. Although the government promoted rice production through setting a high purchase price for rice and subsidizing inputs, the area under rice and the total production are decreasing. The decline in rice cultivation is largely because it has remained an uneconomic activity. Without subsidy schemes and under free market conditions, the decline would have been steeper than it is now. The reasons for the ongoing decline of rice growing, particularly in W Malaysia, are shortage of labour, high wage rates, stagnating yields, poor farm management, and decline in cultivated area due to the migration of young farmers.

3.8. Discussion, Malaysia

The following discussion and conclusions on the situation in Malaysia reflects the author's impressions gained from research, seven months working experience in and frequent visits to Malaysia and many hours of recorded interviews with Malaysian experts.

A key to understanding developments in agriculture in Malaysia is the complexity of its multi-ethnic population. The migration of large numbers of Chinese from S China to Malaya and their success in gaining the upperhand in the economy stirred up much discontent. When civil unrest threatened to impair foreign investments, the English began to extend their administration from the Straits Settlements to the Malay States on the peninsula. This move brought the stability on which a regulatory and commercial infrastructure could be build.

The establishment of the Department of Agriculture in Malaya happened in the same year (1905) as the founding of the DoA in the Dutch East Indies. The motivations and preparations leading to a DoA in both countries differed considerably. The DoA of Malaya lacked the strong research foundation on which the DoA of the Dutch East Indies was built. The DoA of Malaya undertook the development of indigenous agriculture, but only by its reorganisation in 1928 it obtained the structure and means needed for the task.

Malaysia is not endowed with vast stretches of fertile soils. Only two perennial crops really suit the environmental conditions, rubber and oil palm, and both became winners. Rubber initially and oil palm after 1960 became major export commodities. These are the only crops which have their own research institutes for production and processing. The estate industry benefited from a smooth transition from foreign to Malaysian ownership and was not confronted by a break in management expertise, as in Indonesia.

Rice cultivation was given little attention in the 20th century. There was a scarcity of irrigated land and labour, and rice productivity was low. The huge revenues from tin mining and rubber easily made up for the costs of importing rice from Siam, Vietnam and Cambodia. The Japanese occupation, 1941-45, deeply changed the attitude concerning food security. Between 1950 and 1970, eight large irrigation schemes were developed and the efficient production of rice became a national issue. There were two motives, *1.* strategically, to strive for a high degree of self-sufficiency in rice in view of the growth of the population, and the increasing need for rice imports; and *2.* to improve equity of income for the Malay rice farmers in the multi-ethnic society of Malaysia. Since rice production became a political issue, the Green Revolution package of variety improvement, cultivation technique and pest control was readily adopted and research for rice received priority status.

Integrated pest management in rice and in particular in vegetables received much attention. Malaysian scientists made great contributions to the knowledge base of pests and diseases, natural enemies and biological control. Malaysia joined the regional FAO Inter-Country IPM Programme in 1980. Implementation of IPM in rice and other crops by government agencies was only followed up within the large rice irrigation schemes.

Contrary to Indonesia, not the outbreaks of BPH and leafhoppers led to adoption of integrated pest management in rice, but rather the chronic shortages of irrigation water and labour which necessitated direct seeding as the leading method for rice crop establishment. For direct seeding and the associated Integrated Weed Management, Malaysia is ahead of its neighbouring countries. It could make a valuable contribution to regional IPM programmes.

3.9.Conclusions, Malaysia

1. Any discussion about developments concerning Peninsular Malaysia requires an basic understanding of the history of its multi-ethnic society. Ethnic diversity determined policy formulation in the past and present.

2. Agricultural development in Peninsular Malaya was delayed till the establishment of an English administration around 1865. Pacification of the sultanates and authority over the then unruly Chinese inhabitants were conditional to foreign investment in agriculture.

3. Chinese farmers had since long grown crops as sugar, gambir and vine pepper in a shifting garden pattern of agriculture. The English administration did not encourage this type of swidden agriculture.

4. Although the Straits Settlements possessed Botanical Gardens at Penang and

Singapore, these Gardens did not develop into the scientific core of research. Much knowledge of and expertise in tropical agriculture was brought in by English civil servants and scientists from India and Ceylon.

5. The establishment of a Department of Agriculture in Malaya did not evolve from within, rather it was imposed by the Colonial Office, which commissioned the Director of the Botanical Gardens of Ceylon to draw up the Plan of Organisation.

6. Agricultural research in Malaya dealt with few crops, as the topography and soil structure of Malaya limit the economic potential of agriculture more than in Indonesia and Thailand.

7. Initally, the development of estate agriculture in Malaya was hampered by pest and disease problems and the lack of resistant planting material. The breakthrough came with the development of rubber production, which stands poor soils and is little affected by pests occurring in Malaya. Rubber became the leading estate export commodity, presently it is the leading smallholder crop.

8. Research on indigenous food crops received little attention until the founding of a Central Agricultural Research Institute at Serdang, Selangor, in 1935.

9. The Japanese occupation caused considerable damage to the agricultural research institutions, plantations and factories. Rehabilitation of public and private institutions and estates could begin immediately after World War II, because the British administration continued until 1957. Independence was achieved without struggle or disturbance of administrative and financial relations.

10. Owing to the considerable revenues from tin mining and rubber and the relatively small population, food security was not an issue for the government of independent Malaysia.

11. The main reason for the GoM to turn its attention to the food crop sector was the growing inequity in the society, in particular between the Malay and Chinese segments of the population.

12. The 1969 riots led to an amendment of the Constitution, which gave considerable political power and privileges to the Malay constituency. The new policy had an obvious impact on the rice sector and an increase of rice production to improve farmers' income became a political objective.

13. The main instruments for increasing rice production included the construction of large irrigation schemes managed by autonomous Irrigation Scheme Authorities, the adoption of high yielding rice varieties and improved rice technology, and the prioritizing of rice research. Socio-economic measures included the founding of a strategic rice purchasing agency (*LPN*), the construction of a huge rice storage capacity in the schemes, and the regulation of advantageous farm-gate prices for *padi*, a kind of hidden subsidy for Malay rice farmers.

14. The government founded the Malaysian Agricultural Research and Development Institute in 1968 to strengthen research on food crops and others sectors.

15. Recommendations by Scheme Authorities included calender spraying against rice insect pests. Injudicious spraying induced the appearance of BPH and leafhoppers as major pests in the Schemes. Inputs were supplied through the farmer associations at whole-sale prices.

16. The DoA and the Rice Scheme Authorities successfully relied on resistant high

yielding rice varieties and on a Surveillance and Early Warming System to control outbreaks of BPH and leafhoppers, and epidemics of virus diseases in rice.

17. Malaysia joined the FAO Inter-Country IPC in Rice Programme for S and SE Asia in 1980. Even though IPM was declared agricultural policy in rice, the implementation of a National IPM Program was frustrated by lack of political will.

18. Malaysian researchers made valuable contributions to the development of IPM, in particular through studies of parasitiods and other aspects of biological control.

19. The major development in rice cultivation was the shift from transplanting to direct seeding as the dominant method of crop establishment in the irrigation schemes. Labour scarcity rather than pest problems necessitated the transformation.

20. The shift from transplanting to direct seeding was ably guided by researchers of the Scheme Authorities. Despite increasing weed problems, production of rice rose consistently.

21. The shift to direct seeding gave the Malaysian researchers an advantage in knowledge about integrated weed management (IWM).

22. The estate sector is dominated by the cultivation of oil palm, a tree eminently suited to the physical and socio-economic conditions of Peninsular Malaysia. The growing of rubber, though the major smallholder crop, decreases due to shortage of labour for tapping.

23. The exodus of young farmers from agriculture to the towns and to more remunerative employment opportunities as well as the lack of agricultural students are matters of concern for the Malaysian government and will reduce opportunities for IPM implementation.

Notes

1. Malaya contributed tin, gold and iron ore, pepper, fragrant woods, resins and herbs from the jungle, as well as hides, cowrie shells and coral.

2. Melaka was probably founded by a Sriwijayan prince around 1400 A.D.. Sriwijaya's cultural heritage has greatly contributed to Melaka's pattern of government and lifestyle which became the basis of 'traditional Malay culture and statescraft'. Hence, Melaka became recognized as the origin of Malay identity, adat and language (Watson & Andaya, 1982).

3. The present name of Province Wellesley is District Prai in the State of Kedah.

4. Reference ch 2.3.4. Decline of *VOC*.

5. The Anglo-Dutch treaties determined the partition of Malaya and Indonesia along the Melaka Straits, thereby effectively shielding the peninsula from Dutch and Siamese influence. To date, the partition is still regarded as a border demarcation between Indonesia and Malaysia.

6. Nutmegs and cloves remained important export commodities of the northern Malay States until 1860 when diseases almost destroyed these industries (Grist, 1935). The growing of coffee was reported in Melaka in 1779 and in Penang in 1802.

7. Gambir is a leaf-extract of the tree *Uncaria gambir* Roxb. which contains catechine (an ingredient for sirih chewing) and catechu-tannic acid (for tanning and dying of fine leather). Gambir, with its year-round productivity, could be combined profitably as cover crop with vine pepper (*Piper nigrum* L.), which is seasonal and slower to mature (Grist, 1935).

8. A Chinese community provided the European administration with a guaranteed source of revenue through taxes levied on pawnbroking and sales of opium, spirits and pork, the collection of which was rented out to Chinese individuals or syndicates (Watson & Andaya, 1982).

9. A written authorization empowered the Chinese headman to open up plantations, supervise cultivation and act as revenue farmer. The last-mentioned privilege, the right to collect taxes, was more lucrative than agriculture itself.

10. In 1873, London's instructions to the new governor of the Straits Settlements had a different tone. Any wish to intervene in the Malay States was still disclaimed; 'but looking at the long and intimate connection between them and the British Government...Her Majesty's government find it incubent to employ such influence as it possesses...to rescue, if possible, this fertile land from the ruin it must befall them if the present disorders continue unchecked'. The medium through which this influence should be exercised, it was proposed, was the person of the British agent or Resident appointed for each State (Winstedt, in: Allen & Donnithorne, 1956).

11. In 1874, the Pangkor Treaty signed between the pretender Sultan of Perak and the British Governor in Singapore accelerated the British involvement in the affairs of the Malay states. In return for his recognition as a sultan, the ruler accepted a British resident whose 'advice must be asked and acted upon on all questions other than those touching Malay religion and custom'. It essentially became now a question of how and when British rule would be extended across the entire peninsula.

12. The basic concept of the British Residential system was indirect rule, which depended on the cooperation of the Malay ruling class. Rulers, princes and chiefs were compensated with high positions in the bureaucracy. They gained independence, prestige and a private income which enabled them to sent their sons to schools in England. Consequently, the ruling class alienated from their peasant subordinates. The association between the Malay ruling class and the colonial authorities served to disguise the fact that real power ultimately resided with the British (Watson & Andaya, 1982).

13. The Dutch East India Company (*VOC*), which occupied Ceylon from the early 16th till the late 18th century, began the first commercial planting of cinnamon. The English, who took over from the Dutch, introduced the plantation production system in the 1830s, initially for coffee and, after outbreak of the coffee leaf rust disease in the 1880s, under tea and rubber (Loganathan, 1990).

14. The oldest firm is Guthrie and Company Ltd which opened a shop in 1821 and a gambir and spices plantation in 1823. By 1931, Guthrie was managing agent for 26 plantation companies and engaged in tin mining, banking and shipping. By 1952, Guthrie employed 200 Europeans and 42,000 Asians and controlled about 80,000 ha of rubber, oil palm, tea and coffee (Allen & Donnithorne, 1956).

15. The Torrens system, copied from Australia, required land transactions to be registered in the Registry of Titles for validition. Except for short term leases, all land was alienated under a perpetual lease, subject to rent, liable to revision at intervals of not less than thirty years and subject to conditions of use. The indefeasibility of the registered title and the ease, certainty, and cheapness with which transactions in land could be carried out greatly facilitated development (Grist, 1935).

16. A most significant service provided by the colonial government was the organization of much needed labour for the tin mining and booming rubber industry. Between 1911 and 1931, the government encouraged unrestricted immigration from India, China and the Dutch East Indies. The guaranteed source of cheap labour was a strong inducement to private investment in British Malaya.

17. Estates held in private ownership by individuals.

18. The hawk moth caterpillar caused serious injury to coffee in the Selangor and Petaling estates. It appears that in 1902 some crows were imported from Ceylon for biological control of the hawk moth (Sivaram, 1980).

19. H.N.Ridley, appointed director of the Botanical Gardens in November 1988, studied the new accessions and promoted the planting of rubber on estates in the Federated Malay States. Ridley discovered the bark-saving system of reopening tapping cuts. High rubber prices and the discovery of the use of acetic acid to coagulate the latex were further important incentives to the rubber industry.

20. European and Shanghai investors were willing to support rubber ventures because of the experience and expertise associated with such prestigious firms as Guthries, Sime & Darby, and Harrisons & Crosfield.

21. Copra is dried kernels of coconut from which coconut oil is extracted.

22. In colonial time, 60% of the total rice area was located in the NW states Perlis, Kedah, Penang, Port Wellesley and Perak, and some 23% in the NE states Terengganu and Kelantan.

23. This inititive was noteworthy because, except for restricted areas in Kedah and Kelantan, rice farming was not a profitable venture. Many poor tenant farmers, in need of credit, could supplement their income by planting export crops, but this was discouraged officially. The government preferred to see the Malays become a 'settled peasantry' and reliable suppliers of rice (Sivalingam, 1993).

24. 'The Agricultural Pests Enactment, 13/1913, Federated Malay States' was published as Gazette Notification 3679, on 19th December 1913. Adjustments were made through Amendment Enactments 24/1914; 5/1920; 10/1921; 9, 27/1922.

25. All the larger plantation groups possessed their own research stations, of which most are still operating by the end of the 20th century (Chung GF, pers. comm., 1996).

26. E.J.Butler was the original author of the famous book 'Plant Pathology' by Butler & Jones. Butler was director of the IARI at Pusa since 1911.

27. Existing rubber research stations were either closed or taken over by the RRIM. The creation of RRIM set the precedent for many agencies to be formed from the various agricultural activities initiated and nurtured by DoA.

28. Observations on the coffee hawk moth, *Cephanodes hylas* L. and the coffee berry borer, *Stephanoderes hampei* Ferr. were made by the government entomologists GH Corbett and M Yusoff in 1932 and 1933.

29. Up to 80% parasitation of hawk moths eggs by a parasite, *Oencyrtus malayensis*, was reported by a field survey in a major outbreak in Johor, 1929 (Corbett & Yusoff, 1932, 1933).

30. The 'Plant Importation Rule, 1925' was amended by Ordinance 166 (Agricultural Pests), cited as 'Plant Importation Rules, 1936', to include the States of Johore, Kedah, Negeri Sembilan, Melaka, Selangor.

31. In 1934, after prolonged negotations, a new rubber regulation scheme was introduced which, unlike the Stevenson Scheme, was international in scope. Hence, the financial situation in the rubber industry improved considerably .

32. Government measures included lower taxes for the agricultural industry and cost reduction including waivers of part of the quit rents on rubber lands and at a later date on coconut lands.

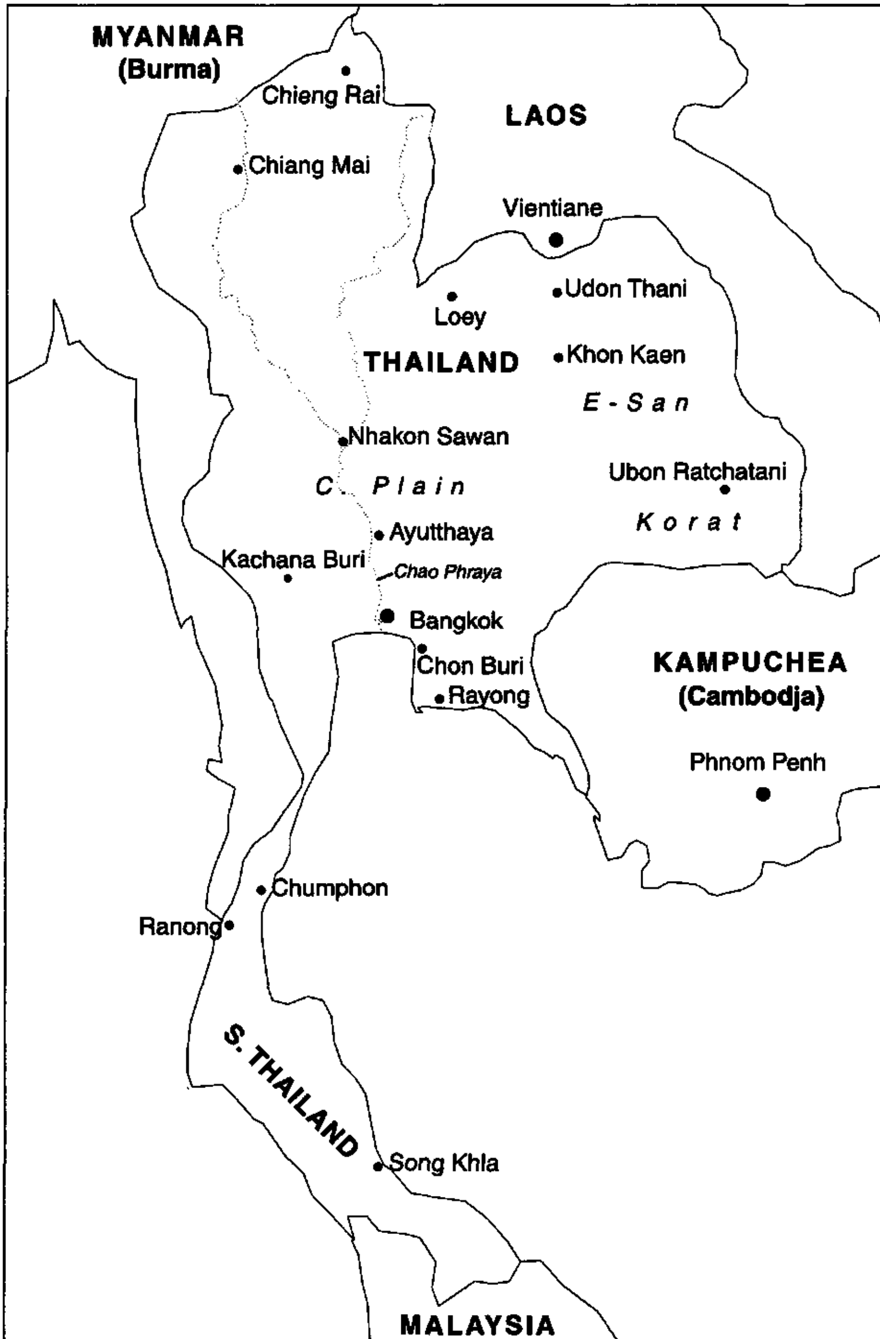
33. This policy was relaxed between 1947 and 1957 to restore production to pre-World War II levels. In this way and over the years, the colonial government succesfully adjusted its immigration policy to supply labour for the export industries.

34. The change in constitution obliged DoA to update the Plant Protection Regulations. 'The Agricultural Pests and Noxious Plants Ordinance, 1953 was enacted as Ordinance 59/1953, Federation of Malaya.

35. The Padi Cultivator Ordinances ruled that the maximum rental for crop sharing should be one-third of the crop, while fixed rentals should vary according the quality of the land (Watson & Andaya, 1982).

36. In 1970, nearly 50% of all households (about 800,000, of which three-quarter Malay) in Peninsular Malaysia received incomes below the poverty line (Watson & Andaya, 1982).
37. The National Economic Policy, 1971/90, had two principal objectives, *1.* reduction and eventual eradication of poverty; *2.* restructuring of society so that identification of race with economic function would be reduced and ultimately eliminated.
38. Off-season, being in fact the first planting season of the year, begins in February/March and ends in July/August. The main rainy season begins in August/September and ends in January/February of the following year, thus being the second planting season of the calender year.
39. Of the three early Taiwanese varieties Pyushu, Taichu 65 and Pebifun, only the latter remained popular with farmers till 1964. Pebifun and Taichu 65 were used for breeding the two high yielding and early maturing varieties Malinja and Mahsuri, which enabled considerable expansion of double cropping after 1965 (Ho, 1993).
40. In the 1960s, about 97 % of rice farms in Peninsular Malaysia was <4 ha and 33 % <0,8 ha. Owner-operated farms accounted for 45% of the total, and pure tenant farms only 17%.
41. The state's extension service supplied IR8 seeds to replace the numerous indigenous late-maturing rice varieties which did not fit in a double cropping schedule. Tractor service for land preparation, fertilizers and pesticides were provided through interest free (subsidized) credit (Ho, 1983).
42. Expansion of third grid irrigation and drainage facilities enabled better water management. Keeping the water at a constant depth of 10 cm throughout the field always gave higher yields than maintaining a deeper water layer but with portions of the field remaining above the water level due to poor levelling of the soil (Cheong, 1978).
43. In 1975, the variety Seribu Gantang (IR8 x indigenous varieties) became popular even though it was not officially released due to its susceptibility to false smut, bacterial leaf streak and tungro disease. The variety occupied almost 80% of the planted area in 1977, 25% in 1983, and disappeared in 1984 (Ho, 1983, 1993).
44. The Malaysian government subsidized fertiliser for use in rice from season 1979/2 up to a maximum of 2.4 ha per farmer (Ho, 1985). It is unknown whether the subsidy is still being provided.
45. The Muda scheme was designed for a cropping system with modest water requirements and full utilisation of rainfall. The whole engeneering infrastructure was only a 'second grid' lay-out of irrigation, drainage and farm road network without proper terminal facilities for efficient supply of water to individual farm lots (the third grid) (Ho, 1983).
46. Transplanting by hand is labour intensive requiring 130 manhours/ha. Escalating costs led to careless planting with upto 8 seedlings planted per hill at a spacing of less than 10 hills instead of 16 hills per m^2. This slovenliness resulted in more weed growth and uneven ripening of the numerous tillers per hill, a disadvantage for combine harvesting (Ho, 1983).
47. While IR5 performed better under transplanting, the varieties Jaya, IR20 and IR22 produced higher yields under direct seeding (Samy & Phang, 1975). Direct seeded plants matured 11 days earlier and broadcasting required less than 5% of the labour involved in transplanting (Yeoh, 1980).
48. Shallow dry tillage after the harvest of the main season prevented the formation of deep cracks and the shrinking of *padi* soils, conserved soil moisture and minimized water requirement for pre-saturation of the fields (Ho, 1993).
49. Variety IR42 was quickly adopted because of tungro virus (TV) resistance, it was planted on more than 40% of the area in season 1984/2. In 1985, variety IR42 was replaced by MR84 which combined resistance to blast and TV with high fertility and yielding quality. In 1993, MR84 still occupied more than 80% of the planted area (Ho, 1993).

50. The many seeds shattered by combine harvesting area are rotavated into the dry soil. MADA techniciens called this method of crop establishment 'volunteer seedlings'.
51. Around 1980, chlorphenoxy herbicides (2,4-D dimethyl amine, 2,4-D isobutylester, 2,4-D sodium salt and MCPA) were used in many transplanted and almost all direct seeded fields. The W.P. formulation of 2,4-D butyl ester was most popular and broadcasted together with urea and insecticide granules. The recommended rate was 1 kg a.i./ha at 15-25 days after transplanting (DAT). In the Muda area by 1990, usage of 2,4-D compounds was estimated at 400-430 t/y (Ho, 1991).
52. The first introduced pre-emergence herbicides were trifluralin, molinate and oxadiazon. The post-emergence herbicides included propanil, thiobencarb and metsulfaron methyl.
53. Dry seeded rice with early rains established 3-4 weeks earlier than the wet seeded crop so that it escaped lodging and wet harvesting during monsoon rains.
54. ETL levels for BPH and WBPH were 7 adults/hill and 15 respectively 25 nymphs/hill. Both planthoppers are serious pests of, in particular, the off-season irrigated rice crop (May-September) (Ooi, 1982).
55. Medical doctors in the Tanjung Karang area reported severe incidence of intoxication from insecticide use (Vos, pers. comm., 1996).
56. Early 1996, the author lectured two months at University Pertanian Malaysia, Serdang, and interviewed students and teachers about career opportunities and preferences.
57. Prior to 1958 the majority of the oil palm plantings consisted of the 'Dura'-type. In later years, the hybrid 'Tenera' (cross Dura x Pisifera) was extensively cultivated because its fruits contain a thicker oil bearing mesocarp.
58. In compliance with the Pesticide Act 1974, DoA carried out inspections of premises licenced for sale and storage of pesticides. These activities resulted in 93 confiscations and 92 summon cases in 1982 (ADB, 1987).
59. For example, in 1992 DoA issued a total of 2,592 import permits for various crops, 1,164 export licences and 12,056 phytosanitary certificates for ornamental plants, fruits, coconut and others (Anonymous, 1994).
60. The National Equity Corporation was founded as a government-funded agency acquiring shares in trust for the 'Children of the land', *bumiputra*, with the objective of achieving the NEP's goal of 30% Malay ownership in the corporate sector.



Map 4.1. Thailand

Chapter 4

Development of agriculture in Thailand

4.1 Introduction

Thailand (*Muang T'hai*, Land of the Free) is an ancient Bhuddist kingdom in SE Asia, until 1949 known as Siam. Thailand shares borders with Myanmar on the W and N, Laos on the NE, Cambodia on the SE and Malaysia on the S. Owing to its location on the continent, Thailand played a pivotal role in the struggle between French and English colonial powers, but never became a colony itself. Politically, Thailand takes part in the alliances of the Mekong River States and the Association of South-East Asian Nations (ASEAN).

Thailand, with extensive areas of favourable relief, is divided into four administrative regions. The centre of the country consist of a vast, fertile[1] lowland, the tributary of the Chao Phraya river, which is enclosed to the W, N and E by mountain ridges running down from the Himalayan range. The Central Region consists of three sub-regions, *viz.* the western mountains, the eastern coast lands and the Central Plain located in the alluvial Chao Phraya river basin. The Central Plain is the granary and cultural core of Thailand. The Northern Region, with several fertile valleys, consists mainly of mountainous woodlands which are the homelands of various hill tribes. The North-eastern Region consists of the Khorat Plateau, an extensive level area of moderate elevation. The North East takes up about one third of Thailand's total land area and harbours about one-third of the Thai people. It is a barren region with infertile, sandy and silty soils[2]. The Southern Region, located on the Malay Peninsula, has a mountainous backbone with relatively short river valleys.

Thailand has a monsoon climate with a rainy season from May till October, a cool dry season between November and February and a sweltering hot period in March and April. Regional variation in temperature is relatively limited with mean maximum temperatures ranging between 31°C and 33°C and mean minimum temperatures between 19°C and 23°C. The number of rainy days averages 104 to 167 throughout the kingdom. Variation in intensity and duration of rain is marked with more rainy days in the SE bordering Cambodia and on the S Peninsula. The Peninsula, the centre of plantation agriculture, still has an important forest reserve. In the NE rainfall is very irregular with alternating periods of excessive drought and flooding. Due to run-off and porosity of the soils, a rapid loss of water is a major problem. The region, called E-san, is agriculturally the most backward and lacks water management structures.

The population of Thailand stood at 59 million in 1995, of which 31 M persons depended on agriculture. The agricultural sector contributed only 15% of the Gross Domestic Product (GDP) to the country's economy, but 59% of the Thai labour force was employed in the agricultural sector (FAO Production Yearbook, 1997).

4.2. Early history

The history of the Thai can be separated into three periods under three capital cities. The first period under the Kingdom of Sukhotai lasted from A.D. 1247 till 1350. The second period under the Kingdom of Si Ayutthaya ran from 1350 till 1777. The third period began at Bangkok under the first Chakri King in 1778 and lasts till to-day. For the four hundred and seventeen years of the second period, Ayutthaya, located on the border of the Chao Phraya river, remained the splendid capital of Siam. The European powers posted envoys at the King's court and the Dutch East India Company (*VOC*) established a trading post (*factory*) within its precincts in the 17th century. In 1777, Ayutthaya was besieged by the Burmese for more than one year, captured, and destroyed. The Thai abandoned the ruined city for strategical reasons and chose to build a new capital, Bangkok, from Thon Buri, a fortress-town guarding the Chao Phraya river some 40 km inwards from the Gulf of Siam. General Chao Phraya Chakri founded Bangkok in 1782 and was crowned King Rama I, the first of the Chakri Dynasty and ancestor of the present King Bhumibol. The wild lands surrounding Bangkok were drained and prepared for rice growing and, later, during the 20th century, developed into a centre of fruit and vegetable growing (Sternstein, 1982).

Since the high days of Ayutthaya, foreign trade has been an important source of income for the Thai kings and the elite. Siam was never sealed off from foreign influence as China and Japan were. Since 1825, each year some 250 to 350 junks sailing in from China and other countries landed some 75,000 to 100,000 tonnes of merchandise. Siam exported mainly unprocessed forest and animal products and some agricultural produce. Precious wood species, resins, herbs and cardamom were mainly gathered from the forest by native Thais. Cash crops such as rice, sugar, pepper and cotton were mostly produced in small quantities by Chinese in seaside areas on the E coast from where it was easy to export to China. Imports mainly were textiles, earthenware, tea and sundries for the Thai elite and resident Chinese.

Siam was not a free-trade country. Thai and Chinese merchants, patronized by the king, enjoyed buoyant profits whereas Western traders were discriminated against. The latter payed higher taxes, were forced to sell their imports at lower prices, had to purchase export wares at higher prices and were barred from exporting rice, sugar and pepper, the royal monopolies. In 1826, the English East India Company succeeded in obtaining a trade treaty, the Burney Treaty, from King Rama II of Bangkok. A few years later, the king granted a similar treaty to the United States of America (USA). The terms of both treaties remained limited as royal monopolies, and Chinese trade privileges, were maintained, and the establishment of consulates was refused. The terms of trade remained so skewed that, by 1830, Siam's imports of English goods through Singapore were firmly in Chinese hands.

Dissatisfied, the foreign powers tried for new negotiations while considering to resort to gunboat diplomacy. In 1851, the remarkable King Mongkut[3], Rama IV, ascended the throne. This enlightened king prepared a new policy which would open the country to the world whilst preserving its independence. In 1855, a British mission succeeded in obtaining the king's approval of a second treaty, the Bowring Treaty, which established freeer diplomatic and commercial relations. Its signing was partly the result of King Monkut's anxiety over the outcome of the Anglo-Burmese War of 1824-26. Within three years, similar free trade treaties were concluded with the USA and eight European powers, among which the Netherlands (Manarungsan, 1989).

At the beginning of Third Period, when Bangkok was founded, the government was in the style of the previous Ayutthaya Period with separate Ministries for the Interior, Defence and Finance. By a coup d'état in 1932, the absolute monarchy was changed into a constitutional monarchy. In the next year, Siam's administrative system was altered through the Thai Administration Act, which created a central administration and a regional administration. The central administration consisted of ministries and departments; the regional administration ruled the provinces (*Changwat*) and districts *(Amphhoe)* into which the country was now divided (Praisont, 1982).

4.3. Agricultural development before 1950

4.3.1. Development of rice production in Siam before 1910. Agricultural development in Thailand in the 19th and early in the 20th century began in the rice sector. Until the mid-19th century, foreign trade had little meaning for Thai farmers who were self-sufficient in the production of food and basic household goods. The traditional pattern of farmers cultivating rice and some indigenous field crops, vegetables and fruits for their own needs was broken up from the outside. for, this reason, events in the rice sector until the Second World War are described as a policy frame. Thereafter, a more diverse agriculture policy evolved through the eight National Economic Development Plans since 1961.

By 1850, domestic trade of rice[4] was small and amounted probably to about 17% of the total rice production of the Central Plain, which was estimated at 377,000 tonnes/year (Manarungsan, 1989). After 1850, the agricultural economy of Siam moved gradually from self-sufficiency to an export oriented production of specific commodities, among which rice became the most important. Manarungsan (1989) distinguished two phases in the early development of rice production, the period between 1850 and 1910, characterized by a strong growth of exports due to socio-ecomomic factors, and the period from 1910 to 1950, when technological development provided the stimulus.

4.3.2. Socio-economic stimuli to rice production. Before 1900, over 85% of Siam's population depended on agriculture and on rice farming in particular. Of the total rice production, two-thirds served the farmers' own needs, about 9% was traded in the domestic market for non-farming consumers, and the remainder (25%) was exported. Although the export of rice was small in comparison with domestic consumption, it played an important role in absorbing farmers' marketable surpluses, especially for producers of the Central Plain (Manarungsan, 1989). In 1855 a clause of the Burney Treaty of 1825, which excluded Western traders from exporting rice, was repealed by the Bowring Treaty between Siam and Great Britain. The new treaty opened the market for participation by Western traders in export and import commodities. The free-trade policy brought relatively cheap foreign goods within reach of Thai farmers, who were easily induced to grow more rice to obtain purchasing power[5].

Between 1850 and 1910, the steadily increasing foreign demand for Thai rice was an external stimulus for producing a rice surplus. Demand for rice from Siam arose, for instance, in the Dutch East Indies, Malaya and Ceylon (*Sri Lanka*) in reaction to the rapidly expanding plantation and mining industry. The indigenous rice production by Indonesian, Malay and Sinhalese rice farmers was totally insufficient[6] to feed the large numbers of Chinese and Indian contract labourers. Production for the market became so attractive that Thai farmers of the C Plain left the stage of self-sufficiency and gathering of forest products to produce rice for export. Since it took time to adjust to commercial production and since the infrastructure for transport was lacking, the growth rate of rice exports[7] remained rather low initially. At the end of the 1870s, about 200,000 tonnes of rice or some 15% of Siam's total production was exported. By 1920, exports amounted to about one quarter of total rice production (Manarungsan, 1989).

Domestic causes for such growth of rice exports were the farmers' responsiveness to price incentives, ample availability of the production factors labour and land, and easily forthcoming investment in rice milling capacity, rural infrastructure and transport (Manarungsan, 1989). Government action to encourage rice production consisted of monetary and physical measures. New rice lands had to be taken into production with the help of animal traction for land preparation. King Mongkut, Rama IV, introduced a new system of land taxation which resulted in a 17% tax reduction on land property if waste lands were converted into cultivated rice land. For new rice land, a tax waiver was granted for the first year and reduced rates were charged for some more years. Land tax rates remained always much lower than those levied in Vietnam (Indo-China) and Burma, Siam's main competitors in the rice trade. The government undertook large projects for canal excavation to improve transportation of rice from distant areas. During the period 1885 and 1899, when rice export volume and value grew rapidly, nine major canals[8] were constructed. This operation opened about 330,600 ha of new land for rice cultivation, which amounted to 17% of arable lands in the C Plain (Manarungsan, 1989).

In the middle of the 19th century, an estimated 25% of the Thai population were bonded workers or 'slaves'. An important institutional change was the abolition of slavery and corvee[9] work. In 1874, the Great King[10] Chulalongkorn (1868-1910) began to dismantle the institute of slavery[11]. In 1899, a law was enacted to replace corvee by a capitation tax[12]. The abolition of corvee and slavery freed labour for new market opportunities which resulted from the opening of the country to free trade. This also benefitted the absentee land owners[13], the elite and merchants living in Bangkok. Scores of Thai farmers, released from rigid corvee and bondage, became tenants. The boom in rice production stimulated the creation of other employment such as rice trading, rice and lumber milling and boat building.

These industries mostly employed Chinese immigrant labour as Thais preferred to work in the rice fields.

An external factor contributing to the growth of rice production was the lowering of ocean freight rates due to the appearance of steam vessels[14] towards the end of the 19th century. Lower shipping costs integrated the rice markets of SE and E Asia and increased competition[15] between imported and domestically produced rice in many countries (Manarungsan, 1989). The opening of the Suez Canal in 1869 for steam vessels shortened the journeys to the extent that rice could be shipped as milled rice instead of as unhusked *padi*, thus reducing costs. Demand for milled rice from the side of exporters stimulated innovation in milling technology and a large investment in rice mills in Siam and Burma. The installation of telegraphic network connections in Siam, since 1883, provided one more stimulus to a competitive export rice trade.

4.3.3. Technological stimuli to rice production. The rapid increase in rice export from Siam during the period 1850-1910 did not reflect the rate of productivity growth, which in fact remained low. Important reasons were the limited growth in domestic consumption which kept prices low, and scarcity of labour due to Siam's sparse population and slow population growth[16] in the 19th century. In the commercialized C Plain, expansion of the rice hectareage, notwithstanding permanent shortage of labour, was realized through a change from the traditional transplanting to a more labour extensive direct seeding technique. Around 1900, probably half of the commercial rice land in the C Plain and, by 1930, more than 70% were direct seeded (Manarungsan, 1989). Direct seeding required less investment[17] of capital and labour in land development, and enabled to grow a larger hectareage of rice, which compensated for the lower average yield. Productivity of direct seeded rice fields was one-third lower than of transplanted fields. Likely reasons for low yields were low seed rates and untimely weed control, because in the Muda Irrigation Scheme, Malaysia, 200% higher yields are achieved with improved direct seeding technique (ch 3.6.4.6).

At the end of King Chulalongkorn's reign in 1910, the growth of rice exports slowed down. Whereas between 1857 and 1910 average annual compound growth of export volume was 5.7%, it was only 1.2% in the subsequent period, 1910-50. Since 1914 and throughout the inter-bellum, Europe and the USA protected their own grain farmers by tariff walls and quota restrictions on cereal imports (Manarungsan, 1989). The prolonged lull of the international rice trade after 1910 coincided with the surplus capacity of productive land and draft animals (the main capital stock for rice farming) relative to farm labour. The level and downward trend of the rice price made it less attractive for farmers to invest in technological innovation and to produce rice for the market beyond their own needs.

Siam's total rice production, nevertheless, increased over the period 1910-50. This growth was mainly induced by an increase in domestic consumption as the farmer population expanded healthily. The slump in rice exports after 1910, however, halted investment in irrigation and canal-digging projects in the C Plain. Communication and overland transport between Bangkok and the outlying regions remained difficult and time consuming. Early in the 1900s, some major railway extensions[18] opened access to the N and NE. Hence, glutinous rice was shipped from the outlying provinces to city markets, although transport costs by rail and boat remained high (Manarungsan, 1989).

There was little technological development in Thai agriculture before 1950. A survey, carried out in 1929-1930 (Zimmerman, 1931), showed that only districts in the C Plain, where farmers cultivated more than 4 ha per household, produced a marketable surplus. Zimmerman observed that 'commercialized farmers differ from others by working larger economic units, and less intensive agriculture, but too often it is nearly the same agriculture as in self-sufficiency districts'. Farmers did not try to improve their practices with respect to using manure or fertilizers, seed selection, ploughing and water management. Reasons for this negligence were the relative abundance of land and the structural scarcity of labour. Feeny (1982) remarked that it was the government's ignorance of irrigation that caused the long term decline[19] in rice yields. The lack of institutional incentive played a crucial role in slowing down development of modern technologies such as mechanization, use of agro-chemicals and high yielding varieties.

Around 1930, even in the most commercialized rice areas, such as Rangsit, farmers did not bother to obtain improved rice cultivars, issued by the Rangsit Experimental Station which the government had established in 1916 (Zimmerman, 1931). Although tractors were available for ploughing and land preparation in the 1930s, harvesting still had to be done by hand and, thus, labour availability remained the bottleneck. Mechanization was, furthermore, little adopted at the time because draft animals were still numerous and available at low cost. Moreover, farmers planted an assortment of early, medium and late maturing local varieties which could be harvested at the right time through effective neighbour assistance, known as '*long khaek*'.

4.4. Agricultural development since 1950

4.4.1. The agricultural situation in Thailand. In the second half of the 20th century, Thailand showed an impressive economic development. Despite a rapid population growth over the period 1950-1982, the overall real GDP growth rate was 6.7% and the per capita GDP almost 3%. The agricultural growth rate over this period was 4.1% and showed a slightly increasing trend for the crops sub-sector (Rijk & Van der Meer, 1984).

Expansion of the cultivated area rather than intensification was a major factor contributing to agricultural growth. It was estimated that, towards the end of the 20th century, out of Thailand's total land area of 51 M ha about 23 M ha, or some 45% of the total area, were being used for permanent cropping, swidden cultivation or grazing. Up to the 1980s, much public land was brought into cultivation by the growing rural population[20]. Encroachment and illegal logging halved the forest resources within 30 years time leaving current reserves below 30% of total land. Growth through expansion of agricultural land is no longer an option since fertile land and water have become scarce resources.

Concerning land tenure patterns, Thailand is primarily a land of owner-occupiers without the problem of iniquitous landlordism. Farmers of the relatively backward N and NE provinces, generally, were owner-occupiers whereas in the fertile C Plain and coastal provinces cash renting or tenancy[21] was more common. Before 1980, 90% of the farmers owned their holding, a feature giving Thailand more social and economic stability than her neighbours. During the 1990s, however, tenancy appears to increase, even in the rich C Plain (Jungbluth, 1996). Table 4.4.1. gives data concerning agricultural development in Thailand. Despite the rapid population growth, there was no evidence of fragmentation of holdings. Early in the 1990s, there were about 5.2 million farms with an average size of 4.5 ha (Rumakom *et al.*, 1991).

During the 1960s, the Royal Thai Governement (RTG) invested about two-third of its development expenditures in land development and irrigation schemes. The area planted with rice and major field crops expanded by 110% over the period 1960 to 1982. The Thai farmers increased productivity of agricultural labour through mechanization and better management which enabled them to cultivate larger areas. They spent, however, comparatively little on land improvement[22] and high yielding technology. The use of improved cultivars and agro-chemicals remained limited even though informal and cheap institutional credits[23] were available to larger farmers. Thai farmers appeared to prefer extensive farming systems since, in most situations, these yielded high returns to labour input.

Therefore, the government reduced investments in land improvement, particularly in irrigation facilities, to less than 40% at the end of the 1970s. Early in the 1980s, irrigated agriculture and flood control were still of limited scale[24] and mainly restricted to rice cultivation in the C Plain. Multiple cropping was estimated to cover not more than 25% of the irrigated area (Rijk & Van der Meer, 1984).

The most important factor for increasing land productivity (GDP per area planted), was the shift towards crops with higher added value. Traditionally, the most important crop was rice grown on irrigated fields, on bunded rainfed fields, or as 'deep water' rice. Only since the Second World War, more attention was given to grow secondary food crops, in particular maize and cassava for export to feed the

Table 4.4.1. Land tenure and utilization in Thailand, 1975-1990. Sources: Panayotou, 1985; Jungbluth, 1996.

Category\year	Unit	1975	1980	1995
Total land area	M ha	51.0	51.3	51.3
Agricultural land	M ha	18.2	18.6	20.4
Number of farms	M	4.1	4.5	5.2
Mean farm size	ha	4.4	4.1	4.0
Rice land	M ha	11.4	11.8	11.3
Field crops	M ha	3.2	4.2	4.6

more than half the Ministry's budget for research and extension. From this allocation, about one-third is spent on research projects and two-thirds on extension targets (Siamwalla, 1992).

4.4.2.3. Plant protection research and budget allocation. Plant protection issues are dealt with by several divisions of DOA, by the Plant Protection Service Division of DOAE, and by the National Biological Control Research Centre (NBCRC). The DOA divisions concerned include, among others, Regulatory Control, Toxic Substances, Phytopathology, Zoology and Entomology. Since the late 1960s, the DOA divisions were mainly occupied with pesticide efficacy and application studies, which were largely directed at the control of grasshoppers in maize and sorghum, and other insect pests in rice, vegetables and fruit. DOAE advised the farmers on pesticide use and actual application.

In 1969, the Pesticide Research Branch of DOA established one of the best analytical laboratories in SE Asia with the support of a UNDP/FAO Programme for Strengthening Plant Protection Services. The work program of the laboratory, and its two satellite stations at Khon Kaen and Sukhothai, included residue analyses in market samples of food crops, quality control of market samples[29] of pesticides, studies on efficacy of pesticides and development of resistance to pesticides, and monitoring of environmental pollution. Because of this priority of pesticide problems before 1990, more than 95% of DOA's research budget was spent on agrochemical projects (Farah, 1993).

At the end of the 1970s, UNDP/FAO initiated a project to help Thai researchers in developing a crop loss assessment methodology (James & Reddy, 1977b). Between 1981 and 1988, the departments DOA and DOAE worked jointly on the development of the national surveillance and early warning system for rice pests, and of crop loss assessment procedures in field crops (Jungbluth, 1996). They received support from the German/Thai Programme for Strengthening of the DOAE's Plant Protection Service Division (Hameling, pers. comm., 1981).

4.4.2.4. Institutional constraints. Research on Thailand's agriculture is mostly carried out by the Research Organizations of the Ministry of Agriculture and Cooperatives (MOAC), the Universities and the Regional Agricultural Centres[30]. Each has its own reporting lines for finance, policies and programmes. National coordination is to be effected through committees for specific crops. The result is that researchers can propose virtually any line of research that suits their particular discipline, irrespective of its priority in achieving production growth. Research is therefore carried out on strictly disciplinary lines according to subjects such as agronomy, entomology, pathology, breeding and so on. Each has its own department, line of reporting and budget. Cooperation between disciplines is limited to budget allocation (Laosuwan & Macartney, 1992).

The disadvantage of this fragmentation of effort is that individual disciplinary recommendations are made to maximise yield, irrespective what factors are seen as major problems. The costs and benefits from the actions proposed are mostly theoretical. The package of practical recommendations, which exists for all crops, is therefore drawn up as a conglomerate of individual discipline recommendations. The result is that a complex and expensive package is produced which is usually beyond the comprehension of the ordinary farmer and beyond his financial possibilities. Government-supported research was fairly successful in irrigated agriculture, but far from adequate for upland agriculture where risks are higher, particularly in areas of marginal rainfall. When packages are delivered through credit, the end result is frequent farmer indebtedness (Laosuwan & Macartney, 1992).

The DOAE is responsible for the field testing and communication to the farmers of research results and new technology. To achieve this goal the extension workers should be mobile, well trained, briefed on the technology packages for promotion and respected by the farmers. Since the early 1970s, DOAE employed the Training and Visit system of extension. The poor acceptance by farmers of recommendations from extension workers and the general failure to increase production and profit showed that DOAE operated with little efficiency. The unclear lines of reporting and non-accountability for personal performance are part of the problem. Administratively the extension officers usually report to the provincial administrative office and technically through their headquarters. There is limited dialogue between the central, the provincial and district officers who define and award priorities according to area programs. There is, therefore, no guarantee that operational procedures set by the headquarters will be implemented in a timely and effective manner.

Thailand received considerable foreign assistance for its development efforts. Foreign assistance was relatively successful in the transfer of agricultural technology, but less successful in projects which required institutional reform and coordination among various government agencies (Rijk & Van der Meer, 1984). For example, under sponsored projects, such as the Thai/German Plant Protection Programme, DOAE was given training and funds to operate on-farm testing and demonstration programmes. But research has developed far beyond the level of performance to be expected from farmers whilst the linkage between research and extension is distant and contentious. Even the cooperative approach mostly did not prove to be effective (Laosuwan & Macartney, 1992). Rijk & Van der Meer (1984) remarked that government agencies had insufficient capacity for research, extension, development planning and implementation, whilst coordination between agencies was often deficient[31].

To remedy the problem, the Ministry of Agriculture and Cooperatives (MOAC) has set up, under an agricultural research project financed by the World Bank, a Farming Systems Research and Development Institute (FSRI) as the link organization between research, extension and the small farmer. The FSRI tests the results produced by research stations and universities on farms and feeds back the results. It assesses the farmer response to research recommendations and packages within the social and financial constraints of the farming system (Laosuwan & Macartney, 1992).

4.4.2.5. DOAE's outbreak budget and emergency service. DOAE was responsible for surveillance and control of pests in the field. Since the 1960s, the DOAE managed a regular budget for its surveillance service and for the procurement of pesticides to control serious pest outbreaks. The Plant Protection Service Division of DOAE, on the request of farmers representing a minimum of 80 ha of infested field crops or orchards, treated emergency situations free of cost. In the mid-1970s, the DOAE treated on average 2.7 M ha of badly infested crops per year under this provision, for which it purchased around 1,000 t/y of formulated products. Treatments concerned insects (40%), pathogens (35%), field rats and snails (together 25%). Between 1963 and 1976, emergency operations included aerial spraying against locusts and grass hoppers[32] in maize and sorghum (Roffey, 1969). Disease control concerned rice for 90%, with preventive seed treatment as the major method.

DOAE's budget for emergency treatments rose from 1,7 M US$ (40 M Baht) in 1974 (James & Reddy, 1977) to 3 M US$ (78 M Baht) in 1995 (Jungbluth, 1996). DOAE calculated the budget requirement for each following year on basis of current infestation rates and pesticide prices, taking 10% of the cropping area as a benchmark figure. When outbreaks threatened to get out control, the budget might be substantially increased. Thus, in the 1989/1990 brown planthopper emergency, the budget was increased to almost 10 M US$ (250 M Baht) (Farah, 1993).

Of the 1995 outbreak budget 30% was spent on rice, 51% on other field crops, 8% on vegetables and 10% on the fruit sector. Apparently, the pattern of budget allocations did not change significantly over the past three decades. To-date the budget still covers all costs of pesticide procurement[33] and distribution through DOAE channels. The DOAE was the only major user of agro-pesticides in the public sector, because DOAs requirements for research have always been small.

Although portrayed as a measure of food security, critics regard the DOAE outbreak budget as a major subsidy instrument which contravened the pesticide reduction effort entailed in the IPM policy to which the RTG subscribed since 1980. It is questionable whether the timing of the allocations and subsequent releases of pesticides were appropriate for efficient control of the infestations. The effectiveness of DOAE's outbreak measures has never been investigated (Farah, 1993; Jungbluth, 1996).

4.4.3. Rice production in Thailand since 1950

4.4.3.1. Export rice production and the Green Revolution. Rice has always been Thailand's principal staple and major export crop and the rice sector has been subjected to government intervention. At the end of World War II the RTG nationalized the rice export trade and placed it under control of a Rice Office. Private exporters could sell to foreign buyers but had to pay an export premium to obtain a licence for actual shipment and an even larger export tax[34]. Export duties were maintained at a high level and, furthermore between 1962 and 1982, exporters were required to supply rice at below market price to the government to be used in a consumption subsidy program reserve. The Ministry of Commerce dictated quotas and selling prices and even established an Rice Reserve Committee in 1960 for direct government-to-government rice trading (Siamwalla & Setboonsarng, 1989).

In 1965, a sort of rice price support program was established but due to lack of funding it did neither influence the actual farmgate price nor did it benefit the farmers. The question of the rice reserves and rice price support was a political issue, markedly subject to Thailand's alternating periods of parliamentary democracy or military regime. Siamwalla & Setboonsarng (1989) explained the dominant role of the Ministry of Commerce in managing the rice export from the leading position of Thailand in the global rice trade[35]. 'The Ministry feared that, if exporters were left free, they would undercut another's selling prices and thus loose revenue for the country'. The Ministry of Agriculture had little influence on rice price policies until 1974[36].

Around 1970, the Green Revolution in S and SE Asia substantially raised cereal production in Asia and caused a slump in rice prices. The economic consequences of the Green Revolution in Thailand led to the passage of a Farmers' Aid Fund Act in 1974 which provided the Ministry of Agriculture with resources and power to play a role in rice price policies. Unfortunately, not the poorly organized farmers, but the rice mill owners became the main beneficiaries. The founding, in 1974, of the Marketing Organization of Farmers (MOF), basically an instrument of MOAC, has not been of much help to the farmers.

The development of rice production and yields under Thailand's seven National Development Plans from 1961 till 1995 is summarized in table 4.4.3.1.a. Over the whole period 1961 till 1996 national rice production almost doubled. Between 1961 and 1981, mean rice yields on farmer fields stagnated at 1.7 t/ha, whereas trials at DOA's Rice Department (RD) yielded an average of 4.6 t/ha. The main constraints to yield improvement in irrigated rice were lack of reliable water management, lack of technology to handle resistant HY varieties, deficiencies in direct seeding, pest control and fertilizer use, and adverse input costs/output value ratio for rice and agro-chemicals. Constraints facing rain-fed rice growing, moreover, included shortage of suitable land, lack of early maturing rice varieties, lack of knowledge and adequate extension, and lack of cash resources (World Bank, 1983; Rijk & van der Meer, 1984).

Table 4.4.3.1.a. Thailand. Rice production under seven National Economic and Social Development Plans from 1961 till 1996. Averages of area planted (M ha), production of rough rice (M t) and yield (t/ha) and mean annual growth rates in the respective Plan periods. Sources: Panayotou, 1985; FAO Production Yearbooks.

Category\Plan	Unit	I	II	III	IV	V	VI	VII
Area	M ha	6.6	7.3	8.2	9.5	9.4	9.4	9.0
Production	M t	11.1	12.2	14.2	16.1	19.1	19.3	20.6
Yield	t/ha	1.7	1.7	1.7	1.7	2.0	2.1	2.3

Five-Year Plans, I = 1961-66, II = 1967-71, III = 1972-76,
IV = 1977-81, V = 1982-86, VI = 1987-91, VII = 1992 - 1996.

For such reasons, the farmers of the NE provinces, while planting 45% of the totale rice area, obtained only 30% of the total production, whereas the C Plain farmers planted 26% of the total area and reaped 35% of the total production of Thailand.

In the 1960s, Thai farmers grew at least 30 traditional rice cultivars. By 1973, in the C Plains the adoption of improved RD-varieties was still below 6% on irrigated and rain-fed bunded fields and only about 40% of the rice area was treated with fertilizers (Framingham *et al.*, 1978). The miracle rice lines IR5, IR8, IR20 and IR22, which did wonders in other Asian countries, were not so effective in Thailand, where water control was deficient. Farmers found them to be too short, easily flooded and poorly resistant to diseases and pests.

Between 1972 and 1982, rice production increased by about 3% per annum. Since the population growth averaged only 2.5% per annum, Thailand could export more than 3 M tonnes of rice per year valued at up to 1 billion US$ (Rijk & Van der Meer, 1984). The growth in production stemmed mainly from improvement of irrigation and opening up lesser quality land for rice growing under rain-fed conditions in response to greater market demand (Kulick & Wilson, 1992). Annual rice production consisted for two-third of non-glutinous rice and one-third of gluti-

Table 4.4.3.1.b. Thailand. Rice production in the period 1980-96. Index: a. area harvested (M ha); b. total production of rough rice (M t); c. annual production in relative values (1996 = 100%); d. yield of rough rice (t/ha). Source: Various FAO Production Yearbooks. (See also fig.7.4.3.a).

Year	a	b	c	d
1980	9.1	17.4	80	1.9
1981	9.1	17.8	82	2.0
1982	8.9	16.9	77	1.9
1983	9.6	19.6	90	2.0
1984	9.6	19.9	91	2.1
1985	9.8	20.3	93	2.1
1986	9.2	18.9	87	2.1
1987	9.1	18.0	83	2.0
1988	9.9	21.3	98	2.2
1989	10.0	20.2	93	2.0
1990	8.8	17.2	72	2.0
1991	9.3	19.8	91	2.1
1992	9.1	20.4	94	2.3
1993	8.5	18.4	85	2.2
1994	9.0	21.1	94	2.3
1995	9.0	21.1	97	2.3
1996	9.2	21.8	100	2.4

nous rice. Glutinous rice was grown in particular by farmers of the NE Region (66%) and the N Region (33%) since its higher price compensated for its low yield.

In the 1980s, a more suitable high-yielding rice cultivar, Suphanburi-60, was introduced. In the 1990s, most owner-farmers used the two government-issued varieties, but many tenant farmers continued the planting of indigenous rice varieties which require less fertilizer and pesticide inputs (Jungbluth, 1996; Kenmore, 1991b).

Since the late 1970s, rice occupied over 9 M ha, or some 40% of all cropped land (table 4.4.3.1.b). In the period 1983-89, the largest mean hectareage under rice was harvested. In the 1990s, the planted area decreased by about 0.4 M ha, but mean annual production of rice increased by about 1 M tonnes. Many Thai farmers abandoned rice growing in favour of higher priced products, such as fruits, vegetables and livestock.

4.4.3.2. IPM as the leading policy for rice. In Thailand, knowledge on insect pests and diseases in rice and other crops was gradually built up after 1960. The most noxious rice insects at that time were pyralid stemborers, noctoid cutworms, leafhoppers (*Nephotettix* spp.), the rice gall midge (*Pachidiplosis oryzae*) and the rice bug (*Leptocorisa acuta*). Heavy grasshopper infestations in NE and C Thailand were attributed to extensive deforestation (Wongsiri & Kovitvadhi, 1964). DOA researchers developed recommendations for calender-based spraying of insecticides, in particular against rice stemborers and rice gall midge.

Around 1970, MOAC introduced high yielding rice varieties form IRRI to improve rice production in Thailand. The government encouraged double cropping and heavy reliance on pesticide use. Traditional infestations of stemborers, leafhoppers and rice gall midge became worse and a new pest, the brown plant hopper (*Nilaparvata lugens*, BPH) appeared. The concept of pest management was introduced in Thailand in 1973 when a graduate course in pest management was offered at Kasetsart University (KU). The East West Food Institute of the East West Centre, Hawaii, USA, conducted a series of conferences and workshops on pest management from 1972 to 1977, and provided support to the National Biological Control Research Centre. DOA intensified research on rice pest management in 1976 and commenced with large-scale field demonstrations in which insecticide treatments formed an important means of control (Rumakom *et al.*,1989, 1991).

In 1980, the FAO launched an Inter-Country Programme for the Development and Application of Integrated Pest Control in Rice in S and SE Asia (ICP-IPC Rice) (ch 5). ICP phase I concentrated on research and later phases of the program on extension. In 1981, the Thai government subscribed to the FAO ICP-IPC Rice Programme and declared IPM, based on the regulation of pesticides use, to be the national policy for plant protection (Rumakom *et al.*, 1989, 1991). A Steering Committee was installed to manage the National IPM in Rice Program. The DOA and DOEA both established a sub-division for biological control of insects. The research divisions of DOA worked on IPM projects in cotton since 1981, rice since 1983, and sugarcane since 1985. During 1982-84 and 1985-87, DOA conducted 'IPM in rice' demonstration trials on a scale of 84 ha only, in which the planting of resistant rice cultivars and need-based pesticide use were the main tactics (Rumakorn *et al.*, 1986, 1991). No further reports on IPM field research by DOA were found.

The IPM program on DOAE began with the development of a Surveillance and Early Warning System (SEWS) in 1981, with the assistance of the Thai-German Plant Protection Program. This program, executed by the German Technical Aid Agency (GTZ) since 1975, helped to develop IPM technology by establishing economic threshold (ETL) values for pests and diseases[37], and procedures for monitoring, treatment and demonstration. The plant protection service units of DOAE were strengthened and a nationwide scouting network was installed. There is no evidence of a lasting impact of the Thai-German Program on current methods of agricultural extension. The German program included surveys of field rats and improved methods of rat control in food crops.

Around the same time, an Agricultural Spraying Machinery Evaluation Centre (ASMEC) was set up at DOA in Bangkok, by the Centre of Overseas Pest Research (COPR) under a British bilateral program (Sutherland, pers. comm., 1979). The ASMEC was taken over by DOA's Pesticide Research Branch in the 1980s. In 1979, the Agricultural Requisite Scheme for Asia and the Pacific (ARSAP), a Dutch funded project of the Economic and Social Commission for Asia and the Pacific (ESCAP) at Bangkok, began in Thailand with a series of planning workshops for trainers from the public and private sector on safe and efficient pesticide use. The ARSAP project covered ten countries between 1979 and 1983. The ARSAP-training module was the first of its kind installed in DOAE in 1980 (Oudejans,1992).

In the 1980s, IPM demonstration projects on cotton, sugarcane and vegetables (crucifers and onions) were carried out with the support of FAO/UNDP. In response to the government policy to promote the export of fruits, DOA and DOAE requested long-term assistance from the German Technical Aid Agency (GTZ) to undertake a Thai-German IPM project for improvement of fruit trees. The project began in 1989 on mango, tangerine, pomelo, durian and longan (GTZ project office, pers. comm., 1993).

The pest problems in rice aggravated around 1989, when BPH outbreaks became increasingly severe in 25 provinces. BPH and Ragged Stunt Virus (of which BPH is the vector) damaged, in 1990, an estimated 0.6 M ha of rice fields, causing yield losses of about 0,3 M US$ (8 M bahts). The widely adopted rice variety Suphanburi-60 proved to be disastrously vulnerable to BPH. The use of organophosphate and pyrethroid insecticides against rice thrips (*Thrips oryzae*) and leaffolders (*Cnapholocrocis medinalis*) were named as a further cause of the BPH outbreak (Rumakorn *et al.*, 1991).

In the 1990s, DOA and DOAE intensified their work on the development of IPM and bio-control technology. Of the 1993 budget of DOA's Entomology Division (2.5 M US$ or 63 M Baht), 36% was allocated to control (7% to IPM-related research, 10% to biological control, 19% to chemical control) and 20% to crop related projects such as crop loss assessment and plant resistance (Jungbluth, 1996).

The government strengthened the capacity of DOEA for IPM development and promotion by doubling the department's annual budget between 1991 and 1995. This was in line with the Seventh Five-year Plan (1992-1996) which emphasized IPM, biological control, pest surveillance and forecasting, and education in efficient and safe use of pesticides. The allocation to DOAE's Plant Protection Service Division for IPM extension was raised four-fold to about 0.8 M $/y. Its allocation for development and extension of biological control[38] increased eight-fold. In comparison with DOAE's outbreak expenditure, however, allocations for IPM and bio-control related activities remained relatively small (Jungbluth, 1996).

Recognizing the importance of healthy improved seeds, the RTG established a first seed multiplication project with USAID assistance in 1976. Within MOAC, the departments DOA and DOAE were made responsible for the improvement and distribution of quality seed. DOA's Agricultural Technology Division (ATD) and Kasetsart University produced breeder and foundation seeds at the agricultural experiment stations. The Seed Division of DOAE produced registered and certified seeds at its Seed Multiplication Centres and through contract farmers. MOAC departments could only produce[39] about 1% of the estimated demand. DOAE sold annually about 12,000 tonnes of seed which was mainly procured from the private sector. The private seed companies concentrated on multiplication, through contract farmers, of maize and sorhghum seed, since the profit margin for rice seed and oilseeds was unattractive (Rijk & Van der Meer, 1984).

4.4.4. Other field crops and estate agriculture. Before 1950, no other crop could compete with rice in value, although sugarcane and rubber also had a long history in Thailand. Since World War II, considerable diversification took place with major crops such as maize, cassava, soybean, tobacco and a whole range of other food and cash crops gaining interesting market shares. In several instances, the introduction of new crops resulted from international developments which endangered Thailand's political stability. Two examples are given.

In 1957, a neglected area on the NE Khorat plateau with a strong Laotian culture, called E-san, was struck by a combination of extreme drought and locust outbreaks. Its inhabitants fled in large numbers to Bangkok where they were housed in refugee camps. The crisis and fear of insurgences in Thailand's border provinces, inspired by the communist regimes of neighbouring countries, necessitated the Thai government to undertake the development of the NE region. A massive aid effort[40] freed the E-san from its isolation, gave it access to the market economy and brought rapid agricultural development. For E-san farmers, who produced mainly glutinous rice and sorghum for self-sufficiency, improved maize, kenaf, cassava (*Manihot esculenta*) and mung bean (*Phaseolus aureus*) became major cash crops.

In the N Region, the homeland of the Meo, Karen, Lisu and other hill tribes, shifting cultivation was the common pattern. The range of subsistence crops included upland rice, maize, millet, yam, sweet potatoes, fruits and vegetables. However, the traditional mainstay of the hill tribes' economy was opium poppy (*Papaver somniferum*), a crop with a peculiarly high value per unit weight and not readily perishable. A United Nations Survey in 1967 found that some 1800 ha of opium poppy were grown (O'Reilly & McDonald, 1983). In 1980, the Thai government and the United Nations launched, under the patronage of King Bhumibol, a joint Highland Agricultural Marketing and Production (HAMP) Project aimed at developing crops which would be economic to grow in remote uplands. Arabica coffee seemed a good choice and a Highland Coffee Research and Development Centre was set up with Dutch funding at Chiang Mai (Rijk & Van der Meer, 1984).

Under the successive Five-Year Development Plans intensification and diversification were promoted, but often rather by private sector initiatives seizing the opportunities of a free market than by the government. Intervention by the RTG in the development of individual crops usually concerned policies of price stabilisation, levies, exports taxes and cess funds rather than investing in improvement of seed and planting material and technology (Siamwalla & Setboonsarng, 1989). For example, the use of fertilizer and pesticides by Thai farmers was for many years much lower than the average level in SE Asia because of high agro-chemical prices[41] (Waibel, 1990a,b; Panayotou, 1985).

Other field and tree crops included a whole range of plants such as sugarcane, sorghum, the oil crops soybean and groundnut, the fibre crops kenaf and cotton, mung bean, tobacco, coconut and kapok. Although these crops occupied a smaller hectareage, they were profitable because they suited local conditions or were the farmers' response to temporary developments in market prices. Sugarcane growing expanded considerably since the 1970s and amounted to 1 M ha with a production of 6.3 M t raw sugar by 1996. Tobacco was a crop of similar value as cassava and maize, but its cultivation, including the supply of seed and chemical imputs, was largely controlled by the private sector. Generally, the government did little to promote the cultivation of plantation crops[42] (Rijk & van der Meer, 1984) but, in recent years, interest in growing rubber and oil palm was increasing. The cultivation of higher priced horticultural crops and fruits increased rapidly (ch 6.4).

4.5. Discussion, Thailand

The following discussion and conclusions reflects the authors' interpretation of the agricultural situation in Thailand. During my stay at UN ESCAP, Bangkok, 1979-83, and in later visits I worked with and interviewed a fair number of Thai experts in Kasetsart University, DOA and DOAE. My contact with provincial officers and farmers was very limited because of the language barrier.

Thailand, known as Siam till 1949, remained an independent kingdom by liaising with the English colonial administration in Burma and Malaya and with the French in Cambodia and Laos. This fact determined the course and pace of agricultural development in Thailand till present times. During the 19th century, foreign planters and agronomists introduced exotic crops into Indonesia and Peninsular Malaya and invested in the production of commodity crops for export, which created a need for scientific research. Siam kept the foreign (*farang*) influences at bay and began agricultural development autonomously.

Remarkably, agricultural development in Siam too began with export commodity production. But Siam exported rice and mainly to Asian markets. The factors which allowed Siam to become a major rice exporter included ample availability of fertile land in the C Plain, low domestic consumption due to its small population, and under-utilization of labour. The demand in the Asian markets grew with the expansion of the mining and plantation industry in Malaya and the Dutch East Indies. The government of Siam furthered rice export through measures which kept the price of Thai rice competitive with prices offered by Indo-China and Burma. It maintained low land tax rates, invested in road and canal construction to improve transportation, opened 0.3 M ha of uncultivated land for rice production and expanded the rice milling capacity. By dissolving servitude constructions in the rural society, the King freed labour for tenant farming and employment in positions which supported agricultural development.

Around 1900, Siam could not meet the Asian demand for rice because labour became the limiting factor in the C Plain. Higher prices induced the farmers to shift from labour intensive transplanting of rice seedlings to less labour demanding direct seeding. By 1930, about 70% of the rice area was direct seeded (Manarungsan, 1989). Thus, direct seeding of rice was practised in Thailand about 50 years earlier than in the Irrigation Schemes of Malaysia, but for the same reason of shortage of labour for transplanting.

The Malay researchers accompanied the shift in method of crop establishment by weed studies and development of integrated weed management. No reference was seen to Thai research projects for weed control in rice. It is likely that the weed problem was a major cause for low productivity in rice in Thailand (table 4.4.3.1.b).

After World War II, the Royal Thai Government (RTG) allowed the opening of new land and promoted production of other food crops. The Cold War and the fear for an increase of communist insurgencies in the backward provinces in the N, E and S of Thailand were a major incentive to extend the road system to the border provinces and to begin construction of irrigation dams in the N and NE regions. Owing to the massive presence of the United States Forces in NE Thailand, during the 1950s in connection with the Vietnam War, agricultural technical aid began to arrive. New opportunities were the growing of maize and cassava in the outlying provinces for export as feed stock to European markets. Much of the expansion was realized by the private sector, which provided the seeds, agro-chemicals and credit facilities. Since the export revenues from agricultural commodities contributed substantially to the national economy, the Ministers of Finance and of Trade and Commerce had more power in directing agriculture than the Minister for Agriculture.

The fact that Thailand never experienced nation-wide shortage of food nor a structural lack of food security might have delayed agricultural development. National revenues from commodity trade (rice and rubber) received more attention than the need to increase productivity. The policy concerning export taxes and floor prices for rice discouraged Thai rice farmers to spend more on inputs. For example, the RTG imposed high tariff rates on agro-chemical imports to protect Thai investment in the fledgling fertilizer and pesticide industry (Waibel, 1990b).

In Thailand, institutional development in agriculture began at least hundred years later than in Indonesia and Malaysia. The RTG founded a Rice Department in the 1950s only but lacked experienced researchers. Therefore, the RTG invited international technical assistance in the 1960s to strengthen research and education. Plant production and plant protection are still weak in terms of experts and expertise.

The gap between the government institutions and the farmer is wide in Thailand, largely due to Thai culture and attitudes (Heim, 1990). The Agricultural Extension Service (DOEA) has collaborated with international agencies such as the German Ageny for Technical Cooperation (GTZ) to improve extension. Still, it is not sufficiently equipped to meet the needs of the 20 million farmers (Laosuwan & Macartney, 1992).

4.6. Conclusions, Thailand

1. Agricultural development in Siam (since 1949, Thailand) differed essentially from that in Indonesia and Thailand. In Thailand development began in indigenous agriculture, in the rice sector, as an autonomous process.
2. Increasing opportunities to export rice induced farmers of the C plain to produce a surplus, elsewhere farming for self-sufficiency persisted.
3. Rice production for export became possibly because, in the 19th century, Siam's C Plain offered the right conditions and the government provided the adequate incentives. The King dissolved traditions of labour bondage and servitude and thus freed labour for agricultural development.
4. Export rice production was valued for its contribution to the national economy, but no attention was given to improving productivity.
5. Foreign investment in Thai agriculture was delayed till after World War II owing to restrictive terms for land lease and high export taxes. The cultivation of coffee, rubber and oil palm remained restricted to smallholders in S Thailand. Thus, there was little need for research on pests and disease control in estate crops.
6. Siam was less damaged by the Japanese presence during World War II than Indonesia and Thailand. Commodity export from Siam was, however, interrupted and no investments were made during the 1940s.
7. Only the farmers in C Thailand could avail of the higher prices for export rice and participate in export production. Farmers in most of the other provinces lived in self-sufficient communities.
8. Thai agriculture contributed substantially to the Gross Domestic Product and mainly through export of rice and rubber. As an inportant source for taxes, agriculture was dominated by the Ministers of Finance and Commerce. The Minister of Agriculture had little influence.
9. The fear for political instability in backward rural areas after the Second World War provided a greater impulse for agricultural development than the low political interest for advancement in agriculture.
10. Adoption of improved rice varieties, fertiliser use and mechanisation remained low. The government used the floor prices for rice to regulate export rather than to stimulate the development of rice technology.
11. In the past and the presence, farmers, in general, missed the incentive to spend more on inputs to improve rice production

12. The commercial attitude of Thai Ministers and civil administrators towards agriculture gave plenty of opportunity to the private sector to operate on a virtually free market.
13. The Thai government joined the FAO ICP-IPC Rice Programme in S and SE Asia in 1980 . The RTG established a National IPM Program, but did not officially declare IPM as national policy in rice. There is no evidence of IPM programs in the field other than a few IPM demonstrations in rice, cotton, sugarcane and vegetables in the 1980s.
14. The National Biological Control Research Centre acquired a considerable expertice in biological control, the rearing of natural enemies and quarantine. However, no information was found to what extent biological control is *de facto* applied in field crops and orchards.
15. Well-executed technical aid projets on rat control and pesticide application equipment maintenance from the late 1970s were not continued.
16. Major obstacles for international development assistance programs to Thailand appear to be the difficulty for foreigners to understand the intricacy of Thai customs and language, and to deal with its bureaucratic system.
17. The RTG executed a joint Thai-German IPM Programme for Selected Fruits (ch 6) which aimed at the improvement of rootstock and reduction of pesticide use. The effort looked promising, but no evaluation results were available yet.
18. The markets for agrochemical inputs, seeds and agricultural machinery were managed by the private sector with little regulation and control by the government. The fact that the RTG joined FAO's regional IPM initiatives had no visible effect on the pesticide market in Thailand (ch 7).
19. In the 1990s, the RTG appeared to have little interest in agriculture due to a general expectation in the society about accelerated development in other economic sectors such as industry and services.

Notes

1. The soils of the Central Plain and northern valleys have a generally similar illitic clay-mineral composition and high humus content (O'Reilly & McDonnald, 1983).

2. The soils of the North East have low carbon content, are almost deficient in phophorous, exchangeable potassium, calcium and magnesium, and some are rather kaolinitic. Lack of water retention and salinity are general problems (O'Reilly & McDonnald, 1983).

3. King Mongkut (1851-1868) had lived as a Buddhist monk for 27 years, mastered several foreign languages and he was well informed. The opening of China after the Nanking Treaty, 1842, and the annexation of Lower Burma by the English army, convinced King Mongkut that also for Thailand the days of isolation were over. Thus, in 1855, he entered into negotiations with the English mission under Sir John Bowring in a constructive mood (Manarungsan, 1989).

4. In 1850, the capital Bangkok, by far the largest town at that time, required not more than 39,000 tonnes of rice per year for its 160,000 inhabitants. Since export of rice amounted to 15,200 tonnes in the same year, the marketable surplus of 1850 was less than 60,000 tonnes. Data series on rice production during the 19th century are not available and those for the 20th century are ambiguous (Manarungsan, 1989).

5. Farmers' lack of material incentives led to the relatively low development of a money economy in rural areas. Siam's first bank, the Hong Kong and Shanghai Banking Corporation, was established in Bangkok in 1888. Bank notes were issued but their circulation remained mostly limited to Bangkok. In village markets transactions was chiefly done by barter (Manarungsan, 1989).

6. Rice production in the Indonesian and Malay Archipelago was limited by low productivity, almost exclusive attention for plantation agriculture, and the numerous insurgences against the colonial administration.

7. Average annual exports increased fifteen-fold from 62,370 t/y volume of 1857-1860 to 929,457 t/y in 1906-1910 (Manarungsan, 1989).

8. Nowadays, some of these early canals have become indispensable arteries of drinking water supply to the metropolis Bangkok.

9. Corvee was an ancient obligation of every free man to perform services for the king and the local overlords during three months of the year. Since the free Thai was uncertain when he would be called for corvee services, the system hindered the expansion of rice production. Free people sold themselves into bondage for reasons of financial problems, such as insolvency, or for economic security provided in the form of food, shelter, clothing, and protection by their masters. Since slaves were automatically exempted from corvee, the lot of the debt slave was not too unpleasant in comparison with that of the free man (Manarungsan, 1989).

10. The Great King Chulalongkorn, reigning as Rama V from 1868-1910, was an enlightened monarch who reformed Thai society despite its deeply ingrained and pervasive traditionalism. His many reforms, which constituted a 'revolution from the throne' brought the kingdom well into the modern world (Sternstein, 1982).

11. King Chulalongkorn decreed that children born after a certain date could not be enslaved, and that debt slaves were to be credited with 4 baht per month until their debts were paid off and they became free.

12. The per caput tax rate replacing corvee duties varied from 1.50 to 6 baht per year depending on the status of the individual and the prosperity of the region.

13. With the abolition of slavery landowners got the chance to rent their abundant, untilled rice lands out to tenants. In Rangsit area, 95 per cent of the farmers were tenants (Manarungsan, 1989).

14. By 1891, steamships accounted for 90% of all shipping tonnage at Bangkok port already (Manarungsan, 1989).

15. The large imports of relatively cheap Thai rice upset in particular the Chinese rice trade. Between 1893 and 1930, integration of the Thai and Chinese rice markets in Thailand and China, respectively, became so intense that the correlation coefficient between Chinese and Thai rice prices was calculated at 0.86.

16. The mean annual growth rate of Thailand's population increased from 0.95% around 1850 to 3.0% between 1880 and 1900, and peaked at 3.8% between 1960 and 1970 (Sternstein, 1982).

17. Investment in seed differed as seed rate for broadcast sowing amounted to 21 kg against 7 kg for for transplanting.

18. The Thai government invested in rail construction rather than irrigation in view of a treatening colonial expansion from Indo-China. The ecomonic effect of the railways was limited because the expansion was modest and freight rates prohibitive for bulky commodities (Rijk & Van der Meer, 1984).

19. According to the Statistical Year Book, the padi yields in the C Plain, particularly in the Chao Phraya basin, were relatively stable at about 1.5 t/ha during the period 1921-1950. Average yields in the N and NE provinces and on marginal land of the C Plain declined considerably from 1.5 t/ha to 1.1 t/ha (Manarungsan, 1989).

20. Thai statistics on land use are contradictory because swidden cultivation is not recorded as agriculture and minority groups, e.g. the hill tribes, are not recognized as Thai citizens and, thus, cannot own land officially. Further, unstoppable encroachment on public land is an offence and not recorded since registration would signal acceptance and legitimation of the actual land occupation (Rijk & van der Meer, 1984).

21. Around 1980, the lowest tenancy rate (<0.1%) was found in the N province of Nan, whereas Thon Buri N province, adjacent to Bangkok, showed the highest tenancy rate (23% only). Tenancy points to the phenomenon that in a commercial, fertile environment the value of land increases rapidly (O'Reilly & McDonald, 1983).

22. Rijk & Van der Meer (1984) noted that statistics on land use and registration were lagging behind actual occupation. Since land use rights were secured for only 50% of total agricultural land, unclear rights formed an obstacle for cultivating newly expanded agricultural land and intensification of production.

23. The credit needs of Thai farmers were for at least 50% catered for by private parties, such as middlemen, money-lenders, and relatives. Farmers had access to cheap institutional short term loans, such as from the Agricultural Credit Bank. Many small farmers, however, lack the collateral or shun the cumbersome procedures involved (Rijk & van der Meer, 1984).

24. The low utilization of dry season irrigation facilities was attributed to an unfavourable benefit/cost relation, to deficiencies in design, maintenance and government services, and to low pressure on the land. The Thai government focussed more on small scale irrigation schemes than on large ones and on rehabilitation of older schemes. The return on investment in irrigation was little studied (Rijk & van der Meer, 1984).

25. The massive road construction programme since the early 1960s was principally inspired by political rather than by developmental arguments. The Indo-China and Vietnam wars and growing Communist insurgency urged the Thai government to undertake extensive road programmes with foreign assistance in order to establish more direct control by the armed forces over its outlying rural areas.

26. Kenaf (*Hibiscus sabdariffa* L. and *H. cannabinus* L.) is a fibre crop and a substitute for jute.

27. Rice exports valued 2 billion US$/y and other commodities, such as rubber, maize, tapioca, prawns and sugar earned another 3 B US$/y. Reduction in tapioca trade caused a decline in the value of agricultural exports to roughly 4 B US$/y.

28. In 1960, the U.S. Operation Mission (USOM) provided funds for research on rice insects, but Thailand lacked experienced researchers. Therefore, the government asked UNDP/FAO to organize training (Wongsiri & Kovitvadhi, 1964).

29. Between 1974-76, quality testing of pesticides taken from shop shelves showed that 26% out of 753 samples analysed were sub-standard (James & Reddy, 1977b).

30. There are over 100 research stations and experimental farms widely distributed over the major agroeconomic regions of the country.

31. In the intricate fabric of Thai administration, the delicate division of competency between the two departments might constitute a major obstacle for program implementation. An importent concept in Thai communication is 'kriengchai' which might be translated as indulgence.

32. Large scale locust and grasshopper outbreaks occurred in 1963, 1969, 1970 and 1973. In the latter year, locusts were controlled on 312,650 ha by the Agricultural Aviation Unit, flying 4 Pilatus Porter-aircraft, at the cost of around 0.5 M US$ (James & Reddy, 1977b; Roffey, 1969).

33. The outbreak budget features a post for the purchase of biological pesticides such as *Bacillus thuringiensis*, neem and bio-agents produced by the Bio-Control Centre (Jungbluth, 1996).

34. The combined proceeds from the premium (a quota rent collected by the Ministry of Commerce) and additional tax (imposed by the Ministry of Finance) made up a quarter of total government revenue between 1949 and 1955 (Siamwalla & Setboonsarng, 1989).
35. Thailand emerged as the world premier exporter of rice in 1964-66, 1971-72, 1977, and 1981-86. It obtained a 37% share of the global rice market in 1985 (Siamwalla & Setboonsarng, 1989).
36. Since 1977, all of Thailand governments have consisted of shifting coalitions among the military, the technocrats and the elected politicians. The Commerce and Agriculture portfolio became the preserve of elected politicians. This opened the position for ministers with an agricultural training background, who backed programs to improve producers' prices (Siamwalla & Setboonsarng, 1989).
37. Economic treshold values were determined for the fungal rice diseases Rice Blast, Sheath Blight, Sheath Rot, and the viral diseases Ragged Stunt, Leaf Curl, and Yellow-Orange Leaf (Rumakom *et al.*, 1991).
38. Within DOAE the research on non-chemical control technology was prioritized and the bio-control section in its Plant Protection Service Division up-graded to the status of division. Of the Plant Protection Service budget for 1995/96, amounting to about 1,6 M $ (40 M Baht), 30% was allocated to bio-control development (Jungbluth, 1996).
39. During the years 1975 to 1979, the average annual production of non-glutinous rice seed was 645 tonnes (15 t breeder, 362 t foundation and 267 t registered seed). Additionally, about 110 t glutinous rice seed and 137 t maize seed were produced by ATD and DOAE (Panayotou, 1985).
40. In its struggle against communism, the Thai government found an ally with the USA, which were engaged in the Vietnam War. Since the US airforce operated from five large military bases in E-san, the US government invested largely in road building, irrigation and the economic situation of the region.
41. In Thailand, a combination of tariff policies on the production and import of fertilizer, intended to protect domestic fertilizer industry during its infancy, led to very high fertilizer prices and unfavourable rice/fertilizer price ratios (Panayatou, 1985; Waibel, 1990b).
42. By restrictions on the size of concession (maximum 800 ha) and heavy taxes on production and export, the RTG, in fact, discouraged foreign investment in rubber planting (Manarungsan, 1989).

Chapter 5

Development of Integrated Pest Management in SE Asia

5.1. Episodes in the history of plant protection

The knowledge of and skill in protecting crops against pests and diseases have improved greatly over the centuries. The advance in science and technology, particularly during the 20th century, changed men's approach to pest and disease management. Crop protection has developed into a new branch of science in which Zadoks (1991) recognized four distinct periods: *a.* pre-scientific period before 1890; *b.* pathogenistic period from 1890 until 1940; *c.* chemistic period from 1940 until 1990; and *d.* ecologistic period after 1990.

From ancient times till late 19th century many important discoveries were made with regard to plant and animal life and their interrelationships. Chinese literature of 2,500 years old shows that the Chinese understood and employed the process of predation to control orchard pests. The Dutch scientist A. van Leeuwenhoek, in 1700, observed and correctly interpreted the behaviour of parasitoid insects (van Lenteren, 1993a). Réaumur (1683-1756) proposed the introduction of natural enemies for the control of pests, *in casu* the release of lacewings in greenhouses for the control of aphids (Flint & van den Bosch, 1981).

In Europe, the period between 1750 and 1880 was regarded as a time of agricultural revolution in which farming left the stage of subsistance enterprise. In the second half of the nineteenth century, European countries and some of their colonies were stricken by agricultural disasters, such as the Potato Blight in Ireland, grape phylloxera in France and Coffee Leaf Rust disease in Sri lanka. These epidemics sparked off a chain of research activities in the field of pest control. Biological control through predators and parasites was put to practice in France and Germany since 1840 (Van Lenteren, 1993a). In 1841, Harris published the first American textbook on the control of insects under the title 'Treatise on some of the insects injurious to vegetation'. The first (modern) textbook on plant pathology by Kuhn appeared in 1858. It listed climatic and soil conditions, insects, parasitic higher plants and microorganisms as causes of plant diseases. At that time there were still few useful control methods for plant diseases (Flint & van den Bosch, 1981).

In 1890, Koch stated his 'postulates' which determine the conditions to identify a certain micro-organism as the causal agent of a particular disease. Zadoks (1993a, c) takes this year as the turning point from the pre-scientific to the pathogenistic[1] period. In the latter period, great progress in diagnostics brought an understanding about infectiousness, transmission by vector insects, and the properties of sub-microscopic pathogens. Such understanding offered possibilities to avoid contamination and thus led to a wide range of preventive measures in pest control.

The chemistic period from 1940 till 1990 began with the discovery, in 1939, of the insecticidal properties of DDT by the chemist P.H. Müller of the J.R. Geigy

Company, Switzerland (BCPC, 1979; 150). During World War II, the Western Allied Forces developed pesticides of the chlorinated hydrocarbon group, whereas the German side came up with insecticidal compounds, such as parathion and schradan, in the organophosphate group (Flint & Van den Bosch, 1981). When DDT and other chemicals were released by the War Production Boards, they immediately became commercial successes in agriculture. Chemical companies continued the synthesis and screening of numerous new compounds on biocidal properties and invested heavily in marketing. The highly effective organochlorine and organophosphate insecticides replaced the old pre-war assortment of anorganic materials (such as calcium arsenate, lead arsenate), and botanicals.

Whilst chemical control technologies acquired a greater prominence, technologies based on biological control, habitat sanitation and cultural practices were disrupted or abandoned. Moreover, research emphasis in entomology shifted from biological studies towards studies of insecticides (Perkins, 1980). The arrival of synthetic herbicides contributed to increase labour productivity and farm size. The development of systemic fungicides, around 1960, opened a new road to curative control of plant diseases as the new chemotheropeutic products offered a possibility to treat already infected plants from within (Zadoks, 1991, 1993a).

During the 1950s, evidence emerged on insecticide-induced resurgences of pests and the appearance of secondary pests caused by pesticides. Ever more cases of pest resistance[2] to pesticides, a phenomenon already known since 1946, were reported. The common reaction to such nuisances was an increase in pesticide use through increased dosage, use of another pesticide, or use of a combination of several pesticides. When the application resulted in target pest resurge, the pesticide would be applied more and more frequently. The result was more pesticide resistance, more pest resurgence, and more secondary pest outbreaks. The syndrome was called 'the pesticide treadmill'. Once caught, the farmer could not get off (Flint & Van den Bosch, 1981). A major reason for the failure of insecticides was their destructive effect on the natural enemy complex which in an non-contaminated environment often suffices to keep potential pests in check.

As a reaction, entomologists and ecologists developed new approaches such as 'supervised', 'harmonious' and 'integrated' control, guided by research on population dynamics. They perfected several new control tools which were compatible with the Integrated Pest Management concept and minimally disruptive to ecosystems. Concomitant with these entomological results, an awareness of the hazards to men and environment from pesticide usage sprang up. In 1962, Rachel Carson published 'Silent Spring', a book that not only documented crop-centered problems with chemical pest control, but also exposed the broader implications of their unrestrained use for human health and non-target organisms. Rachel Carson's warning had a tremendous impact on the scientific world. It set off a chain of consumer oriented actions[3].

Public scrutiny brought new research in the field of hazard avoidance, such as reduction of the number of applications, of dosage and spray volume, improvement of formulations and application technology and equipment, development of less toxic, more selective pesticides, and usage of insect pathogens, pheromones and growth inhibitors. The excessive use of pesticides and fertilizers caused environmental pollution, particularly with respect to drinking water quality (Gezondheidsraad, 1992; Vijftigschild *et al.*, 1995). Introduction by various governments of policies for pesticide reduction and sustainable agriculture marked a gradual transgression to the fourth periode.

The ecologistic episode was ushered by the Brundtland report 'Our Common Future' published in 1987 (WCED, 1987). The Brundtland Commission outlined a political route to sustainable food security which was internationally acclaimed. Zadoks (1993) placed the beginning of the ecologistic episode in the Netherlands in the year 1990, when the Dutch government issued its Multi-Year Crop Protection Plan (MYCPP) (Anonymous, 1990, 1991). This Plan outlined a pesticide reduction policy, as was also being implemented in several other European countries such as Sweden, Danmark and the United Kingdom (Oudejans, 1993).

5.2. Development of Integrated Pest Management in SE Asia

5.2.1. Political choices regarding pest control in SE Asia. In 1985-86, integrated pest management was proclaimed the overriding agricultural policy in several countries of S and SE Asia. Within a period of fourteen months, the Presidents of Indonesia and the Philippines, and the Federal Ministers of Agriculture of India and Malaysia officially declared[4] Integrated Pest Management (IPM) a priority objective for agricultural research and extension in rice.

The prioritizing of IPM, which in Indonesia was accompanied by a ban on 57 brands of insecticides for use in rice, had great consequences, not in the least for the chemical industry and private investors (ch 7.2). It involved a massive reallocation of manpower, public resources and private investment. A policy change of such impact must have been supported by convincing arguments of proven validity. Moreover, these arguments must have been familiar to the thinking of agricultural experts because response at the executive level was rapid. The motivation for installing IPM as a regular policy in SE Asia in the late 1980s is to be found in two streams of events, concurring at the international and national levels, which brought motives, occasions and parties together at the right time.

The first stream consisted of developments in the national economy of several SE Asian countries in general and their food production sector in particular. These developments included the consecutive intensification programs through which the governments, in particular Indonesia, invested large amounts of money in irrigation, introduction of Green Revolution technology and strengthening of agricultural services with the objective of attaining self-sufficiency in rice production. Agricultural intensification with its emphasis on higher yields through resistant, short straw cultivars, chemical imputs and improved water supply greatly exacerbated crop pest problems in the tropics. Pest populations could build-up because host plant resistance had often been traded for yield potential in breeding programs, fertilizers made plants more nutritious for pests, and irrigation permitted continuity of host plant exposure. Higher pest incidence led to increased dependance on synthetic pesticides which in turn aggravated problems through destruction of natural enemies (Way, 1987). During the 1970s, ever larger and more frequent outbreaks of insect pests in particular of the brown planthopper (*Nilaparvata lugens*, BPH) threatened to jeopardize the very goal of self-sufficiency in rice in Indonesia. The alerted governments strengthened agricultural extension, established Surveillance and Early Warning Systems and Emergency Control Services, and encouraged frequent use of insecticides.

The second stream pertained to developments at the international level. The experience gained in a.o. California, USA, Canada and Europe with Supervised and Integrated Pest Control (IPC), had brought an understanding of the relationship between higher frequency of pest outbreaks and indiscriminate use of broad-spectrum insecticides, and an awareness of inherent environmental hazards. Serious pest outbreaks in cotton in S America and maize in C America had instigated the establishment of Integrated Pest Management (IPM) programs by national and international institutions (Brader, 1987). These involvements were precursors to the FAO Inter-Country Programme for the Development and Application of Integrated Pest Control in Rice in SE Asia (ch 5.7.3).

Other political developments of great consequence included the 'oil crisis' of the early 1980s when, following the release of the OPEC price agreements, Middle East producer countries over-supplied the global markets. The resulting oil glut drove prices down. Indonesia in particular, its Gross Domestic Product existing for some 90% of income from oil and natural gas, was hard hit (World Bank, 1986). Facing rapid increases of yield losses in rice due to insect pests and the high expenditure on agricultural credit and input subsidies, certain quarters of the Indonesian government grew very sceptical about the failing domestic agricultural policies (Oka, pers, comm, 1995). In Malaysia, the calamitous civil disturbances of 1969 resulted in the proclamation by the government of the New Economic Policy which was largely focussed on improving the well-being of the Malay section of population, the *Bumiputra* (Mahathir, 1970; Rehman Rashid, 1993). Serious losses in rice yields due to pests went against the government's political need to secure a fair income for Malay rice farmers. Finally, in Thailand, rice contributed up to 60% to the national export earnings in the 1970s. Thus, when pests induced losses in rice production soared in the late 1970s and early 1980s, the governments of Indonesia, Malaysia and Thailand each had a clear reason to accept the proposed FAO/UNEP ICP-IPC in Rice Programme which appeared to offer a solution to the disquieting BPH and Tungro outbreaks.

5.2.2. The FAO Integrated Pest Control Programmes. Recognizing that pesticide misuse can potentially create serious problems in tropical climatic conditions, FAO called a meeting of experts in 1959 to review pesticide use practices, the inherent hazards and the need for relevant legislation. The meeting recommended that goverments should support research leading to harmonization[5] of chemical and biological control, and that FAO should intensify its activities concerning registration and control of pesticide usage. Thus, the meeting marked the beginning of the official support given by the FAO to the development of IPM (Brader, 1987) and, later, to safe use programs. In 1963, the 12th Session of the FAO Conference recommended that FAO should give greater emphasis in its crop protection program to integrated control.

As a first step, FAO organized a Symposium on the subject in Rome, October, 1965. During this event the term 'Integrated Pest Management' was accepted for common use (Waterhouse, cited in Shangi, 1998), and the establishment of an Expert Group on Integrated Pest Management was proposed. The Director General of FAO installed, in 1966, a Panel of Experts[6] on Integrated Pest Control with the task of helping to define and effectuate relevant methods of pest management in developing countries. During the first ten years, the Panel of Experts focussed on the development and evaluation of IPM research, thereafter its function as an advisory body to FAO programs in execution became more prominent. In these early years, FAO launched two field programs[7], the control of the rhinoceros beetle (*Oryctes rhinoceros*) in coconut in the S Pacific (1964-75), and the control of insect pests in cotton (1970), with an extension into maize in 1974 (van Huis, 1981), in Nicaragua. Encouraged by the results achieved in these field programs, but recognizing the need for a more systematic approach, the Panel, in a jointly sponsored meeting in 1974, prepared a FAO/UNEP Cooperative Global Programme for the Development and Application of Integrated Pest Control in Agriculture (FAO/UNEP, 1975). Since the United Nations Environmental Protection Agency (UNEP) had already shown interest as a sponsor, the Panel of Experts on IPC became a joint FAO/UNEP advisory body in 1979. The Global Programme began officially in 1975 with the appointment of a program coordinator by FAO on UNEP funds. The aims of the Global Programme included the preparation of Inter-Country Programmes (ICP) for cotton in E Africa and C America, rice in S and SE Asia, and sorghum and millet in Sahelian Africa.

The proposals for the ICPs were completed early, but the search for funds from donors proved to be difficult. D.F. Waterhouse, the initiator of IPM programs for rice in Asia, raised the funds for an 'FAO Inter-Country Programme for the Development and Adoption of Integrated Pest Control in Rice in S and SE Asia' with the government of Australia (Sanghi, 1998). On Waterhouse's warnings for an imminent food crisis in S and SE Asia the Australian Freedom from Hunger Campaign provided the initial funding of about US$ 120,000 (Way, pers. comm., 1997; Sanghi, 1998). In 1978-79, consultations with seven countries resulted in an agreement about the project proposal. The FAO Intercountry Programme for IPC in Rice became operational in April 1980 (ch 5.7.3).

At the time when the Panel of Experts on IPM was set up, the term 'Integrated Pest Control' had been firmly adopted by entomologists as a rational approach to pest control instead of over-reliance, sometimes total reliance, on synthetic pesticides. In a key paper titled 'The integrated control concept' (Stern *et al.*, 1959), a group of Californian workers -V.M. Stern, R.F. Smith, R. Van den Bosch, and K.S. Hagen- proposed a set of formal definitions, statements of principles and necessary techniques[8] (Perkins, 1980). It was the same R.F. Smith who chaired the first meeting of the FAO/UNEP Panel of Experts in September, 1967, (Brader, 1987) at which the FAO definition of IPM was proposed (ch 5.2.3). Apparently, American entomologists had considerable influence on policy development in FAO and on the conceptual development of crop protection, and one may wonder about the development of IPM in North America during the 1950s.

5.2.3. Various definitions of Integrated Pest Management

A simple representation of the ideas of Stern, Smith and van den Bosch is the following definition (Flint & van den Bosch, 1981):

> In integrated pest management, various combinations of methods are utilized in a compatible manner to obtain the best control with the least disruption of the environment'.

According to Perkins (1980), this first formal articulation of the integrated control paradigm in 1959 referred to the integration of only two techniques, biological and chemical control. The term 'Integrated Pest Management' is synonymous with the term integrated control (Stern *et al.*, 1959). At an FAO Symposium on Integrated Control in Rome in September 1965, R.F. Smith and H.T. Reynolds offered a more inclusive concept which called for the integration of all feasible techniques guided by an understanding of the ecology of the agricultural system (Smith & Reynolds, 1966). This concept was the basis for the formal FAO definition of IPM, issued by the FAO/UNEP Panel of Experts in 1968 (FAO, 1968; Brader,1979):

> 'A pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury'.

The President of the United States of America in his 1979 Environmental Message stated:

> 'IPM uses a system approach to reduce pest damage to tolerable levels through a variety of techniques, including natural predators and parasites, genetically resistant hosts, environmental modifications and, when necessary and appropriate, chemical pesticides. IPM strategies generally rely first upon biological defenses against pests before chemically altering the environment'.

Thus, Integrated Pest Control -the term is synonymous with Integrated Pest Management- is a broad ecological approach to pest control using a variety of control technologies. The principle is that whilst synthetic pesticides may be essential, they should be used to compliment rather than to jeopardise controls based on host plant resistance, cultural practices and use of natural enemies. Kenmore *et al.* (1985) summarized the above in a most practical definition of Integrated Pest Control:

> 'The best mix of available tactics for a given pest problem in comparison with the yield, profit and safety of alternative mixes'.

The agro-chemical manufacturer Novartis (Kaufmann, 1995) gives the following definition of IPM:

> 'Integrated Pest Management (IPM) is the farmer's best combination of cultural, biological and chemical measures that yield the most cost-effective, environmentally sound, and socially acceptable insect, disease and weed management for crops in a given situation'.

5.3. IPM, made in Canada

In the 1940s, the earliest IPM program in deciduous fruit tree crops opened the road to IPM (Flint & van den Bosch, 1981). The spraying of apple orchards with pesticides was common practice across the North American continent since the early 1900s because of the high product value. In Nova Scotia orchards, in the 1920s and 1930s, frequent and heavy dosages of insecticides were required to suppress key pest such as codling moth (*Laspeyresia pomonella*) and eye-spotted bud moth (*Spilonota ocellana*). Target pest resurgence and secondary pest outbreaks aggravated the problem. The latter included outbreaks of the oystershell scale (*Lepidosaphes ulmi*) in the 1930s, and of the European red mite (*Panonychus ulmi*) and the grey banded leafroller (*Argyrotaenia mariana*) in the early 1940s (Pickett, 1949).

The Nova Scotia program was empirically[9] developed by Pickett and co-workers, one step at the time. The oystershell scale problem appeared to be caused by applications of sulfur-based fungicides which killed the scale's natural enemies. By substituting Cu-based (Bordeaux mixture) and ferbam fungicides for the sulfur-based fungicides, the parasites and predators were sufficiently spared to achieve effective biological control of the oystershell scale. The second target was the red mite whose predators were eliminated by insecticide sprays against codling moth and other key pests. In the early 1950s, introduction of selective botanicals, such as ryania, and a need-based application regime allowed predator populations to recover which in turn effectively controlled the European red mite population. In a simular way, a third secondary pest of the late 1950s, the Lecanine Scale (*Lecanium coryli*) was overcome. Shortcomings in the biological control of the apple maggot (*Rhagoletis pomonella*) and codling moth were resolved through sanitary measures (removal of wild hosts and infested drop-fruit), monitoring of population build-up and need-based spraying of selective insecticides. The principle of the Nova Scotia IPM program in apple orchards was adopted throughout North America since the 1950s (Flint & van den Bosch, 1981).

5.4. IPM, made in the United States of America

5.4.1. American entomology and its influence abroad. The Department of Agriculture of the United States and its Division for Crop Protection always had strong influence on the development of agriculture both at home and across the borders. In 1892, for instance, the Dutch zoologist J. Ritzema Bos was commissioned to the United States to report on the potential threat of the San José Scale to the fruit tree sector in the Netherlands. His findings (Ritzema Bos, 1898,1899) led to the establishment of a national phytopathological service in the Netherland in 1899 and to amendments to the Dutch legislation according to the American model (box 5.4.1).

At about the same time in the Netherlands East Indies, M. Treub (box 2.5.3) proposed the establishment of a Department of Agriculture, for which the United States Department of Agriculture (USDA) served as the model. In the field of pest rise again. Growers then generally applied an insecticide, decimating the recovering predator populations and setting off an ever more rapid resurgence of the aphid. Secondary pest outbreaks of insects, such as alfalfa caterpillar, required additional sprays which contributed to the development of insecticide resistant strains of the spotted alfalfa aphid. To break the vicious cycle three hymenopterous parasites were imported of which *Praon palitans* gave the best aphid control (van den Bosch *et al.*, 1959). As a cultural control, the alfalfa was harvested strip-wise whereby the remaining strips provided refuge for natural enemies. Another cultural control measure, timely irrigation, enhanced virus infection in the aphid population. Further, an economic threshold for the spotted alfalfa aphid was established, and a sweep-net sampling method for predators standardized. In field tests for selective insecticides, which would least disrupt natural enemy activity, demeton (Systox^{R}) was found to control the aphid effectivily when biological control was insufficient (Smith & Hagen, 1959). In 1960, an alfalfa cultivar resistant to the spotted alfalfa aphid was sown. Research on economic thresholds for all major pests further reduced the need for spraying insecticides in alfalfa. Early mowing was effective to keep the alfalfa weevil under control without spraying. In the 1970s, use of microbial insecticides, *e.g. Bacillus thuringiensis* and *Verticillium lecanii*, for the control of loopers and the alfalfa caterpillar were included in the program (Flint & van den Bosch, 1981).

5.4.3. Environmental concern and legislation in the USA. In the United States, Perkins (1980) distinguished three overlapping phases since 1945, particularly marked by changes in entomology. The phases were approximated as: Euphoria and Crisis of Residues, 1945-55; Confusion and Crisis of the Environment, 1955-60; and Changing Paradigms, 1960-present. Euphoria refers to the conviction of many agriculturists that insect pest problems were finally overcome by the superior control provided by the synthetic insecticides. Researches and farmers were compelled to jump the bandwagon of insecticide promoters least they would loose out in their professional carreer or in competation with more progressive farmers. When the negative sides of intensive insecticide usage -target pest resurgence, emergence of secondary pests, resistence in pests, and residue problems- became visible, professionals got confused. The multitude of factors shaping commercial agriculture made the situation fairly complex. Ever more capital was invested in farm mechanisation and inputs whilst the number of people working in agriculture decreased rapidly. The scaling up in farm size and productivity per hectare and per person-hour made a return to more labour intensive production impossible. The changing agricultural practice and the production stimulating price policies had made farmers dependent on pesticides. For example, insecticides with nematicidal activity made less profitable crop rotation schedules redundant in potato and corn growing and herbicides became indispensible for grain production.

Right from the beginning in 1945, some ecologists expressed their concern about the safety of the new insecticides for environment and human health. The first hearings on residues of insecticides were held by he U.S.Food and Drugs Administration in 1949. A Committee of the U.S. Congress concluded that the insecticides then in use frequently had insufficient toxicological or pharmacological information to establish their safety and that new laws were needed. An amendment to the Food, Drugs and Cosmetics Act was introduced that required pesticide manufacturers to test their products for human safety and to obtain a tolerance or exemption before marketing them (Perkins, 1980).

In 1962, Rachel Carson protested against the widespread use of insecticides by the publication of 'Silent Spring'. This book made the American Congress and the public realize the dangers inherent to an unrestrained release of deadly chemicals into the environment. Perkins (1980) called the shift from unrestrained pesticide promotion to the search for alternatives the phase of the Changing Paradigms[13] (1968-present). In the early 1970s, both the USDA and the National Science Foundation (the latter joined later by the Environmental Protection Agency) approached insect pest control in a more holistic way, that is to concentrate on a given crop or cropping system in a limited farming area. They sought a thorough understanding of the ecosystem, especially in regard to crop growth and pest impact, and of cost-benefit relationships of pesticide use. This was in essence putting into practice what Stern and his fellow entomologists had been saying since 1959 (Huffaker & Messinger, 1964).

As a consequence of convincing evidence from research and pilot schemes in various crops, the President[14] and the Congress of the United States urged adoption of IPM in one way or another. The State of California legislature was the first to decree by law that IPM must be employed 'wherever feasible' (Smith, 1980).

Alfalfa and apple belonged to the first crops in which a holistic approach to pest management was instigated. The key to IPM programs is to recognize the importance of assessing population numbers of both pests and natural enemies to predict future population trends and to decide if pest control action is actually needed (Flint & Van den Bosch, 1981). As farmers are interested mainly in financial losses and the ways to decrease them, economic considerations are crucial in taking decisions for or against action (Zadoks, 1986). Way (1987) considers the definition and utilisation of economic injury thresholds[15] for insect pests, combined with the selective use of insecticides, fundamental to integrated control of such pests. The results in alfalfa and apple clearly illustrated that heavy reliance on insecticides resulted in destruction of natural enemies, rapid target pest resurgence, and innocuous insects becoming secondary pests. Political interest was aroused to the extent that the government of the United States of America directed its agencies to modify programs to support and adopt IPM startegies whenever practicable (Perkins, 1980). This directive sanctioned American efforts to employ IPM promotion as an instrument to further international agricultural development whilst obtaining political good-will in developing countries. Consequently, IPM oriented projects became important components in the technical aid programs of USDA, USAID and the internationally operating Foundations.

5.5. IPM, made in the Netherlands

5.5.1. The Dutch approach to harmonic control. Immediately after World War II, which caused much destruction and a major famine in the Netherlands in 1944-45, the Dutch government gave priority to reconstruct agriculture. The Department of Agriculture, established in 1897 within the Ministry of the Interior (Vermeulen, 1966), was upgraded to an autonomous ministry in 1947. New technologies, including seeds and pesticides were imported and tried. Chemical control soon eclipsed older cultural and biological technologies and per hectare usage of pesticides rose faster in the Netherlands than in neighbouring countries. It did not take long before resistance in key insect pests[16] developed (Briejèr, 1949). In 1955, when resistance was found to be building up against organophosphate insecticides in European red mite (*Panonychus ulmi*) on fruit trees, a 'Committee de Wilde' was formed[17]. This committee initiated research leading to a more limited use of pesticides. In 1958, the committee was transformed into a 'Working group for Harmonic Control of Insect Pests[18]' (*Werkgroep voor harmonische bestrijding van plagen*) operating under the aegis of the Dutch National Council for Agricultural Research (*Nationale Raad voor Landbouwkundig Onderzoek NRLO/TNO*) (de Fluiter, 1969a). The objective of the working group was to attain an economically remunerative and sustainable control of diseases and pests in agriculture through combining, in a harmonic way, ecological (i.e. through biological and cultural measures) and technical (i.e. through mechanical, physical and chemical means) control. Chemical control should only by applied when the natural resistance factors fail to keep the population of noxious organisms below the economic threshold[19] level (de Fluiter, 1969a).

The Dutch scientists D.J. Kuenen and J. de Wilde found that factors, which influence the physiological condition of the crop, also exert an effect on the population dynamics of the noxious and beneficial organisms living on the crop and *vice versa* (de Wilde, 1969). Therefore, they emphasized preventive measures, which included the raising of natural resistance against pests within individual plants as well as in the crop and its environment (de Fluiter, 1969b). Kuenen allegedly was the first to describe, independent from Stern *cum suis,* the concept 'economic damage level' (de Wilde, 1969). The threshold concept was applied in the Dutch East Indies in the 1920s already. S. Leefmans, Chief Entomologist of Department of Agriculture at Bogor, argued that chemical control of insects should be based on population counts and related to expected damage, an approach later known as 'supervised control' (Leefmans, 1928). Leefmans put his ideas into practice by organizing an effective coconut leaf moth (*Artona catoxantha*) monitoring and control service on Java and Sumatera, which employed biological, chemical and sanitary measures (ch 5.6.6).

Around 1960, the Dutch Working Group for Integrated Pest Control began an orchard pests program, modelled after the Nova Scotia example set by Pickett *cum suis* (1958). However, Pickett's scheme and the pesticides used (such as Bordeaux mixture and ryania) did not suit the conditions in the Netherlands. The problem was addressed through basic research of its individual components, *i.e.* the entire orchard environment, the population dynamics of injurious and beneficial organisms, their sensivity to prevalent pesticides, and the tolerance of apple cultivars. Only after effective measures were elaborated, in laboratory and orchard experiments, an intensive control schedule was composed for release to professional growers through the extension service (Gruys, 1980). The schedule included control of key pests, such as spider mite, apple aphid, codling moth, and wintermoth. It took about three years to re-establish balanced natural fauna in a formerly intensively sprayed orchard. At the time, the use of insecticides and fungicides on fruit trees had increased to 25-30 sprays per season. Hence, the transition from routine spraying to integrated control needed to be pursued through a gradual substitution of broad spectrum insecticides by selective ingredients (de Fluiter, 1969b, Gruys, 1980). IPM for orchard pests was rapidly adopted as the result of a special, government funded, extension drive. The number of Dutch apple growers applying supervised control increased from 8 in 1973 to 700 in 1978 on a total of 4,000 holdings. Control of fungal diseases such as apple mildew (*Podosphaera leucotricha*) and apple scab (*Venturia inaequalis*) remained a problem for a long time (Zadoks, pers. comm., 1998).

5.5.2. IPM in protected crops. In the Netherlands, the development of biological control has been has been unexpectedly rapid in greenhouse crops. Greenhouses are relatively isolated units in which high-quality products are grown in large quantity on a small area. Glasshouse crops require well-trained, intelligent growers who cannot afford to risk any damage. Because consumers demand unblemished and residue-free fruits, vegetables and flowers, growers use pesticides only if the result of biological control is not assured (van Lenteren, 1993b). In relation to the very high capital investment, the cost of pest control is minimal, in tomatoes less than 2% of overall cost of production (Oskam *et al.*, 1992).

The number of pests in isolated greenhouses is limited but they reproduce rapidly due to climate optimization and virtually year-round cultivation of crops. Some field pests, such as spider mites, have acclimatized to the glasshouse environment to the extent that they no longer respond to diapause-inducing factors (van Lenteren, 1995). Preventive control measures in protected crops include cleansing of greenhouses before new crops come in, standard use of pest-free growing media instead of soil, monoculture, and use of resistant cultivars. Advantages are that isolation prevents massive immigration of pest organisms and that pest management programs can be tailored to each separate greenhouse unit, thus providing optimum protection for the crop and introduced natural enemies. In warmer climates, greenhouses are often temporary structures made of wooden frames and plastic, which can hardly be kept clean and climatized. There, pests and pathogens can easily penetrate from surrounding fields all the time.

Biological control of insects in greenhouses was already practiced in the United Kingdom since 1926, when an English research station reared 1.5 million pupae of a parasite (*Encarsia formosa*) per year to control of the greenhouse whitefly (*Trialeurodes vaporariorum*) in nurseries and for export to Commonwealth and European countries (van Lenteren, 1995). In the Netherlands, in 1950, resistance against parathion was demonstrated in the two-spotted spider mite (*Tetranychus* *urticae*) on glasshouse crops. In 1959, a predatory mite (*Phytoseiulus persimilis*) was imported from S Africa which controlled spider mites so well that it was taken into commercial production. Since 1968, *P. persimilis* is reared commercially for spider mite (*T. urticae*) control in greenhouse crops. In the early 1970s, outbreaks of the tobacco whitefly (*Bemisia tabaci*) created serious damage throughout Europa. The parasite *E. formosa* appeared to be also effective against *B. tabaci*. Hence, production of *E. formosa* was resumed without delay and biological control in greenhouses had come to stay. In the 1990s, biological control of the two key pests in greenhouses, whitefly (*T. vaporariorum*) and spider mite (*T. urticae*) was adopted by about 25 countries (van Lenteren, 1993a, 1995).

The successful implementation of IPM in the Dutch greenhouse industry was the result of collaborative public and private research. Private firms produced virus and fungus resistant cultivars and some 30 natural enemies of 18 pests in commercial vegetables crops (Malais & Ravensberg, 1992). For instance, plant breeders developed partial resistance in tomato and cucumber against whitefly and spidermite (de Ponti & Mollema, 1992; van Lenteren 1995). To-date, more than 35 commercial companies, mostly located in W Europe, mass-produce and distribute[20] world-wide biological agents, such as predators, parasitoids and microbial pesticides. In general, registration of predatory or parasitic insects, mites and nematodes, is not required. Microbial pesticides based on entomopathogenic micro-organisms, such as bacteria, fungi, viruses and protozoa, need to be registered through identical procedures as those used for chemical pesticides. The relatively high cost of registration impeded the development of biological pesticides in most European countries (Ravensberg, 1994). Since biological control sometimes needs to be backed up by use of compatible pesticides, a Working group 'Pesticides and Beneficial Arthropods' of the IOBC/WPRS, continued testing of selective pesticides and of selective application techniques. A sophisticated development was the use of insecticide-resistant strains or natural enemies, *in casu* the release of an organophosphorous-resistant strain of *P. persimilis*. Integrated control of diseases in greenhouse crops, such as tomatoes, cucumbers and flowers, became a priority since 1990. By lack of biological control agents of pathogens, fungicides are still the major option, although problems of resistance are increasing.

In glasshouse crops as in orchards, IPM posed the problem, how to combine two or more control technologies into programs in which each individual method reinforces the effectiveness of the others and thus create a level of suppression greater than that provided by a single technique. An essential question to be answered in the intensive, high investment greenhouse industry is: Can a complete IPM program be developed in which chemical pesticides do not interfere negatively with non-chemical means of control? Only if the answer to this question is positive, the organisation of such IPM program can be undertaken (van Lenteren, 1995). A decisive element in the adoption of IPM by the greenhouse industry has been the intensive support by regional research and extension instititutions during the first years. The voluntary IPM study groups of growers played a vital role in directing research to the many problems in practice.

5.5.3. Phytopathology, epidemiology and Farming Systems Research. Phytopathologists seemed less prominently involved in developing the principles of IPM than entomologists (Box 5.5.3). In the Netherlands, a computerized advisory system, called EPIPRE (EPIdemology, PREdiction and PREvention) was introduced in 1977 for the supervised control of certain diseases and pests in winter wheat[21] (Blokker, 1982; Zadoks, 1989). EPIPRE was developed by phytopathologists of the Wageningen Agricultural University as a forecasting and intervention model to optimize treatment frequency. Farmers participating in EPIPRE were trained to recognise and monitor the injurious organisms in the wheat fields. Calculations[22] on the basis of disease progress models were made for each field separately with the aid of a computer. The EPIPRE system predicted when the action threshold would be reached.

The use of various thresholds was described by Stern *et al.* (1959) and applied as an instrument of disease management by Zadoks (1986, 1989). Zadoks and Schein (1979) suggested to employ the economic-injury level as a funtion of time to be represented on a sliding scale, which must be determined emperically[23].

In the 1970s, some researchers realized that IPM and crop protection in general appeared to be marginalized to rationalization of pesticide inputs in the prevalent cropping systems. Other causes, such as insufficient crop rotation, susceptible cultivars and high nitrogen applications were also responsible for losses. The obsession with maximum production goals with the help of technologies overly dependent on agro-chemicals was perceived as a major cause for the complex problems in agriculture. In a reaction, the International Organisation for Biological Control introduced, in 1979, the concept of Integrated Farming Systems (IFS) for Arable Agriculture, which includes crop protection. The crux of the farming systems approach is the substitution of expensive and potentially polluting inputs, particularly fertilizers and pesticides, by agricultural and ecological knowledge, labour and non-chemical cultivation techniques (Teng & Savary, 1992). The flora and fauna in and around the field are conserved and encouraged in order to stabilise the agro-ecosystem as a major preventive measure against outbreaks of pests, diseases and weeds (Vereyken, 1989). The two oldest projects are the Lautenbach-farm near Stuttgart, Germany, and the experimental farm at Nagele, the Netherlands. In IFS trials at three locations in 1986-90, a reduction was achieved of 50-65% per ha and year in the use of active ingredient, excluding nematicides, and of 85-90% per ha and year, including nematicides, in comparison to the convential reference system (Wijnands *et al.*, 1993). Herbicide spraying could be largely reduced through mechanical control and band-spraying. Fungicide use was reduced through resistant cultivars and supervised control. Insecticide use could almost be avoided through control thresholds, low dose technique and band spraying. In all IFS systems the convential use of huge amounts of soil fumigants against potato cyst nematodes (*Globodora rostochensis* and *G. pallida*) is substituted through a combination of resistant cultivars and detailed soil monitoring (Been & Schomaker, 1998). The financial results showed that in the integrated farming systems the average gross margin equalled that of the convential systems (Wijnands *et al.*, 1993).

Box 5.5.3

Phytopathology and IPM development

Traditionally, phytopathologists perceived pest management more in terms of plant health, whereas entomologists thought in terms of reduction of pest numbers and populations. It was often difficult to determine the cause of an injury, particularly when the pathogen was little known, such as viruses, or if abiotic factors were involved, such as nutrient-deficiency, toxic elements or water stress. Phytopathologists were obliged to consider all biotic agents and abiotic factors in the plant's environment for clues and learned that way to think in terms of systems approach earlier than entomologists.

When entomologists already had effective synthetic insecticides to kill insects and mites, phytopathologists still had few means for curing diseased plants. They had to rely on preventive measures, such as protective copper-based sprays (Bordeaux mixture), to prevent fungi from entering the plant. Curing plants from diseases caused by fungi inside the plant became possible only when systemic fungicides became available which kill fungi growing inside the plant. Prevention required a thorough knowledge of sources of inoculum and of pathogen transmission. Prevention, moreover, included measures aimed at increasing the resistance of the plants against abiotic or biotic injurious factors. Breeding for resistance and techniques such as grafting, frame pruning, balanced plant nutrition, weeding, flooding and drying off, and shading were routinely advocated by phytopathologists long before entomologists elaborated the concept of Integrated Pest Management. Finally, the repercussions of indelicate pesticide usage showed up first and most prominently in the form of insect pest resurgence, and secondary insect pest emergence.

Where in the course of the 20th century, the entomologists deviated more from the systems approach than phytopathologists they had to be more vociferous to return to that approach by way of IPM, against the interests of a naiscant pesticide industry (Zadoks, 1991). In contrast to the entomologists, plant pathologists had few natural enemies available to satisfactorily control diseases.

Since about 1970, the phytopathologists in the USA opted for 'plant health' rather than for 'IPM' (Cook & Veseth, 1991), thus phrasing a difference of means rather than a difference in objectives.

IPM programs in greenhouse crops and orchards are commonly adopted in the Netherlands and other W European countries. These programs could succeed because their use was promoted only when a complete IPM program had been developed covering all aspects of pest and disease control for a crop. The total cost of the crop protection in the IPM program were not higher than in the chemical control program. Non-chemical control agents (natural enemies and resistant cultivars were easily available, and as reliable and as constant in quality as chemical pesticides (van Lenteren, 1993b).

The Netherlands gave considerable financial and technical support to international IPM programs. The fact that the Netherlands' contribution to FAO was less institutional and more program-oriented, provided a certain leverage on program execution in fields in which the Netherlands held a comparative advantage. This included ample expertise in tropical and temperate agriculture and and progressive schools in relevant disciplines of crop protection. Prominent scientists such as J. Dekker (phytopathology), J.C. Zadoks (epidemiology) and J.C. van Lenteren (entomology), and their co-workers, succeeded in translating the high political commitment in the Dutch society into effective crop and pest management projects in developing countries.

5.6. IPM in estate crops, made in Indonesia and Malaysia

5.6.1. The treasure box of colonial agriculture. Research literature and annual reports of the Directorates of Agriculture of the Dutch East Indies and Malaya contain many data concerning the control of pests, diseases and weeds at a time that no synthetic pesticides were yet available. Selection for resistence and yield, soil cultivation, weeding, handpicking of insects, removal of diseased plants and use of sulphur fumes were practized since early times. By combining preventive and curative measures in the regulatory sphere and in the field and by a continuous search for more resistant varieties threats to specific cultures could often be overcome.

A number of control methods, which were successfully applied, went out of sight. Some are rediscovered or evaluated for use in a different field. For example, isolations of the fungus *Metarrhizium anisopliae* were cultured in the Phytopathological Institute of the *Plantentuin*, Bogor, and applied in the Dutch East Indies against larvae of the cassava borer in the 1910s (Rutgers, 1916) and larvae of the rhinoceros beetle (*Oryctes rhinoceros*) in coconut palms during the 1920s (Franssen & Mo, 1952). Today, in the 1990s, an international program studies the formulation and application of *M. anisopliae* against grasshoppers with funds of the European Commission.

Examples are given below of research on and practical application of non-chemical ways of pest and disease control in plantation and smallholder crops during colonial days. The examples pertain to three estate crops (sugar, cacao, and tobacco) and two smallholder crops (coconut and coffee). Each section begins with a note on the major pest problems and relevant research capacity for the specific crop. Table 5.6.1 gives an modern overview of the means of control applicable in IPM. It is remarkable to note, how many of the elements listed were already applied in colonial agriculture. The sections conclude with some information on recent IPM applications in that particular crop.

Table 5.6.1. Listing of elements of integrated pest management. Most of the elements were practised in estate agriculture in SE Asia before or after World War II. Author's list after Zadoks (1993b) and van Lenteren (1993b).

1.	**Prevention**
1.1.	Regulatory program
1.1.1	Quarantine (prevent introduction of new pest, containment)
1.1.2	Inspection, certification, fumigation
1.2	Selection and breeding program (plant resistance)
1.3.	Grafting program (resistance, vigour, productivity)
1.4.	Pest-free propagation material
1.4.1.	Healthy and clean seed (basic seed, farmer seed)
1.4.2.	Healthy propagation material (tissue culture, disinfection
1.5.	Pest-free soil or culture medium
1.5.1.	Soil sterilization (steam, fumigation, solarization)
1.5.2	Crop rotation, green manure, cover crop
1.5.3	Prevention (disinfection of equipment, seclusion)
1.6.	Sanitation
1.6.1.	Removal of crop debris (sources of infestation and infection)
1.6.2.	Removal of unwanted vegetation (alternate host plants)
1.7.	Environmental protection
1.7.1	Shade, wind breaks, mulch, controlled humidity
1.7.2	Protected cultivation (netting, seclusion, avoidance)
1.7.3.	Establishment and protection of natural enemies
1.8.	Cultural measures before planting
1.8.1.	Soil tillage (no-till, low-till, normal tillage)
1.8.2.	Crop species level (monoculture, mixed cropping)
1.8.3.	Crop cultivar level (resistance, cultivar mixtures)
1.8.4.	Seed and plant material (seed treatment and pelleting)
1.8.5.	Planting dates
1.8.6.	Spatial arrangement (plant spacing, seed rate)
1.9.	Cultural measures after planting (crop care)
1.9.1.	Fertilization, manuring, minor elements
1.9.2.	Water management (irrigation, drainage)
1.9.3.	Tillage (soil breaking, harrowing, hoeing, ridging)

5.6.2. Sugarcane

5.6.2.1. Major problems and research. Around 1880, the emerging private sugar industry in Indonesia was hit by the devastating *sereh* disease at a time it was already in a state of crisis due to competition from European beet sugar. The planters' associations decided to search for scientific advice for the control of *sereh* and improvement of the sugar manufacturing process. They founded three regional

Continuation of table 5.6.1. Listing of elements of integrated pest management

2.	**Intervention**
2.1.	Control of diseases
2.1.1.	Diagnosis
2.1.2.	Surveillance, monitoring
2.1.3.	Sanitary measures (removal of diseased plants or plant parts)
2.1.4.	Biological control (antagonistic organisms)
2.1.5.	Incidental chemical control (method, means, frequency)
2.1.6.	Supervised chemical control (threshold, combination)
2.2.	Control of non-vertebrate pests (insects, mites, snails, nematodes)
2.2.1.	Identification, study of life cycle and physiology
2.2.2.	Surveillance, monitoring (pests, natural enemies)
2.2.3.	Cultural control (trap crops, repellant crops)
2.2.4.	Mechanical control (hand picking, roguing, light trap, excision, burning, flooding, drainage)
2.2.5.	Incidental chemical control (methods, means, frequency)
2.2.6.	Calender chemical control (methods, means, frequency)
2.2.7.	Supervised chemical control (threshold, combination)
2.2.8.	Semiochemical control (pheromones, growth regulators)
2.2.9.	Biological control (antagonistic organisms/viruses)
2.3.	Control of weeds and volunteer plants
2.3.1.	Cultural measures (inundation, mulching, planting time, cover crop)
2.3.2.	Mechanical measures (soil tillage, weeding, flaming)
2.3.3.	Biological measures (herbivores, antagonists)
2.4.	Control of vertebrates (rodents, birds, wildlife)
2.4.1.	Rodents (mechanical; catching, hunting, sanitary measures)
2.4.2.	Rodents (chemical: baiting, fumigation)
2.4.3.	Birds (poisoning, chasing)

experiment stations, i.e. Station W Java near Tegal in 1885, Station C Java at Semarang in 1886 and Station E Java at Pasuruan in 1887. Soon regional congresses were organized with the *sereh* disease as major topic. The Sugar Research Station C Java was closed after several years. In 1907, the remaining stations W Java and E Java merged into the 'Association of Research Stations for the Java Sugar Industry' (*Vereeniging het Proefstation voor de Java-Suikerindustrie*). The station at Pasuruan, E Java, housed the cultivation department and the station at Pekalongan, W Java, the chemical-technical department. Subdivisions of the cultivation department were established at Jokyakarta, Ceribon and Banjumas to work on location specific problems. A General Syndicate of Sugar Manufacturers (*Algemeen Syndicaat van Suikerfabrikanten in Nederlandsch-Indië*) was founded to represent the interests of the industry. The Syndicate collected the cess funds[24] for research to which member companies contributed *pro rata* of area planted.

During World War II, the Pasuruan Institute, which had become the centre of the Java sugar research, was taken over by the Japanese. In 1943, Dutch scientists were interned, Indonesian staff was dismissed, scientific equipment and records were confiscated and breeding material got lost. In July 1948, the laboratories and library of the Pasuruan Institute were destroyed by fire during the political struggle for Independence. In 1957, the former Dutch private 'Research Institute for the Java Sugar Industry' at Pasuruan was nationalized. It was renamed the 'Indonesian Sugar Research Institute' (*Balai Penelithian (Penyelidikan) Perusahaan Gula*, BP3G). From that year the Department of Agriculture (DoA), and after 1970 in particular the Agency for Agricultural Reserach and Development (AARD), became responsible for sugarcane cultivation and pest management research (Pawirosemadi & Wirioatmodjo, 1986).

5.6.2.2. Selected pests and diseases

a. *Sereh*. Around 1882, a new disease, called *sereh*[25], was detected in factory fields near Ceribon. By 1896, the disease had spread to Bali, Kalimantan, the Straits Settlements of Malaysia and probably to Queensland, Australia (Went, 1898). As the disease caused great crop losses, the sugarcane planters soon financed research on the causal agent[26] of *sereh*. F. Soltwedel[27] contributed greatly to solving the *sereh* problem. Soltwedel presumed that nematodes caused *sereh*, and therefore recommended planting *bibit*[28] gardens on uninfested soils, which he found in mountainous areas (Went, 1898). Mountain *bibit*, cut from 8 months old cane, could be multiplied once in the lowland to provide sufficiently healthy bibit for planting the factory fields. Planting second generation lowland bibit resulted in seriously infected fields and third generation bibit in crop failure. As even mountain gardens could not be kept disease free, special mother gardens were laid out in isolated places (Went, 1898). Growing mountain *bibit* became a profitable undertaking[29] which factories left to specialist entrepreneurs. Because the Priangan Regency was particularly suited for growing mountain bibit, the government declared the area off-limits for planting factory cane (Koningsberger, 1948).

In the early 1890s, some planters and researchers decreased *sereh* incidence in their fields considerably through perpetually selecting top parts of symptom-free cane for bibit. F. Went (1898), Director of Station W Java, held the opinion that such selection for resistance, if consequently maintained, would ultimately make mountain *bibit* superfluous. The idea appeared to be realistic in the unique situation of the highly disciplined private Java sugar industry applying a legally imposed annual crop rotation schedule. However, elimination of the infectious *sereh* in this way would require ample funds for temporary purchases of mountain *bibit* and rigid selection of healthy cane sets. It could never work with smallholders' and ratoon-cropped sugarcane.

Soltwedel recommended crossing with resistant sugarcane types as the most effective way to solve the *sereh* problem. After overcoming problems of sugarcane fertility[30], Soltwedel initiated a breeding program with sugarcane types that differed greatly in susceptibility to sereh. Wild sugarcane types, such as Glagah, and the variety Kassoer (see below) were not susceptible and some imported varieties 'Canne morte' or 'red Fidji' and 'Manila cane' remained free of infection (Went, 1898). The most commonly grown variety Black Cirebon was so sensitive to *sereh* that it was used for standard symptom description. To improve the chances for obtaining resistance, many sugarcane accessions were imported from the Outer Islands and from abroad. Soltwedel recognized the risk of introducing alien diseases and pests and established, around 1890, a quarantine station for imported cane on the Karimun-Djawa islands, 190 km N of Semarang (Koningsberger, 1948). In later years, sugarcane quarantine gardens were also laid out on Banka (Sumatera) and, in 1928, on the South slope of the Smeru volcano at 1,200 m elevation, E Java.

The Pasuruan Station[31] became the centre for cultivar improvement through breeding and selection, known as 'nobilisation' (Koningsberger 1948). Several successful planter-breeders selected for higher sugar content only because, by using mountain *bibit*, they could manage the *sereh* problem. Breeders at the Research Station insisted on resistance against *sereh*, but made little progress[32]. Sugarcane varieties imported from India[33] brought the desired *sereh* resistence, but hybridization with Java varieties did not yield commercially interesting progenies. Finally, hybridization of a botanical bastard variety Kassoer[34], found in the wild on Java, 1880, with the cultivar 100 POJ brought the break-through and led to the development of the *sereh* resistant high-yielding 2878 POJ and 2883 POJ cultivars (Koningsberger, 1948). Within 5 years 2878 POJ had replaced practically all older cultivars. The development of resistant hybrid varieties, around 1930, ended the mountain *bibit* industry and saved the sugar industry millions of guilders per year.

b. **Top Rot**. Large scale acceptance of the new hybrid POJ-cultivars brought another disease, Top Rot or *pokkah bung*[35], to the fore. Top Rot, caused by the fungus *Fusarium moniliforme*, was a disease of little importance until the 1930s. However, the popular *sereh* resistant cultivar 2878 POJ appeared to be very susceptible to Top Rot. In autumn 1934, high percentages of Top Rot infestation were reported from E Cirebon, C Java (Mededeelingen IPZ 87). In the 1950s, Top Rot of sugarcane appeared still to be a prevalent disease, because the Pasuaruan Sugar Institute placed it on the priority list for research (AARD, 1986).

c. **Pineapple Disease.** The general practice of vegetatively propagating sugarcane through cane sets (*bibit*) made the crop vulnerable to soil-borne fungal diseases. For example, the soil-borne Black Rot or Pineapple Disease often caused serious losses in the field. Went (1898) described the fungus *Thielaviopsis aethaceticus* as the causal agent. To protect *bibit* against Black Rot, the set ends were dipped in tar diluted with arak or in a copper sulphate solution (Went, 1898). In later years, solutions containing (highly toxic) mercury compounds, and after 1970, benomyl or other fungicides were used for disinfection of *bibit*.

d. **Yellow Stripe Disease.** Virus diseases, such as Yellow Stripe, could inflict great damage to non-tolerant varieties. Yellow Stripe Disease, caused by a Sugarcane Mosaic Virus, was first described by Van Musschenbroek[36] in 1892 (Went, 1898), but its causal agent could not be detected at that time. Wilbrink proved that Yellow Stripe was transmitted by the aphid *Aphis maidis* from maize, a common rotation crop of sugarcane, at the end of the dry season (Koningsberger, 1948). As a prevention young *bibit* gardens were inspected one month after the onset of the rains and infected plants destroyed. Various predatory insects, such as a ladybird beetle (*Chilomenes sexmaculata*), were identified as effective and ubiquitous enemies of the vector aphids and white fly (*Bemisia tabaci*). After 1950, selection work was continued at Pasuruan for resistance against Yellow Stripe Disease of which seven strains were identified. The research program also included Ratoon Stunting Disease, a virus disease first reported by Steindl in Australia in 1950, that had spread to Java. It was found that Ratoon Stunting Disease can be controlled by hot water treatment of *bibit* at 50°C for 2 hours.

e. **White top borer.** The white top borer (*Tryporyza nivella*) was the most destructive insect pest of sugarcane and wild *Saccharum*. It was observed in Java in 1890 and described by J.C. Koningsberger in 1898. Because of its economic importance, the borer was the main research target of the entomologists Hazelhof and Hart of the Pasuruan Institute, 1927-39. Borer infestation appeared to be correlated with amount of rainfall and tissue hardness of the cane top (*pupus*), the latter a factor hindering penetration by young larvae. The *sereh* resistent varieties 2878 POJ and 2883 POJ, with softer tissue, were heavily infested. During monsoon, white top borer, in W and M Java, infested more than 20% of the tillers of these varieties (Kalshoven, 1951). Koningsberger (1948) estimated the average loss of sugar due to this pest at 5-7%.

A mechanical method of controlling white top borer, introduced by estate manager J. Poll in 1925, existed of carefully cutting out (excision) the borer infested tissues by specially trained labourers at frequent intervals[37]. Poll's method of surveillance and control decreased infestation of cane stems by 50% and increased sugar production by 1-3 t/ha (Kalshoven, 1951). Burning or inundation of cane stubs, catching moths with lamps, and removal of egg masses, proved less effective.

Good results were obtained with biological control of the white top borer through egg parasites among which the parasitic wasps *Phanurus beneficiens* var. *elongatus* and *Trichogramma* spp. were the most employed. Parasitized borer egg masses were laid out in the sugercane fields in specially constructed '*Phanurus* boxes' in which the borer larvae remained trapped while the emerging parasitic wasps could disperse (Koningsberger, 1948). The Sugar Research Station and the estates kept statistical records on parasitation of sugarcane white top borer[38].

f. **Stemborer.** The striped stem borer (*Diatraea venosata*) and the shiny stem borer (*Chilotraea auricilia*) were the most harmful sugarcane stemborers. The striped stem borer occurred over entire Java and caused on average 5-7% loss of sugar

(Koningsberger, 1948). As the striped stem borer was also parasitized by *P. beneficiens*, '*Phanurus* boxes' served two purposes. Chemical control of sugercane stemborers was studied by Ruinard (1958) who found the botanicals ryania and derris, and the mineral cryolite[39] to be effective for that purpose.

In the 1970s, AARD carried on with research on biological control of the white topshoot borer (*T. nivella*) and the shiny stemborer (*C. auricilaea*), in particular on a parasite *Allorghas* spp. (AARD, 1986). AARD claimed over 80% control of white top borer in trials in which excising borer larvae from cane tops was combined with application of carbofuran granules. Pawirosemadi & Wiriodmojo (1986) reported that the AARD program included efficacy studies on pheromone-traps for borer control and synthesis of the sex-hormone of the shiny stemborer (*C. auricilia*).

g. **White woolly aphid.** The white woolly aphid (*Ceratovaruna (Oregma) lanigera*) was another serious pest of sugar cane. In 1926, a ladybird beetle species, *Coelophora biplagiata*, was imported from Formosa and reared in the Pasuruan station and Bogor Phytopathological Institute for release in the sugar estates. Outdoors in the cane fields, *C. biplagiata* larvae controlled the aphids well, but the beetle did not establish itself. When release of reared beetles was stopped, *C. biplagiata* was no longer found (Kalshoven, 1951). The most effective enemy of the white woolly aphid was the parasitic wasp *Encarsia flavoscutellum*. Since on Java sugarcane was planted as an annual rotation crop, biological control had to be furthered by inundating newly planted fields with woolly aphid colonies, highly parasitized by *Encarsia* larvae, which had been taken from older cane fields. Microscopical inspection of seven months old aphid colonies revealed 60-80% parasitization by *Encarsia* (Koningsberger, 1948; Kalshoven, 1951).

h. **Weeds.** Where sugarcane was grown in rotation with rice and secondary crops, weeds in young plantings could be controlled by handweeding. Frequent ridging and cleaning of irrigation gullies helped to suppress weeds. On factory land with fallow rotation, cover crops were sown to prevent weed growth and soil erosion. Cover crops included *Crotalaria anagyroides* and *Colopogonum mucunoides*. When fields were neglected, the perennial *alang-alang* or *lalang* grass (*Imperata cylindrica*) often became troublesome. Chemical weeding with sodiumtrichloroacetate (TCA), 2,4-D or 3% formulation of lalang oil was tested by Duyverman in 1957, but results are not reported (Oei-Dharma, 1969). When soil tillage was mechanized *Cyperus rotundus* and other sedges, and *Ipomoea* spp. became major weeds because power tillers divided their root system in to small, germinative parts which were readily dispersed.

5.6.3. Tobacco

5.6.3.1. Major problems and research. In Indonesia, the centres of tobacco production were situated in the Principalities (C Java), in Besuki (E Java) and in Deli (E coast of Sumatera). The Principalities produced the so-called '*Vorstenlandsche* *tabak'* (Java or 'Principalities' tobacco) and the Sumateran sultanates the 'Deli tobacco'. In 1898, several tobacco companies in Java established the first Tobacco Experiment Station at Klaten, E Java, under technical supervision of the *Plantentuin* laboratories at Bogor. In 1907, other companies established a second station for tobacco which resorted under the Central Experimental Station at Salatiga, C Java. In 1912, the two stations merged into the Experiment Station for 'Principalities' Tobacco (*Proefstation voor Vorstenlandsche Tabak*) at Klaten, E Java. The most serious disease of Java tobacco was '*lanas*', a wilting disease of seedlings and older plants caused by *Phytophthora parasitica* var. *nicotianae*. Sanitary control of *lanas* through removal of all sources of infection and selection for resistance were practised (Beets, 1949). Other diseases of Java tobacco included Leaf Spot (*Cercospora nicotianae*) and Tobacco Mosaic Virus.

On the E coast of Sumatera, pest and disease pressure in tobacco was heavier than on Java, because there is no pronounced dry season in Deli and tobacco was grown on long, narrow fields situated between large stretches of fallow land which were continuous sources of infestation. In the 1890s, the tobacco growers of E Sumatera sought the help of the *Plantentuin* laboratories[40] to find a solution to a serious tobacco nursery disease. In 1906, the Deli Planters' Association (*DPV*) founded the Tobacco Research Station at Medan. The most important disease of Deli tobacco was Slime Disease caused by the soil-borne bacterium *Pseudomonas solanacearum*. Damage from caterpillars -in particular, inflicted by four Noctuid species *Heliothis assulta, H. obsoleta, Plusia signata* and *Prodenia litura*- to the famous Deli wrapper leaf caused losses of 20% to 30% of harvested leaves annually.

5.6.3.2. Selected pests and diseases

a. ***Lanas*** in Java-tobacco. As other *Phytophthora* diseases, *lanas* was very infectious and caused great damage over a wide area. D'Angremond (1920) found that *lanas* was spread by contaminated manure from the villages. When disinfecting manure before application -with carbondisulphide or through self-heating on heaps- had been generally adopted, this source of infestation was excluded. Thung (1938) noted that *lanas* disease occurred regularly on plantations at higher altitudes with much water and inclining soils where contaminated mud was deposited on the land. Thung demonstrated that muddy water, carrying fungal spores, was the main vehicle to spread *lanas*. Runn-off of infested water from plots with diseased plants or debris, from floors of tobacco barns, and from village gardens with native tobacco, infested pathogen-free soils immediately. Strict implementation of sanitary instructions issued by the Tobacco Research Station[41] helped to greatly reduce *lanas* incidence on the estates. In Java, tobacco was ususally planted after two or three crops of rice, depending on water availibility during the east monsoon. Rotation of tobacco with *sawah* rice was effective in suppressing *lanas*, because the *P. nicotianae* fungus was killed by microbial degradation and temperature changes in flooded and dry *sawah* soils (Thung, 1938).

At Klaten, d'Angremond (1920) began to cross tabacco varieties for resistance against *lanas*. Several hybrids with improved resistance were obtained, but their quality remained poor. In the 1930s, C. Coolhaas (1936) succeeded in producing *Timor x Vorstenlanden* hybrid tobacco lines of good *lanas*-resistance and high quality.

b. **Slime disease of Deli tobacco.** Of the numerous pests and diseases of Deli tobacco, slime disease was the most damaging and difficult to control. J. Honing showed that it is a soil-borne bacterial disease[42], caused by the extremely infectious *Pseudomonas solanacearum*. Tobacco seedlings could only be taken from seed beds in which no single plantlet was infested, least this could increase infestation in transplanted tobacco by more than 30% (Honing, 1910). Sanitation was so strictly adhered to that each year about 50,000 seed beds were destroyed. Some estates with badly infested soils even had to procure all seedlings from outside. Steam sterilisation of seedbeds made the soil disease-free for 3-4 years. By 1940, several estates had invested in steam equipment for large scale use on semi-permanent seed bed compounds (van der Laan, 1949). Van der Poel (1933) found that a green cover crop, *Mimosa invisa*, beside enriching the nitrogen content, suppressed the bacterial infestation of the soil

c. **Tobacco Mosaic Virus.** Mosaic Virus caused considerable damage to estate tobacco during the 1920s and early 1930s. Large scale removal of diseased plants was the recommended way of control. When it was recognized that contaminated hands of labourers working in nurseries and fields and of children picking caterpillars were the main reason of the virus epidemic, decontamination was recommended. Thung (1934) found that disinfecting the hands of labourers with a 4% cent formaline solution sufficed if it was done carefully before any handling of plant material. When, in 1934, the estates adopted Thungs' advise Mosaic Virus incidence decreased rapidly. Since the smoking or chewing by labourers of native tobacco, which was usually heavily infected, was another major source of contamination, tobacco consumption during work was forbidden.

d. **Tobacco Curl Virus.** The control of Curl or Crinkle (*Krupuk*) Virus disease of tobacco was deemed important, because they reduced the growth, weight and quality of the tobacco product. Symptoms of Curl Virus disease were already described by Keuchenius (1915) in Besuki tobacco. *Krupuk*-disease was transmitted by one species of whitefly (probably *Bemisia tabaci*), mainly from sources around villages which were still largely unknown in 1931. Thus, Thung (1934) judged control of Curl-Virus diseases impossible at the time. Aphids (*e.g. Myzus persicae* ssp.), vector of a less important Pox Virus disease (*pokziekte*) in nurseries, were controlled by brushing a 0.5% nicotine solution onto infested plants. Aphids had to be controlled before the infestation could spread over too many nursery beds. Thung (1932) found that the practice of brushing was by itself the main route of transmitting Mozaic Virus between seedlings. When the estates began to apply nicotine solutions by using sprayers instead of brushes, Mosaic Virus ceased to be a problem.

e. **Thrips.** Thrips infestation in the nurseries and plant beds was controlled because thrips frequently caused white veins on the upper and lower tobacco leaves, which deminished the value of the product. Thrips are the only vector insects of Tobacco Mosaic Virus, although of minor importance. A thrips infestation in tobacco was sprayed immediately with a derris powder suspension or an emulsion of petroleum soap. Fumigation of thrips-infested beds was tried with cyanide and sulphurdioxide formulations but equipment was too primitive for large scale applications.

5.6.4. Cacao

5.6.4.1. Major problems and research. From its beginning cacao in Indonesia and Malaysia had two major insect pests, the cacao mirid (*Helopeltis* spp.) and the cocoa pod borer (*Conopomorpha cramerella,* CPB). The first record of symptoms due to *Helopeltis* in Indonesia dates from 1841 (Giesberger, 1983). Zehntner (1903) and Leefmans (1916) described two species of *Helopeltis* (Fam. *Miridae*) in Java, *H. antonii* and *H. theivora* (tea mosquito bug), the former predominantly on cacao and the latter mainly on tea. *Helopeltis* mirids puncture pods and young shoots resulting in severe die-back and reduction of leaf canopy. None of the cacao varieties was resistant to *Helopeltis* although some were more heavily attacked than others[43]. The recent expansion of cacao cultivation throughout Indonesia since 1985 -with the largest area planted in Sulawesi- was soon followed by numerous outbreaks of the CPB. In early 1997, the severity of CPB infestation reached about 10% in twelve provinces (Mumford, 1997).

To find solutions to the *Helopeltis* and CPB problems, the Cacao Planters Association founded, in 1901, a private Cacao Research Station[44] at Salatiga, C Java. By 1905, the Salatiga Station for Coacao was enlarged and renamed 'General Experiment Station (*Algemeen Proefstation*) at Salatiga'. Its mandate was extended to include all highland cops (*bergcultures*). In 1934, after 33 years of continuous operation, cacao research was transferred from Salatiga to nearby Semarang, C Java, for reasons of convenience. At Semarang, the work was continued until 1950. In view of the current expansion of the crop, AARD carries out research on cacao at the Jember Research Institute for Estate Crops, E Java[45].

5.6.4.2. Selected pests and diseases

a. ***Helopeltis***. Around 1900, cacao mirids were generally controlled by handpicking throughout the year, especially at the time of low population density. Hand picking was done by gangs of women and children who used bamboo sticks with cotton wool drenched in resinous exudates. Because hand collecting was labour and cost intensive, scorching of the bugs resting on pods with flares was recommended (Zehntner, 1903). Roepke (1916) combined scorching for periods of high density and handpicking for low density. Scorching was discarded in the 1920s, but handpicking was continued on some smaller estates well into the 1930s. When Betrem (1940) established that only one third of the mirid population present in cacao plantations was eliminated by hand collecting, this practice came to an end.

Studies on the biology of *Helopeltis* spp. and their relationships to over 30 host species and to other insects provided the basis for an effective biological control system. More than 50 publications from 1901 till 1995 bear testimony to the continuous attention paid to the *Helopeltis* problem (Giesberger, 1983; Lee & Sidhu, 1984). Predators and parasites of *Helopeltis* are numerous. The braconid wasp *Euphorus helopeltidis* was given much attention because it was the first parasite of *Helopeltis* detected (Kalshoven, 1951).

In 1908, two planters had observed that the cacao black ant (*Dolichoderus bituberculatus (thoracitus)*) protected cacao trees against *Helopeltis* to a large extent. By experimentation planters discovered that white cacao mealybugs (*Catenococcus (Pseudococcus) hispidus (lilacinus)*) were tended by the cacao black ants and that the two species, ant and mealybug, appeared to have a reciprocal relationship with *Helopeltis*. In the years 1915-17, W.K. Roepke and P. van der Goot (Toxopeus & Wessel, 1983) studied this complex relationship between *Helopeltis*, two ant species and two species of mealybugs. The result was a practical method of cacao mirid control based on the antagonistic action of the association of the cacao black ant and the white cacao mealybug on *Helopeltis* feeding. The black ants protected the mealybugs which could reproduce undisturbedly. Together, the black ants and mealybugs disturb *Helopeltis* adults to such an extent that their feeding and reproduction on cacao are considerably impeded so that almost no mirids occur. If the black ant-mealybug populations declined due to an invasion of predatory gramang ants (*Anoplolepis longipes*), the situation could be easily corrected by exterminating the latter[46] and re-introducing the black ants and mealybugs whilst the *Helopeltis* pest was temporarily controlled with botanical insecticides.

By 1920, artificial black ant nests and pod husks with numerous mealybugs were routinely placed on leading estates (Giesberger, 1983). The effectiviness of the ant-mealybug association was reconfirmed in the 1930s by Ph. Levert[47] (1940) and G. Giesberger. The latter stated (1983) that for over forty years the mirids were controlled effectively on the large cacao plantation *Siloewok Sawangan* in C Java by introducing mealybugs and black ants when needed and by controlling the gramang ant. During the Japanese occupation 1942-1945 and the early postwar years the mealybug-black ant complex was greatly disturbed, but when the cacao plantation came again under Dutch management, the former population balance of these insects was restored within 2 years time. But for incidental 'knock-down' treatment of gramang ants and *Helopeltis* in heavily infested fields, no insecticidal control was practised.

Giesberger (1983) wrote that the mealybug-black ant association was no longer used in the cacao estates of E Java and N Sumatera to control *Helopeltis*, and that knowledge of this biological control system seemed to be lost. In Malaysia, research on the effectiveness of the black cacao ant (*D. thoracicus)* for suppressing the cacao mirid were resumed around 1988. Artificial nests of the black ant and cacao chips with the mealybug (*C. hispidus*) were introduced in a cacao garden that had been sprayed with the pyrethroid deltamethrin to reduce the population of antogonistic ants. After 30 months, the black ant had become well established and the benefit-cost ratio was positive in comparison to chemical control of the mirid.

(Ho & Khoo, 1994; Liew, Khoo & Leong, 1994). Malaysian scientists are also investigating the introduction of black ants in cacao plantings in Sulawesi, Indonesia.

Regarding chemical control of cacao mirids, J.G. Bertrem (1940) demonstrated on the estates *Djati Roenggo* and *Getas* that *Helopeltis* could be controlled effectively by dusting derris powder (rotenon content 0.7%, talc as carrier). He recommended a threshold of 80 mirids per 100 trees and 4-6 dust applications at fortnightly intervals. Giesberger (1983) reported in 1940 that spraying of plots with 2% lead-arsenate effectively controlled nypmhal stages of *Helopeltis* but not the adults.

b. **Cacao pod borer.** The cacao pod borer (*C. cramerella*, CPB) attacks the cacao pods on the tree and may cause total loss of yield. Since 1900, the CPB was controlled by stripping the cacao trees of all fruits (a practice called *rampasan*) once a year (usually in November/December) (Wessel-Riemens, 1983).

Since 1995, an IPM program is implemented for CPB control in smallholding cacao in Sulawesi. Since 1996, the Chocolate Manufacturers' Associations of the United States and the United Kingdom are funding the establishment of an extension network to this effect. *Rampasan* is still recommended but to-date it includes complete, frequent, regular harvesting throughout the year of the ripe pods (Mumford, 1997).

At Pesantren, placing polythene bags over the pods (sleeving) as a protection against borer attack yielded 82% uninfested cacao pods (Wessel-Riems, 1983). The fruits of rambutan, *Nephelium lappaceum* and of namnam, *Cynometra cauliflora*, were recognized as host plants of the CPB moth. Therefore, the removal of these host plants is recommended as a prevention.

Selection for resistance against CPB appeared possible. The *Djati Roenggo* hybrids[48] and Forestero cacao were less attacked by the CPB than Criollo types. Control of the CPB on a large scale by insecticides proved to be too costly[49] and too risky. At the *Siloewok Sawangan* estate, after 1958, about 1.200 ha of cacao had to be uprooted as a result of a disastrous outbreak of the stem and branch boring beetle *Glenea novemguttata*[50]. Giesberger (1983) suggested that indiscriminate spraying of endrin and other insecticides against CPB on this estate since 1957 could have destroyed the natural enemies of this initially minor pest and, thus, have caused the collapse of cacao production. Wardojo (1980) stated that over-use of organochlorine insecticides resulted in an excessive damage to cacao trees by the red branch borer (*Zeuzera coffea*) and ultimately in abandonment of several estates in C Java.

In Malaysia, heavy CPB infestations were recorded in Sabah, Serawak and Malaka. Throughout the 1950s, the control of CPB in E Malaysia existed mainly of frequent sprays with contact insecticides. Since 1961, the provincial DoA of Sabah recommended the cessation of spraying contact insecticides on young cacao plantings because such sprays disrupted natural control of borers by indigenous parasites and predators (Conway & Tay, 1967). DoA's instructions included regular pruning to give the cacao trees a light open frame, removal of fruits (*rampasan*), and application of pyrethroids. Since that time, pyrethroids have been unabatedly used by Malaysian cacao growers against the CPB. Although no resistence against deltamethrine was reported yet, the Malaysian Cocoa Board, in collaboration with Golden Hope Plantations, began to use insect growth regulators, such triflumeron and flufenuron, for CPB control (Lee & Sidhu, 1984).

c. **Vascular Streak Die-back.** In Malaysia, prior to 1956, the mostly planted cacao type was Amelonado. Amelonado clones and hybrids proved susceptible to the disease Vascular Streak Die-back (*Oncobasidium theobromae*), especially on locations where growth vigour is weak and rainfall is high. The pathogen first infects the flush leaves and causes a die-back of branches and stems. Vascular Streak Die-back was a major limiting factor to cacao cultivation on estates in Peninsular Malaysia and a cause of catastrophic die-back in the large replanting programs using Amelenado material (Turner & Shepherd, 1978). The introduction, in 1965, of hybrid 'Upper Amazone' cacao allowed a revival of the cacao culture as this hybrid material proved to be, in general, more vigorous, high-yielding and less susceptible to Vascular Streak Die-back than the Trinitario and Criollo clones (Jayawardena *et al.*, 1978; Mardi, 1992).

The recommended treatment of Vascular Streak Die-back is removal by pruning of infected branches and stem parts at a three months interval. Bending infected stems to encourage chupon forming before pruning saves valuable rootstock for budding. Within-canopy pruning to improve aeration reduces the disease because high moisture is required for sporulation and spore germination (Turner & Shepherd, 1978). Prior to 1969, young cacao was planted (often under coconut) at a very high density of 2,000 saplings/ha, with the main objective of reducing weeding cost before thinning. Vascular Streak Die-back incidence was found to be much higher at such high density planting. Therefore, planting density was gradually reduced to 1,200 plants/ha in the years 1969-75, and later to 900 plants/ha (Jayawardena *et al.*, 1978).

5.6.5. Coffee

5.6.5.1. Major problems and research. In the 1870s, the government and estate coffee plantations in Indonesia and Malaysia were devastated by the Coffee Leaf Rust fungus[51] (*Hemileia vastatrix*). Research on the Leaf Rust disease was commenced by the Phytopathological Laboratory of the Bogor Botanical Gardens at Bogor. In 1901, an experimental garden for coffee was openend at Bangelan near Malang, E Java. In 1905, the new DoA became responsible for developing smallholder coffee. Research for estate coffee was later included in the mandate of the private Research Station for C and E Java at Malang and of the Busuki Research Station at Jember, E Java. The stations also studied various insect pests of which the coffee berry borer (*Hypothenemus (Stephanoderes) hampei*) caused the most damage.

5.6.5.2. Selected pests and diseases

a. **Coffee Leaf Rust.** When, in 1885-88, Coffee Leaf Rust attacked the Arabica coffee gardens, the average production of the ill-maintained government plantations decreased to one fourth within two decades (van Hall & van de Koppel, 1949 IIb). Only Arabica coffee in the highlands escaped from infection for reason of temperature. In 1875, a coffee species originating from Liberia (*Coffea liberica*) was imported into Indonesia via the Netherlands and test-seeded in the *Cultuurtuin*. Since Liberica coffee showed resistance to *H. vastatrix*, private estates and smallholders replanted with this species. In the 1990s, several spontaneous hybrids of *C. arabica x C. liberica*) were detected on estates which were very insensitive to Coffee Leaf Rust and produced better quality than Liberica plants. The hybrids were vegetatively propagated by grafting on Liberica rootstock. Large scale planting of hybrid coffee became superfluous when in 1900, *C. canephora* or Robusta coffee was successfully introduced[52] into Java. Robusta coffee was much more productive than hybrid Liberica and highly resistant to Coffee Leaf Rust, only its taste was less refined. Selection on quality and resistance in Robusta coffee was undertaken since 1914, but proved to be difficult due to almost complete self-sterility of this species. As propagation through seed gave a very heterogeneous progeny, long-term selection programs were executed to obtain superior clonal seed and grafting wood from Robusta mother trees. Vegetative propagation through grafting became the common practice in coffee (van Hall & van de Koppel, 1949, IIB).

b. **Coffee berry borer.** The beetle *H. hampei* (*bubuk*), which was first observed in 1909 in W Java, caused up to 20% yield loss during its major outbreaks of 1920-24, because it was not controlled by indigenous parasites. The estates opened a *bubuk* research fund, employed an entomologist and sent a mission to Uganda in 1923 to search for parasites. A parasitic wasp, *Prorops nasuta*, was imported and reared by the stations. Despite its release in large numbers on estates, the wasp did not establish (Kalshoven, 1951). Better control of the coffee berry borer appeared possible by removal of the coffee fruits. Adult female borers deposit the eggs on coffee berries, because larval development can only take place in berries with ripening seed. In particular, pre-mature berries on the tree, shedded berries and harvested dried berries offer favourable conditions for breeding. Control of the coffee berry borer requires complete picking of all mature and ripening berries on the tree (*rampasan*), and removal of all berries on the ground (*lelesan* = fallen berry) in successive picking rounds. In regions with a harvest-free period, clean-picking of all berries remaining after the last picking round interrupted the population build-up for at least 3.5 months. Smallholders were advised to weed 6-12 times per year and to burry all dropped berries and pruning waste in deep pits after disinfection with *e.g.* carbonsulphur or cyanodust. (Leefmans, 1924). Harvested coffee was commonly sun-dried on drying floors adjacent to the gardens. As the process could take several weeks, the layers of drying, infested beans constituted a major source of reinfestation. Therefore, harvested berries were soaked in hot water of fumigated before drying to kill the borer larvae within.

5.6.6. Coconut. The coconut palm (*Cocos nucifera*) is a native crop of SE Asia which was always planted as a food and cash crop around the house or in smallholdings. The most destructive pests of the coconut palm included the coconut moth, rhinoceros beetle and various hispid beetle species.

a. **Coconut moth.** The coconut moth (*Artona (Brachartona) catoxantha, klapper mot, wangwung klapa*) is capable of massive reproduction and can ravage palm crowns completely, causing fruit fall and interrupt fruit bearing for several years. The coconut moth was detected on Java in 1864 and described for Java and Melaka in 1904-08 (Franssen & Mo, 1952). Between 1914 and 1924, outbreaks occurred repeatedly on Java[53] and Sumatera, and various ways of control were tested by DoA[54]. In 1911 DoA recommended smallholders to cut (*bekappen*) all fronds from heavily infested trees, leaving 3-4 emerging leaves. An empirical action threshold for cutting was determined at five coconut moth caterpillars per leaf per tree. Palm owners protested the low ETL value because almost complete defoliation interrupted fruit bearing for several years. They refused to report the beginning of outbreaks (Kalshoven, 1951).

Chemical control was introduced but caused difficulties since only highly toxic arsenic compounds were available and equipment for spraying of tall trees was insufficiently developed. In 1933, field trials were carried out with dust formulation of botanical pyrethrum powder (Dusturan[R]) applied by adjusted motor-blowers. The dusting trials were successful but pyrethrum had a too short storage life. DusturanR was replaced by derris powder (10% rotenon) from 1935 onwards. Application was improved by spraying derris-talcum suspensions with the help of pressure pumps through long rubberhoses which were carried up into the palm crowns by the spraymen (Kalshoven, 1951).

Around 1925, the chief entomologist of DoA, S. Leefmans, developed a surveillance and monitoring system for the coconut moth (*Brachartona* surveillance)(Leefmans, 1928). From 1925 onward, trained surveillors performed regular counts of coconut moth caterpillars in known outbreak areas. When the ETL level was approached, DoA, in collaboration with the Phytopathological Institute at Bogor, monitored the coconut moth population taking into regard larval stages and presence of parasites and hyperparasites. When an need-based supervised spraying by the Agricultural Extension Service[55] did not give adequate control of the coconut moth, the treatment was supplemented by cutting of fronds in the most heavily infested plantings.

The complex of parasites and hyperparasites of the coconut moth comprised over 30 species. The most effective parasite of the coconut moth was the Braconid wasp *Apanteles artonae* which parasitized the second instar larvae. Ichneumonid and chalcidid wasps, and tachinid flies also caused a high degree of biological control (Kalshoven, 1951). The results of the studies on parasites were not put to practice because the parasites were neither reared nor released for the purpose of controlling the coconut moth pest.

b. **Coconut hispids.** The hispid beetle, *Brontispa longissima.* caused serious outbreaks in S and N Sulawesi between 1918 and 1934. The larvae (grubs) damaged the apical leaf of young coconut palms and caused up to 15% tree mortality. Around 1930, the pest spread to the Moluku and Sunda islands, Bali and E Java.

the Philippines, were introduced in many countries. IRRI recommended high use of nitrogen fertilizer and application of pesticides since the early IR-cultivars had low resistance to pests and diseases.

Indonesia was under pressure to act decisively because it had to import ever greater quantities of rice due to a shortfall in food production and a rapid population growth. Indonesia began its first large scale Bimas (*Bimbingan masal,* Mass guidance) intensification program in 1966 (ch 2.6.3.2). Indonesia's approach was conventional. The scale of the operation was, however, so impressive that the state organisations charged with the distribution of inputs and administration of the credit failed to meet the targets. Therefore, in 1968, the GoI reorganized the Bimas program to *Bimas Gotong Royong* (= Mutual cooperation) program. The GoI contracted[60] several multinational companies to assist DoA with the distribution of rice seed, fertilizers and pesticides to the villages and with application and extension. The problems of an acute shortage of application equipment and meddled logistics were partly solved through aerial ULV spraying of organophosphate insecticides on more than a hundred thousand hectares of rice in W, C and E Java during two years (ch 2.6.3.4).

In the 1960s, the major rice pests in the rice fields of SE Asia allegedly requiring control were various rice stemborers -striped borer (*Chilo suppressalis)*, yellow borer (*Scirpophaga incertulas*), white borer (*S. innotata*), leafhoppers as vectors of Tungro Virus Disease -green leafhopper (*Nephotettix* spp.), whitebacked leafhopper (*Sogatella furcifera*) and zig-zag leafhopper (*Recilia dorsalis*)- , rice gall midge (*Orseolia oryzae*), and the rice seed bug (*Leptocorisa* spp.) (De Datta, 1981; Oudejans, 1994). In most years field rats (*Rattus argentiventer, R. brevicauda*) caused serious damage in rice too (van de Fliert *et al.*, 1994). Extension agents instructed farmers to apply insecticides at fixed intervals without reference to actual infestation rates in their fields. The brown planthopper (BPH, *Nilaparvata lugens*), indigenous to SE Asia and a vector of Grassy Stunt and Ragged Stunt Virus Diseases, was never reported to be a major pest before 1970. In 1970 and 1971, however, outbreaks of BPH[61] were reported in sub-districts of W Java where farmers sprayed intensively against white stemborers. The introduction of the Bimas input package with its corollary of insecticides appeared to be accompanied by BPH outbreaks (Kenmore, 1991a). In the Bimas program areas Tungro Virus, transmitted by several leafhopper species, became epidemical (van Emden & Peakall, 1996). Alarming BPH and leafhopper outbreaks and virus epidemics on Java in 1975-77 -after the government first subsidized insecticides directly- caused losses that necessitated a 44% increase of Indonesia's annual rice imports. The GoI tried to control this upsurge in 1976 and 1977 with aerial applications on W, C and E Java and N Sumatera. The blanket spraying by air of large rice areas was followed in 1977 by the greatest yield loss from BPH so far recorded in any country in history: over a million tons of rice, worth hundreds of millions of dollars, or enough to feed more than 2.5 million people (Kenmore, 1991a).

The GoI countered the crisis of 1977 in two ways. First, the GoI, unaware of the cause of the outbreaks, increased the supply of insecticides and spray equipment to program farmers at subsidized prices and instructed the extension service to step up farmer training. Second, it replaced the sensitive cultivars in the Bimas package, IR5, IR8, and C4-63, with cultivar IR26 and other cultivars from the series IR20 to IR34. These varieties contained genetic material that gave rice a repellant taste for BPH biotypes in Indonesia. Through a process of natural selection, BPH populations in E and C Java were, within three seasons, able to feed on IR 26. With the help of increased insecticide subsidies[62] and of a domestic insecticide formulation industry since 1976 completely protected from imported competition, 1979 became the second worst year for losses on record (Kenmore, 1991a).

The 1979 BPH crisis was temporarily resolved by the planting of IR36 from the wet season 1976/77 onwards. This was a short duration hybrid containing the BPH2 gene for resistance to BPH biotype 2, which had evolved in N Sumetera and on parts of Java. IR 36 became the most widely planted rice cultivar in history, world-wide, up to the mid-1980s. Indonesian breeders incorporated the same BPH2 gene in Indonesian hybrids of which *Cisadane* and *Krueng Aceh*, released in 1981, outyielded IR36 on Java. Since *Cisadane* and *Krueng Aceh* fetched considerably higher prices owing to their superior milling quality and taste, these cultivars covered half the rice area in C Java by 1984 (Kenmore, 1991b; Jatileksono, 1993).

Whilst the wide acceptance of the resistant cultivars IR36, *Cisadane*, and *Krueng Aceh* relieved the BPH problem for a period of four years, chemical control of rice pests was not yet questioned. Thus, during an outbreak of Tungro Virus on Bali in 1981/82, some 12,000 ha were immediately sprayed by air to control its vector, the green leafhopper (Van Emden & Peakall, 1996).

The continuous expansion of irrigated areas planted to high yielding varieties with an increase of fertilizer use to about 90 kg/ha of urea and TSP (Jatileksono, 1993), and low crop losses made Indonesia self-sufficient in rice in 1983 (imports equalled exports) (Kenmore, 1991b). According to FAO statistics, Indonesia's growth in per capita rice production, especially contributed by Javanese rice farmers, between 1975/76 and 1984/85 was the second highest in Asia, after Myanmar (FAO, 1986). Meanwhile, the GoI increased insecticide subsidies[63] ever more, thereby stimulating a strong growth of the insecticide formulation output in Indonesia from about 5,100t f.p./y in 1978/79 to 25,000 t f.p/y in 1983/84, a five-fold increase (Staring, 1984).

By 1984, rice fields planted with *Krueng Aceh*, *Cisadane* and IR36 in C Java and Yogjakarta were seriously 'hopperburned', which raised the suspicion that a new biotype of BPH had evolved against which the cultivars had no resistance. By 1986, the areas infested by BPH and the corresponding damage were approaching the levels of the mid-1970s (ch 2, fig.2.6.3.4.d). Other rice pests, such as rice leaffolder (*Cnaphalocrosis medinalis*), stemborer and gall midge became more damaging too (van de Fliert, 1993).

5.7.2. Brown planthoppers, insecticides and natural enemies. From 1977 till 1979, Kenmore and co-workers (Kenmore, 1980) studied the population dynamics of the BPH in relation to its natural enemies in rice fields at IRRI, Los Baños, the Philippines. Since the results from this study became a key argument for the change from pesticide driven to IPM oriented plant protection policy in Asia, its main findings are recapitulated below. Kenmore *cum suis* sampled the cultivars IR20 and IR1917, both susceptible to Philippine phenotypes of BPH, for eggs, nymphal stages and adults, and for prevalent natural enemies. The surveys revealed that in untreated fields less than 4% of the planthoppers reached the adult stage, with over 65% mortality before the first nymphal stage. Factors contributing to this mortality included parasitation and predation of eggs, and failure of 10-30% of the eggs to hatch. Spiders[64] were the most prominent predators on the nymphs and adults of BPH and whitebacked planthopper (WBPH). Veliid predators (ripplebugs) attacked the many newly emerged nymphs, which were seen falling in the water, and the adult planthoppers on or near the water surface. No untreated BPH populations ever increased steadily throughout the crop season and no hopperburn level was ever reached in untreated rice fields. The entire community of spiders and, to a lesser extent, the community of generalist predators at the water surface (veliids) responded numerically to prey density. BPH populations appeared to be controlled in all rice fields without insecticides (Kenmore *et al.*, 1984).

To see the effect of insecticides, a normal crop of IR20 was sprayed[65]. In about one third of the treated fields severe hopperburn symptoms appeared and yield of rice was reduced by one third. Egg production per female adult in the insecticide treated field was about double that expected for the observed density[66] of BPH females. The BPH outbreak, which caused hopperburn, could thus be explained by the disruption of population regulating factors due to insecticides. Disruption occurred first because BPH survival was much higher when predators were not allowed to respond numerically to BPH densities and second because egg production may have been higher in the treated than in non-treated females (Kenmore *et al.*, 1984).

The most significant result of Kenmore's study was that over a range of high immigration rates[67] of up to 80 brown planthoppers per plant, densities were kept below hopperburn levels without insecticides or varietal resistance[68]. In contrast, even when immigration was apparently *minimal,* the use of insecticides caused an outbreak by blocking the numerical response of predators (Kenmore *et al.*, 1984). Further, if no insecticides were applied, neither higher fertilizer levels nor the use of non-resistant modern or older cultivars could cause the 100- to 1000-fold increases in BPH densities observed in hopperburned fields.

The study showed that the mainstay of any BPH control technique is varietal resistance. When a cultivar exhibits resistance to the local BPH phenotypes, is otherwise acceptable to farmers and is economically rewarding to grow, it eliminates the need for insecticides in BPH control. Resistance can amplify the effectiveness of individual predators, by weakening planthoppers through inadequate feeding so that they fall more easily prey. Varietal resistance and natural enemies thus seem complementary (Kenmore *et al.*, 1984).

The observations of Kenmore *cum suis* were confirmed by studies carried out by IRRI economists in farmers' fields in 1969. Farmers' profits decreased the more frequently they applied insecticides. Farmers applied pesticides as an insurance against crop loss, not to improve profits. It was argued that their motivation was fuelled by ignorance about agro-ecosystems. Another Philippine study, concerning production costs incurred by rice farmers during 1970-73, showed a 4-fold increase in spending on insecticide use. When the farmers surveyed had reached their peak of spending, BPH outbreak seriously damaged (hopperburned) the majority of their fields, and over 20% of the farmers lost their crop (Kenmore *et al.* , 1987).

5.7.3. FAO's Programme for Integrated Pest Control in Rice. In view of the unexpected pest outbreaks resulting from the Green Revolution technology in rice in Asia, the FAO/UNEP Panel of Experts on Integrated Control and Host Plant Resistance advised FAO repeatedly since 1967 to initiate a cooperative Regional Programme on the integrated control of rice pests in Asia. FAO investigated, in 1977, the status of integrated pest control (IPC) in rice in S and SE Asia and tested the interest of the governments in the region to develop of a cooperative inter-country program. Subsequently, at a technical consultation, held at Bangkok in March, 1978, a proposal was drafted for an Inter-Country Programme for the Development and Application of Integrated Pest Control in Rice in S and SE Asia (acronym: ICP-IPC Rice). Late 1978 and early 1979, a FAO mission finalized the Plan of Operation with the governments of the seven prospective countries: Bangladesh, India, Indonesia, Malaysia, Philippines, Sri Lanka, Thailand (Waterhouse *et al.*, 1983). The Australian government, through the Australian Development Assistance Bureau (ADAB), began funding the FAO ICP-IPC Rice Programme (ICP for short) in 1979 on an annual basis. Phase I began on 1 April 1980 when the Regional Programme Leader, Dr John A. Lowe from USAID, assumed duty. The activities of ICP were expanded in June 1982, when the Netherlands government signed a FAO/Netherlands Government Cooperative Programme Agreement contributing its support for a period of five years. In 1986, an additional grant became available from the Arab Gulf Fund. The objectives of Phase I, which covered seven countries, focused on applied research[69] in farmers' fields, traditional approaches to extension, national IPM policies and capacity building. In each participating country a corresponding National Integrated Pest Control in Rice Program was initiated under a National Program Leader. Close working relationships were established with relevant research and extension agencies in an effort to link up with and strengthen ongoing national rice programs. Effective collaboration developed with the plant breeders and pest control specialists[70] of the International Rice Research Institute (IRRI) and other major rice institutes in Asia, who helped to adapt the objectives of ICP to the reality of Asian rice cultivation. Since by that time the pesticide induced nature of BPH outbreaks was proven, the vital first step was to limit insecticide usage on the basis of an economic injury threshold (Kenmore, 1987). The research findings at IRRI allowed to formulate and implement appropriate strategies for an integrated control of BPH which were instrumental in bringing about major changes at the national policy-making level, particularly in Indonesia (Eveleens, 1992).

In 1978-80, basic training principles were developed and a pilot ICP-IPC in Rice training program was conducted in the Philippines (Matteson *et al.*, 1992). Farmers were trained in groups in weekly two-hours sessions throughout the growing season. Demonstrations, exercises and discussions in the field, using real plants and insects, replaced traditional class room lecturing and hand-outs. Farmers learned to recognize pest insects and natural enemies and to take their own decisions. Pesticide use, and thus pest control costs, by trained farmers decreased (Kenmore *et al.*, 1987). The rice yields of some participating farmers allegedly increased, probably as a result of increased use of fertilizer that could be purchased from the money saved on pesticides (van de Fliert, 1993). Some Philippine farmers in Leyte increased their income by investing, for instance, in additional coconut trees with the saved insecticide expenditure (Oudejans & Mumford, 1988). In the Philippines training intensity and quality, however, detoriated as the program was scaled up. The same enthusiasm that had inspired the pilot group of IPM trainers could not be achieved at a larger scale (van de Fliert & Matteson, 1990).

Farmer group training were supplemented by multimedia strategic extension campaigns[71] after farmers' training needs and information channels had been identified. Training efforts through NGOs complemented national IPM extension activities in the Philippines, but their scale of operation remained limited. Throughout Phase I and II of ICP (1981-92) similar IPM training was extended to the other participating countries[72] through the national extension services which employed the T&V extension approach (Whitten *et al.*, 1990).

ICP phase II, which started in 1987 with two additional countries (China and Vietnam), was funded by the same donors, Australia and the Netherlands. The donor contributions[73] to Phase I and II amounted to almost 13 M US$ (Eveleens *et al.*, 1986a). Once ICP had worked out effective economic injury thresholds (ETLs) and had identified suitable insecticides, its priority shifted to the adoption of the IPM message by farmers (Kenmore, 1987). Hence the objectives of Phase II emphasized the empowerment of farmers[74] through participatory forms of training.

The 1990 review of Phase II found the IPM 'technology package' and the training process, which had been developed by ICP for transferring IPM skills to farmers, highly adequate. From then on the ICP could concentrate more on supporting the implementation of IPM technology and the training process by national programs. Actually, this meant overcoming bureaucratic hurdles which often were in the way of translating political acceptance of IPM into effective action at the field level (Eveleens, 1992). The review further showed that by October 1990 over 380,000 farmers and over 13,000 extension agents had been trained in the nine participating countries. By the end of 1992, the total of farmers trained amounted to 530,000.

In April 1993, ICP was extended into Phase III for five years with donor grants[75] totalling about 13.9 M US$ from the Netherlands, Australia and Switzerland. Due to a political controversy[76] between Indonesia and the Netherlands in 1991, Dutch donor contributions were not longer acceptable to Indonesia. The breach led to an immediate departure of Dutch experts and a much regretted diminishment of a century-old scientific collaboration. The FAO used Dutch grants in particular for ICP's expansion in Vietnam and other participating countries. Their number had expanded to thirteen when Cambodia, Republic of Korea, Laos and Nepal joined the program.

Throughout the 1990s, ICP continued to play a pivotal role in implementing the

IPM strategy in the region. It facilitated transfer of information and expertise in all directions, between and within countries and between and among researchers and practitioners. It continued its efforts to bring together all expertise, engaged in related donor-funded activities in individual countries, into the IPM rice network. An example was the EC-funded IPM Program in rice in Bhutan which country had not yet developed a national IPM program. ICP also facilitated the establishment of the 'FAO Inter-Country Programme for the Development and Application of IPM in Vegetables in S and SE Asia' since 1996. A particular critical function of IPC was the securing of continued external funding of existing national programs.

5.7.4. The National IPM Program of Indonesia

5.7.4.1. The declaration of Indonesia's IPM policy. Indonesia is the ICP member country in which the concept of Integrated Pest Management became deeply entrenched and in which ICP achieved its greatest impact. The history of ICP's implementation in Indonesia illustrates well the manyfold opportunities and difficulties encountered even under politically favourable conditions. ICP's progress in other member countries is well documented in various review reports (Waterhouse *et al.*, 1983; Zadoks *et al.*, 1986; Whitten *et al.*, 1990; Eveleens *et al.*, 1996a; van Huis & Buurma, 1998) and documents (Martin, 1988; Kenmore, 1991b; Eveleens, 1992; FAO, 1994, Sanghi, 1998; Wynn, 1997).

Efforts to introduce IPC for rice farmers in Indonesia had started as early as 1975 when the Directorate of Food Crops Protection, Pasarminggu, Jakarta, adopted the concept in its policy and became responsible for its implementation (Oka, 1978, 1990; Partoadmodjo, 1981). National IPM pilot projects were already executed on Java, Sumatera and S Sulawesi. Between 1980 and 1983, the National IPM Program received technical support from an IRRI outreach group and a Japanese research project[77] (FAO, 1989). ICP began to strengthen the indonesian National Program in 1980 by upgrading the training packages and technology with the experience gained from the scaling-up of the Philippine National Programs. DITLIN organized IPM demonstrations with the same T&V extension approach as was used in the Bimas programs. Meanwhile, DITLINS Surveillance and Forecasting Service (ch 2.6.3.5) frequently alarmed DoA's emergency control units to spray rice areas with high pest incidence[78]. In 1984, ICP and DITLIN surveyed the IPM demonstration fields and found that pest populations in some of these areas were increasing alarmingly (van de Fliert, 1993). In 1985-86, BPH populations exploded and destroyed an estimated 275,000 ha of rice (fig. 2.6.4.4). Similar outbreaks occurred in Malaysia and Thailand between 1977 and 1990 (figs. 7.3.3.a and 7.4.3.b) (Whitten *et al.*, 1990)

At this crisis point in 1985-86, when the second nation-wide BPH outbreak had seriously affected the recently achieved self-sufficiency in rice production, the GoI chose an IPM approach. It announced the Indonesian National IPM Policy on November 5, 1986, as Presidential Instruction No. 3 of 1986 (INPRES 3/86).

'As written it (the GoI) did three major things: *1.* On explicit ecological grounds (BPH multiplication by destruction of natural enemies) banned 57 trade formulations (brands) of insecticides from use on rice, and ordered that resistant varieties be grown in affected areas; *2.* Increased from less than 1300 to over 2900 the numbers of pests observers assigned to rural extension centres; and *3.* Ordered that observers, extension staff and farmers be trained in IPM as national pest control strategy' (Kenmore, 1991b; Thomas & Waage, 1996).

As a reaction to INPRES 3/1986 declaring IPC the national pest control strategy, an inter-sectoral group of ministers was assigned to implement the IPM policy. The responsibility for implementing the IPM policy was transferred from the Ministry of Agriculture to the State Planning Bureau (BAPPENAS). Top priority was given to changing the behaviour of farmers, administrators and agricultural staff through improvement of knowledge and skills. A first activity was the recruitment and crash course IPC training of master trainers, pest observers[79], village extension workers and farmers. The World Bank approved the reallocation of the remainder of its loan to the National Extension Project (4.2 M US$ destined for NAEP-phase II) to fund IPM training (table 5.7.4.1). FAO's ICP helped DITLIN to obtain IPM field data and to extend training to specialist staff. BPH resistant varieties (IR36 and IR 64) were more actively promoted, and the Surveillance and Early Warning network expanded for immediate control of BPH infestations (van de Fliert, 1993).

The pesticide market of Indonesia was confronted with two measures at the same time, the ban on 57 brands of insecticides[80] and a rapid reduction of the subsidy on pesticides for rice. Their impact on the pesticide market and industry was deep and lasting (ch 7.2). The subsidy was reduced step-wise from 85% to zero over three years and was terminated in January, 1989. At the time of INPRES 3/86, the subsidies consumed 130-160 M US $ from the country's annual foreign currency expenditures.

The Indonesian crash program achieved that trained farmers reduced insec-

Table 5.7.4.1. Indonesia, World Bank's funding of research and extension programs. Source: World Bank Staff Appraisal Report, Indonesia Integrated Training Project, March 5, 1993.

Period	Project	Original Loan M US$
Research		
1975-80	Agricultural Research and extension	21.5
1980-90	National agricultural research	65.0
1989-95	Agricultural research management	35.3
Extension		
1976-82	National Food Crops Extension	22.0
1980-88	National Extension II	42.0
1987-92	National Agricultural Extension III	70.0

ticide applications from over 4 to less than 2.5 per season on average. 'Contrary to the popular belief fanned by the pesticide industry, rice production in Indonesia could be massively uncoupled from insecticides. BPH infestation declined quickly and steadily since 1986' (Kenmore, 1991b).

An evaluation of the 1987-89 training showed a less satisfactory picture. In this crash program, conducted through the T&V system, great efforts[81] were made to train trainers and farmers and to develop effective training aids. Though the activities had Presidential priority and special facilitation by the Finance, Planning and Economics Ministries, training funds and materials arrived late. The goal of the crash project was to train 125,000 farmers, but only 10,300 actually received training. Where the farmers were reached, trainers used top-down approaches[82] and did not utilize the farmers' own experience so that the desired changes in behaviour did not occur (van de Fliert, 1993; Untung, 1995).

5.7.4.2. Breakthrough in Indonesia's National IPM Program. In order to achieve the desired change in farmers' behaviour in Indonesia, BAPPENAS contracted in March, 1989, FAO's ICP to strengthen the training effort of the National IPM Program[83]. Phase I of this large scale training program, 1989-92, was financed by reallocating money[84] from abolished pesticide subsidies which had previously been granted by USAID. The greatest innovation was the change from the T&V form of extension to the Farmers' Field School (FFS) form (Box 5.7.4.2.a and b). By mid-1990, at least 60.000 farmers were trained and savings were estimated at 20 US$ per ha and season. For the year 1990 alone an amount of 2.4 M US$ was saved by IPM trained farmers in Indonesia (Whitten *et al.*, 1990). The distribution among farmers of financial benefits[85] from IPM practices was independent of farm size and land tenure status (World Bank, 1993a).

In season 1990/91, the Indonesian National Program was challenged by an unexpected outbreak of white stemborer (*T. innotata*) on Java. This traditional but sporadic pest damaged 13,000 ha of rice in the Jalur Pantura, a NE coastal region of W Java. National media attention drew forth frequent calls from various sources to relax the Presidential IPM Policy and allow the use of banned organophosphates. The pressure was resisted by the sustained action of a number of Cabinet Ministers and provincial government officials. National funds were used for an additional training program on how to recognize egg masses of white stemborer in seedbeds and fields. Farmers then could remove egg masses by hand instead of applying insecticides against larvae of which the majority had entered the rice stems already. Over 75,000 farmers in the affected district were trained in FFSs (Dilts, 1990). Over 300,000 people were mobilized to destroy egg masses during the critical late 1990 immigration period of stemborer moths, and less than 1,000 ha were damaged in 1991 during the wet season. *Ex post* analysis of the white stemborer outbreak showed that sub-districts with highest damage were those that, for at least three prior seasons, had been exposed to the highest dosages of carbofuran[86]. Farmers who had continued to plant the more profitable *Cisadane* had a much lower damage from stemborers than those who followed central government recommendations to plant IR64. Although in W Java *Cisadane* was never as badly damaged by BPH as it had been in C Java and

Box 5.7.4.2.a

The Training & Visit System of Agricultural Extension

Management of agricultural extension appeared to have great influence on agricultural development in Asia. In the 1960s and 1970s, the Training & Visit (T&V) form of extension was commonly adopted to spread the Green Revolution technology and the messages of the intensification campaigns in rice production down to farmers' level.

The T&V system applies a 'transfer of technology' model, which relies on a two-way diffusion process. It emphasizes regular training of extension field workers and 'contact farmers' and improvement of linkages between extension and research. Briefly described, a single line of administrative control and technical support is established from the Directorate of Agriculture to the extension field worker.

Ideally, under this system the work schedules, duties, and responsibilities are clearly specified and closely supervised at all levels. A specific schedule of visits to a manageable number of farm families is rigidly followed. In weekly one-day training sessions the extension workers are instructed in the most important recommendations for the forthcoming one or two weeks of the crop season. This preparative training helps the extension workers to understand and to more convincingly transmit the message to the farmers. The extension workers should extend the extension messages to selected contact farmers, who are supposed to spread the new practices to their neighbour farmers and friends. The system relies on the communicative abilities of contact farmers and on the curiosity of non-contact farmers to watch and ask (Benor & Harrison, 1977).

The information is expected to flow from research via Subject Matter Specialists and (village) extension workers to contact farmers and, finally, to follower farmers. In Indonesia, each village extension worker cared for 1000-3000 farm families, divided into 16 farmer groups. A farmer group (*kelompok tani*) consisted of all farmers operating in a certain tract of rice fields. The contact farmers (*kontak tani*) were to be visited once in two weeks to receive recommendations. Frequently, this did not happen, or the information conveyed did not correspond with the field conditions (van de Fliert, 1993). A low social status and payment affected the motivation of the extension workers and made them looking for additional income opportunities (van de Fliert, 1993).

Generally, the T&V system fitted well in the hierarchical, top-down structure of the Ministries of Agriculture and the Extension Services of S and SE Asia. A fundamental shortcoming of T&V is that it failed to build the farmers' capacity to access external information when they need it, to develop farmers' ability to experiment and draw conclusions, and to enhance farmers' individual and collective ability to take sound decisions (Röling & van de Fliert, 1994).

Box 5.7.4.2.b

The Farmer Field School System of Agricultural Extension

Since the late 1980s, the Farmer Field School (FFS) has become the form of extension preferred by FAO and NGOs for implementing IPM programs for rice, vegetables and cotton in Asia and Africa.

The Farmer Field School system aims at empowering farmers to make their own decisions based on knowledge, field monitoring, pest identification and experimentation. Highly motivated pest observers and village extension workers select active farmer groups or villages for training. In Indonesia, the FFSs followed the original model of season-long training, a study plot, agro-ecosystem analysis, presentation and discussion, and planning farmer experiments. A field school is run one morning per week during 10 to 12 weeks. Farmers appreciate to be trained in the field by way of facilitation rather than by frontal instruction in a school room and to be regarded as competent farm managers. Through attending IPM field school training farmers increase their skill as observer in the field and gain more self confidence (van de Fliert, 1993).

The FFS helped to preserve and utilize indigenous knowledge. Innovations usually do not only require external supply of new technology, but also the development of internal capacity to innovate (van de Fliert, 1993).

While IPM for rice is still the entry point in the FFS and in the follow-up activities, the farmers increasingly want to discuss a widening range of crop management topics. These include diseases, variety testing, manuring, fertiliser application, planting distance, irrigation management, time of planting rice and rotational crops such as soybean, and IPM in vegetables (ch 6.2.3). During 1996, FFS graduates in 800 localities planned and conducted their own season long-experiments (Eveleens, 1996b). By 1998, the number of Indonesian farmers who graduated from a season-long FFS approached one million, of which about 17,000 volunteered as farmer-trainer (FAO ICPV, 1998).

Horizontal spread of the IPM message from trained to non-trained farmers remained a matter of concern. Continued political interest at the central and provincial levels of administration is essential for the future allocation of extension personnel and funds to IPM implementation through FFS training.

Van de Fliert (1993) observed that IPM rice farmers in C Java, after being exposed to production intensification programs for more than twenty years, have become modern, high external-input farmers who tend to rely more on their own experience than on recommendations of the state extension service. It is expected that empowerment of farmers will finally result in demand driven extension and in an improvement of their socio-economic position *vis-a-vis* other groups. In this way the FFS approach may escape the institutionalisation which made T&V ineffective (Eveleens *et al.*, 1996b).

Yogjakarta, the major reason for pushing IR64[87] had been insecticide-induced BPH outbreaks. IPM thus staged a comeback for *Cisadane*.

With such results to show, the National IPM Programme in Indonesia was extended with a second phase (1993-98). Its core activity, the 'IPM Training Project', was funded by a loan of 32 M US$ from the World Bank, a grant of 7 M US$ from the United States Agency for International Development (USAID) and a contribution of 1 M US$ from the GoI (World Bank, 1993a). The technical assistance contract with FAO through ICP and with international and national experts was continued. The program's objectives included training of trainers (ToT) and farmers following the FFS model, to support field studies[88], and to strengthen the regulatory and environmental management of pesticides. The National IPM Program operated in 12 of 26 provinces of Indonesia, including the eight provinces, where three quarters of the nation's rice is produced. In 1994, the administration of the National IPM Programme was transferred from the National Development Planning Agency (BAPPENAS) to the Ministry of Agriculture. By 1996, DITLIN staff, consisting of 350 field leaders guiding about 2000 pest observers[89], as well as field extension workers of the provincial agricultural services and around 8000 farmer trainers were holding FFSs at village level. Through this combined effort about 650,000 farmers[90] had been trained in FFSs in 1996. The pace of IPM training went up when farmers, who had graduated from season-long IPM classes, were involved in farmer-to-farmer training (Oka, 1995). The FFS training approach in Indonesia became the model for the other Asian countries participating FAO's ICP, phase III (van de Fliert, 1993). Only 14% of the Indonesian participants in FFS were women (Eveleens *et al.*, 1996b).

In June, 1996, a major breakthrough with regards to pesticide policies happened. The original ban of INPRES 3/1986 on the use of 57 brands of pesticides in rice, was extended to include all food crops. Further, the United States Environmental Protection Agency (EPA) began to strengthen the regulatory and environmental management of pesticides in Indonesia (Eveleens *et al.*, 1996b).

In the mid-1990s the National IPM Program in Indonesia appeared to be confronted by competing paradigms, namely the nationwide forecasting system resulting in spray/no spray recommendations on the one hand and on the other hand the IPM approach in which farmers make a decision after conducting an agro-ecosystem analysis in their rice fields. Field workers of the DoA Division of Crop Protection were facing the dilemma that they had to conduct pest surveillance[91] and FFS extension training. The rapid expansion of the National IPM Program threatened the quality[92] standards of IPM training and the enthusiasm among the Indonesian officials at the mid-level of the central bureaucracy. In spite of various efforts the link between research and extension was still considered to be weak (Eveleens *et al.*, 1996b). IPM activities of the Indonesian National Program are reviewed in Wynn *et al.*, 1997.

In Indonesia, several NGO's are engaged in IPM training a.o. on Java and N Sumatera (ch 6.2.5). NGO activities are basically directed at empowerment of the farmers through community organizing, consciousness raising and education, public advocacy, capacity building, and support services for income generating activities. In general, national governments have well defined structures and employ staff up to vilage level who have technical skills and basic knowledge on agronomy, ecology and farming. NGOs, on the contrary, do not have well developed agricultural policies, and most of their workers miss a technical background. However, they usually work for groups which are not reached by government agency programs. The extension approach of governments is generally top down, with limited participation of farmers in defining their own needs and in developing the product or model. NGOs on the other hand are process oriented. Participation and analysis by farmers, and group dynamic processes are the key components The involvement of NGOs in national IPM programs, usually, improves their quality through the combination of the strengths of both approaches (FAO, 1992b).

5.7.5. The National IPM Program of Malaysia. Following the Green Revolution, Malaysia saw a rapid expansion of rice production through intensification and centralisation in large, efficiently managed irrigation schemes. Since 1970, the rice industry passed from a stage of traditional, mostly manual cultivation into large, highly mechanized rice production cooperatives. Lack of water in the off-season and a combination of labour shortage and skewed age distribution of farmers led to shift from transplanted to direct seeded and ratoon rice crops, and these to very serious weed problems (ch 3.6.4.4).

As happened in Indonesia, the Malaysian researchers and farmers followed IRRI's recommendations regarding fertilizer and pesticide use in the early IR-varieties which lacked resistance against major rice pests and diseases. Generally, farmers made two applications per season, at 30 and 60 days after transplanting. An increase of stemborer infestation drove the frequency of preventive spraying up, in Sekinchang and Tanjung Karang even to 8 applications per season (Lim *et al.*, 1978). In the late 1970s, Malaysia experienced serious outbreaks of the brown planthopper (BPH) and green leafhopper which in turn caused epidemics of Grassy Stunt and Tungro Virus Diseases (Ooi & Heong, 1988; Ho, 1993). As a first measure the GoM distributed high yielding rice varieties with resistance against BPH and Tungro. In 1977, a Pest Surveillance and Forecasting Service was set up for all major rice growing states of Peninsular Malaysia to monitor the population development of rice pests and their natural enemies (Ooi, 1982, 1992). From that time the spraying of insecticides was encouraged through free supply of insecticides when economic threshold values were approached (supervised control). The concerted effect of growing resistant rice cultivars and spraying on the basis of monitoring data brought BPH and virus diseases under control (ch 3.6.4.7) (Heong *et al.*, 1985, 1992b).

Malaysia signed the agreement with FAO on the Inter-Country Programme for IPM in Rice in S and SE Asia in March, 1978. DoA was made responsible for IPM demonstrations in rice and MARDI for IPM research and development. A National IPM (Steering) Committee[93] was established for liaison with FAO's ICP and for the coordination of six working groups[94]. By mid 1980, the National IPM Program began its activities[95] in the Rice Schemes, but only a small number of farmers participated and achievement was low (Lim *et al.*, 1980). In March 1984, a national

Box 5.7.5

Children brigades scouting for rice pests in Malaysia.

In 1986, an FAO/donor mission observed the performance of children as pest scouts (age about 12 years) in a village koran school in the State of Perlis. The children appeared to be efficient monitors, who made an important, weekly contribution to the district surveillance network. The kids, boys and girls, enjoyed the experience. They monitored a total of 15 pest and 5 beneficial insect species, especialy BPH and whitebacked planthopper, and used economic threshold values to make control recommendations for the farmers. The children's brigade, an idea and initiative of the koran school teacher, kept the nicely uniformed children busy on Saterday morning, making observations and completing observation forms. Together, they arrived at a no spray/spray recommendation and closed the excercise with singing. This activity was appraised as having long-term significance in terms of raising the rural population's awareness of pest mangement. It was also usefull general education of the children (Zadoks *et al.*, 1986).

Ten years later, in 1996, the number of children scouting brigades, engaged in monitoring rice fields of the states of Perlis and adjacent Kedah throughout the season, was said to have increased. Farmers encouraged the children scouts by contributing to their fund, from which school books and recreational activities were payed (Chen Yew Moi, pers. comm., 1996).

The Director General of the Department of Agriculture, acknowledging the importance of participatory training at farm level, sought to export the model of children brigades to the other rice growing states. In his opinion, the Pest Surveillance and Forecasting System would remain the mainstay of pest management in Malaysia. It was used as a back-up to farmer training because adult farmers appeared to lack training in surveillance and IPM-skill. DoA allegedly hoped to involve farmers in monitoring of pests and to use their data with the help of computer systems for identification of pest trends and forecasting (Datuk Abdul Jamil, DG DoA, pers. comm., 1996).

IPM workshop reconfirmed the T&V system as the main form of extension. The T&V system was slightly modified to accomodate training and extension to farmers' groups. The National Agricultural Policy dictated a farmers' group[96] approach in order to instill an awarenes of the opportunity for lowering costs of production if farmers would form commercial farmers' groups. The Agricultural Extension Service collaborated with the Pest Surveillance and Forecasting Service to back up farmer training. The only significant participation of the farmer community in field monitoring of pests took place in the northern section of the Muda Irrigation Scheme, State of Perlis, where children were trained as pest scouts (Box 5.7.5). In

1986, the Malaysian National Program organized a large scale rat control campaign in Penang State. The campaign was designed on sound technological and sociological principles and its communication strategies were well documented and pre-tested (Zadoks *et al.*, 1986; Asna, pers. comm., 1996). The field-oriented Malaysian scientists achieved a break-through in rice-virus diagnostics on the farm. They used an Elisa technique to detect the presence of virus infestations in order to issue early warning for spraying against leafhoppers. In this way the risk for Tungro Virus epidemics was reduced (Zadoks *et al.*, 1986).

In 1986, IPM implementation appeared to have full political support from national and state governments. DoA seemed to adopt a more participatory approach to farmers, the latter making their own decisions. By 1990, the National IPM Committee claimed that 38,000 farmers had been trained in IPM but the FAO review found that farmers were weak on details related to skills (Whitten *et al.* 1990). The Rice Scheme Authorities, such as the Muda and Kemubu Agricultural Development Authorities (MUDA and KADA) organized training and campaigns on weed and rat control (Ho *et al.*, 1990; ch 3.6.4.5). and on crop and human health in the Tanjung Karang Scheme). DoA claimed an annual saving of 30-27 M US$ through IPM implementation during the 1980s. There were 9 pest surveillance centres serving 131,000 ha, 36 farmer IPM clinics and 7 emergency control brigades.

Although Malaysia had a declared policy on IPM as part of the overall rice intensification policy, the Director General of Agriculture in charge[97] did not lent it active support (Whitten *et al.*, 1990). The DoA and MADA authorities had no confidence in farmers' abilities to make good decisions on pest control but, rather, relied on top-down instruction to farmers in order not to jeopardise production targets. Malaysia had no pesticide subsidies, but government agencies continued to release sprayers and pesticides during declared outbreaks. In irrigation schemes there was a conflict of interests since the authorities responsible for IPM also handled pesticide advertising and subsidized incentives to increase sales through farmers' associations. If the National IPM program lacked political support, the Plant Protection Branch and members of the National IPM Committee remained staunch promoters and, in a discrete way, continued with some IPM activities. Thus the spending of the annual budget of 3.3 M US$ for plant protection depended in fact more on the interest of individuals than on government policy[98] (Whitten *et al.*, 1990). Over the years disappointed IPM scientists[99] left government service or were transferred to a position outside the IPM program. Since 1996, under a new Director General of Agriculture, more attention was directed at reviving IPM implementation but there seems to be a lack of orientation and a los of grip on the rapidly changing conditions in Malaysia agriculture (Oudejans, 1996).

Malaysia acquired a leading position in integrated weed management (IWM) in rice (ch 3.6.4.5). Direct seeding, which has become general practice in the Rice Schemes, caused an increase in weed densities and herbicide use, and raised the costs of land preparation and water management (Whitten *et al.*, 1990). During the 1990s, the Irrigation Department, in collaboration with DoA, carried out large scale soil levelling (planing) operations to improve weed control by submersion of rice fields with water (Oudejans, 1996). Since 1996, MARDI tries to complete its IPM research with an ecologically based synthesis (Eveleens *et al.*, 1996b; Oudejans, 1996). Malaysia continued with IPM in vegetables, fruits (ch 6.3) and other crops such a cacao.

5.7.6. The National IPM Program of Thailand. Thailand was one of the seven initial members of the FAO ICP. Allegedly, IPM in rice received attention since 1976. ICP strengthened the work on IPM since 1981 when the Plant Protection Division of DOA was designated as counterpart to the ICP. This division, which was also responsible for the Surveillance and Forecasting Service, issued the national IPM policy guidelines. However, the responsibility for developing and applying IPC in rice fell on two departments, DOA being responsible for IPM research and demonstration, DOAE for IPM extension. In the first years, ICP's activities were limited to the training of researchers and DOAE staff, providing expertise and holding workshops and meetings. In the years 1982-84, the Plant Protection Division of DOAE performed three trials[100] in farmers' rice fields but failed to involve the farmers' neighbourhood. In 1988, ICP supported a Strategic Extension Campaign on Surveillance and Early Warning System Technology which was targeted at 12,000 farmers and 5,000 school children in Chai Nat province.

FAO's ICP kept good relations with two other plant protection programs directed at the strengthening of Thailand's plant protection infrastructure. These were the Thai-German Plant Protection Program[101], fielded by the German Technical Assistance Agency (GTZ) from 1975-83, and the Thai-Japan Program funded by Japan International Cooperation Agency's (JICA) program from 1978-86. The presence of these two strong programs reduced the need for inputs from ICP.

Thailand was hit by a huge BPH outbreak in season 1989/90. ICP provided funding for a survey to determine the extent of the BPH infestations in the C Plain. The study indicated that, in 1989 about 150,500 ha, and in 1990 over 300,000 ha of rice fields were damaged. The cause of the BPH outbreak was attributed to the high export price of rice during 1987-88, which incited Thai farmers to go for maximum yields and to take risky decisions. They began cultivating susceptible high-yielding cultivars, such as Suphanburi 60, at planting densities twice as high as normal, while using high doses of fertilizers. They liberally sprayed organophosphate and pyrethroid insecticides during the successive seasons (Kenmore, 1991b). The outbreaks occurring between 1976 and 1984 and the 1989/90 outbreak were preceded by upswings in insecticide use. Predictably, the treatments triggered extensive BPH outbreaks, and many farmers experienced total crop failure.

The RTG countered the 1989/90 outbreak by accelerating the multiplication and distribution of cultivar RD23, which had the same resistance gene (BPH2) as IR36. By November 1990, most farmers grew the new varieties RD23 and Suphanburi 90 as well as traditional varieties for which the government supplied the seed at a subsidized rate. Farmers in the outbreak areas reduced fertilizer use to compensate losses with lower production costs.

A national IPM conference was held at Bangkok in October 1990. Indonesian policy makers and scientists explained to Thai Members of Parliament, central and provincial administrators and policy analysts the causality of pesticides and brown planthopper outbreaks and IPM adoption in Indonesia. Follow-up was insufficient to secure understanding of the message amongst senior government officials and to generate a public commitment to the philosophy of IPM.

The Thai-German Plant Protection Program (TGPPP) had experienced a comparable lack of sustainable impact in Thailand. The TGPPP could not obtain lasting support from relevant policy makers nor could it establish a solid foundation in Thailand's administrative structures. The ICP and the TGPPP both depended upon the Plant Protection Division of DOAE for passing IPM knowledge and skills to extension field workers and rice farmers. The IPM knowledge base was divided between -DOA and DOAE, which did not seem to have close liaison. The necessary collaboration with the Research Branch of DOA, and with other departments also having in-country expertise and overlapping responsibilities, could not be sufficiently effectuated (Zadoks *et al.*, 1986). DOAE persisted in its rigid top-down approach along the T&V extension system. Typical features of Thai social culture and hierarchical attitudes (*acharn*-ship) within the civil administration seemed to constitute obstacles for technical dialogue between administrators and scientists. An ICP-review mission concluded 'The lack of clear commitment in Malaysia and Thailand was considered a significant factor in the Inter-Country Programme falling short of its potential in these countries' (Eveleens, 1992).

The RTG had not yet arrived at a policy on IPM or on pesticide restriction by 1998. Thailand enjoyed a relatively free economy, and an ample supply of over a thousand legally registered rice insecticide formulations and of hundreds unregistered ones (ESCAP/CIRAD, Pesticide Index, 19 . Pesticide import was charged a very low excise duty, the tarriff and tax total being less than 7% as compared to 25% for other agricultural inputs such as fertilizers and machinery (Waibel, 1990a,b; Jungbluth, 1996). More distorting than this significant hidden subsidy were indirect subsidies enjoyed when the government declared an outbreak and, usually with a compliant bilateral donor, released insecticides[102] for free in arbitrarily defined areas.

5.7.7. Integrated rat management in rice. In most years field rats (*Rattus rattus brevicaudatus*), white stemborers (*Scirpophaga inotata*) and root rot (*omo mentek*), a physiological disease) were the major causes of crop loss in wet (*padi sawah*) and dry (*padi gogo*) rice in Indonesia (van der Goot, 1948a). The annual reports of the Central Research Station, Bogor (*Mededeelingen IPZ*, 34-39, 1933-36), mention the exemption of landtax because of excessive crop damage[103]. The high amount of exemption granted in outbreak years and local food shortages induced the Inland Administration to call for large scale rat control. Following widespread outbreaks of field rats in W Java during the season 1932/33, DoA organized large campaigns existing of surveillance and monitoring and actual control by poisoning and clubbing (*battue*, 'blanket' killing). The Division of Agricultural Extension and the Inland Administration jointly supervised the distribution of rat poison and placement of tenth of millions of baits by the peasants. The costs[104] of supervision and poison material was borne by the government agencies, the *battue* was incidentally encouraged by a premium for killed rats. The campaign was continued till 1938 and involved per year between 25,000 to 86,000 ha of *sawah* during the west monsoon (November-April) and up to 15,000 ha *sawah* during the east monsoon (June-October) in each of the Residencies Bantam, Batavia (W Karawang), and Priangan. In the Residency of Cirebon, where sugarcane was grown in rotation with rice, the sugar factories joined in the organization of the campaign at their own costs as an effective rat control in rice meant a smaller population in the following sugarcane crop. A major effect of rat control during the rainy west monsoon was that it enabled the cultivation of dry season rice (*padi gadoe*) in irrigated areas during the east monsoon[105].

In the 1930s, rats in sugarcane fields were killed in their burrows with thallium sulphate or arsenic trioxide tablets or dusting with cyanic or sulphur-dioxide formulations (van der Goot, 1942). Rats created an acute problem in sugarcane during the 1960's. Effective control was achieved by placing baits containing 1 per cent zinc-phosphate or 5 per cent warfarin. In later years less acute toxic ingredients such as tomarin and cumarin were used. Rats in rice were controlled by baiting with phosphor paste[106], arsenic compounds or less toxic barium carbonate on sliced batatas (*ubi*) was practised (Kalshoven, 1951). In the Regencies of Jogyakarta and Bali introduction of the above control methods required extra convincing because of superstitious ideas about rats among the population (Mededeelingen van het IPZ, 1933-36). In 1935, trials with rodent killing viruses were undertaken, but soon abandoned.

In Malaysia and Thailand, during the 1970s and 1980s, large training programs on rat control were organized by the German Agency for Technical Cooperation (GTZ). Large scale extension and implementation of rat control by the national DoA took place in several countries of SE Asia with support of GTZ. In 1985, a rat control extension program was implemented in Province Penang, Malaysia (Asna, pers. comm., 1986). The methods were said to be effective but the results were not published.

During three rice seasons in 1989-90, the FAO IPC-IPM in Rice Programme organized a pilot Integrated Rat Management project in C and W Java. In some districts of C Java, rats had almost completely destroyed the rice crop for six consecutive seasons. DoA estimated crop loss by rats (mainly *Rattus argiventer*) in rice over the decade 1985-95 at 1.5 M US$, several times higher than the total loss by other rice pests (van de Fliert *et al.*, 1994) The integrated approach emphasized the need for action by a whole farming community, as was a premise of the former regional GTZ programs. The pilot project reaffirmed that the proven methods of monitoring of population build-up, destruction of burrows, rat drives (*battue*) and systematic baiting with anti-coagulants were as effective as before once the community was organized and action coordinated. If left to their own, farmers hardly adopt bait stations and anti-coagulant rodenticides (van de Fliert *et al.*, 1994).

5.7.8. Integrated Weed Management. Weed control is essential in the humid tropics because of the lush plant growth. Early forms of weed control included handweeding, grazing, slashing and burning of unwanted vegetation. Inundation of land for the purpose of controlling weeds was closely connected with the development of the wet rice (*padi sawah*) cultivation method, probably because of immense weed problems in dry rice.

Weed control on *sawah* is a combination of tillage and water management (Grist, 1935). First, the field is inundated to enable ploughing and puddling of the soil, and then drained to allow germination of available weed seeds. Second, the field is inundated again to suffocate emerging weeds and draft animals are driven around to trample the weeds into the mud. Third, the mud is leveled (planing) and the field covered with a 10 cm layer of water (*sawah*) into which the rice seedling are transplanted from the nursery beds. Skilful *sawah* preparation provides an effectice control of weeds and gives the transplanted rice an advantage of several weeks over competetive weeds. Today, *sawah* preparation is largely mechanized but for narrow rice terasses. The requirement of a larger plot size for tractors and power tillers has frequently spoiled the capacity of traditional *sawah* lay-outs to hold water. Uneven *sawah* soils and higher work speed allow more weeds to escape and to become a problem. In Malaysia during the 1990s, agricultural policy included the levelling of vast stretches of *sawah* land with the help of laser-guided tractor/planer units in irrigation schemes. The purpose was an improvement of water management on *sawahs* for beter crop growth and weed control. The program was implemented by the Public Works Department in collaboration with DoA (Director DoA, pers. comm., 1996).

In Malaysia, the direct seeding of wet rice (*padi sawah*) became the standard practice in the rice schemes (ch 3.6.4). Greater weed densities, which accompanied the shift to direct seeding, necessitated many experiments on seed rates, seedling density and herbicide usage (Ho, 1991, 1993). This work has given Malaysia a lead in Integrated Weed Management (IWM) in rice. An increasing problem in wet rice stems from the grassy weeds, such as *Echinochloa crusgalli,* because these grasses are indistinguishable from rice in the early stages and their seeds are difficult to separate from rice seed (ch 3.6.4.5).

The extensive planting of rubber and oil palm in SE Asia by the estate industry, the Land Development Schemes and smallholders requires intensive control of weed during the first years of tree establishment. Weeding is almost completely done by use of herbicides (ch 7.3). There is ample literature on the use of herbicides in estates crops, but little reference is made to Integrated Weed Management.

5.8. Discussion

Agricultural research in the three countries of SE Asia, in particular in Indonesia, during the 19th and 20th century yielded a huge amount of information on the control of pests in native and introduced crops. The incentives for such research followed a curious Mobius-type of loop. The absence of synthetic pesticides before World War II necessitated a search for methods of cultural, biological and regulatory control which could offer sufficient protection to make certain cultures financially attractive. The mainstay of plantation agriculture was selection and breeding for characteristics of high yield, suitable habitus and a fair resistance against pests and diseases. In the process, ingenious techniques of breeding, grafting, pruning and avoidance of contamination were developed, which remained valid till today. Colonial research on mechanisms, properties and application of biological control through natural enemies was fundamental and well documented.

After World War II, the fast killing synthetic pesticides appeared to offer a more efficient solution to the management of pests in crops. Public and private investments in research were soon almost entirely directed at the development of chemical pest control. Old practices of non-chemical control became redundant if an easier or cheaper method of chemical control was feasible. The chemical euphoria lasted until the 1970s when symptoms of pest resurgence, increasing pesticide resistance in noxious organisms, and externalities, such as human intoxication and environmental contamination, were recognized and understood.

The conclusion that synthetic pesticides provide at best only a partial solution to pest problems has re-opened the search for alternatives and a renewed appreciation of biological control. An essential difference between past and presence in biological control is the availability of synthetic pesticides. Researchers showed that pesticides, when used in a judicious way -*i.e.* the need-based use of a suitable pesticide applied with an adequate technique at the right time and place- can make a decisive contribution to integrated control. The controversy, usually, lays in the interpretation of 'need-based'.

SE Asia learned the necessity for restraint in pesticide use the hard way. Extensive outbreaks of insect pests and virus epidemics in rice followed intensive calender based application of insecticides in the national rice intensification programs. Coincidence of various events established the IPM programs in SE Asia. The events included *a.* the recognition that the brown planthopper and Tungro Virus outbreaks in the new high-yielding rice varieties, which endangered the gains in rice production, were pesticide-induced; *b.* a concern about the deteriorating food security situation in Asia persuaded international organizations and donors to finance a regional Programme for the Development and Application of Integrated Pest Control in Rice in S and SE Asia as proposed by FAO; *c.* in Indonesia, the recession on the world-oil market in the early 1970s opened the country's door for IPM. The concurrence of low revenues from oil and gas, on which Indonesia's economy depended for over 85% at that time, with the heavy drain of its foreign currency reserves by increasing imports of rice and inputs, made the Indonesian Minister of Trade question the appropriateness of pesticide subsidies for rice. The FAO Inter-Country and Indonesian National IPM Programmes, in collaboration with Indonesian scientists, pursued with success Indonesia's commitment to IPM in rice as a national policy.

Since 1987, high-level policy makers in Indonesia, persuaded by the effectiveness of the Presidential Ban on insecticide use in rice in abating pest outbreaks, funded national development of IPM. Indonesia arrived at a classic example of a win-win situation: farmers (less hazards, less expenses), government (rationale was provided for abolishing costly pesticide subsidies) and public at large (environmental gains) (Eveleens *et al.*, 1996a). The National IPM Program in Indonesia showed in the 1990s a continuing development towards consolidation, expansion and institutionalisation. With technical assistance from the FAO Inter-Country Programme, the Indonesian National IPM Project trained about 800,000 farmers on IPM in Rice Based Cropping Systems which, increasingly, included elements of IPM for vegetables and soybean. Numerous farmer groups had emerged from the FFSs and farmer trainers had organised themselves in associations. These associations organized local IPM programs in almost all districts under the program (FAO, 1998).

In Indonesia, the occurrence of several localized pest outbreaks revealed the existence of an active IPM network, that organized an effective integrated control before the authorities resorted to pesticide applications. Examples were the white stemborer outbreak in Indramayu, E Java, in 1991; outbreaks of BPH, Tungro and rice stemborers in C Java in 1996; and, in 1998, outbreaks of BPH in N Sumatera following strong advertisement by the industry for use of endosulfan against the golden apple snail. The growing capability for rapid action by an IPM Farmer Network before the national Surveillance and Early Warning Systems (SEWS) engages DoAs Emergency Spraying Units or before the extension service advises to use insecticides, needs to be treasured as an indispensable component of national IPM implementation. The organized pressure of empowered, critical farmers is needed to impress the authorities and the agricultural services and to enforce policy changes at district level.

In 1988, after the currency devaluation, the costs of an FFS averaged 200 US $ per season or 8 US$ per farmer when attended by 25 participants. The National Program commissioned health impact and gender studies and produced maps showing the agro-ecosystems of Java's major rice bowls (12 sheets), the pest patterns and the cultivars planted. The continuation of IPM implementation on a scale as in Indonesia will depend on the availability of strong management capacity and considerable funding from international and national resources.

To safeguard IPM as a plant protection and FFS as an extension approach a critical mass of supporters is needed among the Indonesian officials in the mid-level of the central bureaucracy. The class of field-oriented Indonesian administrators and scientists, who participated in the national rice intensification schemes of the 1970s and 1980s and who saw the hopperburned fields, will retire early in the 21st century. Donors should realize that an internationally supported regional program will be needed to keep, with fresh arguments and data on results, the attention of policy-makers focused on the issue of national IPM implementation.

The strategy of the FAO-backed IPM programs in Rice in S and SE Asia is based on preservation of the natural biodiversity of the rice field. Tropical rice is a complex and stable agricultural system because of the high species richness, abundance and dispersion of natural enemy populations. The abundance of alternate food sources (non-herbivores) for parasitoids and predators at the various trophic levels of a rice ecosystem early in the growing season boost natural enemy populations well in advance of a rise in pest population numbers. If, nevertheless, pest populations would approach economic threshold levels, insecticides would almost always be counter-productive.

The application of herbicides in direct seeded rice is increasing rapidly throughout SE Asia. The relationship between the technique of direct seeding, development of weed populations and herbicide efficacy is best studied in the large Rice Irrigation Schemes of Malaysia. The effect of herbicide use on natural enemy populations and their food sources in rice is, however, not known nor is any research program of the kind announced.

The control of rats and snails as also undertaken by the Inter-Country and National IPM Programmes in S and SE Asia. Control of these pest is, usually, successful, but only for the short period that the cooperation of all farmers is obtained

5.9. Conclusions

1. The development of colonial agriculture without synthetic pesticides yielded ingenious combinations of regulatory, cultural and biological control measures.
2. Research on mechanisms, properties and applications of biological control through natural enemies was fundamental, particularly in the Dutch East Indies, and well documented.
3. The need to preserve and utilize the colonial records is evident.
4. Considerable private investment in agriculture appeared to be a premise for the establishment of an initial agricultural research capacity and its proper management and funding.
5. The absence of such incentive delayed the development of agricultural research in Thailand.
6. Development of IPM, before 1930, stemmed from a need to devise effective control mechanisms in the absence of synthetic pesticides. After 1945, the need to avoid the negative effects of pesticide use re-opened the search for alternative approaches to pest management.
7. The findings of research on IPM in apples (Canada and the Netherlands), alfalfa (California) and protected crops (the Netherlands) had shown the causal relationship between pest outbreaks and pesticide use and led to an effective integrated control strategy.
8. The large scale rice production intensification programs in SE Asia in the 1960s on the basis of Green Revolution technology and inherent over-use of insecticides caused outbreaks of planthoppers and leafhoppers in rice followed by virus epidemics and great losses in *padi* yield.
9. The insecticide-induced character of BPH, leafhopper and virus outbreaks (Tungro, Ragged Stunt and Grassy Stunt) was proven by IRRI scientists in the early 1970s.
10. Trials demonstrated that indigenous natural enemies in untreated rice efficiently prevented the build-up of insect populations.
11. Contrary to the stance taken by the industry, the IPC and national programs maintain that insecticides are not an indispensable production factor in rice.
12. The use of insecticides in rice tends to be counter-productive since it affects the stable composition of its natural enemy fauna.
13. The effects of herbicide use in direct seeded rice are poorly understood.
14. In view of the rapid increase of direct seeded rice and the corrolary use of herbicides, the effect of herbicides on the rice ecosystem and its natural enemy populations needs to be studied intensively.
15. Numerous experiments in rice by IRRI and by the regional and national programs, yielded conclusive evidence that not using insecticides coupled to using adequate agronomic practice increases the likelihood of higher yields and, gener-

ally, results in lower production costs by savings on pesticide application.

16. The lack of resistance against BPH, leafhopper and viruses, in particular Tungro Virus, in early released IR-cultivars and in local improved selections was a major reason that insecticides were included in the Green Revolution technology package.

17. Lack of resistence in early high yielding varieties and calender based spraying, jointly and in a synergistic fashion, unleashed the outbreaks of secondary pests such as BPH.

18. The establishment of Surveillance and Early Warning Systems (SEWS) in SE Asia initially led to an increase in insecticide application in rice, a.o. by engaging the Emergency Control Units of DoA in the three countries, and thus contributed to a worsening of the situation.

19. Aerial spraying operations on large tracts of rice in W, C and E Java, NW Sumatera and Bali triggered the large outbreaks of the 1970s by almost eliminating pest control by natural enemies during two years in sequence.

20. Severe outbreaks of BPH in rice in Thailand occurred in the late 1980s only, when insecticide use in rice was stepped up due to an increase of the rice price.

21. The implementation of IPM in rice based cropping systems was most successful in Indonesia.

22. In Malaysia, IPM related activities were incorperated in the technological guidance for rice production extended to rice farmers in the large Rice Irrigation Schemes of Peninsular Malaysia.

23. The lack commitment to the cause of IPM in Malaysia has much to do with the delegation of the management and education of rice farmers to the Scheme Authorities and with the countries *Bumiputra* politics.

24. In Thailand, the IPM implementation in rice hardly reached the farmers due to a lack of political commitment and funding.

25. In Thailand, inadequate communication between departments prevented the unity of mind needed for IPM implementation.

26. The T&V method of extension, which is still the preferred approach in agricultural extension in Malaysia and Thailand, demotivated the extension field officers and farmers. It could not compete with the sales efforts of pesticide suppliers in the country side.

27. The FFS method of extension jolted farmers out of their traditional role as passive recipients of ill-understood and poorly appreciated instructions from above and into an active engagement in informed decision making on their own crop.

28. The establishment of the FAO Inter-Country Programme for Integrated Pest Control in Rice in SE Asia, although born from need in view of increasing pest outbreaks, was an audacious undertaking in view of the high interests of the chemical industry and of certain policy makers in an undisturbed pesticide market.

29. Indonesia gave a strong boost to the credibility of IPM as a superior alternative to current practices and prompted re-adjustments in prevailing national crop protection policies in other ICP member countries (drive towards policy changes).

30. The most injurious pest in rice on record are the field rats.

31. The techniques and means for an Integrated Rat Management (IRM) are well-

known and proven. Large-scale campaigns in the Dutch East Indies (1930s), Malaysia (1985-87), and Indonesia (1988-90) invariably stranded on lack of concerted, sustained action by the village community.

32. The plague of the golden apple snail in rice provokes increased use of insecticides (endosulfan) and, thus, creates a new danger for BPH resurgence.

Notes

1. Pathogenitism claims that one well-defined pathogen is the exclusive causal agent of one well-defined disease (Zadoks, 1993).

2. In 1946, the first case of tolerance to DDT in the house fly (*Musca domestica*) was reported in Sweden. Within 20 years, 127 agricultural pests were recorded as resistant to one or more groups of insecticides (Flint & Van den Bosch, 1891).

3. In a reaction to 'Silent Spring' the Environmental Protection Agency (EPA) reviewed pesticide registration procedures. The USDA banned most uses of DDT in 1972, and subsequently banned or severely restricted use of aldrin, dieldrin, endrin, heptachlor, DBCP, and chlordane (Flint & Van den Bosch, 1981).

4. Indonesia, Presidential Instruction 3/1986, November 5, 1986; Philippines, President Corazon Aquino on Policy Directions in Agriculture, point 5, Speech at Awarding ceremonies for 'Outstanding farmers of the year', May 30, 1986; Manila Bulletin, May 31, 1986; Malaysia, Minister of Agriculture, Anwar Ibrahim, declared at the Opening of the 2nd International Conference on Plant Protection in the Tropics that 'the current IPM program in rice, jointly implemented with FAO, will be expanded to include crops such as cacao and vegetables'; India, the Federal Minister of Agriculture declared IPM national policy in a speech, September, 1985 (Zadoks *et al.*, 1986).

5. Voûte & Fluiter (1961) introduced the term ' harmonious control' in the Netherlands for the concept that internationally became known as 1Integrated Pest Management'. The term 'harmonious' was used by Pickett and consorts (1958).

6. Initially, 37 entomologists from various countries were invited on personal title to join the Panel for a term of four years. The Panel convened every one or two years at FAO, Rome. The American R.F. Smith was appointed as chairman. The Netherlands was represented by J.J. de Fluiter and J. de Wilde, and England by M.J. Way. After 1974, phytopathologists and herbologists were also invited as Panel member (Brader, 1987).

7. In January 1980, FAO and UNDP launched an Action Programme for Improved Plant Protection with the objective of strengthening national plant protection services in various developing countries. This program was advised bij another Expert Committee on Pest Control (members included N. van Tiel (PD-NL), R. Kaske (GTZ-D), P. Haskell (COPR-UK), F,W. Whittemore (USAID).

8. Among these American scientists, V. Stern is said to have masterminded the Integrated Control Concept. R.F. Smith was the politician who, although being a poor speaker, achieved great results through sheer tenacity (Way, pers, comm., 1997).

9. De Fluiter (1969b) noted that the effective, integrated control of diseases and pests in Novia Scotia apple orchards was developed by trial and error before the mechanism of the system was understood. Pickett's system appeared to be rather location specific and the study of its principles followed later.

10. E.W. Knipling worked with USDA on screwworm fly control in Texas since 1931. During World War II, he directed the testing of DDT for the army. In 1953, he shifted federal entomological research into non-chemical control projects. In 1959, Knipling introduced the paradigm of Total Population

Management which led to the eradication of the screwworm fly through sterile- male technique in Texas (Perkins, 1980). The Texas sterilization facilities were used for the elimination of the scewworm fly infestation in N Africa (FAO/Lybia Screwworm eradication project) during the 1980s.

11. Supervised insect control. Control of insects and related organisms supervised by qualified entomologists and based on conclusion reached from periodically measured population densities of pests and beneficial species (Stern *et al.*, 1959).

12. Smith recognized the need for pest management-consultants, trained to identify pests and their state of health, to carry out monitoring programs and to assist growers. The first supervised control expert, K.S. Hagen, was hired in 1946 to implement the integrated control program against alfalfa caterpillar (Flint & Van den Bosch, 1981).

13. Paradigms consist of the results or exemplars of past work that are accepted by a community of scientists and that supply the foundation for their further work. The two essential characteristics of paradigms are *a.* their abilty to attract an enduring group of adherents away from competing modes of activity, and *b.* the presence of a sufficient number of problems for the adherents to resolve (Kuhn, 1970).

14. In his 1979 Environmental Message, President Carter instructed the Council on Environmental Quality "to recommend actions which the Federal Government can take to encourage the development and application of techniques to be used for sound IPM programmes" (Smith, 1980).

15. Stern *et al.* (1959) defined the economic-injury level as: 'The lowest population density that will cause economic damage. Economic damage is the amount of injury which will justify the cost of artificial control measures; consequently, the economic injury level may vary from area to area, season to season, or with man's changing scale of economic values'.

16. In 1949, the Director of the Plant Protectio Service of the Netherlands, C.J. Briejèr, warned for resistance in insects and residues as the inevitable outcome from the excessive reliance on chemical control (Briejèr, 1949). In 1956, Briejèr wrote 'Zilveren sluiers'('Silver veiles'), a Dutch pendant of R. Carson's 'Silent Spring', with his advice 'Spray as little as you dare' (de Fluiter, 1969) (1969a).

17. J. de Wilde, professor of entomology, was among the Dutch pioneers who saw the need to reduce pesticide use and to take the initiative in searching for alternative ways of pest control. Others were H.J. de Fluiter, D.J.Kuenen and E.D.Voûte.

18. In 1967, the name of the Dutch Working Group was changed into 'Working Group Integrated Control of Pests TNO', to adjust it to the internationally accepted terminology.

19. Economic threshold is 'The density at which control measures should be determined to prevent an increasing population from reaching the economic-injury level' (Stern, 1973).

20. Distribution has vastly expanded due to great improvement in formulation and packing technology for the living biological agents (Malais & Ravensberg, 1992).

21. The diseases in winter wheat monitored by EPIPRE include Yellow Rust, Brown Rust, Mildew, Septoria Leaf Spot and Septoria Glume Blotch. Three species of aphids were taken together (Blokker, 1982; Zadoks, 1989).

22. In EPIPRE the farmers mailed data on soil type, cultivar, sowing date, developmental statge, nitrogen application dates and rates, pesticide applications, and the observations from successive inspections per individual plot to a central computer unit. Within 2 to 3 days, EPIPRE advises the farmers about the need (yes/no) of pesticide application for each registered plot. Sometimes a warning threshold is applied which is lower and earlier than the economic threshold to allow the farmer time to react (Zadoks, 1986).

23. As field trials are costly , Zadoks (1986) recommended to employ the the new instrument of dynamic simulation to substitute for field trials to a certain degree.

24. The cess paid by the estates over 200,000 ha sugarcane planted in 1930 provided a research budg-

et of approximately 1.5 M NGL (Koningsberger, 1948).

25. The symptoms of *sereh* included diseased roots, red coloured gummed phloem vessels, shortened internodes and telescoping leafsheaths which made the sugarcane plant resemble *Sereh*-grass (*Cymbopogon nardus* Rendle).

26. Research on *sereh* and its causal agent was undertaken at the *Plantentuin* in Bogor, and at the three research stations. M. Treub (Bogor) and F. Soltwedel (Semarang) attributed *sereh* to nematodes, H.J. Wakker (Pasuruan) to physiological disorder, and F.A. Went (Tegal) suspected bacterial infection. Its contagious character was confirmed in 1923 by Ms. G. Wilbrink who detected that warm water treatment cured *sereh*-infested bibit (Koningsberger, 1948). Now-a-days, *sereh* is attributed to a virus infection (Eveleens, 1976).

27. The German F. Soltwedel, Director of the Research Station of C Java, made contributions which included overcoming low sugarcane fertility, disease-free propagation through mountain bibit and establishment of a quarantine station. He died in 1892 at the age of 30 years.

28. Sugarcane was commonly propagated through *bibit*, short sets of 3-5 internodes cut from the top part of factory cane (*maalriet*) at harvest. Cane from mountain gardens was entirely used for *bibit* production, one hectare producing sets for planting 24 ha of factory fields.

29. Mountain *bibit* was expensive due to the frequent field inspections and transport over great distances. In the 1890s, the costs of import bibit often exceeded NGL 15,000 per year for individual estates (Went, 1898).

30. Before it had been assumed that sugarcane did not produce seed which could germinate (Koningsberger, 1948). Soltwedel obtained germination of sugarcane seed in 1886, the year in which Bovell and Harrison achieved the same feat in Barbados (Went, 1898).

31. The Sugar Research Station at Pasuruan, E Java (*Proefstation voor Suiker Oost Java*, hence its acronym POJ) is one of the few places where sugarcane flowers easily. Many commercial cultivars have a parentage including one or more POJ-cultivars.

32. Sugarcane, usually vegetatively propagated and highly heterozygous (compare potatoes), produces a heterogeneous F1-progeny. At Pasuruan, hundreds of crosses were made wich required planting of hundreds of thousands plants for line selection. Selected lines were thereafter vegetatively propagated as factory cane (*maalriet*) (Koningsberger, 1948).

33. In 1890, the colonial government commissioned the plant breeder J.C. Kobus to India to search for resistant sugarcane varieties. Hybridization of Indian cane accessions Chunnee and Ruckree with Java cultivars, such as Black Cirebon, provided many new POJ-lines with high *sereh* resistance but generally uneconomic habitus (Koningsberger, 1948).

34. Jeswiet decided in 1915 that Kassoer was a spontaneous bastard of the botanical species *S. spontaneum* (*Glagah*) and *S. officinarum* (Black Cirebon). In 1911, J. Wilbrink obtained from the cross (100 POJ X Kassoer) the resistant line POJ 2364. Crossing of the latter with EK-28 (the best cultivar developed by planters) yielded the resistant POJ 27 and 28 series, rich in sugar. Further crosses with these lines yielded, in 1921, the *sereh* resistant, high yielding 2878 POJ and 2883 POJ cultivars (Koningsberger, 1948).

35. As indicated by its name (*pokkah* = malformed), *bung* = shoot) the disease causes breakage of the young leaves still enclosed in the leafsheath and rot of the top shoot. It occurs at the onset of the rains which stimulate sudden, strong cane growth.

36. Description of Yellow Stripe Disease by Van Musschenbroek (Circulaire No .42, *Surabaya Vereeniging*, 16 Oct. 1892: 327). Nitrogen application remitted the mosaic symptoms in the sugarcane leaves temporarily.

37. The effectiveness of controlling white top borer by excising borer infested tissue in three-weeks intervals was analysed from estate data collected over the period 1930-34 (Kalshoven, 1951).

38. Analysis of the statistical records of the Sugar Research Institute over 1931-32 showed that, for instance, the ubiquitus wasp *Elasmus zehntneri* parasitized on average only 3-4 per cent of the white top borer larvae in W and E Java (Kalshoven, 1951).

39. Cryolite (aluminium trisodium fluoride) is an about 98% pure, naturally occurring mineral with a stomach and contact insecticidal action (BCPC, 1979: 132).

40. The phytopatholgist J. Van Breda de Haan was sent by Treub from Bogor to Deli on 6 month missions. Van Breda de Haan identified *Phytophthera nicotianae* as the causal agent of the nursery disease. In 1906, van Breda de Haan, was appointed as the Director of the Deli Tobacco Research Station at Medan.

41. The Research Station for Java-tobacco, Klaten, issued detailed instructions for removal and burning of all diseased plant in field furnesses, for cleaning of harvested fields before tillage, for disinfecting soil around infested plants before their removal, for common use of plant debris by the people and composting of debris of healthy plants (Thung, 1938).

42. Slime disease causes wilting of the leaves at one side of the plant and rotting of tops and roots. Whitish slime oozing from cut stems contains great quantity of bacteria and is very infectious.

43. Differences in resistance against Helopeltis are also reported for cacao varieties in Ivory Coast, Africa (Zadoks, pers. comm., 1997).

44. The *Cacao Proefstation* at Salatiga was instituted in March 1901 and L. Zehntner was appointed Director. It was built amidst cacao estates and financed by the cacao cess fund to which members contributed on basis of area planted. The Station's Bulletins (*Mededeelingen*) reported on results (Toxopeus & Wessel, 1983).

45. Jember Research Institute for Highland Crops, E Java, is the new name given, in 1980, to the former Besuki Research Station, E Java, which had been the centre for coffee research since 1911. Research at Jember includes improvement of coffee, cacao, rubber and Besuki tobacco, as well as the management of pests and diseases in these highland crops.

46. To whipe out the gramang ants pits were dug in the soil under the trees which were filled with dead leaves. Within days the restless gramang ants build their nests in these pits, which there upon are fumigated with HCN or carbonbisulphide under a layer of earth (Giesberger 1983).

47. Ph. Levert was agronomist of the 1500 ha *Siloewok Sawangan* cocoa plantation - by far the largest cacao estate in E Java at the time - and G. Giesberger microbiologist of the Experiment Station at Malang. These scientists and Betrem re-activated the research on *Helopeltis* control in the late 1930s (Levert, 1940).

48. *Djati Roenggo* hybrid cacao was the result of crossing Venezuela X Criollo varieties; the basterd was named after the plantation in E Java (Wessel-Riemens, 1983).

49. Laoh (1955) showed that application of endrin at a frequency of 16 sprays per year gave effective control of CPB and *Helopeltis* in field trials. But costs were prohibitive.

50. The stemboring beetle *Glenea novemguttata* Cast. was formerly a minor cacoa pest in C Java. Control took place by catching beetles at certain times of the year and by excising its larvae from infested stem tissue (Kalshoven, 1951).

51. Coffee Leaf Rust, an African fungal disease, was first detected on Ceylon in 1869, where it destroyed the thriving coffee cultivation. The disease reached via Padang Highlands, Sumatera, the Botanical Garden *(Cultuurtuin)* at Bogor and the adjacent estates in 1876.

52. In 1900, a Dutch plantation company bought 150 robusta seedlings from a Belgian company, which

copies were distributed.

82. A FAO mission reviewing the Indonesian National IPM Programme commented: "A rigid system equipped to move simplistic messages to a large number of passive farmers could not absorb the energy of IPM's field skills training. A transformation from within was needed to meet the new challenges from outside" (Whitten *et al.*, 1990).

83. The National IPM Program was managed by a National Steering Committee, chaired by BAPPENAS, and a Working Group with members from various ministries and national universities. It established field training centres and organized courses for extension and plant protection officers and farmers.

84. The GoI received a grant from USAID to the value of about 4.2 M US$ to finance the services of FAO for a duration of 24 months. The counterpart commitment included costs of staff, administrative services and facilities, local supplies, transport and communications (FAO, 1989).

85. A survey of 2,000 Indonesian rice farmers before and after IPM training carried out by the national program in 1991 showed that IPM farmers reduced pesticide use by an average of 58% per season.

86. Carbofuran was still permitted on rice under the IPM policy and was included in the intensification package (SUPRA INSUS). A major carbofuran formulation plant had been built in Jalur Pantur.

87. The variety IR64 has yet another gene for BPH resistance (BPH3) but appeared to be more susceptible to white stemborer attack. Kenmore (1991b) called it a precise example of the limits of applying that specific form of biodiversity called genetic diversity.

88. Field studies included white stemborer problems in W Java, a health impact study in C Java (Kishi *et al*, 1993), training evaluation studies, and integrated disease and weed management and integrated rat control in rice and *palawija* crops. An IPM database was set up too (van de Fliert, 1993; Eveleens *et al.*, 1996b).

89. DITLIN's field leaders at sub-provincial and district level supervised about 10-15 pest observers per district with an average population of 1 to 2 million people (Eveleens et al., 1996b).

90. The 600,000 farmers correspond to 3% of the 20 million farmers living in the 12 provinces covered by the Indonesian IPM project (Eveleens *et al.* 1996b).

91. Pest Observers and Extension Workers, acting as trainers in FFSs, were at the same time often involved in the supply of intensification 'packages', which at times still contain pesticides, which they were often compelled to promote (Eveleens *et al.*, 1996b).

92. Quality of FFSs was of particular concern due to shortage of funding and low attendance rates (on average 16 participants instead of 25 targeted per FFS). The 1996 budget for a FFS amounted to 550 US$. A locally funded FFS of similar quality conducted by a Farmer Trainer costed around 50 US$ (Eveleens *et al.*, 1996b).

93. The National IPM Committee, chaired by the Director of Crop Protection, consisted of a Secretariate within the Section Plant Diseases of the Crop Protection Branch of DoA; a Technical Committee for Rice IPM chaired by the MARDI Research Director for Rice; and Operational Units in the Rice Irrigation Schemes of Peninsular Malaysia.

94. Working groups included DoA-MARDI groups for biological control, development of ETL-values for rice pests, and for screening and improved application of insecticides.

95. In Tanjung Kareng Irrigation Scheme at Selangor two IPC pilot areas were selected. The most advanced farmer IPM training in Tanjung Kareng, Sawah Sempadan, in 1981 involved 39 groups of 5 persons meeting 2 times per week during the season.

96. Group farming entails that the farmers of an irrigation block join together to manage larger tracts of land thus bringing economies of scale in labour, mechanisation, harvesting, credit, information activities and IPC effectiveness. In the MADA scheme during the 1980s, harbouring 63,000 farm families,

there were 238 farmers' groups.

97. The DG DoA held the view that the origin of IPM was to be sought in residue problems from pesticide over-use in 1983 rather than in pesticide-induced outbreaks. He argued that IPM in rice effectively reduced only insecticide use, whereas the use of herbicide and rodenticide increased all the time (Whitten *et al.*, 1990).

98. The FAO review mission remarked in 1990 that "lip service is given to a national IPM policy and program but implementation is truncated and dependent on individuals" (Whitten *et al.*, 1990).

99. Prominent Malaysian IPM scientists and administrators, after leaving MARDI or the Plant Protection Branch, took up positions with the FAO Inter-Country Programme, the International Institute for Biological Control, IRRI or FAO. The enthousiastic and effective Secretary of the National Committee was transferred to Alor Setar as head of extension training.

100. Three trials were conducted in Pathumthani Province on 82 ha of rice fields of 22 farmer families. Although called 'Demonstration IPM Paddies' the DOAE did not try to involve neighbouring farmers. The finding that reducing treatments from 7 to less than 3 per season did not decrease rice yields was not exploited. Kenmore (1991b) observed that DOAE's staff seemed not to be appreciative of the social technology that had proven necessary in other countries to make IPM projects work with farmers.

101. Under the Thai German Plant Protection Program, the GTZ built 31 well-equipped Plant Protection Centres in the regions of Thailand in the neighbourhood of DOAE extension officies. GTZ further organized training in IPM and rat control, and provided overseas fellowships.

102. The Extension Service (DOAE) had a policy of providing free pesticides if a local infestation affected more than 85 ha (500 rai). Free samples were given to farmers for smaller areas so that the farmers knew what they could purchase through private outlets (Kenmore, 1991b).

103. The landtax office (*landrentekantoor*) reported the follow-ing amounts of tax exemption granted because of rat damage in sawah in the Residency Chirebon, NW Java: NGL 76,691 in 1931, NGL 18,084 in 1932, and NFL 31,181 in 1933. The amount of exemption for 1933 in the Residency Bantam amounted to 24% of the total tax on sawah (Mededeelingen van het IPZ, 84, 1933: 7-15).

104. Mededeelingen van het IPZ, 84,1933; 85, 1934; 86, 1935; 89, 1936, reported various cost items but not in a systematical way. The cost of rat control appeared to vary from 5 to 20 cents/ha in west (October-Februari) and east monsoon (May-Augiust) respectively.

105. Before 1934, farmers of W Karawang considered growing padi gadoe in the dry monsoon as too risky in view of the high rat density. Around-the year rat control increased the planting of *padi gadoe* in W Karawang from 1,750 ha in 1934 to 14,891 ha in 1936. Therefore, in a cost/benefit analysis the *padi gadoe* yield of 37,500 tonnes valued at NGL 660,000 was considered as return on investment W Karawang over whole 1936. (Mededeelingen an het IPZ, 89, 1936: 14-15).

106. Phosporpaste was a concoction of white phosphor, palm oil, rice flour and sugar. The paste is diluted with water and the bait ingredients are is dipped in the slur.

Chapter 6

Horticulture and IPM in SE Asia

6.1. Horticultural production and Integrated Pest Management

6.1.1. Introductory remarks to horticulture in SE Asia. Horticulture is a collective noun for a range of cultivation practices pertaining to the production of vegetables, herbs, fruits, ornamental plants and flowers. For a discussion of plant protection issues, pesticide use and pest and disease management in horticulture, three main types of horticulture are distinguished, each with considerable diversity in crop protection practices.

1. Mixed home (kitchen) garden, planted with a great variety of fruit bearing trees and plants, herbs, and annual and perennial vegetables[1]. The production of the garden is often supplemented by the leaves, fruits and tubers of crops the farmer grows in rotation with rice, such as groundnut, soybean, cassava, jute, sweet potato, taro and cowpea. Production is partly for household needs but surplus is traded in the local market.

2. Intensive market gardening which accounts for a large part of the local market supplies in SE Asia. This type arose in response to the development of roads and transportation, and to the rapid urbanisation (Oomen & Grubben, 1978).

3. Large scale commercial horticulture, which includes fruit orchards, vegetables and fruit plants grown as field crops, and flower or ornamental plant nurseries. Commercial enterprises, demanding a considerable investment, came into existence where and when structured market organizations garanteed a regular and reliable demand. It includes the production by contract growers for nucleus processing industries such as fruit canning and sap extraction.

Horticultural production for the market usually entails farmers using intensive cultivation practices to obtain high quality produce. The production systems are characterized by relatively high inputs of knowledge, cash, labour and materials (seed, planting stock, fertilizers and pesticides). For vegetables and flowers the production cycle is usually short, two or three months. Generally, several crops are grown in monoculture or rotation on the same plot in one year, which may lead to an increase in infestation rates by injurious organisms. Some 80 species of vegetables are sufficiently profitable for today's labour-intensive market garden production. Some 20 species are exploited in highly commercialized protected cultivation systems (Terra, 1966; Oomen & Grubben, 1978).

Commercial vegetable growing is concentrated in the highlands for temperate type vegetables (e.g. head cabbage, potato), and in the lowlands for annual hot-season type vegetables (e.g. hot pepper, pumpkin, amaranth) or in swamp soils and ponds for waterplant-type vegetables (lotus lily, kangkong, watercress) (table 6.1.1.a). Nurseries for flowers and ornamentals are recent developments although flowers, such as lotus, hibiscus and jasmine are traditionally grown in quantity for use in religious and civil ceremony.

Commercial lowland orchards grow fruits such as citrus, mango, papaya, rambutan, litchi and durian. Banana, pineapple and water melon are major fruit bearing plants grown as field crops (table 6.1.1.b). Highland production of grapes is important in Thailand. The production of apples, restricted to few high plateaus of Java and Malaysia, is not very successful.

The vegetable and fruit sector created an important processing industry and

Table 6.1.1.a. Estimated production of major vegetables in a. planted area (x 1,000 ha) and b. produce (x 1,000 tonnes) in Indonesia and Thailand in 1988. Sources: Lembang Horticultural Institute, Indonesia; Department of Agricultural Extension, Thailand.

Vegetable crop	**Indonesia**		**Thailand**	
	a	**b**	**a**	**b**
Lowland				
Allium cepa (shallot)	66	391	21	269
Amaranthus spp. (amaranth)	22	84	?	?
Capsicum spp. (hot/bird pepper, chili)	137	441	121	328
Cucumis sativus (cucumber)	40	291	16	143
Cucurbita spp. (pumpkin, gourds, okra)	4	173	10	108
Ipomoea aquatica (kangkong)	10	133	5	23
Phaseolus vulgaris (kidney bean)	51	63	?	?
Solanum melongena (eggplant)	32	168	?	?
Vigna unguiculata (yard-long bean)	97	280	10	75
Zea mays (maize, young cobs)	?	?	13	82
sub-total lowland vegetables	**459**	**2024**	**196**	**1028**
Highland				
Allium fistulosum (Welsh onion)	25	163	2	41
Allium sativum (garlic)	16	90	31	330
Brassica oleracea (cabbage, Chinese kale)	44	809	15	186
Brassica juncea (leaf mustard)	?	?	5	43
Brassica rapa (Chinese cabbage, caisin)	27	220	5	46
Daucus carota (carrot, wortel)	11	124	?	?
Lycopersicon esculentum (tomato)	32	195	6	70
Phaseolus vulgaris (French bean)	23	105	?	?
Raphanus sativus (Chinese radish)	4	28	3	32
Solanum tuberosum (potato)	36	411	?	?
Sub-total highland vegetables	**218**	**2145**	**67**	**741**
Total	**677**	**4169**	**263**	**1769**

therewith new earning capacity and employment opportunity. Statistics on vegetable and fruit production are not very reliable because they record, at best, only the planted area and the production of major crops which enter the trade. The many minor crops and the large home garden production cannot be properly estimated. Practices such as mixed cropping, relay cropping, repeated harvesting ('ratooning'), and alternating bearing of fruit trees blurr any estimation of production (Grubben & Siemonsma, 1993). Therefore, the tables 6.1.1.a, b and 6.3.1, showing production data for vegetables and fruits, serve as an indication only for the dimension of plant protection problems.

6.1.2. Factors influencing vegetable and fruit growing. The population development of noxious organisms and the chance that crops become infested is *i.a.* influenced by temperature, humidity, origin of crops, cultivation system, water management, and quality of the planting material.

Indonesia, Malaysia and Thailand have a monsoon-type climate with a high mean temperature and high relative humidity during most of the year. The highlands, which are the traditional areas of commercial vegetable production, are characterized by markedly distinct wet and dry seasons. Many insect pests, such as lepidopterous larvae, cause more damage during the dry months July/August than in the rainy months March/April. In the rainy season, larval mortality is high due to fungal parasites (Eveleens & Vermeulen, 1976; Buurma & Nurmalinda,

Table 6.1.1.b. Mean production (x 1,000 t) of fruits in Indonesia and Thailand in 1986 and 1987, and production in Peninsular Malaysia in the year 1989. Sources: Various, Indonesia; Ministry of Agriculture, Malaysia; Department of Agricultural Extension, Thailand.

Fruits	**Indonesia**	**Malaysia**	**Thailand**
Banana, *Musa* spp	1994	200	572
Cashew nut, *Anacardium occidentale*	68	?	35
Chempedak, *Artocarpus integra*	?	81	23
Citrus, *Citrus* spp	530	10	559
Durian, *Durio zibethinus*	175	299	414
Guava, *Psidium guajava*	?	54	55
Jackfruit, *Artocarpus heterophyllus*	?	23	392
Langsat, *Lansium domesticum*	64	72	101
Mango, *Mangifera indica*	416	25	380
Mangosteen, *Garcinia mangostana*	?	33	67
Papaya, *Carica papaya*	285	12	?
Pineapple, *Ananas comosus*	559	129	?
Rambutan, *Nephelium lappaceum*	146	59	477
Watermelon, *Citrullus lanatus*	?	82	?

1992a,b). Serious fungus diseases such as *Phytophthora infestans* (late blight on potato), *Colletotrichum capsici* (anthracnose fruit rot), *Plasmopara* and *Peronospora* spp (downy mildews), and *Pythium debaryanum* (damping-off) are more prominent in wet periods (Yang, 1989).

Pest and disease pressure is, generally, high in vegetable and fruit crops. This is not only due to the fast reproduction rate of noxious organisms in humid warm weather, but also because most commercially planted highland vegetables were introduced from temperate climate zones in the 20th century. The following factors are involved, *a.* these temperate-type vegetables possess resistance or escape mechanisms well adapted to countering noxious organisms in their area of origin, which generally fail in the new tropical environment (Lim, 1990a). In commercial vegetable farming such failing defence mechanisms were routinely substituted by pesticide applications (Eveleens & Vermeulen, 1976); *b.* if water supply is sufficient, vegetable crops are grown on a year-round basis. This enables a continuous reproduction of pest insects and pathogens. Without adequate rotation, multiple cropping causes a rapid build-up of soil-borne diseases and nematodes; *c.* commercial vegetables are often planted in mono-cultural or simple inter-cropping patterns with poor ecological balance, largely devoid of effective natural enemies. Examples are the large area monocultures of shallot in Brebes, N Java, and Chieng Rai, N Thailand, and of leek in Brastagi, N Sumatera; *d.* several exotic pests have been introduced which may remain uncontrolled for lack of matching parasitoids (Lim, 1990a). An example is the beet army worm (*Spodoptera exigua*); *e.* damaging organisms are easily spread throughout the region because of the lively trade in fresh produce, and in non-disinfected seed and planting material. Implementation of quarantine regulations and fumigation at points of entry is often failing.

The pest and disease pressure in a traditional home garden is relatively low though fruit flies and viruses are ubiquitous. Its mixture of fruit trees, herbs and vegetables provides a more balanced ecosystem conducive to natural enemies. Family members protect valuable fruit by bagging, control pests by hand picking and repellent herbs and weeds by handweeding rather than resorting to chemical control. AVRDC proved in garden experiments in Taiwan, that a non-sprayed kitchen garden of 16 m^2 yields a year-round supply of fresh vegetables for a family of six persons. In Vietnam, kitchen gardens are routinely planted with *Tagetes* spp, which suppress nematodes (Lim & Oudejans, 1991). It is common practice to plant vegetables in open spaces within field crops, on field borders and on bunds along flooded rice fields. Vegetables planted in greater quantity in an extensive rain-dependent production with low use of fertilizer, pesticides and labour, yield a considerable part of the low priced, poor quality produce found in any tropical market (Grubben & Siemonsma, 1993). Little is known about pesticide use in such extensive vegetables production systems. When vegetables are grown close to or amidst heavily sprayed cash crops, the produce may be heavily contaminated (Oudejans & Mumford, 1988).

In commercial farms vegetables are grown under rainfed or irrigated conditions either in permanent production or in rotation with other upland food crops such as maize and soybean. In wet field (*sawah* and deep water rice) systems, vegetables are grown on residual soil moisture during the dry season following wet season rice. The flooding during the rice season largely eliminates soil-borne pests and diseases and suppresses in particular the growth of broadleaf weeds (Grubben & Siemonsma, 1993). But easily dehiscing grassweeds (*Echinochloa crus-galli*, and wild rices), which mimic rice plants, may become very troublesome in crops grown after rice. The sedges (*Cyperus rotundus*, *C. irea*) have become a real problem already since ever more rice fields are turned into permanent vegetable plots (Grubben, pers. comm., 1998).

Many vegetables are grown in inter-cropping systems, often taking the form of relay cropping, in which the growing period of earlier and later planted crops, or of crops with long and short production periods concur. Advantages of relay cropping are, *1.* spreading the risk of crop failure, *2.* more intensive use of scarce land, *3.* protection of crops against some pests and diseases, *4.* higher economic returns from expensive chemical inputs and, *5.* more regular income.

From the view point of plant protection, mixed cropping contains important elements of IPM. Certain combinations of crops lower the risk of insect, fungus or virus infections. For example, tomato repels diamondback moth in cabbage whereas rape (*Brassica campestris* ssp. *oleifera*) is a trap crop for DBM (Sudarwohadi, 1987). An older crop shields a younger crop against sunburn and shades out weed growth. The mixed and relay cropping systems have, however, certain disadvantages, such as hindering crop specific measures as e.g. rotation and solarization for nematode control, and the application of selective pesticides and selective chemical weeding. Generally, intercropping augments the number of factors involved in decision making in an integrated approach. It requires considerable knowledge and skill of the vegetable growers and a high input of (family) labour.

A major obstacle to commercial horticulture is the lack of healthy seed and sufficiently resistant varieties (van der Riet, 1988). Many resistant varieties developed for the temperate climate are not adapted to humid tropical conditions with high night temperatures[2] and do not produce seed. Selection and breeding of resistant vegetable types adapted to the climatic conditions prevailing in SE Asia has yet yielded only few commercially interesting cultivars. But the number of public institutions and private seed companies working on tropical vegetables is rising[3] in response to growing demand (Asian Seed Vol. 1/1:6-7, Vol. 1/6:10, 1994; Groot, 1990). Unfortunately, maintenance of good germinative power of seed and planting material in storage and trade, and protection against infestation are often poor (Groot, 1990; author's observations). Pelleting of seed with fungicides and insecticides offers good prospects but pelleting equipment is hardly available locally.

Seed certification and quality control are receiving too little attention (Zadoks, pers. comm., 1998). In the case of vegetatively propagated crops, the lack of disease-free planting material posed a serious limitation to productivity. Seed potatoes obtained through selection in local potato lines, multiplied during many generations, are often infested by viruses or soil-borne pathogens. The main methods used to control virus diseases are basically those intended to prevent infection (Beukema & Van der Zaag, 1990). Under tropical conditions, the production of virus-free seed potatoes could formerly only be achieved by rigorous roguing and control of vectors (a.o. aphids). Today, laboratory facilities for meristem culture and micropropagation are available in Thailand, Indonesia and Vietnam for the production of virus-free seed stock (Commandeur & Pistorius, 1992; Oudejans, 1996). Tissue culture is also used for virus-free vegetative propagation of onion, leek and garlic (Centerpoint Vol. 13/1, 1995: 6-7) and ornamentals (orchid, *Chrysanthemum*, rose) (MARDI, 1975).

6.1.3. General situation regarding pests, diseases and weeds. Vegetables in general are succulent, nutritious plants which attract all kinds of pests and pathogens. The total assortment of vegetables and field legumes (Grubben & Siemonsma, 1993; Terra, 1966; Saturaya & Grubben, 1995) and their associated key pests and diseases is wide (Lim, 1989, 1990b; Yang, 1989, 1990; Jangi *et al.*, 1991).

The economically most important botanical families of vegetables, such as *Cruciferae* and *Solanaceae,* are attacked by a wide variety of pests and diseases. Among the most destructive pests of crucifers (Chinese cabbage, Chinese kale, head cabbage, cauliflower, leaf mustard, and edible rape) are the diamondback moth (DBM) (*Plutella xylostella*) (Lim, 1988) in highland and lowland areas, and the cabbage webworm (*Hellula undalis*), which causes the forming of multiple heads in cabbage, in the lowlands (Syed & Loke, 1995). Other serious cabbage pests are the beet army worm (*Spodoptera exigua*), flea beetles (*Phyllotreta vittata*), cabbage semiloopers (*Trichoplusia chalcites*) and the cabbage head worm (*Crocidolomia binotalis*) (Sutarya & Grubben, 1995; Ooi *et al.*, 1992). Common diseases of crucifers are Bacterial Soft Rot (*Erwinia carotovora*), Black Rot (*Xanthomonas campestris*), Club Root (*Plasmodiophora brassicae*), Black Leg (*Phoma lingam*), Downy Mildew (*Peronospora parasitica)*, Cabbage Mosaic (turnip mosaic virus TuMV) (Yang, 1989; Praasterink, 1996 a).

Solanaceous crops (potato, tomato, hot pepper, eggplant) are threatened by a range of polyphagous borers, such as the tomato fruit worm (*Helicoverpa armigera*) and beetles (*Epilachna* spp.) Serious diseases are Late Blight (*Phytophthora infestans*) on potato, *P. solani* on tomato, Bacterial Wilt (*Pseudomonas solanacearum*) and viruses such Tomato Mosaic Virus (TMV) (Beukema & Van der Zaag, 1990; Praasterink 1996 b; FAO, 1998b). The worst diseases of hot pepper include anthracnose (*Colletotrichum capsici*) and various viruses (Vos, 1994).

As happened with brown planthopper in rice, certain minor pests of vegetables have become major problems. Thrips, a complex of species with a wide host range affecting *a.o.* tobaco, are difficult to control due to resurgence following development of pesticide resistance and lack of effective parasites and predators. For DBM, cabbage webworm and certain fruit boring caterpillars, effective parasitoids are available (Lim & Di, 1990; Jangi *et al.*, 1991; Talekar, 1991; Jusoh *et al.*, 1992; MARDI, 1992) but their activity is often impaired by wanton application of pesticides. The situation might be aggravated when serious pest and disease problems occur for which no adequate control is available yet. For instance, citrus cultivation on Java suffered heavily from Citrus Vein Phloem Degeneration disease (CVPD) caused by a mycoplasma and transmitted by a psyllid (Eveleens & Vermeulen, 1976).

Weeds constitute a major cost-increasing factor for vegetable and fruit growers.

The major weeds in horticulture are well described[4] for Asia in general and for Indonesia in particular. Although the plots of commercial farms and nurseries are intensively tilled and planted with crops over the greater part of the year, pressure of weed growth is usuallly high. Weeds are controlled by flooding, handweeding, hoeing, or with the help of a powertiller. The placing of vegetative mulch on vegetable beds and around individual plants or trees is a common method of suppressing weed growth, preserving soil moisture and controlling soil erosion by rain and wind. Where labour is scarce and costly, chemical weeding with herbicides is on the increase. An integrated approach to weed control aimed at stabilization of weed populations, depletion of weed seed reserves (seed bank) in the soil, and maintenance of control efficacy has not yet received much attention. Integrated weed management (IWM) striving for sustainable forms of control at low costs (Post & Wijnands, 1993) is still a largely unexplored field for farmers of SE Asia. Presently, IWM practices for tropical horticulture appear to receive most attention from biological farmers practising low-external input sustainable agriculture (LEISA) (Reyntjes *et al.*, 1992). Since IWM and IPM have a number of overlapping strategies (e.g. fermenting of compost to kill pathogens and weed seeds, roguing of weeds which host pest insects, timely burning of debris on the field), messages on integrated weed control could be incorporated in IPM field school training (Lim & Oudejans, 1991).

6.1.4. Pesticide issues in vegetable and fruit farming. From the 1960s on, growers have sprayed heavily with insecticides and fungicides against pests and diseases. Generally, they either preferred inexpensive pesticides with broad-spectrum activity or applied mixtures of several insecticides and fungicides as a safeguard to injury (Eveleens & Vermeulen, 1976; Buurma & Nurmalinda, undated). In commercial vegetable, fruit and flower growing, where any injury or blemish lowers the market value of the produce, preventive application of pesticides is the rule (van der Noll & Savitri, 1989; Jourdain & Rattanasatien, 1995). Insecticides gave good control for reasonable prices. Research is mostly concentrated on pesticide efficacy tests and since researchers were often payed by the industry for registration trials alternative control methods were not sought. In fact, most vegetable farmers believe that it is impossible to grow vegetables without frequent and high dosage applications of pesticides (van Keulen & Schönherr, 1992).

Because the market share of pesticides for vegetables, ornamentals and fruits has been growing rapidly (ch 7), the industry continues to invest heavily in new product development and promotion. Consequently, vegetable farmers are exposed to a stream of information about product performance from commercial sales agents and extension agents, without having the knowledge and means to verify the claims. It was, however, observed in Indonesia and Thailand that farmers rely on a limited number of favoured chemicals[5] applied repeatedly rather than taking risks with new products (Buurma & Nurmalinda, 1992b; Jourdain & Rattanasatien, 1995).

In SE Asia, as elsewhere, researchers in the public and private sector performed innumerable trials since World War II to test and demonstrate the use of pesticides.

Generally, the quality of research is high and recommendations correctly based on findings in well controlled experiments. However, the translation of research findings to the practice of a complicated pest and disease situation in exotic vegetables growing in the humid tropics requires expert extension. Since the latter is lacking and the average grower has a poor understanding of causal agents and of the ways to manage pests and pesticides judiciously, ineffective schedule spraying and product misuse are common practice. Buurma & Nurmalinda (1992a) concluded from a survey of farmers' practices on shallots in Brebes, N Java, that growers do not follow a clear-cut strategy for chemical control. A high pesticide use, involving mixtures of varying composition, was found to increase incidence of armyworm (*Spodoptera* spp) larvae and to lower shallot yields, thus tempting the farmers to spray more often.

Through overreliance on chemical control, genetic resistance against pesticides began to build up in many pests and, in the 1990s, no single chemical gives adequate control of the whole pest complex in vegetables (Soekarna & Kilin, 1988). Farmers respond by increasing dosages and frequency, and by applying mixtures or 'cocktails' of insecticides and fungicides (Talekar,1995; Jourdain & Rattanasatien, 1995; Vos, 1994). The resistance of DBM on cabbage to all major classes of synthetic and biological insecticides is notorious and the direct result of excessive use and poor understanding of pesticide activity (Sudderuddin & Kok, 1978; Lim, 1989; Sinchaisri *et al.*, 1990; Verkerk *et al.*, 1996). Exceptional misuse of insecticides for the control of four *Spodoptera* species[6] occurring simultaneously on shallot and onions in Brebes, C Java, was reported by Talekar (1995).

Throughout the region the trend in insecticide use for vegetables and the resulting resistance pattern has been essentially the same, a shift from early botanicals in the 1930s to organochlorines in the 1940s, then to organophosphates and carbamates, and in the 1970s to pyrethroids (Soekarna & Kilin, 1988). In the 1980s, acylurea insect growth regulators (IGRs), which induce inhibition of chitin synthesis, and insecticides with anti-feeding or repellant effect at sub-lethal dosages were applied against DBM (Tan, 1988). Pheromones, biorational insecticides based on *Bacillus thuringiensis* Berliner (*Bt*) and abamectin proved to be effective against DBM and certain armyworms in Malaysia (Syed, 1992) and elsewhere. *Bt*-resistance in DBM was, however, reported in Taiwan (AVRDC,1996).

IGRs, *Bt*-based products and abamectin were extensively used by farmers in the Cameron Highlands, Malaysia, for their compatibility with parasitoids as control agents (Ooi & Lim, 1989; Loke *et al.*, 1992, 1996). Alarmingly, even against these IGRs and biorational insecticides resistance[7] appeared rapidly after their introduction (Verkerk *et al.*, 1996). As a result, farmers decreased the use of abamectin and *Bt. kurstaki* (*Btk*) leading to increased reliance on *Bt. aizawai (Bta)*. In order to prevent a complete loss of environmentally-compatible insecticides such as *Bta* due to insecticide resistance an Insecticide Resistance Management (IRM) program in Malaysia was proposed in 1996 (Verkerk *et al.*, 1997). Such IRM program for DBM entailed a tentative pesticide alternation scheme[8] on a 'one mode of action per generation' basis. Resistance developed also against fungicides in certain pathogens. For example, in Malaysia resistance against benomyl and carbendazim was demonstrated in an isolate of *Colletotrichum capsici* (Lim, 1989).

Vegetable farmers know little about selectivity of individual pesticides and, generally, do not keep records of production costs and pesticide usage. Few data on actual use patterns are available to identify key features of pest management problems faced by farmers (Heong *et al.*, 1994; Jourdain & Rattanasatien, 1995; Talekar, 1995). Highland cabbage growers sprayed at least two to three times per week against DBM (Lim, 1990b). In E Java, hot pepper and potatoes were sprayed every four to five days, tomatoes were treated weekly and carrots every 20 days. Javanese farmers also tended to overdose in 37%- 64% of the cases examined in surveys in order to achieve a quick knock-down of the pests (van der Noll & Savitri, 1989). Onion and shallot growers in Brebes, N Java, sprayed upto five times a week (Talekar, 1995). A detailed analysis of the socio-economic parameters, planting methods, and fertilizer and pesticide use involved in shallot and hot pepper production in Brebes was made by Buurma & Nurmalinda (1992 a, b; Buurma, undated). In the dry season (9 weeks in May/June 1990), farmers sprayed on average 17 times/season with 2.4 active ingredients per treatment at an expenditure of 250 US$/ha. In the wet season (Jan./Feb. 1991) on average 15 treatments with 1.1 a.i. per spray were made at an expenditure of 50 US$/ha. The survey showed that the farmers of some villages preferred to control army worms (*Spodoptera* spp) by handpicking whereas those in other villages rather sprayed insecticides. But there were also considerable differences in army worm incidence and labour availability between the villages.

The escalating use of pesticides has an ever greater impact on the farmers health (Mustamin, 1988; Kritalugsana, 1988; Cheah & Suratman, 1992; Kishi *et al.*, 1993), on the environment (air and water) (Untung, pers. comm., 1996), and causes an increasing residue problem in produce (Cheah & Suratman, 1992; Rosli & Dzolkhifli, 1996). Growers tend to ignore pesticide residue hazards for consumers, but often do not spray their home garden and family supplies planted on separate plots (Oudejans & Mumford, 1988; various personal communications). Understanding farmers' pest management practices, their perceptions, their constraints to certain options and their objectives is vital to improve poor pest mangement practices (Norton & Mumford, 1993; Whitten, 1996). The examination of the trade-offs between environmental and economic impacts of agricultural policies is crucial in defining an acceptable pesticide policy.

6.1.5. Development of IPM policy in vegetables. Following the 15th session of the Asian and Pacific Plant Protection Convention (APPPC) in 1987, three regional working groups were set up to assist APPPC for *1.* IPM in Vegetables, *2.* Fruit fly, and *3.* Post-entry plant quarantine. In November, 1988, the FAO Regional Office for Asia and the Pacific (RAPA), Bangkok, held an Expert Consultation[9] on IPM in major vegetable crops (FAO/RAPA, 1988). The Consultation concluded that the indiscriminate use of pesticides in vegetables had created the following major problems. Pest resistance against pesticides was increasing. Residue contamination of marketable produce had already led to rejection by importing countries (e.g. Singapore). Intoxication of farmers was serious[10] although little realized by the applicators themselves and not publicly admitted. Costs of vegetable production continued to escalate due to higher losses and more work notwithstanding increasing use of pesticides[11] (Lim, 1988; FAO/RAPA, 1988). Wide gaps existed in yields obtained by farmers and experiment stations. Singh (1990) pointed at the acute shortage of extension staff[12] specifically trained in vegetable production. To break the pesticide deadlock, the development and application of an adequate IPM approach was deemed necessary for the sector as a whole and for individual vegetable crops. In particular were needed suitable IPM components, adequate local research and expertise, effective extension infrastructures, public commitment and funding support from governments and donors. In all SE Asian countries some IPM activities in vegetable and fruit were on-going, but implementation of IPM technology differed greatly (FAO/RAPA, 1988, Lim & Di, 1990). Available information was scattered over different organizations, collaboration was lacking and efforts were sometimes duplicated. The necessary collaboration between separate government institutions responsible for research and extension could only be enforced by National IPM Steering Committees. Information on many aspects of social economics of vegetable IPM was seriously lacking and public awareness of pesticide residues hazards had received scant attention (Lim & Oudejans, 1991).

Hence, the Expert Consultation on IPM strongly recommended that FAO should formulate a regional project for IPM in vegetables similar to the model of the FAO Intercountry IPM in Rice Programme in S and SE Asia. An analogous FAO Intercountry IPM in Vegetables Programme should stimulate and support national and regional institutions to develop national IPM projects in selected vegetable production systems on the basis of available expertise.

The need for a regional programme on IPM for vegetables in SE Asia was expressed again at the Fourteenth Session of the FAO/UNEP Panel of Experts on Integrated Pest Control in Rome, October, 1989, at the Regional Workshop on Pest Management in Vegetables, October 1990, Cameron Highlands, and at the Conference on IPM in the Asia-Pacific Region, 23-27 September, 1991, Kuala Lumpur. In November, 1990, a joint FAO/Netherlands identification mission was fielded to five countries[13] of SE Asia with the objective to design a Plan of Operation for a FAO Inter-country Programme for the Development and Application of Integrated Pest Management in Vegetables in SE Asia (Lim & Oudejans, 1991). The FAO ICP-IPM in Vegetables Programme began in January, 1995, in four countries: Bangladesh, Laos, the Philippines, and Vietnam. The Netherlands, as the major donor, contributed 4.14 M US$ for a period of four years (FAO, 1995). Indonesia joined the FAO ICP-IPM Vegetables programme in 1998, when Australia provided funding.

The FAO has not yet launched a separate Inter-Country initiative for IPM in fruits or flowers in S and SE Asia. Thailand executed, however, a joint Thai-German IPM Program for fruit trees since 1992 (ch 6.4.2).

6.1.6. Regional institutional capacity for IPM development. Several international research agencies have acquired a long time expertise in the field of tropical agronomy, entomology, phytopathology and other subjects of relevance for the development of IPM programs in food and fiber crops. The following agencies are currently involved in IPM development in SE Asia.

a. Asian Vegetable Research and Development Center (AVRDC). AVRDC operates from its headquarters in Taiwan, from an outreach program at Kasetsart University, Bangkok, and from a research station at Chiang Mai, Thailand. Since 1971, AVRDC has contributed to the improvement of tropical vegetable production. Its program includes preservation of genetic resources, selection and breeding for productivity, heat tolerance and resistance to a broad spectrum of pests and diseases, screening of viruses, tissue culture technique and biological control studies (AVRDC, 1996; Talekar, 1995). AVRDC participated in biotechnological research on the production of disease-free seed, insertion of *Bt* genes for DBM resistance in crucifers, methodology for detection and genetic mapping of viruses of tomato and hot pepper, and the breeding for resistance against tomato fruit worm and nematodes. Relevant achievements were *i.a.* the breeding of heat-resistant tomato cultivars, which were widely adopted in sub-tropical China, and the development of IPM recommendations for DBM and other cabbage pests, for the use of parasitoids, predators, sex pheromones, NPV virus and biologicals on the basis of *Bt*. By 1990, AVRDC established AVNET-I, an IPM research network for DBM, which included Thailand, Malaysia, Indonesia and the Philippines. AVRDC assisted the countries in SE Asia with IPM training, funding of parasite mass rearing facilities, and the undertaking of pilot projects. In 1993, AVRDC initiated AVNET-II, a collaborative Vegetable Research Program for SE Asia, with financial support from the Asian Development Bank (ADB). Besides AVRDC's annual reports, no evaluation reports were found showing the rate of adoption of improved vegetable cultivars issued by AVRDC and its impact with farmers in SE Asia.

b. CABI Bioscience (CB). The institution was formerly called International Institute of Biological Control (IIBC). CB promotes the biological means of pest control and their integration into sustainable pest management systems through cooperative research, training and information. CB is an institute of CAB International, UK, which is an intergovernmental organization providing services on behalf of more than 30 member countries to agriculture, forestry, human health and the conservation of national resources. The roots of the Commmenwealth Agricultural Bureaux (CAB) are the Imperial Bureau of Entomology (since 1911) and Imperial Bureau of Mycology (since 1920), the clearing houses for research and information on pests and diseases of tropical agriculture in Asia and Africa (Scrivenor, undated).

The FAO ICP-IPM for Vegetables Programme subcontracted research on IPM components for vegetables to CB. The regional office of CB in SE Asia, located at the Malaysian Agricultural Research and Development Institute (MARDI), Serdang, in Malaysia, developed and tested training exercises for vegetable IPM (for cabbage, hot pepper, tomato and other vegetables) for use in farmer field schools organized by the FAO Inter-Country ICP-IPM Rice (Vos, pers. comm., 1998).

c. International Potato Centre (CIP). The International Potato Research Centre (CIP, Peru) assisted the Biotechnology Centre (BC) at the National Centre of Scientific Research, Hanoi, in the development of techniques for tissue culture and regeneration of disease-free potato seeds. Under a joint project BC-CIP tested over 7,000 genetically different potato plants from some 100 varieties (Commandeur & Pistorius, 1992). Through micropropagation and *in vitro* techniques good results were achieved in particular for resistance against late blight (*P. infestans*) and for increase of yield. The expertise was made available to national IPM programmes in SE Asia.

In a joint undertaking with Indonesian partners[14], CIP and UPWARD jointly initiated, in 1994, a participatory project to develop Integrated Crop Management (ICM) technologies for sweet potato. During phase I, 1994-1997, CIP developed the ICM technology and extension approaches dealing largely with cultivar selection, fertilisation and pest management. In project phase II, the Indonesian National IPM Program and local NGOs extend the ICM message through Training of Trainers (TOT) and Farmer Field School (FFS) sessions (van de Fliert *et al.*, 1995, 1996; van de Fliert, 1997).

d. Asian Institute for Technology (AIT). In the 1980s, the Asian Institute for Technology, Bangkok, through its Department of Agricultural Economics, contributed to the understanding of the influence of pesticide subsidies and externalities of pesticide use in SE Asia (Waibel, 1990a,b). Field trials were performed at AIT concerning the repellent effect on DBM and other pests of certain herbs such as sweet basil (*Ocimum basilicum*), citronella (*Cymbopogon nardus*) planted as border crops around cabbage plots (Bender, pers. comm., 1990). The trials had no follow up and no impact.

e. International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), India. The institute has a mandate for the improvement of pulses (grain legumes). Pulses are often grown in rotation with rice together with lowland vegetables for domestic consumption. Thus, IPM recommendations for popular grain legumes, such as groundnut, deserve attention.

f. National Biological Control Research Center (NBCRC), Thailand. Although a national institution, the NCCRC has a regional significance as a Natural Enemies Reference Depository (NERD) and because of its expertise in identification, rearing and management of biological control agents (Napompeth, 1998). The NBCRC was established in 1975 by Thai government departments, universities and agencies dealing with agriculture, livestock, fisheries and forestry as a joint network organization. The Kasetsart University (KU) at Bangkhen, Bangkok, manages the NBCRC, in collaboration with the National Research Council of Thailand, on a yearly budget of about 850,000 US$. The NBCRC operates a headquarter with laboratories, quarantine facilities, and depository at Bangkhen Campus of Kasetsart University, four regional centers and several stations. Important achievements included the introduction of predacious snails to control the giant African snail, various specious of predatory and herbivorous insects to control insect pests and (water)weeds in Thailand, and assistance to biological control programs in Asia, S America and S Africa (NBCRC, 1997).

6.1.7. Development of IPM components. Any IPM program approach requires an early survey of the state of the art concerning knowledge of and expertise with the crops concerned, the problems needing attention, the availability of healthy and resistant seed and planting material, and an appraisal of possible options (Napompeth, 1998). Major problems in vegetable cultivation, in need of IPM solutions, are caused by fruit borers in tomato and eggplant, Late Blight and Bacterial Wilt in potato and tomato, DBM and Club Root in cole crops, viruses in potato and hot pepper, anthracnose in hot pepper, armyworms in *Allium* spp, and alternaria in lowland tomato and *Allium* (Lim, 1987; Yang, 1989; Loke & Abdul Aziz, 1992; Grubben, pers. comm., 1998).

Numerous bits and pieces of information are already available and are being brought together by ongoing national (in Indonesia and Vietnam) and international IPM-programs (e.g. by CABI Bioscience, AVRDC and FAO ICP-IPM in vegetables). To facilitate practical extension, research findings and expertise are bundled into training excercises and pre-tested to suit the general conditions of a Farmer Field School (Praasterink, 1996a,b). Farmers are encouraged to develop their own field experiments to clarify ecological processes in the field (Vos, pers. comm., 1998).

6.1.8. Seed and planting material, and quarantine. The use of improved commercial seed and rootstock is rapidly increasing in SE Asia, particularly by commercial vegetable and flower growers. Nevertheless, a large part of the marketed vegetables is grown from seeds or planting materials of local cultivars, landraces or farmers' selections. This is particularly the case for self-pollinated crops (tomato) which propagate true to type, and of vegetatively propagated crops (shallot, garlic, leek, potato). It is more difficult for farmers to select good seed from cross-pollinating plants (cucumber, hot pepper) with segregating characteristics. Farmer selected seeds often carry seed-borne diseases (anthracnose, *Alternaria*, bacterial diseases, viruses) (Vos & Duriat, 1995). The supply of improved disease-free cultivars is still limited and a well organized local seed industry is only just emerging (Groot, 1988; Asian Seed, 1994; Grubben, pers. comm., 1998). Ever more professional growers recognize the advantages of using high-priced quality seed. Demand for quality seed, in a reciprocal cause and effect relationship, stimulates further investment in public and private seed industry and official regulation.

Regulation and implementation of strict quarantine as a prevention of entry or spread of noxious pests and diseases is economically a most effective measure. Clubroot (*Plasmodiophora brassicae*), the worst disease[15] of cruciferous crops, entered SE Asia probably by the mid-1970s (Suhardi *et al.*, 1976; Yang, 1989). *Liriomyza huidobrensis*, a serious leafminer pest of egg plant (*Solanum melongena*) in Bangladesh and Vietnam, has recently entered Indonesia (Whitten, 1998) and threatens potato, tomato, yardlong bean, and cucurbit vegetables, and *Chrysanthemum*. Cabbage fly (*Delia brassicae)* and carrot root fly (*Psila rosae*) have not yet been detected in SE Asia (Grubben, pers. comm., 1998). Demanding political attention for the strengthening of regional and national quarantine services is obviously an important task of National IPM Steering Committees. At the producer level, seed disinfection, isolation of the crop, and keeping diseased or infested propagation material out of the farming area, are useful cultural methods.

6.1.9. Cultural, biological and chemical control. In general, farmers have great skills in cultural methods which help to prevent or remedy pest situations, even if they do not understand the causal relations. Crop rotation has a strong potential for the prevention of population build-up of pests and soil-borne diseases in temperate climates. A similar effect might be expected from rotating wet rice with tomato or hot pepper in the tropics as inundation kills soil-borne organisms, but no documented proof was found. The slime disease (*Pseudomonas solanacearum*) of Deli tobacco was managed by destruction of infected seed beds and a rotation of one season Deli tobacco, two seasons of wet rice and a five years fallow (Honing, 1910). The beneficial effect of crop rotation on upland fields is claimed for crucifers, cucurbits and beans (Grubben & Siemonsma, 1993). Inter-cropping and mixed cropping of vegetables and other crops resulted for hot pepper-maize in a reduction of aphids and virus infestation on hot pepper, for tomato and garlic-cabbage in a lower DBM infestation, and for chinese cabbage-garlic or allium intercrop in a lower infestation of soft rot (*Erwinia* spp.). Mulching with rice straw or plastic improves crop performance in general, and suppresses weed growth (Ding *et al.*, 1981). White and silvery plastic mulches reduce thrips injury (*Thrips parvispinus* Karny) and delays virus epidemics in hot pepper (Vos & Sumarui, 1997).

Use of plastic cover to shield seedlings from rain is common in highland nurseries. Few farmers practice removal (roguing) of host plants, or plant repellent herbs or catch crops. They are ignorant about or cannot afford to use blue light traps for detecting and monitoring moths, nor yellow sticky traps for aphids and thrips. Fine-mesh nylon netting as a physical barrier for aphids and aphid-transmitted viruses and other insects is rarely seen, with the exception of high investment flower nurseries (Vos & Nurtika, 1995). Protected vegetable growing was tried by several farmers near Bangkok in the early 1990s with a subsidy of DOAE. However, farmers found the unsubsidized costs prohibitive, whilst the polyphenyl material was not resistant to UV-light and degraded within one year (personal communications with growers, 1991). Intensive use of plastic in agriculture for sheltering protected crops, mulching, and protective sleeving of fruits (banana, durian) creates an environmental problem.

Much experience exists with the pesticide industry and with public and private research institutions on the efficacy of pesticides in horticulture. Major companies operate research stations in SE Asia, particularly in highland vegetable areas, to experiment with narrow spectrum products *in situ*. The means and knowledge for proper application of pesticides against several important pests and diseases in horticulture are available at the institutional level. For practical and commercial reasons, however, the growers receive at best only part of the available information. Horticultural education and extension on pest control and pesticide use are generally deficient. All the parties involved, producers and users of pesticides, regulatory institutions and consumers, are confronted with the problem of pesticide resistance, residues, intoxication and other externalities. Since pesticide use is particularly high in horticulture, the search for alternatives of chemical control has been ongoing since the 1960s.

In SE Asia, the knowledge base for biological control through parasitoids[16] is available for a few pests of crucifers such as DBM and of solanaceous crops through the AVRDC/AVNET network, for potato and sweetpotato through the CIP-network. Considerable expertise on potential IPM components in hot pepper was obtained through joint research of Dutch, Indonesian (LEHRI) and Malaysian (MARDI) researchers (Vos, 1994; Vos & Nurtika, 1995; Sivapragasam & Lee, 1996). A number of predators of vegetable pests, such as spiders, coccinellid beetles, pentatomid bugs, mites, and dragonflies, were identified (Shephard *et al.*, 1987; van Vreden & Ahmadzabidi, 1986; Lim, 1989). Neering (1988) studied the pests and diseases and their natural enemies of *palawija* crops, in particular of soybean and groundnut. But in general, knowledge concerning use of parasitoids, predators, micro-organisms, sources of natural resistance, and cultural methods is still limited (Lim *et al.*, 1990; Napompeth, 1998). Moreover, the effectiveness of indigenous as well as of some introduced parasitoids, which became established, is often jeopardized by farmers who continue to apply pesticides indiscriminately (Oudejans, 1996; Neering, 1997).

Microbial agents or biopesticides have been used since the late 1970s to control larval stages of moths, beetles and flies. Vegetable farmers spray spore suspensions of *Bacillus thuringiensis* Berliner (*Bt*)[17] to control DBM and army worms (Jangi *et al.*, 1991). *Bt*-products selectively kill larval pests through endotoxin activity, but not the beneficial parasitoids and predators. *Bt*-based products, such as DiPel[R] and XenTari[R], are used in conjunction with selective synthetics such as imidacloprid, or with insect growth regulators (IGRs) to avoid pesticide resistance problems (Quick *et al.*, 1996). In experiments in Thailand, nucleopolyhydrosis viruses (NPV) gave effective control of beet army worm on onion and tomato fruit borer on tomato, whereas the fungal agent *Verticillium lecanii* was used for the control of white fly (a.o. *Bemisia tabaci*) and aphids. In Vietnam and Malaysia, the parasitic fungi *Entomophthora sphaerosperma* and *Beauveria bassiana* were used to control DBM. Natural insecticides, such as neem (*Azadirachta indica*) extracts were employed against DBM on Chinese kale and cabbage (Lim, 1990a). Besides *Bt* products and abamectin, no other biopesticides are used by farmers on a large scale.

6.1.10. Discussion. The preparation of 'technological IPM packages' for vegetables is essentially a *contradictio in terminis*. The current idea about IPM is that it is not a matter of packaging and delivering a set of cultivation and control guidelines adapted to particular crops. The modern point of view is to develop the farmer's capacity to recognise symptoms of disturbed crop growth in the context of his specific field situation, the cultivation practices he uses, and the stage of crop development (Eveleens, pers. comm., 1998; Whitten, 1998), and to let the farmer integrate new information with his own traditional knowledge and experience of growing vegetables on his own plot. Training handbooks, exercises, posters, all are useful instruments to improve the farmer's awareness and knowledge of pest characteristics and control possibilities. The Farmer Field School (FFS) is an adequate approach to motivate and enable farmers to discover the ecological intricacies of the triangle 'crop, pests and treatment' (Matteson, 1992; van de Fliert *et al.*, 1995, 1996). Experience has shown that, particularly in demanding crops such as vegetables, the combination of good instruction material and extension approach (FFS) does not suffice. The IPM-trained farmer still needs to be guided in the control of major pests (Teunissen, pers. comm., 1998). In the Netherlands during the 1980's, 'guided' or 'supervised control' of caterpillars in cabbage was developed on the basis of relating the percentage of injury inflicted to the stage of crop growth as indicator for the appropriate control method and timing (Theunissen & Sins, 1984; Theunissen & den Ouden, 1985, 1987). European researchers developed modules for monitoring, action threshold levels for acceptable injury at recognizable growth stages, and taking of decisions on biological and chemical control measures in field vegetables, wheat (EPIPRE system, Zadoks, 1989), potatoes, sugarbeet. Supervised control is particularly advanced in protected horticulture in the Netherlands, where over 50%-99% of the production of tomatoes, bell peppers (*Capsicum* spp) and cucurbits is obtained with biological control and host-plant resistance against pests and diseases (van Lenteren, 1986, 1995). Recognition of the growth stages in a vegetable crop is more difficult than in rice, where FAO-ICP's advice of no-spraying during 40 days after transplanting creates no misunderstanding. The development of a guided control technology, with levels of acceptable injury as criterion, is necessary for critical problem areas, such as army worm in *Allium*, DBM in cabbage, and *Phytophthora* and bacterial wilt in potatoes and tomatoes. Transformation of monitoring data of injury observations and pest densities into simplified control recommendations is beyond the capacity of the farmers. Rather, it would be a task for the FAO ICP-IPM for Vegetables Programme in collaboration with National IPM program and regional institutions.

Since vegetables are often a rotational crop for rice farmers and since vegetable farmers grow a variety of crops, a vegetable IPM training and FFS exercise should be of flexible design and the trainers be knowledgeable about a considerable range of possible problems and control options.

In the field situation, where farmers do not accept risks of crop failure, the use of synthetic pesticides, in particular fungicides, may be required. The key of the IPM extension in rice in SE Asia was to make farmers knowledgeable about the pest controlling power of natural enemies through keen observation of insect behaviour in the vegetable crop (ecosystem analysis exercises). Thus, in rice the message was to refrain from using insecticides. While in rice the approach is on 'informed non-intervention', the strategy in vegetables is one of 'informed intervention' (Whitten, 1996).

If biological control, involving release of natural enemies, plays an important role, a community-wise undertaking of the IPM activities need to be stressed, least contaminating control methods -such as use of pesticides in a densily occupied area- may undo the efforts of the IPM farmers (van Huis & Buurma, 1998). In biological control studies, the starting point should be a no-spray situation and not a reduction in pesticide use, in order to detect the potential of the natural enemy of biochemical agent (van Huis & Buurma, 1998). In protected horticulture, this approach has paid off well.

As spraying of IGRs, biological and IPM compatible synthetic pesticides may be needed in the unprotected field, it is sensible to include judicious instruction on application equipment and IPM compatible, selective pesticide use in vegetable crops. The Indonesian-Dutch LEHRI project (ch 6.2.2), 1987-92, included research on the use of T-jet spray nozzles for popular types of knapsack sprayer in vegetables in Indonesia (Stallen & Lumkes, 1990). The LEHRI recommendations for IPM in *a.o.* shallot, tomato and yardlong bean, include advice on systemic fungicides, biological insecticides and IGRs (Sutiadi *et al.*, 1994). To-date, the T-jet nozzle, having suitable droplet distribution characteristics for vegetable spraying, is for sale in retail stores on Java (Grubben, pers. comm., 1998).

6.2. Vegetables and fruits in Indonesia after 1950

6.2.1 Introduction. In Indonesia around 1975, the horticultural sector provided almost the same share (13%) to the GDP as rice and a larger share than estate agriculture (Eveleens & Vermeulen, 1976). Table 6.1.1 gives indicative production data on the major lowland and highland vegetables in Indonesia in the late 1980s. Records on hectareage planted and quantity produced nationally and by province are kept by the Central Bureau of Statistics, Jakarta, for some 20 major vegetables and 18 fruit species. Detailed data *i.a.* on yield levels for vegetables and fruits, number of fruit trees amd marketing channels for 1982-85 were reported by van der Riet (1988).

The highlands of Java and Sumatera are the traditional centers of commercial vegetable production in Indonesia. Highland vegetables are, in particular, planted in the areas of Puncak, Sukabumi, Priangan and Pekalongan for the urban centres of Jakarta and Bandung (W Java), at Diem for Yogyakarta and Semarang (C Java), and at Tretes and Batu for Malang and Surabaya (E Java). The highlands of Brastagi[18] and Seribudolog, Karo, supply the markets of Medan (N Sumatera), Penang and Kuala Lumpur (Malaysia), and Singapore. Large concentrated areas of commercial vegetable production have developed in the lowlands, usually in the vicinity of big cities. Cultivation of hot pepper and shallot is concentrated in Tegal-Brebes, C Java. Farmers in the lowlands plant *palawija* crops and vegetables in rotation with rice.

The production of fruits in Indonesia is shown in table 6.1.1.b. The production of banana is almost four times bigger than in Thailand and of citrus about equal. However, no data were found on IPM initiatives for fruits.

6.2.2. Development of horticultural research. In Indonesia after 1950, horticultural research was the responsibility of the Horticultural Research Institute (HRI) at Pasarminggu, Jakarta. Since the mid-1960s, several joint Indonesian-Netherlands programs were undertaken to strengthen horticultural research and to upgrade of staff[19] and facilities. The first joint project (ACP-4), 1968-74, entailed a broad approach for rehabilitation and capacity development of the Horticultural

Research Institute at Pasarminggu. The second project (ATA 111), 1974-77, prioritized research on the highland vegetables cabbage, potato and tomato. Attention was given to pest management and improvement of seed stock through selection and introductions, seed multiplication and upgrading of seed technology (Wessel, 1977). The facilities were expanded with a virology and nematology laboratory at Segunung Experimental Garden, W Java. The seed improvement program[20] was based at Margahayu, a HRI branch station for W Java, where a laboratory for seed testing and storage was set up. In 1975, surveys of 35 major weeds in highland vegetables and weed control experiments were included in the project (Wessel, 1977; Everaarts, 1981).

In the 1970s, the development in horticulture was guided from the Central Research Institute for Horticulture (CRIH) at Lembang, W Java, and at its branch station Segunung, W Java. In 1984, a Horticultural Research Institute for Fruits was established at Solok, near Padang, W Sumatera. Research at Solok is directed at seed production, vegetative propagation techniques and disease control in tree crops. Research on non-rice food crops (*palawija*) was the responsibility of the Malang Research Centre for Food Crops (MARIF), renamed as Research Institute for Legumes and Tuber Crops (RILET), E Java. The latter institute is also engaged in rice research for E Java, Bali and Nusa Tenggara. RILET's priorities include variety improvement and IPM for the major grain legumes soy bean, groundnut and mungbean (Neering, 1988).

A third Indonesia-Netherlands program (ATA-395), implemented at the Lembang Horticultural Research Institute (LEHRI), W Java from 1987-92, had as main objective to strengthen research on lowland vegetables in Indonesia. Its further objectives included the upgrading of LEHRI's research management and laboratory services. Achievements included the establishment of data banks on vegetable production, the pest and disease complex of lowland vegetables and on agro-chemicals use, collection of local germplasm for major lowland vegetables of Indonesia, breeding of shallot and cucumber, development of an experimental garden for lowland vegetables at Kramat, near Tegal, N Java, improved management of LEHRI's experimental gardens, and improved communication with Agricultural Research and Extension Services (LEHRI, 1991). Cooperation with the extension service was essential for the execution of an additional 'On-farm Client-oriented Research' (OFCOR) project in shallots in the Brebes district, N Java, in 1990. (Buurma & Nurmalinda, 1992a, b).

The three joint projects achieved worthwhile results in the form of scientific publications by Indonesian and Dutch staff on pests and diseases of vegetables, on efficient natural enemies and on recommendations for use of fertilizer and pesticides in integrated crop production. The lasting effect of the projects in terms of improved research management and expertise of the Indonesian staff cannot be judged by the author. There is no evidence of a wide adoption of the project's recommendations by the Indonesian vegetable growers in the surroundings of Lembang, W Java. The OFCOR project activities in Tegal-Brebes, C Java, were continued. In 1997, LEHRI researchers performed trials on 50 ha of shallot and hot pepper with the participation of 200 farmers. The problems had, however, worsened since 1992. Rice disappeared more and more from the rotation cycle while monoculture of shallot and hot pepper increased on an ever larger hectareage (Grubben, pers. comm., 1998). Meanwhile, the pest situation, pesticide resistance and pesticide misuse in shallot was described as alarming (Talekar, 1995).

In 1994, Indonesia and the Netherlands signed an agreement on a Joint Cooperative Research Programme on Biotechnology, Plant Breeding and Seed technology for Horticulture (BIOBREES). The collaboration between the Central Research Institute for Horticulture (CRIH-AARD) and the Dutch Centre for Plant Breeding and Reproduction Research (CPRO-DLV) began on July 1, 1994 (Grubben, 1997). The objectives included *1.* transfer of knowledge to AARD on biotechnology for improvement of practical plant breeding and quality research of planting material, *2.* production of plant breeding material with resistance against diseases and pests, *3.* training of young Indonesian and Dutch researchers in biotechnological research and advanced plant breeding, *4.* stimulation of active participation by private companies in the Netherlands and Indonesia.

The research projects on vegetables and ornamentals under BIOBREES phase I (1994-98) included several crops. *a.* Hot pepper, improvement of resistance against Anthracnose (*Colletotrichum* spp), b. Shallot, breeding for resistance to Purple Blotch (*Alternaria porri*), Anthracnose and beet armyworm (*Spodoptera exigua*). *3.* Flower plants, breeding of resistant outdoor cut rose cultivars for the highlands in Indonesia, and breeding chrysanthemum and gladiolus for disease resistance and daylength adaptation.

A first result was the introduction of improved BIOBREES cultivars of rose and chrysanthemum on the market in 1998 by the Indonesian Institute for Ornamental Plant Research in cooperation with CPRO-DLO and Indonesian companies (Grubben, 1997). The BIOBREES program is funded by the Dutch Ministry of Agriculture with a contribution of 1,8 M $ (3.6 M DFL) for four years (phase 1) and a matching counterpart funding by Indonesia. The program was extended in 1998 for four more years (phase 2, 1998-2002) with equal conditions for funding.

6.2.3. Institutionalization of IPM for vegetables. In the late 1980s, when the effect of INPRES 3/86 became visible and IPM training in rice accelerated (ch 5.7.4), Indonesian agricultural administrators began to express their interest for including vegetables in the IPM Rice training curriculum. The FAO-ICP Programme's designation was widened correspondingly to 'IPM for Rice-based Cropping Systems'. The project proposal for 'FAO ICP IPM in Rice for S and SE Asia, phase III', explicitly mentioned inclusion of vegetables (FAO, 1992a). In 1996, the Indonesian National IPM Program conducted 649 FFS training events in non-rice commodities (soybean, potatoes, cabbage, hot pepper and shallots) with some 16,225 IPM graduates from these vegetable FFSs. In the same year, the National Program conducted 5,122 FFSs in rice by IPM Field Trainers and 2,617 FFSs by Farmer IPM trainers (FAO ICPV, 1998). By 1998, the number of Indonesian farmers who graduated from a season-long FFS was estimated at around one million, of which about 17,000 became farmer-trainer (FAO ICPV, 1998). The expansion of the IPM movement from rice to vegetables in Indonesia ran parallel to similar developments of the ICP Programme in Vietnam and the Philippines. (FAO, 1995a,b)

Indonesia joined the FAO ICP-IPM for Vegetables Programme in 1998, when Australia accepted to provide the funds. The action plan identified three activities for initial support. *1.* Action research facility in W Sumatera. The project comprised field studies in Solok district, W Sumatera, designed to isolate, produce and apply suitable biological pathogens (viruses, bacteria, fungi and nematodes) that can be used by vegetable farmers to reduce dependency on imported pesticides. Farmer training in the production, testing and distribution of bio-pesticides takes place through 27 village biocontrol posts. *2.* Vegetable IPM activites in Brebes, which aim to strengthen action regarding conservation of natural enemies and development and production on biopesticides for use on, in particular, shallot, hot pepper and rice. *3.* Operation of a Biotechnology Research Center at Bogor. The facility, comprising a laboratory and quarantine rooms, upgraded by the Clemson University *Palawija* IPM Program, is used to receive, rear and release imported natural enemies of the recently introduced leafminer *Liriomyza huidobrensis*. The Bogor facility will also function as expertise and support centre for activities 1 and 2 (Whitten, 1998).

6.2.4. Achievements of IPM for vegetables in Indonesia. The most consistent research efforts were directed at the control of diamondback moth (DBM) in cabbage and at the Integrated Crop Management (ICM) of hot pepper.

6.2.4.1. Integrated control of diamondback moth. Since DBM is the worst pest of Indonesia's 70,000 ha of head cabbage and Chinese cabbage (*caisin*) crops the search for its natural enemies began early. Surveys held in the centres of cabbage growing in Java, Bali, Sumatera and Sulawesi during 1971-76 and 1981-83, showed that *Diadegma eucerophaga*, a parasitoid of DBM introduced into Indonesia by H.C.A. Vos from New Zealand in 1953, had established itself in highland areas of W Java, C Java, Bali and W Sumatera, but not in N Sumatera and Sulawesi (Sudarwohadi & Eveleens, 1977; Lim, 1990a). In the late 1970s, *D. eucerophaga* could be established in N Sumatera too when the selective microbial *B. thuringiensis* was used to control DBM instead of synthetic insecticides (Sastrosiswojo & Sastrohardjo, 1986). The parasitoid *Cotesia plutella* was introduced in cabbage grown at mid-level altitudes where *D. eucerophaga* does not survive (Talekar, 1991). The feasibility of IPM was studied at Margahayu Experiment Station, LEHRI, Lembang, from 1983 till 1986. The increasing insecticide resistance in DBM strains, resurgence of DBM and high pesticide residue levels in harvested cabbages prompted this study. It was found that *a.* chlorfluazaron and *Bt* ssp *kurstaki* (Dipel^R, Bactospeine^R and Thuricide^R) selectively killed DBM larvae, but not *D. eucerophaga*; *b.* the economic threshold level for DBM was 0.3 larva/plant; *c.* female DBM moths prefered rape (*Brassica campestris* ssp. *oleifera*) for oviposition which made rape a suitable trap crop in DBM management; *d.* male DBM moths could be controlled by the pheromone PX^R (Sudarwohadi, 1987).

6.2.4.2. Integrated crop management (ICM) in hot pepper. Pest control *Capsicum annuum* (hot pepper) and *C. frutescens* (bird pepper), the most important lowland crops in Indonesia, Malaysia and Thailand in terms of hectareage and production, received much attention under the project ATA-395. The study of hot pepper[21] covered several aspects of integrated crop management, such as a survey of farmers practices and problems, field trials on plant raising techniques, mulching and fertilisation to investigate their effects on crop health (Vos, 1993; Vos & Nurtika, 1995; Vos & Duriat, 1995). Plastic and alumina foil mulching repelled thrips (*T. parvispinus*), aphids and whiteflies and thereby reduced virus transmission and infection (Vos & Sumarni, 1997). Anthracnose, caused by the pathogens *Colletotrichum capsici* and *C. gloeosporioides*, on ripening hot pepper fruits could be best controlled by sanitary measures which minimize the source of inoculum.

6.2.5. IPM efforts of international and local NGOs. In Indonesia, some institutions and NGOs, among other objectives, also address the issue of IPM. For instance, the International Potato Institute (CIP) assists local NGOs (e.g. Mitra Tani) on IPM in sweet potatoes (ch 6.1.6) (Van de Fliert *et al.*, 1996, 1995). Several international institutions, such as 'Care' and 'Save the Children', and local NGOs have adopted the Farmer Field School method of agricultural extension developed by the FAO ICP-IPM in Rice Programme. The US-based NGO 'World Education' assists local NGOs with the organisation and implementation of IPM Farmer Field Schools in N Sumatera (Oudejans, 1996). DOA research institutes reportedly collaborate with local and international NGOs in the collection of information on research needs at farmer level and in extension of research findings. In N Sumatera, NGOs are recognized by provincial and district level administrators and agronomists as useful initiators and stimulators of activities, though no subsidies are provided. 'World Education' and CIP received full collaboration from the Lembang Research Institute for Vegetables (LEHRI) for the organization of training on monitoring and diagnosing potato viruses[22] in Brastagi, N Sumatera, 1995 (Chujoy, 1995). No independent evaluation data were found on the impact of NGO activities.

NGOs which try to raise public concern about lax pesticide policy, residue levels in market produce and the environment have difficulty to conform with government control. The Pesticide Action Network (PAN) Branch in Indonesia rather limited its attention concerning pesticide issues in order to be allowed to address less controversial environmental issues (PAN-office, Jakarta, pers. comm., 1996).

6.3. Vegetables, fruits and flowers in Malaysia after 1950

6.3.1. Introduction. In Malaysia, some 50 types of vegetables are grown commercially for domestic consumption and export (Ding *et al.*, 1981). The Cameron Highlands, Pahang State, is the main production centre for temperate vegetables. Selangor and Johor Baru are supply centres of lowland vegetables for Kuala Lumpur and Singapore. Further production of lowland vegetables is scattered over the coastal plains. Table 6.3.1 shows the production of vegetables of Peninsular Malaysia for 1990. The production of Saba was estimated at 50,000 t, whereas no data were available for Sarawak (Malaysia Agricultural Index 1993/94:108). The figures for 1990 on the trade in vegetable produce showed an import of 304,282 t valued at 99 M US$ against an export of 240,064 t valued at 27 M US$. Expensive (highland) vegetables are exported to Singapore mainly, whilst shortages are increasingly compensated through imports of cheaper vegetables from N Sumatera and Thailand.

The production of fruits in Peninsular Malaysia is shown in table 6.1.1.b In 1989, Malaysia exported 378,756 t of fresh fruits, valued at 47 US$, mainly to Singapore and Hong Kong. Temperate fruits such as grapes and apples, are imported from Thailand, Taiwan and Australia. The fact that Malaysia remained a net importer of vegetables to the tune of 72 M US$ and had a sizable shortage of fruits inspired the government to pursue expansion of vegetable and fruit production even at the expense of the rice hectareage. No information was found about IPM initiatives in the fruit sector.

Floriculture started in Malaysia in the 1960s with the production of orchids for cut flowers. In 1991, there were 1,286 ha under floriculture. Centres are in Cameron Highlands for temperate flowers such as roses and chrysanthemum, and in Johor Baru and Selangor for lowland flowers, mainly orchids and ornamental potted and garden plants. Flower production increased rapidly in value from 3.2 M US$ in 1986 to 28.4 M US$ in 1991. Production of cut flowers has high priority in research.

Cameron Highlands is the oldest vegetable production centre[23] in Peninsular Malaysia. Since the late 1980s, the planting of cabbage in Cameron Highlands declined from 1,500 ha to less than 100 ha in 1995/96, the former main crop being largely replaced by other vegetables and cut-flowers for export[24] (Syed, pers. comm., 1996). Pests and diseases, pesticide resistance and poor crop management were named as reasons why farmers shifted from cabbage to more profitable crops, especially flowers (Reerink, 1996). By 1991, some 350 ha of temperate flowers were grown annually producing about 14 US$ worth of cut flowers, mainly for

Table 6.3.1. Peninsular Malaysia. Production of vegetables in planted area (x 1,000 ha), and production (x 1,000 tonnes) in 1990, and value (M US$) in 1989. Source: Ministry of Agriculture, Malaysia.

Category	Area	Production	Value
Leafy vegetables	8.8	148	38
Fruit vegetables	17.1	328	74
Root vegetables	0.8	22	2
Spice vegetables	4.2	71	63
Other vegetables	0.1	1	3
Total	31.0	570	180

export. In view of the many complaints from overseas importers of cut-flowers, the flower nurseries requested MARDI to initiate priority research on pre- and post-harvest prevention of quality problems. The MARDI administration hired a Dutch horticultural expert in 1985 and ordered a redeployement of its experts and facilities from the highland vegetables to the flowers sector. (Syed, pers. comm., 1996)

6.3.2. Achievements of IPM for vegetables in Malaysia. MARDI had separate divisions responsible for, respectively, production improvement of and pest control in vegetables, flowers and fruits. Vegetable research was concentrated in the MARDI stations at Cameron Highland, Klang in Selangor and Johor. In the late 1970s, two task forces were especially set up for the development of IPM in vegetables with the focus on DBM, which caused serious loss almost every year (Sudderuddin & Kok, 1978). Four Malaysian universities and several pesticide companies became involved in IPM research for vegetables.

A national survey, conducted in Malaysia in 1981, showed that over 85% of the vegetable farmers saw pests and diseases as their main problem, and that 65% of them relied completely on chemical control (Ding *et al.*, 1981). Two indigenous parasitoids, *Cotesia plutellae* and *Tetrastichus ayyari*, occurring in the Cameron Highlands, gave insufficient control of DBM. Ooi & Lim (1989) successfully introduced the parasitoids *Diadegma eucerophaga*, *D. semiclausum* and *Diadromus collaris*. Together, the parasitoids formed the basis of an initially successful biological control program in cruciferous crops in Cameron Highlands. (Lim & Yusof, 1992; Chin *et al.*, 1991; Jangi *et al.*, 1991). IPM extension on vegetables, soon narrowed down to integrated management of DBM, was jointly carried out by DoA's extension service and MARDI through the method of T&V. In spite of years of extension on biological control in crucifers, most vegetable farmers continued to employ synthetic pesticides liberally to control pests and diseases (Reerink, pers. comm., 1996; Praasterink, 1996a; author's observations, 1996). In 1996, the MARDI station at Tanah Rata, Cameron Highlands, stopped its 30 years-old research on highland vegetable cultivation except for urgent practical pest and disease problems[25] (Syed, pers. comm., 1996). In 1996, MARDI was reorganized to give priority to sustainable agriculture and the environment. The divisions of entomology and phytopathology appeared to be weakened by this decision.

The study on ICM in hot pepper (*Capsicum annuum*) by Vos (1994) was completed in Malaysia. MARDI focussed on selection and breeding in hot pepper. In Malaysia by 1990, more than 350 accessions of tropical and temperate cultivars and types of peppers had been collected and evaluated. From this collection, 34 sources of resistance or tolerance against CVMV and CMV were identified and certain types of virus resistance were crossed into new cultivars (Lim, 1990a). A local hot pepper strain, showing resistance against anthracnose (*C. capsici*), was used as a parent in the breeding program (Lim, 1990a). No written evidence was found that MARDI's recommendations on ICM in hot pepper are adopted by farmers on any sizeable scale.

6.3.3. IPM efforts of international and local NGOs. The bigger NGOs in Malaysia are the Consumer Association of Penang (CAP), the Environmental Society of Malaysia and the Pesticide Action Network (PAN-Malaysia). PAN-Asia, an umbrella organization representing 20 NGOs, has its regional headquarters at Penang, Malaysia. PAN-Asia addresses unspecific issues concerning pesticide externalities on a regional level rather than raising questions concerning problematic situations in Malaysia (author's impression from a visit to PAN's headquarter in Penang, 1995). The three larger NGOs, well organized, ran several campaigns through newsletters and publications pertaining to externalities of injudicious pesticide use. Another NGO group undertook organic farming as the core activity of community development. In 1991, NGOs organized a Regional Workshop on Organic Farming in Kuala Lumpur, which led to collaboration between NGOs and agencies of the Ministry of Agriculture to evaluate and promote organic farming (Lim & Oudejans, 1991). No report was found on the achievements of the organic farming movement in Malaysia.

6.4. Vegetables, fruits and flowers in Thailand after 1950

6.4.1. Introduction. Compared to other SE Asian countries, the production of vegetables in Thailand is relatively high (table 6.1.1.a). The vegetable production is concentrated in four main areas in NW, NE, SW Thailand and around Bangkok. Crucifers constitute the main group[26] with head cabbage and Chinese cabbage dominating in the highlands and kales in the lowlands. Hot pepper and shallot lead the lowland vegetables. When irrigation became available in some provinces, farmers began to cultivate water melons as dry season crop after rice. In the 1970s, several fruit canning industries[27] established nucleus estate type processing plants which received their supplies of fruits from farmers and large own plantations. More than 14,500 tonnes of canned pineapple were exported in 1973 already. (O'Reilly & McDonald, 1983).

Thailand's production of tree fruits is entailed in table 6.1.1.b. Thai fruit growers produce the best quality fruits of the region but nevertheless face serious disease problems. In citrus orchards, for example, the productive life of the trees is usually less than seven years since they are grown from non-resistant seedlings. Only around 1995 grafting on rootstock, with resistance against *Phytophthora parasitica* root and stem disease spp., was introduced (ch 6.4.4.2) (GTZ-program officer, pers. comm., Kasetsart, 1993).

Thailand is a major exporter of vegetables, of fresh and canned fruit and of cut flowers. Recent data on export of vegetables, fruit and flowers are not readily available.

Thailand has emerged as a major exporter of vegetable seed in the region. In 1992, Thailand exported 2,861 t of vegetable seeds to the value of 23 M US$ to thirty countries[28], of which water melon accounted for 45% and tomato for 36% of the exported value (Asian Seed 1/6, 1994:10). The Seed Division of DOAE produced 118 t of vegetable seed in 1984 (Asian Seed 2/3, 1995:4). Imports of seeds in 1992 amounted to 7 M $ of which 23% head cabbage, 7% Chinese cabbage and 15% watermelon seed. Almost 60 companies in Thailand exported or imported vegetable seed among which Know You Seed Co took almost 30% of the export value and Chia Tai 20% of the import value (Asian Seed 1/1, 1994:6-7).

6.4.2. Insecticide use pattern in Thai horticulture. A survey of treatment patterns in Pathum Thani Province, a major supply area for the capital of Bangkok, found that on the most intensively treated vegetable, Chinese kale, farmers made on average 6.5 applications at intervals of 8 days. On average 15.3 pesticides were included in the mixtures[29] of which 74% insecticides, 22% fungicides and 3 % herbicides (Jourdain & Rattanasatien, 1995). The favoured insecticides for use on crucifers and lettuce were profenefos, chlorfenapyr[30], mevinphos, and tebufenazide. Farmers rarely used biorational insecticides such as *B. thuringiensis* (*Bt*) and abamectin, and if used, they did so in conjunction with synthetic insecticides. They preferred a rapid knock-down effect to keep the vegetables undamaged and fresh-looking. On lettuce and Chinese kale up to 32% of the insecticides fell under WHO Class IA (extremely hazardous) and Class IB (highly hazardous) chemicals. By 1990, the use of organochlorines was prohibited in Thailand. They were replaced by insect growth regulators (IGRs) and pyrethroids. Farmers based their decisions for treatment on visual impressions without a clear understanding of pest monitoring and control thresholds.

All farmers reported heavy infestations and resistance of DBM and beet armyworm (*S. exigua*) to pesticides. The rapid appearance of resistance against, for instance, chlorfluazuron (registered in 1984) was accepted as a normal fact. Without any idea about insect resistance management (IRM) farmers responded by increasing dosages, and more frequent applications with higher costs and more phytotoxicity. They continued using *Bt* and abamectin even when the products had lost their impact. In the case of chlorfenapyr farmers relied on only one chemical, which they thought to be reliable at the time (Nanta, 1996). Public investment in IRM could be justified by reduction of pesticide externalities. No documentation was found that such types of investments were realized.

Excessive pesticide use is reported for fruit orchards (GTZ, 1993) and flower nurseries. Jasmine shrubs, the flower being a national symbol, and fruit trees are often planted on raised beds separated by water filled trenches. The trees are treated frequently with motorsprayers placed on small boats. Heavy contamination of the women and children picking the flowers (pickers' disease) is common (Baumann, pers. comm., 1993).

A 1993 survey covering 157 fruit growers in C, SW and S Thailand, showed that fruit growers had been using paraquat for weed control for almost two decades. Most smallholders applied paraquat as a blanket spray, while a minority carried out strip spraying along the rows or circle weed control around the fruit trees. Some 95% of the owners of the holdings mixed and sprayed paraquate themselves. A combination of stationary pumps, hoses and hand-lances was the preferred equipment, the use of protective apparel was inadequate (Whitaker *et al.*, 1993).

6.4.3. Institutionalization of IPM in Thai horticulture. In 1984, a joint UNDP/FAO-Government of Thailand Programme was started aimed at the development of integrated pest control for secondary crops (cotton, sugarcane, vegetables). The United Nations Development Programme (UNDP) allocated in total 0,5 M US$ for execution during four years. Collaboration was established with the US Consortium for International Crop Protection (CIPC), and international universities and institutes[31]. Working groups were set up for the target commodities, cotton, sugarcane, non-rice food crops and vegetables. The Working Group for Vegetables, consisting of 38 experts of DOA and DOAE, organized workshops, trainings and demonstrations in cabbage and onion crops in particular. The IPM strategy was recommended in policy guidelines of DOA since 1985 (FAO/RAPA, 1988; Nanta, 1996).

During the 1980s, the German Agency for Technical Cooperation (GTZ) supported, in the frame work of the 'Thai-German Programme for Strengthening of the Plant Protection Service', the construction of training centres in Thailand. Many of the training programs contained elements on IPM for vegetables.

Thailand is a member of the FAO ICP IPM in Rice Programme since 1980 (ch 5.2.4). Because of failing interest of the Thai government in implementation of the National IPM Program, Thailand was not included in the FAO Inter-Country IPM in Vegetables in S and SE Asia Programme which comprised Vietnam, Laos, Philippines and Bangladesh. At a later date, however, inclusion of Thailand in the Programme was reconsidered because of its ties with Laos. It was deemed difficult to develop an IPM vegetable program in Laos without acknowledging the intensive political and trade links between the bordering countries[32]. After an initial contact in 1986, through the NGO 'Save the Children''s Regional Initiative for Sustainable Agriculture (RISA), administrators of the Thai Plant Protection Service at a Rice Program Advisory Committee Meeting in Bankok, February 1997, requested Thailand's joining the FAO ICP IPM in Vegetables Programme. The project would assist Thailand in the organization of TOT and FFS training and in facilitating field studies. FAO ICP would provide backstopping and funds, Thailand would provide counterpart contribution (FAO-ICPV, 1998).

6.4.4. Achievements of IPM for horticulture in Thailand. Research on vegetables, fruits and ornamentals was the task of DOA's Institute of Horticulture Science, of the Kasetsart University at Bangkok, and the universities of Khon Kaen and Chiang Mai. All these institutions contributed to the development of IPM technologies. Two examples are given.

6.4.4.1. Integrated control of diamondback moth. The control of DBM in cabbage with synthetic insecticides since the 1960s, had caused serious resistance of this pest. In 1984, DOA and DOAE began an UNDP/FAO supported IPM program against DBM which envisaged application *B. thuringiensis* (*Bt*) when ETL values were surpasssed. In the same year, DOA launched a joint project with Kasetsart University, Bangkok, and the Nagoya University, Japan, called 'Insect toxicological studies and integrated control of diamondback moth'. Research topics were the monitoring of resistance development, egg parasite studies, rotation of insecticides, protection by netting structures and insect trapping. The changes in insecticide use, the increasing application rate of *Bt*, and the introduction of the biocide biomectin were recorded.

The mass rearing and release of the egg parasitoid *Trichogramma* spp. became the most important instrument in DBM control programs[33]. DOA's Division of Entomology received support from AVRDC under the AVNET program for undertaking mass rearing and DBM control trials with egg and larval-pupal parasitoids[34] (Vattanatangum, 1990a). By 1998, Thailand had a massive and commercial production in public and private rearing laboratories of biological control agents such as *Bt,* nucleus polyhydrosis virus (NPV) and the nematode *Steinernema carpocapensae*. Exchange of expertise and organisms takes place with rearing stations set up under the FAO ICP in Vegetable Programme in Vientiane, Laos, in Hanoi, Vietnam, and in Pnohm Penh, Cambodia (FAO-ICPV, 1998; Napompeth, pers. comm., 1998). Expertise on commercial mass rearing of the parasitoid *Cotesia plutella* is provided by the University of the Philippines, Los Baños, which supplies stock cultures under the FAO ICP programme as well as specimens of *Bt* and Cuelure[R], a pheromone trap for fruit flies (FAO-ICPV, 1998). In 1989 and 1990, DOAE organized field days in 80 provinces to demonstrate[35] how well screen netting can prevent infestation of vegetables by lepidopterous and dipterous pests (Nanta, 1996).

6.4.4.2. IPM for fruit trees. The Thai DOA and DOEA addressed in 1989, with the assistance of the German Technical Assistance Agency (GTZ), the huge pest problems in orchard fruit production. Thai fruit growers had a high level of knowledge, but sprayed 20-40 times a year to reach relatively high yields. The first phase of the joint Thai-German Project began with interdisciplinary research on mango, tangerine, pummelo and durian, and with developing pest monitoring systems and IPM technology packages. In Thailand, pummelo and tangerine were for almost 100% affected by one of the three diseases: Citrus Tristeza Virus, Citrus Greening Disease, and *Phytophthora spp.* root and stem disease. The diseases resulted in low yields, frequent replacement of diseased trees and a commercial lifespan of the orchards of less than 5-7 years.

In the second phase, 1993-96, orchard trials were carried out in nine provinces in C, SW and N Thailand. To combat the *Phytophthora* disease, import and nursery production of disease-resistant root stock for citrus cultivars and of disease-free trees under a certification scheme was adopted. A national citrus seed garden was established at Rayong province, SE Thailand, to grow resistant root-stock for grafting. In a second nursery program, thermotherapy and shoot tip grafting techniques were employed for the production of trees free from Tristeza Virus and Citrus Greening Disease. Disease and virus-free tree material was propagated at a national citrus budwood foundation block and further multiplied in regional nurseries under public or private sector management. A model nursery training centre was set up in Rayong, SE Thailand, for education in new propagation techniques and nursery management (GTZ, 1993).

Since balanced orchard systems offer suitable ecological conditions for biological control great attention was given to the identification of natural enemies. The project established mass rearing facilities for predatory mites (*Amblyseius* spp) for control of the red mite (*Eutetranychus africanus*). Research for biological control of two other key pests, the citrus leaf miner (*Phyllocnistis citrella*) and citrus psyllid (*Diaphorina citri*) was continued (GTZ, 1993).

The project aimed, furthermore, to improve knowledge about pesticide selectivity and pesticide application techniques. Selective pesticides, improved formulations, modern (orchard) spray equipment and nozzles, and effective spraying techniques were introduced. Management systems were strengthened through continuous monitoring of the orchard ecosystems, and through technology transfer and extension methodology. During the third phase, 1996-99, emphasis was on IPM extension and strengthening of infrastructure. Project funding up to 1996 amounted to 6 M US$ (9 M DM) from the German side and 8 M US$ from the Thai side. No evidence was found whether the project has made a lasting impact.

6.4.5. IPM efforts of international and national NGOs. In Thailand, intensification of agriculture since the late 1960s and a booming agricultural industry since the mid-1980s caused a considerable growth of agricultural income. However, the benefits of sectoral growth have mainly fallen to the wealthier part of the population. Farmers' income in general has deteriorated due to rising costs and increasing amounts of inputs, unpredictable market prices, and lack of control concerning choice of suitable markets. These developments created conditions for the emergence of strong Thai agricultural cartels[36] as well as the existence of a growing percentage of impoverished, often landless Thai farmers (Levin & Panyakul, 1993).

Under the pressure of industrialisation of Thai agriculture and deterioration of social conditions of Thai farmers, some Thai farmers and NGOs returned to traditional farming for self-sufficiency. Interest arose for organic farming as a possibility to escape the need for costly chemicals. From early initiatives a movement for alternative or sustainable agriculture emerged in the mid-1980s. In 1984, a loose network of NGOs was formed which evolved into the Alternative Agriculture Group (AAG). Its main points are *1.* trust in farmers' contributions towards ecological balance, and *2.* economic autonomy of the farmers is a means to overcome exploitation by a dominating market. A 1992 survey, revealed that over 50 NGOs and numerous farmer organisations worked on sustainable agriculture in Thailand. However only 20,000 households, or 0.4% of Thai farming families, had switched to sustainable agriculture. The production technique for sustainable agriculture was found to be more complicated and more labour intensive than chemical intensive farming (Levin & Panyakul, 1993).

6.4.6. Adoption of biotechnology in Thailand. In 1989, The Thailand Development Research Institute (TDRI) surveyed the technological capabilities of 42 biotechnology-based Thai companies in *i.a.* feed, seed, aquaculture and health related industries. The survey revealed a ubiquitous lack of expertise and financial interest in the private sector and poor public-private sector linkages. The Thai government, however, wanted to developed biotechnology in order to improve value-added production for export. Hence the government founded, in 1991, the National Science and Technology Development Agency (NSTDA) as an umbrella organization of, among others, the National Centre for Genetic Engineering and Biotechnology (NCGEB) and the Science and Technology Development Board. The government also established a Bioservice Unit as a core facility to provide researchers from both governmental and private organizations with appropriate instruments for biotechnical research (Commandeur & Pistorius, 1992). With the objective to attract foreign investment and technology transfer by Japanese and US companies a US-Thailand Commercialization of Science and Technology Program was set up in 1990, in which prominent US agencies[37] were represented. Thai demands for biotechnology products and processes (production of tomatoes and potatoes) were available at US companies, but needed climatological and scale adaptions. The agreements have hardly led to an actual exchange of technology (Commandeur & Pistorius, 1992).

6.5. Conclusions

1. Market-oriented production of vegetables and fruits is characterized by intensive cultivation practices which require a high input of knowledge, materials, cash and labour. This is equally true in the tropics as in temperate zones.
2. Pesticide advertisement for use in horticulture by the chemical industry is strong. Several companies operate research stations in major vegetable production areas on Java under the banner of IPM. In Thailand, the vast supply of brands of pesticides for horticulture is highly confusing for the farmers.
3. The two main sectors of horticulture, growing of temperate vegetable species in highland areas and of (mainly) native species in the lowlands, differ greatly in cultural practices and problems of pest and disease management.
4. Temperate vegetables have always been in high demand and are, therefore, subject to sustained research efforts since colonial times. Still, availability of healthy seed and resistant (against pests and diseases, heat, humidity) cultivars is limited.
5. In vegetable crops, the pressure of pests and diseases is, generally, high, in particular in temperate vegetables due to a.o. the absence of specific parasitoids, predators, or antagonists.
6. Vegetables are usually grown year-round on relatively small plots in short and overlapping production cycles. Hence, the build-up of pests and diseases is continuous and fast.
7. Lowland vegetables grown in rotation with wet rice benefit from the suppressive effect of inundation on soil-borne pests, diseases and weeds.
8. Weeds are a costly nuisance in vegetable growing. Tillage often aggrevates weed problems through fragmentation of the root system of certain weeds, such as sedges. Herbicide use in vegetables is, however, complicated and little practised.
9. Indonesia has a huge production of temperate and native vegetable species on 1.3 M ha of the highlands and lowlands. Fruit production is a more limited affair.

10. Pesticide use is high in the major production areas of cabbage and potato (the highlands of Java and NW Sumatera), and hot pepper and shallot (lowlands on the N coast of C Java).
11. The various Indonesian-Dutch technical assistance programs for the strengthening of horticulture achieved their objectives and contributed to an improvement of knowledge on both sides.
12. Indonesian scientists are catching up on biological control, particularly in cabbage, tomato and potato, and *Allium* crops. Work on disease control is less advanced. Horticultural research still has a shortage of expert horticulturists and specialists.
13. In Indonesia, the National IPM Program for Rice Based Cropping Systems has succeeded in including vegetables (and soybean) in its planning of IPM Farmer Field School Training. Indonesia also organized over 400 special vegetable FFSs since 1996.
14. Malaysia had a relatively small production centre for temperate vegetables (in particular cabbages), the Cameron Highlands. In the 1990s, cabbage growers shifted *en masse* to cut flower production for export owing to high losses from pests in vegetables and to attractive prices for flowers.
15. Control of insect pests of cabbage crops, especially the diamondback moth, was intensively studied and well published by Malaysian scientists. Adequate methods of biological control of the major insect pests were worked out in the field. Application of biological control in highland areas failed due to inadequate extension.
16. Research on highland vegetable production has currently low priority with MARDI. Little information is available on IPM for lowland vegetables except for hot pepper.
17. Thailand has sizeable production of fruits and vegetables for export and domestic markets. The fruit sector leads the market.
18. Thai growers are very professional, the quality of fruits and vegetables is relatively high. For pest control, however, these growers strongly depend on pesticides.
19. Thai researchers mastered biological control of diamondback moth and the culturing of natural enemies. The National Biological Control Research Center has much expertise. Application of IPM in the field appears to be limited.
20. Thailand faced very serious disease problems in fruit trees. Since 1992, the Thai German IPM Program for Selected Fruits developed integrated control methods including the introduction of resistant rootstock, grafting techniques, biological control and training in judicious pesticide application. Published data on penetration and success rates could not be found.
21. The agricultural extension service in the three countries lacked the capacity to implement IPM in horticulture in terms of shortage of staff, expertise, budget and motivation.
22. The general and often excessive use of pesticides in the centres of vegetable production hampers the implementation of IPM due to the decimation of natural enemy populations.

23. Commercial vegetables farmers, usually, purchase high quality seed. Several private seed companies and public institutions, such as AVRDC, are developing resistant cultivars of favourite vegetables. The supply of healthy, vigorous and resistant seeds and plant material still falls short of demand.
24. Seed dressing with fungicides is practised bij many growers. The industrial pelleting of seeds with various kinds of pesticides is underdeveloped in SE Asia.
25. Application of IPM technology in horticulture is a complicated issue since the use of pesticides can not be excluded if non-chemical methods of control are insufficiently worked out.
26. In horticulture, the provision of a IPM technology packet with suitable recommendations on crop production and pest control does not suffice. IPM-trained growers need further guidance in the form a crop specific modules for monitoring of pest populations, injury assessment in relation to growth stages, and advice on the proper means and timing of control.
27. The organisation of such modules for `supervised control' is beyond the capacity of individual farmers and should be extended by influential bodies of expertise.
28. Owing to relatively high level of investment needed in horticulture, growers are risk averse. Failing recommendations may create mistrust of long duration.
29. The organization of large scale IPM needs not only a FFS participatory approach but also administrative guaranties (good extension, reliable supply of improved seeds and natural enemies, adequate regulatory measures) that win the trust of the farmers.
30. Recent agricultural policy of the three SE Asian countries prioritizes an expansion of vegetable and fruit production in view of its potential for employment in corollary processing industry and trade, for income generation and export revenues.
31. Strong growth of the horticultural sector can be expected in view of current shortages in supply in terms of quantity and quality and the growing domestic demand for fruits and vegetables.
32. The FAO ICP IPM for Vegetables Programme began its cooperation with Indonesia and Thailand only in 1998; it has no connection with Malaysia.
33. The current resources of the FAO ICP IPM for Vegetables Programme in S and SE Asia are too limited in comparison to its objectives.
34. Notwithstanding the impressive constraints, the development and application of IPM in horticulture in SE Asia needs to be pursued with priority.

Notes

1. The borderline between vegetables and other classes is sometimes vague. Onion and hot pepper could also be seen as 'spices', cassave and sweet potato as 'staples' and melon and water melon as 'fruits' (Oomen & Grubben, 1978; Grubben & Siemonsma, 1993).

2. Temperate vegetables grow healthier as the microclimate gets dryer and cooler. Older tomato varieties e.g. required night temperatures 10°C below day temperature. Today, several heat tolerant tomato varieties are available (Grubben, pers. comm., 1998).

3. In 1993 Thailand exported seeds (including seeds of water melon, tomato, kangkong and chilli) to the value of 17.9 M US$ (Asian Seed, 1/6, 1994).

4. The worst weeds of major food crops of SE Asia were described by Holm *et al.* (1977), and the weeds of Thailand by the Thai-German Weed Science Research Project (Noda, 1985) with funds of the Japanese International Cooperation Agency. Weeds in the vegetables of Indonesia, in particular, were surveyed by Backer (1973) and Everaarts (1981).

5. Lim & Di (1990) listed nine organophosphate, six carbamate and three pyrethroid insecticides as the most common active ingredients used by vegetable farmers in SE Asia (RAPA 1990/3:112). Shallot growers in Brebes, C Java, considered Indobas^R and Dursban^R essential preventive insecticides and to which curative insecticides Hosthathion^R, Curacron^R and Atabron^R were to be added (Buurma & Nurmalinda, 1992b, undated).

6. Talekar notes that nowhere else than in Brebes, N Java, four species of *Spodoptera* (*S. litura, S exigua, S. exempta, S mauritia*) concur in attacking shallot or any other crop. Several farmers applied five insecticide sprays per week (Talekar in a letter to Director, Central Research Institute for Horticulture, Pasar Minggu, Jakarta, 2 October, 1995).

7. Around 1994, substantial resistance was detected in a DBM population from the Cameron Higlands against abamectin, some degree of resistance to *Bt* ssp *kurstaki* and the possibility of slight resistance to *Bt* ssp *aizawai* (Verkerk *et al.*, 1996).

8. The pesticide alternation scheme envisages an application sequence of *Bta* (XenTari^R), IRGs (flufenoxuron, hexaflumeron), *Btk* (Dipel^R, Bactospein^R), fipronil, carbamates (cartap), and abamectin in the 6th generation (Verkerk *et al.*, 1996).

9. The Expert Consultation was attended by experts from 10 countries in S and SE Asia, FAO Rome and the FAO Regional IPM in Rice Programme, AVRDC and South Pacific Commission (FAO/RAPA, 1988).

10. In 1985, 4,046 cases of pesticide poisoning were reported from 55 provinces in Thailand, with 289 deaths. Most of the cases were farmers who had been exposed to pesticides (Lim & Oudejans, 1991).

11. In the late 1980s insecticides alone accounted for about 30% of the costs in cabbage cultivation in the Cameron Highlands, Malaysia (Lim, 1987, 1988).

12. In 1985, the Extension Service of the Indonesian Directorate-General of Food Crops employed about 14,000 extension workers and 259 subject matter specialists. Allegedly, none had been specially trained in horticultural crops (Singh, 1990).

13. The governments of the countries visited (Vietnam, Malaysia, Indonesia, Thailand and the Philippines) expressed great interest in an early implementation of a separate FAO ICP-IPM for vegetables (Lim & Oudejans, 1991). The main donor, the Netherlands, approved the program only in 1995, for four countries.

14. The Indonesian partners in the ICM for sweet potato project were the NGO Mitra Tani, Yogyakarta; Duta Wacana Christian University (UKDW), Yogyakarta; and the Research Institute for Legumes and Tuber Crops (RILET), Malang. 'User's Perspective With Agricultural Research and Development' (UPWARD) is an Asian network for participatory research in root and tuber cropping systems, affiliated with CIP (van de Fliert *et al.*, 1995, 1996).

15. Clubroot, an economically important disease of crucifers in N Europe, was detected in E Asia around mid-1970s (Ikegami, 1975; Yang, 1989). The fungal spores, released from infected cabbage roots, persist in the soil for many years. Breeding for host resistance to clubroot is difficult due to the existence of many races (Yang, 1989). Some work was done in Cameron Highlands (Reerink, 1996).

16. The potential of parasitoids was intensively studied for the larval parasitoides (*Diadegma*

eucerophaga, D. semiclausum, Microplitis plutellae, Cotesia plutellae), egg parasitoids (*Tetrastichus dygari, Trichogramma* spp), pupal parasitoid (*Xanthopimpla* spp), and larval-pupal parasitoids (*Brachymeria* spp) (Sudarwohadi & Eveleens, 1977; Ooi & Lim, 1989).

17. Bacterial genes present in *B. thuringiensis* (*Bt*) produce proteins toxic to lepidopterous, dipterous and coleopterous larvae. When the endotoxic protein enters the midgut of the insect larvae it causes their rapid death. Biotechnology companies tried to incorporate the *Bt* gene in cabbage plants (Kramer, 1991), but this has not yet resulted in DBM resistance cultivars.

18. The Brastagi area at 1200-1400 m altitude has a high production of temperate vegetables due to its fertile soils and cool humid climate, but a generally low use of pesticides. Up to 80% of the produce is exported to Singapore and Malaysia without reports of residue problems.

19. Project ATA-111 provided introductory courses in plant protection for HRI and university staff, 1975-77, and special subject courses for technical staff. Ten fellows attended courses in the Netherlands (Wessel, 1977).

20. The seed program began with introduction and field testing of vegetable and potato seeds provided by 20 seed companies from 10 countries. Promising varieties were handed over to DoA's Extension Service for demonstration trials, multiplication and distribution to the farmers (Wessel, 1977).

21. When in 1992 the project ATA-395 was terminated early because of a political dispute between Indonesia and the Netherlands, the ICM in hot pepper study by JM Vos (1994) was continued in Wageningen, the Netherlands and completed with MARDI at the Klang Station, Malaysia (ch 6.3.2).

22. The average percentage of infestation with Potato Leaf Roll Virus (PLRV), established with the ELISA test in 78 potato samples collected from Brastagi and Seribudolog, Karo , N Sumatera, was 44% and 46% respectively in third to fifth generation tubers after importation (Chujoy, 1995).

23. In Cameron Highlands vegetables are grown by approximately 1,000 growers, of which the majority are ethnic Chinese. Chinese growers often work in '*kongsi*'-connection, which offer communal advantages of production, transportation, marketing and credit to members. A *kongsi* makes its members more competitive, but less accessible for non-Chinese extension personnel.

24. In 1995, flower cultivation, largely protected by plastic and netting, had increased to 800 ha. Dutch companies are well represented as buyers and suppliers of planting material of e.g. rose, carnation and *Chrysanthemum*.

25. When the author visited the MARDI station at Tanah Rata, Cameron Highlands in March 1986, some experts expressed their disappointment that the results of 30 years of MARDI research on varieties, rotation, fertilization, and biological control had hardly been adopted by the vegetable growers.

26. Thailand cabbage production in the late 1980s amounted to about 10,000 ha each of head cabbage and Chinese kale, from Chinese cabbage on about 8,200 ha, leaf mustard and pakchoi on 7,700 ha each, and Chinese radish on 5,400 ha (Lim & Di, 1990).

27. Companies, such as Universal Food Company, Siam Food Products, Thai Pineapple Industry, and Tropical Fruits and Vegetables Co. established plantations in *i.a.* Chiang Mai, Chon Buri, Samut Prakan, and Prachuab Khiri-Khan provinces. The canned produce includes pineapple, mango, papaya, rambutan, baby corn, asparagus, tomatoes and bamboo shoots (O'Reilly & McDonald, 1983).

28. The countries which imported seeds from Thailand in 1992 included Taiwan (34%), USA (26,4%), Hong Kong (15%) and the Netherlands (8.3%), Malaysia (2.3%) and Indonesia (1.7%) (Asian Seed 1/1, 1994:6).

29. Each active ingredient included in the cocktail and each seed treatment was counted as a separate chemical application, e.g. a mixture of chlorfenapyr, fipronil and enodosulfan was counted as 3 applications (Jourdain & Rattanasatien, 1995).

30. Chlorfenapyr was the second most used insecticide on Chinese kale. Farmers regarded chlorfenapyr as the only product giving control of *Spodoptera* spp as the 'product of the year'. Chlorfenapyr did not yet receive full registration and was, therefore, admitted for trials only (Jourdain & Rattanasatien, 1995).

31. The UNDP/FAO-Thailand IPC Programme for Secondary Crops hired, in 1985, a.o. a consultant in mass rearing of parasites and predators from Guangdong Entomological Institute, P.R. China, and a pathologist of the US Sugarcane Laboratory at Houma (UNDP Report 11.1984-03.1985, project THA/83/015).

32. Thailand and Laos commissioned a Friendship Bridge aimed at improving exchange of goods and technologies (FAO ICPV, 1998).

33. In Thailand, research on DBM began in 1985 with field studies of the DBM life-cycle on cabbage in Petchabun province. The DBM population went through about 17 generations per year with peaks observed during winter (December) and summer (June). The parasitoids *Trichogramma bactrae fumata* and *Cotesia plutellae* appeared to be well established (Keinmeesuke *et al.*, 1989).

34. In highland cabbage in Petchabun, 1987, a release of *Trichogramma bactrae fumata* at the rate of 375.000 parasitoids/ha resulted in a 65% parasitation of DBM eggs. In 1988, releasing egg parasites in combination with *Bt.* application gave 55 % parasitation. Concurrent lowland DBM trials at Kasetsart University Kamphaeng Saen Campus showed up to 45% parasitization by *T. bactrae fumata* and up to 32 % parasitation by *Cotesia plutellae* (Keinmeesuke *et al.*, 1989).

35. The DOAE claimed a reduction of more than 5,000 US$/ha/y on the cost chemical control. Lower use of fertilizer and water, and better quality of vegetables were further propaganda.

36. Less than 20 companies control the Thai market through a vertical integration. They control the entire process from production of raw material to marketing of added-value products. One of the largest cartels, Charoen Phokphand, controls trade in seed (Chia Thai), fertilizer, pesticide, livestock and aquaculture through joint ventures with other companies and contracting farmers (Levin & Panyakul, 1993).

37. The US Agency for International Development (USAID), the Board for Science and Technology for International Development (BOSTID) of the US National Research Council, and Biotechnology International (BTI) of the University of Maryland took part in the Thailand-US Program (Commandeur & Pistorius, 1992).

Chapter 7
The Pesticide Market

7.1. The pesticide market world-wide and in SE Asia

From 1945 till the end of the century, the global use of pesticides has shown a continuous upward trend. Global agro-chemical sales rose to 30,960 M $US at the end-user level in 1997 (Agrow #299:16, 1998). Discounting the effect of inflation and currency factors, average annual growth in real terms amounted to 3.7% over the period 1994-96 (Agrow #299:16, 1998).

In 1996, all major companies reported an increase in turn-over of pesticides (table 7.1). For all companies, growth in the Asian market is an important target for new product introductions (Agrow #235:5 ,1995; #267:5, 1996; #294:16, 1997; #297:6, 1998). Companies set high hopes on non-selective herbicides (glyphosate, glufosinate) and new crop specific insecticides (*i.a.* imidacloprid, fipronil) and fungicides (*i.a.* carpopramid). The production of pesticides in Asia is keeping its position in Japan and grows rapidly in India, China, and South Korea. A large part of the production of China, India and Japan is exported to the rest of Asia (Agrow #263:6, 1996; #288:18, 1997). Major companies, such as Novartis[1], AgrEvo, Rhône Poulenc and Monsanto are entering joint ventures for formulation and packaging in China, S Korea and Vietnam (Agrow #297 and #298, 1998).

World pesticide sales by region and by product category in 1997 are depicted in figure 7.1.a,b. The Far East Asia market lost some of its share since 1996 due to grave economic problems which may affect purchasing power till beyond the turn of century. Herbicides dominated the world pesticide market, absorbing almost half of its value. In 1996, generic pesticide sales were worth 17,000 M US$, just over 50% of total pesticide market value (Agrow #297, 1998).

Data concerning the development of the pesticide market in SE Asia were obtained from two major sources, both covering the three countries under discussion (Box 7.1). Information over the period before 1980, was taken from the Agricultural Requisite Scheme for Asia and the Pacific[2] (ARSAP). A detailed time series of pesticide market data, 1980 till 1996, was generously made available by Bayer AG, Business Group Crop Protection, Leverkusen, Germany.

Table 7.1. World, the twelve leading agro-chemical multinationals and their 1996 sales (in M US$), including pesticides. Source: Agrow #287:1, 1997.

Company	M US$	Company	M US$	Company	M US$
Novartis	4,527	AgrEvo	2,419	Cyanamid	1,989
Monsanto	2,997	Bayer	2,360	BASF	1,541
Zeneca	2,630	Rhône Poulenc	2,210	Sumitomo	693
Du Pont	2,472	DowElanco	2,000	FMC	650

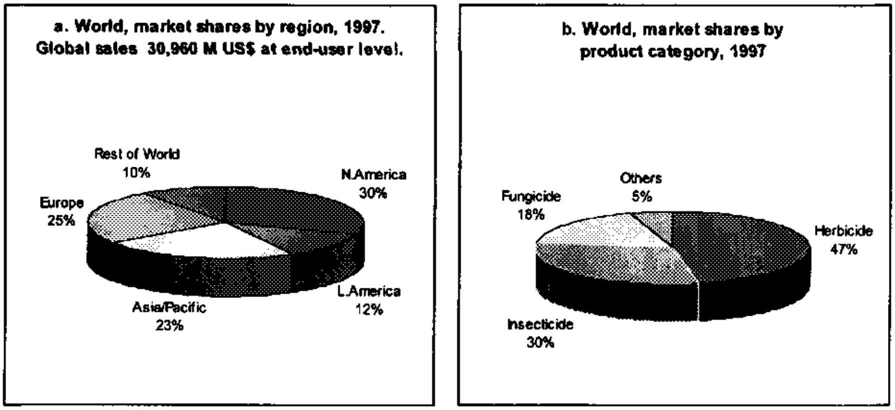


Figure 7.1.a,b. Global pesticide sales by region (a) and by product category (b) in 1997. Source: Agrow 229:16, 1998.

7.2. The pesticide market in Indonesia

7.2.1. Indonesia's pesticide market before 1980. After Independence, Indonesia suffered a serious shortfall in food production. In the late 1950s, the government of Indonesia began to pay serious attention to the issue of food security. The government provided rice farmers with a subsidized technology package of which pesticides formed only a small component in comparison to the huge volumes of improved seed and fertilizer. The ample supply of insecticides was going to have some unexpected effects which deeply influenced agricultural policy in later years.

During the 1960s and 1970s, the Indonesian market for pesticides consisted of two sectors, a subsidized food crop sector, and a non-subsidized free market sector for food and non-food crops (ARSAP, 1980). The main beneficiaries of subsidized pesticides were the farmers who participated in the Bimas/Inmas intensification programs for rice and other crops (ch 2.6.3). The non-food sector consisted of semi-government estate companies (*Perkebunan negara*), private estate companies, smallholder co-operatives and non-organized smallholders.

Although the government encouraged pesticide imports for use by all sectors in accordance with its agricultural development policy, it left the supply of pesticides to the non-food sector almost entirely to private companies. Neither the plantation crop sector nor the farmers growing food crops outside intensification programs were entitled to receive either credit for bridging production costs or subsidized chemical inputs (ARSAP, 1980). In reality, however, a substantial amount of subsidized fertilizer and pesticides were illegally transferred[3] from the subsidized crops to the non-subsidized ones.

The procurement and subsidized supply of insecticides for food crops by the Directorate of Agriculture (DoA) began around 1966. Records were kept by the Customs Office, the Department of Statistics and various divisions of the DoA, such as the Bimas Directorate and the Plant Protection Extension Service.

Box 7.1

The collection and analysis of agro-pesticide data

A data collector may be faced with two extremes, namely an *ad hoc* search for data from scattered sources, or access to a well administered time series of data. Generally, the keeping of data records on supply and use of agro-pesticides is the responsibility of various government departments. Data on procurement and import are recorded by the Departments of Agriculture, of Trade and Cooperatives, the Central Bureau of Statistics and the Customs, and those on local manufacture by Departments of Industry, Health and the Environment. Systems of data keeping are seldom uniform and may show many deficiencies (ARSAP 1981, 1981b; Staring 1984; IRPTC, 1986a, b).

Reasons which limit the usefulness of the data are, *1.* the first collection and analysis of data was done by government personnel, the researcher does not see data from the sources, *2.* the interpretation of pesticide data is hindered by the complexity and number of chemical compounds and formulations on the market, by lack of uniformity in notification, and by significant discrepancies between procurement and distribution records of different institutions pertaining to the flow of pesticides in the same years, *3.* differences in formulation type and concentration of individual brand products make computation of national use in terms of quantity of a.i or quantity of f.p. per crop and year practically impossible if data keeping is not designed for the purpose.

In 1962, the 14th Commision Session of the U.N.Economic and Social Commission for Asia and the Pacific, Bangkok, installed the Agricultural Requisite Scheme for Asia and the Pacific (ESCAP/ARSAP) for the promotion of agro-pesticide use, particularly in food crops. The FAO Regional Office for Asia and the Far East (FAO/RAPA) and ARSAP were the first to collect and analyse data on supply and use of pesticides and fertilisers in the Region S and SE Asia (James & Reddy, 1977a,b; ARSAP 1980, 1981a,b; Staring 1984). In 1972, the tasks of ARSAP was taken over by UNIDO/RENPAP. In a parallel effort ESCAP/CIRAD prepared an Agropesticide Index for Asia and the Pacific, which was transcribed in the IPHYTROP databank in 1997.

The pesticide industry prepares annual market surveys in each country. The national associations of pesticide manufacturers and distributers may issue an annual review summary. Detailed market information collected by companies and data consultant firms are expensive and confidential.

In the underlying study, ARSAP data were used for the years up to 1980. Complete time series or other aggregated data were not found for that period. Data from the years after 1980, collected by other researchers on *ad hoc* basis through record studies and interviews with each relevant institution, show similar shortcomings (Jungbluth, 1996). Detailed industrial time series of data of the total pesticide markets of Indonesia, Malaysia and Thailand from 1980 till 1996 were generously made available by Bayer AG, Leverkusen, Germany, for this study.

Pesticide data from the early years, however, are incomplete and difficult to interpret. The Indonesian data on supply, distribution and use in the 1970s were analyzed by ARSAP. Table 7.2.1 gives an indication of the pesticide market in Indonesia, 1974-78. In 1974, Indonesia imported 10,456 t a.i. equivalents of pesticides, the largest quantity of the decade. The procured insecticides (60%) and fungicides (10%) were destined mainly for subsidized use in food crop intensification programs, and the herbicides (30%) for the estates (ARSAP, 1980). Shortage of application equipment raised doubts about the capacity of farmers to rapidly apply the large stocks of pesticides which the government of Indonesia had purchased. The government agencies had few possibilities to control actual pesticide use or the efficacy of the application. Generally, huge stocks piled up in central depots and warehouses of cooperatives whilst a shortage existed at the farm level. The pesticide companies were not involved in the distribution of government stock and the state distributing agency Pertani was not effective (James & Reddy, 1977a). The decrease in government procurement during the years 1975 and 1976 reflects an import restriction to reduce the excessive stocks built up in 1973 and 1974 in the aftermath of the world oil crisis (ARSAP, 1980).

The DoA assisted the farmers in the actual application of insecticides through the department's pest control units which the farmers could contract. Some 60% of the pesticides were applied by farmers themselves and 40% by pest control units which the farmers contracted (James & Reddy, 1977a). Emergency pest outbreaks were commonly controlled by DoA's own Aerial Unit[4] and Plant Protection Brigades[5]. For this purpose, DoA received a special outbreak budget to procure the necessary emergency supplies, which *e.g.* amounted to 800 t f.p. in 1980 (ARSAP, 1980).

A leading formulator estimated the 1978 value of the pesticide market in Indonesia at 44 M US$ (ARSAP, 1980), of which 65% was used on food crops, 35% on non-food crops of estates and smallholders. Pesticide use by these estates and smallholders concerned mainly herbicides for weed control in young plantings.

Table 7.2.1. Indonesia, total procurement of pesticides (tonnes a.i. equivalents) from import and local formulation in the period 1974-1978. Source: ARSAP, 1980 (data by courtesy of Directorate of Plant Protection).

Category	**1974**	**1975**	**1976**	**1977**	**1978**
Insecticides	6,000	1,121	1,134	2,253	2,945
Fungicides	1,194	539	876	630	665
Herbicides	2,968	1,018	337	772	495
Others	323	176	26	355	171
Total	10,456	2,853	2,373	3,981	4,270

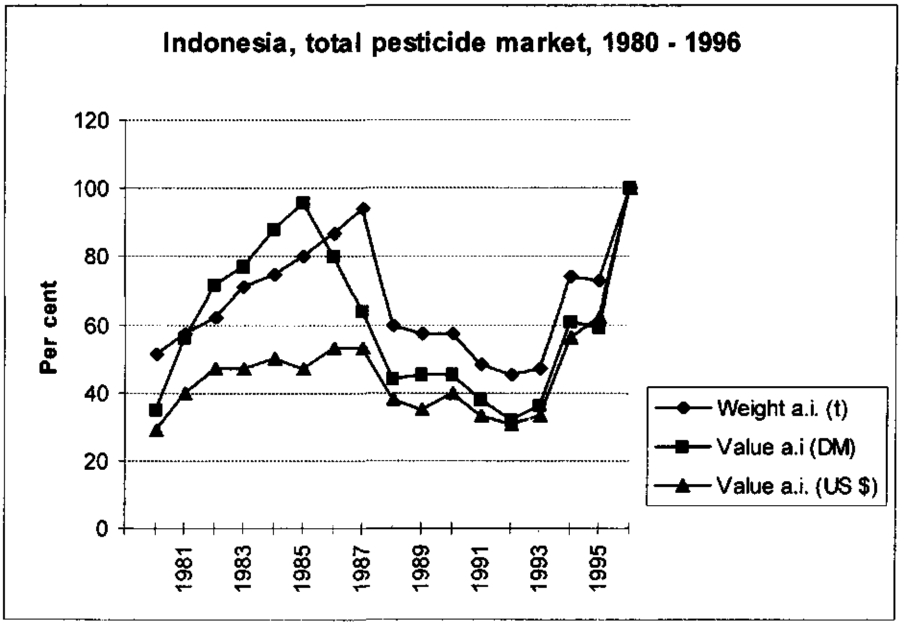


Fig. 7.2.2.a. Indonesia, total pesticide market, 1980-96. Annual procurement of pesticides in relative values for a.i. weight, a.i. value in DM, and a.i. value in US$ (1996 = 100%). Source: Bayer AG, Germany, 1988.

7.2.2. Indonesia's pesticide market since 1980. The total Indonesian pesticide market went through a boom and bust cycle within the period 1980-96 (fig. 7.2.2.a). In 1996, pesticide sales rose to 14,605 t a.i., valued at about 311 M US$, thereby reaching the highest level ever in terms of both value and volume.

An agreggate overview of the total pesticide sales, on basis of a.i. content, in the Indonesian market of the years 1980 and 1996 is given in table 7.2.2.a. Figures 7.2.2.b,c,d show the market shares of the product categories in terms of a.i. weight and value, and in treatable area. Figure 7.2.2.d compares the areas which could be treated with the a.i. volumes sold if products were applied following dossage recommendations. Early in the 1980s, insecticides dominated the Indonesian market. Sixteen years later, insecticides, falling from 75% to 44%, had ceded much of their share to herbicides. Figure 7.2.2.e illustrates the shift of the market shares of pesticides in various crops in the same period. The distribution of market shares over crops, which was rather stable from 1980 to 1986, changed drastically from 1986 to 1991. The market share of rice was halved, that of soybean tripled, whereas vegetables, rubber and 'others' increased considerably. Table 7.2.2.b indicates that in 1996 still half of the insecticide sales (in a.i. value) was for use on rice. The share of herbicides increased 35% mainly because of herbicide application in the extensive plantings of oil palm, rubber and cacao on the Outer Islands. The

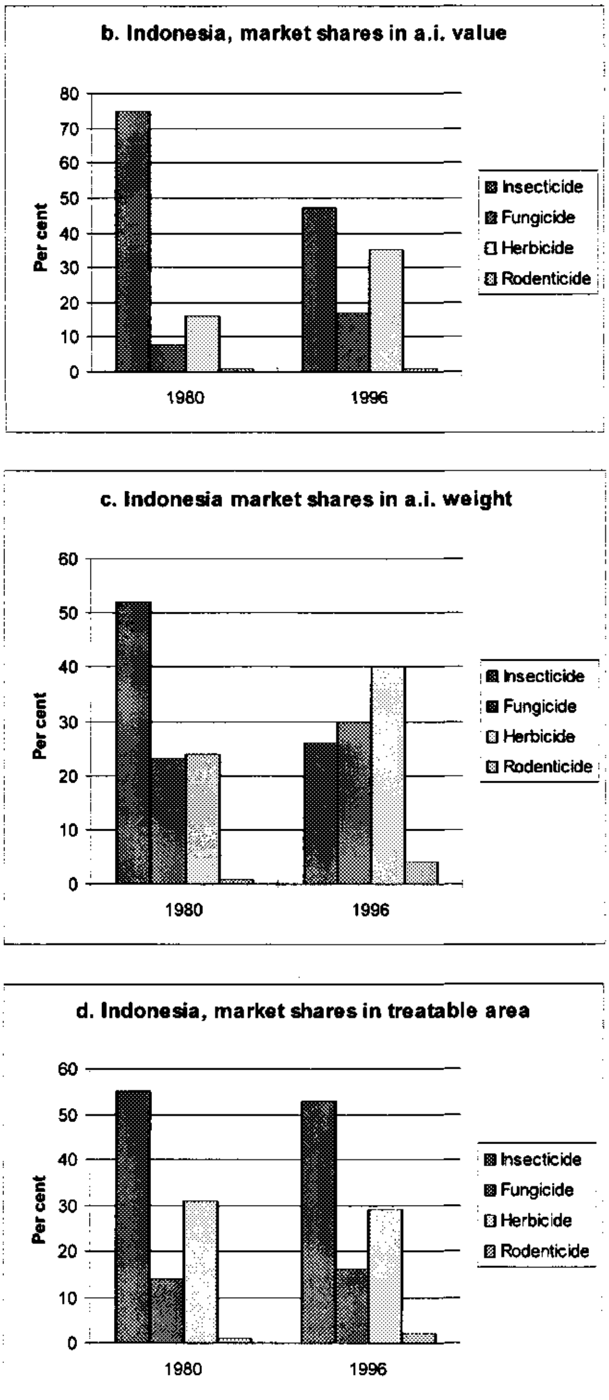


Figure 7.2.2.b, c, d. Indonesia, comparison of market shares of product categories in 1980 and 1996. Source: Bayer AG, Germany, 1998.

Table 7.2.2.a. Indonesia. Composition of the pesticide market in 1980 and 1996, expressed in a.i. weight, a.i. value of chemical classes, and treatable area if applied following dosage recommendations. Source: Bayer AG, Germany, 1998.

Categories and chemical classes	A.i. weight (tonnes)		Trt. area (x 1,000 ha)		A.i. value (M US$)	
Year	**1980**	**1996**	**1980**	**1996**	**1980**	**1996**
Insecticides						
Organophosphates	2,544	1,340	5.092	5,219	46.2	44.20
Carbamates	1,177	1.663	1.864	4,883	15.93	31.38
Organochlorines	78	689	186	2,563	1.94	17,35
Pyrethroids	21	120	163	6.300	1.52	38,20
Others	32	97	122	732	0.63	14.05
Total	3,852	3,909	7,427	19,697	66,22	145,18
Relative	52%	26%	55%	53%	75%	47%
Fungicides						
Organophosphates	0	3	0	12	0	0.16
Carbamates	0	18	0	30	0.28	3.64
Dithiocarbamates	985	4,126	842	4,086	5.49	33.58
Organochlorines	15	226	43	309	0.07	3.64
Others	697	273	964	1,336	1.14	11.79
Total	1,697	4,646	1,849	5,773	6.98	52.81
Relative	23%	30%	14%	16%	8%	17%
Herbicides						
Organophosphates	28	2,641	1,638	4,714	2.43	60.80
Carbamates	0	44	0	107	0	0.75
Sulfonyl urea	0	14	0	2.160	0	11.04
Paraquat	194	1,847	1,318	1,841	5.38	22.14
Others	1,517	1,672	1,157	2,034	6.60	14.58
Total	1,739	6,218	4,113	10,856	14.41	109.31
Relative	24%	40%	31%	29%	16%	35%
Rodenticides	46	643	3	556	0.48	2.35
Relative	1%	4%	0.1%	2%	1%	1%
Grand Total	7,334	15,416	13,392	36,882	88.09	309.65
Relative	100%	100%	100%	100%	100%	100%

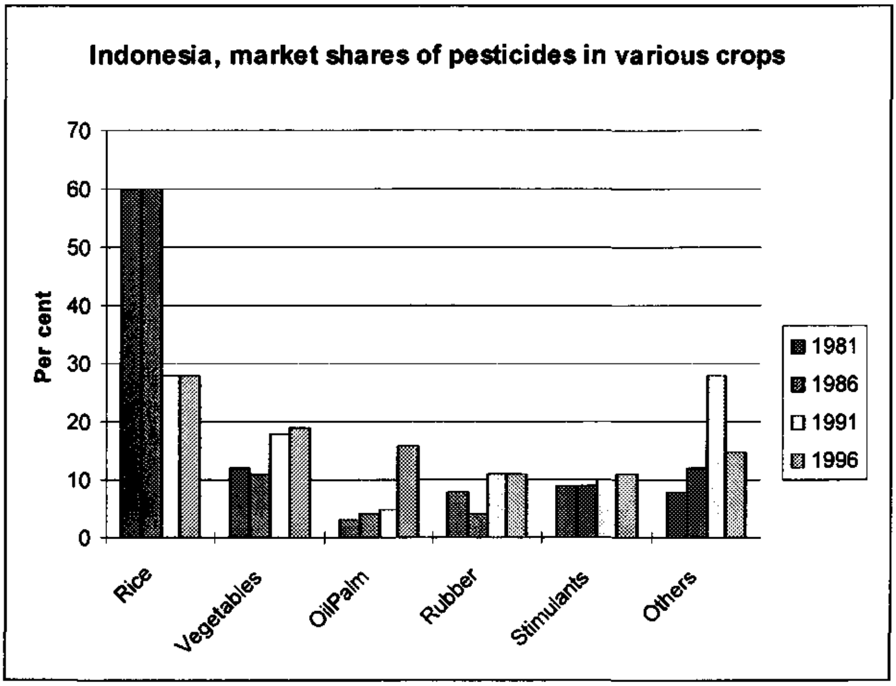


Figure 7.2.2.e. Indonesia's pesticide market change in market shares (in a.i. value) in various crops, 1981-96. Source Bayer AG, Germany 1998.

relatively small increase of fungicides reflects the greater attention to horticulture and fruit sector.

7.2.3. The pesticide market for rice before 1980. The government policy of implementing production intensification programs in rice since 1965 (ch 2.6.3) is the key to understand the trends of the Indonesian rice pesticide market. DoA purchased and supplied insecticides, rodenticides and fungicides to farmers who participated in subsidized programs such as Bimas and Inmas. The farmers obtained a credit package in the form of vouchers for seed of high yielding rice varieties, fertilizers, insecticides and rodenticides at subsidized prices and a cost of living allowance for bridging the growth season. Since the input packages were usually distributed through the village authority, their rapid adoption was stimulated through strict social control and occasional enforcement by the army (van de Fliert, 1993; Ter Weel, pers. comm., 1998). In this way, farmers were instructed to apply insecticides on calender schedule as the most effective way of controlling rice pests. Since the *Bimas Gotong Royong* program covered about 4 M ha of irrigated (*sawah*) rice in 1969/70 already, the propaganda for using insecticides was wide-spread. To assure timely application, some of the foreign chemical companies, which were asked by the Indonesian government to become involved in the

Table 7.2.2.b. Indonesia, market shares of the category insecticides in various crops, 1996. Source: Bayer AG, Germany, 1998.

Crop	A.i. value (M US$)	%	Crop	A.i. value (M US$)	%
Rice	75.7	52	Vegetables	24.5	17
Soybean	18.0	12	Fruits	1.8	1
Spices, herbs	14.1	10	Other	11.1	8

program's execution (various personal communications), sprayed large areas of *sawah* by air (ch 2.6.3.4).

Table 7.2.3.a indicates the quantities of pesticides allocated to the Bimas/Inmas programs in financial years 1973-77. Insecticide supply to farmers tripled in four years time in line with the increase of brown planthopper infestations (Kenmore, 1986). When, in 1978, BPH infestation was less serious[6], the supply, nevertheless, was kept at the same level. Neither DoA nor other parties were able to establish with any degree of accuracy the area actually treated by farmers but could only record procurement and major stock movements.

In the period 1976-78, the proportion of farmers participating in either scheme shifted from Bimas (credit) towards Inmas (cash). Farmers, who failed to repay their loans, were excluded from Bimas credit facilities and had to purchase from Inmas stocks to keep the benefit of the price subsidy. The obligation to pay cash had a definite influence on the usage pattern as Inmas farmers applied half as much[7] insecticides as Bimas farmers did (ARSAP, 1980).

The prices for insecticides and fungicides distributed under the Bimas/Inmas schemes were fixed every year. Around 1979, subsidized formulations were sold at about US$ 1.5 (Rp. 900) per litre or kilogram at the village retail outlet (*kiosk*). Compared to open market prices[8], the subsidies on wettable powder and liquid powder products varied from 40% to 75%. Granular formulations were priced at

Table 7.2.3.a. Indonesia, pesticide supply to Bimas/Inmas programs (tonnes of f.p.) in period 1974-78. Source: ARSAP, 1980 (data from Bimas Directorate).

Year	Insecticides	Fungicides	Rodenticides	Total	Bimas %
1973/74	1,371	0	46	1,417	80
1974/75	2,361	8	83	2,452	88
1975/76	3,439	20	159	3,618	88
1876/77	4,202	41	112	4.355	74
1977/78	4,000	19	120	4.139	63

about US$ 3/kg (Rp 1,800/kg). Herbicides were not included in the subsidy package (ARSAP, 1980).

Until the early 1970s, the Indonesian government had almost completely relied on the import of low concentration pesticide formulations, although these were relatively expensive due to the high volume/low a.i. content ratio. The fear for lack of foreign currency drove the government to negotiate with the pesticide industry on the establishment of formulation capacities in Indonesia (Schonlau, pers. comm., 1998). Soon, various companies started to build formulation plants which would produce ready-for-use products from imported technical material[9]. Table 7.2.3.b indicates that the local formulation plants largely substituted the import of ready-for-use insecticide concentrates within ten years, 1973-83.

However, there was another issue which had to be solved in order to make the farmers use the pesticides in the rice intensification programs. Indonesia did not have enough knapsack sprayers for the treatment of millions of hectares. The industry was asked to support the distribution of knapsack sprayers (Schonlau, pers. comm., 1998; author's involvement, 1966-75). However, the development of low concentration (3%-10%), ready-for-use granular formulations which could be applied without a knapsack sprayer, was deemed to be the best solution. The successful acceptation of granules was reflected by the rapid rise in local production, from 5,100 t.y in 1979 to 25,074 t/y in 1983 (table 7.2.3.b). The distribution of the large lots of fertilizers, seed and pesticides remained a logistic nightmare due to lack of organisational expertise and transport infrastructure.

Table 7.2.3.b. Indonesia, 1973-83, supply of insecticides from import and local formulation (tonnes of f.p.). Index: a. liquid and powder; b. granular; c. per cent supply from local formulation. Source: Staring, 1984 (data courtesy of Directorate of Plant Protection).

Year	Weight in t f.p.		%
	a	b	c
1973	5,825		0
1974	12,746		<10
1975	7,705		<15
1976	5,299		<15
1977	8,547		15
1978	7,411		18
1979	5,952	5,100	70
1980	6,515		75
1981	8,645	6,800	75
1982	13,931	20,425	80
1983	19,400	25,074	85

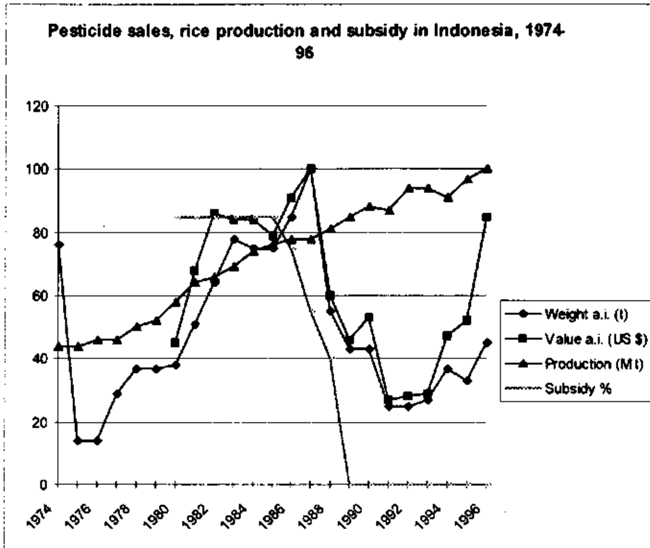


Figure 7.2.4.a. Annual rice production, procurement of pesticides for use in rice, and pesticides subsidy in Indonesia, 1974-96, in relative values. (1996 = 100% for national rice production: 1987 = 100% for a.i. weight and value). Sources: FAO production yearbooks; Bayer AG, Germany, 1988.

During the decade 1970-80, rice production grew at an average annual rate of 3.5% notwithstanding the continuous expansion of the Bimas/Inmas programs from zero to 6 M ha or two-third of the total rice area harvested. The growth in rice production was slowed down by the worsening pest situation[10]. Nation-wide BPH outbreaks occurred during 1975-77, which were temporarily brought under control through the introduction of the BPH-resistant rice varieties IR26 and IR36 (fig. 2.6.3.4.d). These outbreaks invariably resulted from the indiscriminate use of (mainly broad-spectrum) insecticides which induced resistance[11] in pests and destroyed natural enemies (Kenmore, 1980).

7.2.4. The pesticide market for rice since 1980. The 1980-96 data on the pesticide market for the rice sector provide an important yardstick for measuring the impact of the national IPM policy on farmers' behaviour and rice production. The data series covers almost the entire period of the FAO Inter-Country IPM in Rice Programme (ch 5). Figure 7.2.4.a shows the pesticide sales in the rice sector, in a.i. weight and value (US$), the pesticide subsidies and the national rice production during the period 1974-1996. Rice production rose steadily from 1974 through 1996. Minor disturbances could not be related to other variables in the figure. Pesticide procurement (in a.i. weight) decreased sharply from 1974 to 1975 because of excess purchases and over-stocking in 1973-74. Pesticide sales in US$ value followed roughly those in a.i. weight, but recent recovery in value triples recent recovery in weight.

Early in the 1980s, the government of Indonesia, fearing a further deterioration of the pest situation, continued the procurement of ever greater quantities of insecticides for use in rice (fig.7.2.4.a) and dosage recommendations were maintained throughout without a second thought. In 1985/86, another devastating BPH outbreak destroyed an estimated 275,000 ha of rice. The greatest quantity of insecticides (in a.i. weight) was purchased[12] in 1987.

In November, 1986, the President of Indonesia issued the instruction INPRES 3/86, by which IPM was declared official crop protection policy for rice. The instruction banned 35 a.i.s (57 brands of mostly broad-spectrum organophosphate insecticides) in general and particularly from use in rice. An additional measure was the withdrawal of the price subsidy in four steps over 1986-89 from a 85% level up to 1985 to the zero level of 1989. The combined measures hit the market as a double-edged sword. In accordance with the new policy, the government drastically reduced the procurement of insecticides for the food sector. The farmers, spoiled by generous price subsidies, made fewer applications when prices went up.

The IPM protagonists celebrated the inevitable recession of the pesticide market as a victory for the new policy. The widely publicized figure 7.2.4.b was used to convince national authorities and donors participating in the FAO Inter-country IPM Rice Programme in SE Asia of the effectiveness of their investment in IPM extension efforts[13]. When reduced spraying enabled the natural enemy populations to recover and to keep the BPH from breaking the resistance of the new rice varieties, the IPM ideology became everybody's creed.

Of course, figure 7.2.4.b renders the facts correctly. But which facts? It suggests that the withdrawal of the government's price subsidy on pesticides caused a decrease in the production of pesticides. 'Production' is an aggregated denominator which at best accounts for domestic formulation and which ignores import of finished product. The index on the Y-axis does not show how the production was measured (quantity of either formulated or a.i. weight, or value). The figure suggests that the concurrent reduction of subsidies and domestic production boosted the production of rice. The concurrence was certainly true but there is no cause-and-effect relationship because the increase in rice production is a continuous one from 1974 to 1996 (fig. 7.2.4.a). The pesticide production curve shows two peaks, a lower in 1985 and a higher in 1987, for which no reasons were given. Figure 7.2.2.a suggests that currency exchange rates[14] may at least partially explain the two-topped curve.

Rice production was not affected by the subsidy cut as there is no correlation between the curves showing pesticide procurement and rice production. In the late 1980s, the improved Bimas program covered over 90% of the irrigated rice area. It appears that the consistent improvement of rice varieties[15], water management and fertilization were the decisive factors for raising yield levels. The FAO program explicitly paid attention to these three factors.

After the rice pesticide market had hit the bottom in 1991, it resumed growth in terms of both a.i. weight and value since 1993 and almost recovered in 1996. This implies that insecticide use in rice is continuing on a significant, although reduced scale. The Bayer data series enables to calculate a breakdown of the 1996 pesticide market for use in rice, which amounted to 92.4 M US$, into the categories insecticides 77.0 M$ (83%), herbicides 10.8 M$ (12%), rodenticides 2.4 M$ (3%) and others about 2M$ (2%).

It is questionable whether, over the period 1987-91, actual use was reduced to a degree suggested by the pesticide procurement curves. It should be recalled that by 1987-88, after years of high procurement, the stores in the public and private

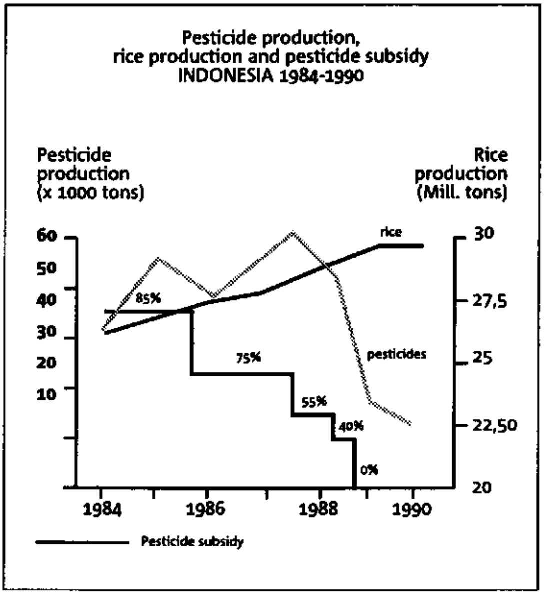


Figure 7.2.4.b Indonesia, political illustration of the effect of the withdrawal of pesticide subsidy on pesticides and rice production. Original figure *i.a.* in: Kenmore (1980); in: Whitten *et al.* (1990) (on the basis of data from the Ministry of Finance, Indonesia).

sector were loaded with pesticides. It appears that after 1987, when the Minister of Finance withheld the subsidy for pesticides and the budget for procurement was lower, the large stocks which had been carried over from year to year were gradually marketed. When, by 1992, the stocks were exhausted, the purchases of pesticides went up again to meet the demand of government agencies and private parties (Schonlau, pers. comm., 1998).

7.2.5. Changing product pattern in the rice sector. In 1980, the supply of subsidized insecticides to the rice sector consisted of 72% organophosphate, 25% carbamate, and 3% 'other' insecticides (fig. 7.2.5). By 1985, systemic carbamate insecticides were as popular as organophosphates, each taking almost 50 % of the rice market. By 1996, these two classes had decreased to about 25% each with pyrethroids as runner up at 20%, while endosulfan (class organochlorine) captured a stable 10% share. A newcomer on the rice market was the product group herbicides, consisting of 5% organophosphates (glyphosate) and 7% sulfonyl urea (metsulfuron) and paraquat. Thus, the actual share of organophosphate insecticides in rice had dwindled to 19% in 1996.

A comparison of older and newer products shows how differences in dose requirements complicate the interpretation of data pertaining the pesticide market. An analysis of the 1996 insecticide sales data for rice[18] (table 7.2.5.a) shows that the sales of endosulfan and cypermethrin needed to treat a comparabe hectareage (proportion = 1) differ in price (proportion = 1.7) and quantity of a.i. (proportion = 20.6). The costs per recommended a.i.dose/ha amounted to 6.45 $ for endosulfan and 3.70 $ for cypermethrin.

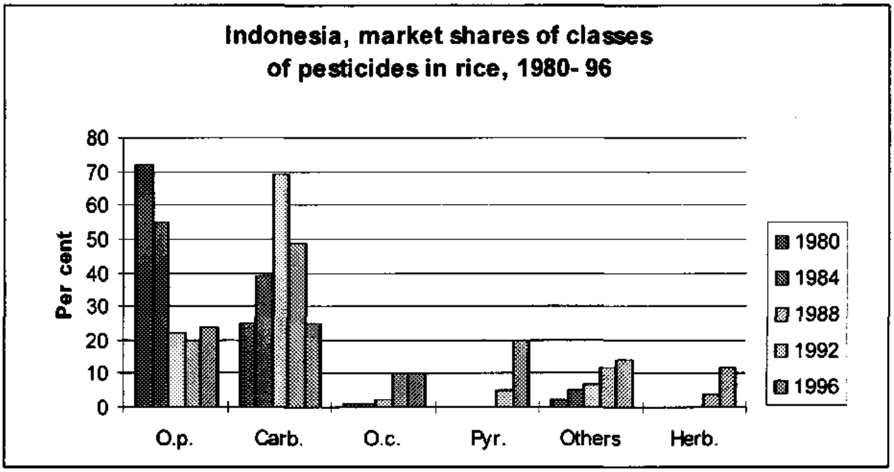


Figure 7.2.5. Indonesia, market shares of chemical classes of pesticides in rice, 1980-96. Source: Bayer AG, Germany, 1998. Legend: O.p.= organophosphates, Carb.= carbamates, O.c.= organochlorines, Pyr = pyrethroids, Herb = herbicides

Table 7.2.5.b lists the most popular insecticide compounds (all formulated in Indonesia) which were purchased, respectively, in 1980 for the Bimas/Inmas programs, and in 1996 by the farmers directly. All organophosphates listed for 1981 and 1996, as well as endosulfan, and the carbamates carbaryl, methomyl and cartap, were explicitly banned by the Indonesian Presidential Instruction No 3/1986 dated November 5, 1986 (Southern, 1987). As a consequence, a large part of the local formulation industry[16] was closed. The carbamates fenobucarb (BPMC) and carbofuran were not banned from use in rice and became major products.

The highest ranking pyrethroids (in a.i. value) in 1996 included cypermethrin, deltamethrin, lambda cyhalothrin and beta cyfluthrin. The group 'others' included

Table 7.2.5.a. Indonesia, comparison of 1996 sales of endosulfan and cypermethrin, expressed in a.i. weight, a.i. value and treatable area if following recommended dosages. Source: Bayer AG, Germany, 1998.

Common name	**Sales**		**Treatable area**
	(t a.i.)	**(M US$)**	**(M ha)**
Endosulfan	639,836	15.85	2.46
Cypermethrin	31,044	9.15	2.47
Proportions	20.6	1.7	1

new products, such as fipronil, imidacloprid, which often require low a.i. dose rates per hectare because of their selectiveness to target pests and novel ways of application. In particular, the Japanese insecticide Applaud[R] (buprofezin) was successful. By 1996, the simple organophosphates/carbamates market of the 1980s transformed into a complex one (fig. 7.2.5). A new development in the rice market was the appearance of herbicides since 1991.

A comparison of the best selling products in 1980 and 1986 (table 7.2.5.b) shows that most banned products (e.g. endosulfan, monocrotophos, diazinon,

Table 7.2.5.b. Indonesia, selection of major insecticides in the market. Listing of compounds, 1980 and 1996 in a.i. weight. Source: Bayer AG, Germany, 1998.

Active ingredients	Toxicity class (WHO)	Weight (t a.i.) 1980	Weight (t a.i.) 1996	Registered brand names
Organochlorines				
Endosulfan	II	25	382	Thiodan
Organophosphates				
Chlorpyriphos	II	102	107	Dursban
Diazinon	II	1,103	55	Basudin, Lorsban
Fenitrothion	II	274	24	Sumithion
Fenthion	IB	176	56	Lebaycid
Monocrotophos	IB	36	150	Azodrin, Nuvacron
Phentoate	II	202	153	Elsan
Carbamates				
Carbaryl	II	580	95	Sevin
Carbofuran	IB	53	456	Curaterr, Furadan
Fenobucarb	II	179	733	Baycarb, Hopcin
Isoprocarb	II	73	15	Mipcin, Etrofolan
		Value (M US$)		
Pyrethroids				
Cypermethrin	II	-	9.2	Cymbush, Ripcord
Deltamethrin	II	-	8.9	Decis, Cistin
Lamda cyhalothrin	II	-	6.6	Karate
Others				
Chlorfluarazon	III	-	2.0	Atrabon
Fipronil	III	-	4.6	Regent
Imidacloprid	III	-	1.5	Admire, Confidor

chlorpyriphos, methomyl and carbaryl) did not disappear from the rice market, which confirms the openly expressed concern that the ban did not much influence[17] the use pattern of the products (Oka, 1995).

Although most pyrethroids are rather toxic to natural enemies, their low dose requirement (10-40 g a.i./ha) may make this class environmentally more acceptable than the organophosphates and carbamates. Low dosage paired to high biological efficacy is a major aim in new product development. New application methods may help to make products more IPM-compatible. For example, imidacloprid granules applied to rice seedlings, 1 g a.i. per seedling box three days before transplanting, protect the rice plants for several weeks after transplanting. The granular formulation and the low dose rate of this neo-nicotine compound, only 25 g a.i./ha, serve the same purpose.

The above observations shed another light on the meaning of the figure 7.2.2.e, which shows a halving of the share of the rice sector on the pesticide market. Table 7.2.5.c shows that the 1996 pesticide sales for rice were approaching the US$ value of 1986, but that in 1996 71% of the area could be treated with 52% of the weight a.i. relative to 1986 (= 100%). In other words, the overall efficiency in kg/ha/year of the newly developed pesticides compared to the generic products increased considerably (27%).

7.2.6. The pesticide market for vegetables and fruits. In Indonesia, pesticide sales for use in vegetables, potatoes[19] and fruits increased rapidly since the early 1990s (fig.7.2.6.a). In potatoes, the market share of dithiocarbamate fungicides - mainly for control of Late Blight *(Phytophthora infestans)*- remained almost continuously between 50% and 74%. More fungicides were contained in the group 'others' with a 10-20% share.

Figure 7.2.6.b shows that pesticide use in vegetables is varied. Use of fungicides, including dithiocarbamates, carbamates and 'others', increased to an estimated 40-50%. Among the insecticides, the organophosphates dominated the scene till 1986, with carbamates trailing at about 14%. In the 1990s, pyrethroid insecticides came up to the same level, around 20%, as the organophosphates. The gain-

Table 7.2.5.c. Indonesia, comparison of total pesticide sales for rice sector in 1986 and 1996 in proportions of a.i. weight and value and of treatable area if following recommended dosages. Source: Bayer AG, Germany, 1998.

Year	**Sales**		**Treatable area**	**Dosage**
	(t a.i.)	**(M US$)**	**(M ha)**	**(kg/ha)**
1886	6,729	98.67	23.88	0.282
1996	3,531	92.44	17.08	0.207
Proportions	1.9	1.1	1.4	1.4

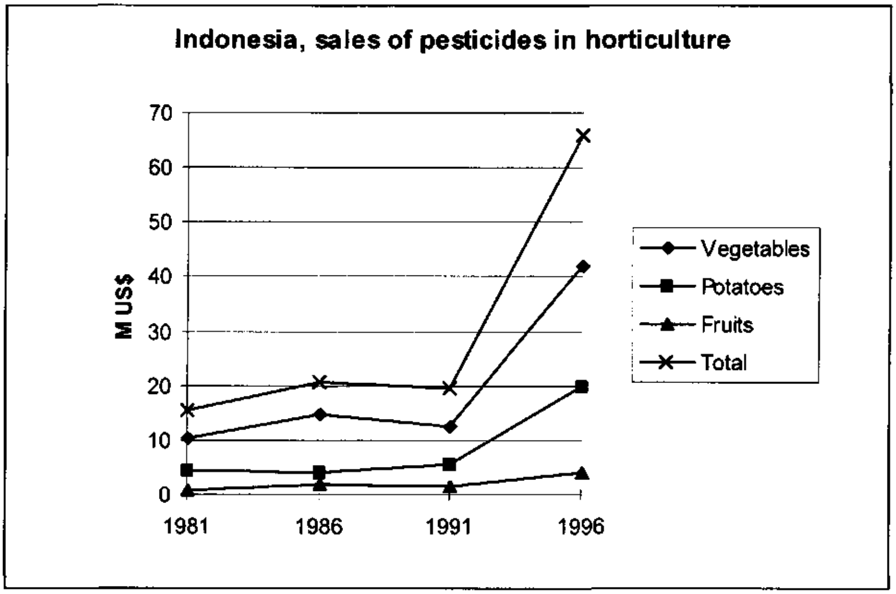


Figure 7.2.6.a. Indonesia, sales of pesticides in vegetables, potatoes and fruits, 1981-96. Source: Bayer AG, Germany, 1998.

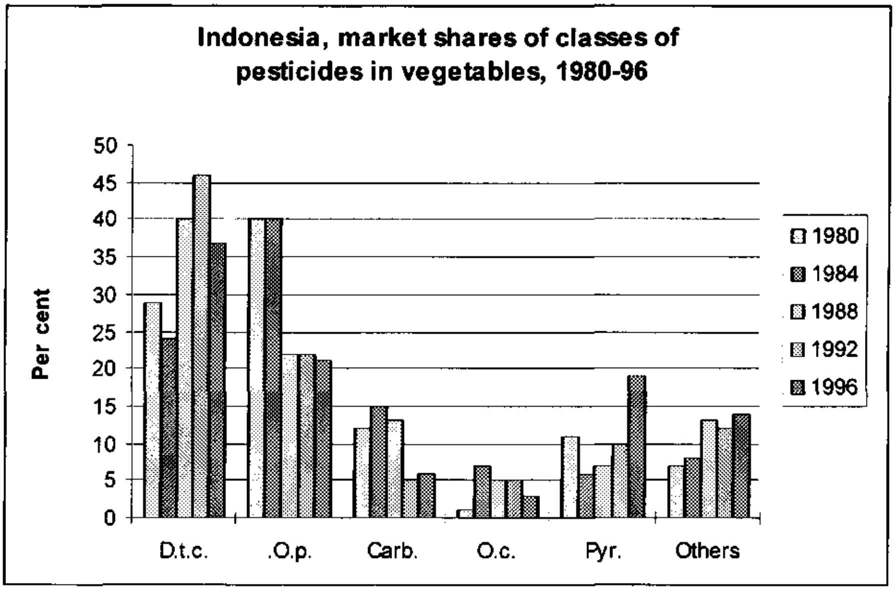


Figure 7.2.6.b. Indonesia, market shares of chemical classes of pesticides in vegetables, 1980-96. Source: Bayer AG, Germany, 1998.

Legend: Dtc= dithiocarbamates, O.p.= organophosphates, Carb.= carbamates

O.c.= organochlorines, Pyr = pyrethroids.

ing popularity of pyrethroids is probably a result of an increasing pesticide resistance of major vegetable pests.

Pesticide use in fruits refers to apples and citrus mainly, data for banana and pineapple indicate zero use. Data on the fruit sector in Indonesia are scant, anyhow.

7.2.7. Discussion, Indonesia. In the context of IPM, two agricultural sectors really matter. These are: *a.* the rice sector for which the government of Indonesia (GoI) committed itself to the IPM ideology because of the sector's immense economical and political importance; *b.* the vegetable and fruit sector because of increasing public concern about health hazards of pesticide use. The large plantation and smallholder perennials sector is a major customer for herbicides, a product group which (with presently available technology) is more a target for a `safe, need-based use' approach than for IPM.

For the rice sector, the enforcement of the input-based Green Revolution technology during the 1960s meant an important watershed in food production efforts. The introduction of high yielding rice varieties stimulated the use of insecticides. Since the early improved rice varieties lacked resistance against planthoppers, leafhoppers and viruses, the Indonesian farmers were drawn into a treadmill of higher application frequency, worsening pest outbreaks and resurgences of secondary pests. When the national rice intensification effort came in danger, the GoI procured ever greater volumes of insecticides and contracted international companies to help in distribution and application. Early in the 1980s, the FAO Inter-Country IPM in Rice Programme began to advise the government on the control of BPH, which led to the Presidential Instruction of 1986 and the ban on insecticides for rice.

Caution in the interpretation of the data on the recession in the pesticide market is needed in view of the modalities of procurement. In 1986, procurement for rice was largely done by the government agencies and the bulk of the products purchased took a very long time to reach the field. In 1996, purchases were made by dealers with short communication lines to the farmers. The 1996 sales would therefore more accurately represent actual use in rice than those of 1986. The composition of the pesticide market has changed drastically but farmers have certainly not given up spraying against rice pests. Instead, they continued to buy unsubsidized insecticides and may thus actually have been spending more on chemical pest control than during the 1980s. The increased costs of pesticides would then be the main incentive for more judiciously targeted (need-based) use.

Another way to measure the effect of IPM policy on pesticide sales is to look for changes in the product assortment over time. The choice of products for rice changed notably after the ban. The market share of organophosphate insecticides fell to about 20%. Their place was take over first by carbamates and later by pyrethroids and new insecticides from the class `others'. Since these relatively new classes of chemicals enable to treat a larger hectareage with less volume of a.i., following lower dose recommendations, a reduction in a.i. quantity is reached in the rice sector.

However, active ingredients and brands, which were mentioned by name on the ban list, are still sold for and used in rice in large quantities. This means that the Instruction has largely lost its effect. Within the Ministry, different departments were responsible for IPM implementation and for input supply. These units worked rather independently from each other. Chief administrators in charge of input supply were less familiar with the ecological consequences of chemical control than others connected with the National IPM Program.

IPM implementation in rice had a visible effect on the market. It seems that the agricultural administration and services understood the danger of overdependency. Farmers learned that spraying in rice is not a must. The informed part of industry has become more cautious in its approach of pest resurgence problems. By 1996, about one million rice farmers, about 2% of the 48 million active farmers (FAO Production Yearbook, 1997), had been reached by the national IPM extension (Whitten, 1998).

7.3. The pesticide market in Malaysia

7.3.1. The Malaysian pesticide market before 1980. At the end of the colonial era, Malaysia inherited an efficient plantation agriculture, which had not been interrupted by a struggle for independence. Rubber and oil palm, occupying about 70% of the hectareage under cultivation, formed the backbone of the private estate and smallholder industry. Weed control in estate crops[20] accounted for 20-40% of total maintenance cost, especially in immature stands. Due to high labour demand in plantation agriculture, the structural labour shortage in Malaysia and consequent high wage levels, chemical weeding was standard practice (Wong, 1972). In the 1970s, the extraordinary growth of the oil palm, cacao, and fruits sectors created a stable market for herbicides (Hassan, 1990).

Until the 1960s, farmers grew traditional rice varieties, which suffered relatively little from insect pests and diseases, in a single cropping pattern during the rain season. Rice and other field crops occupied less than one quarter of the arable land in Peninsular Malaysia. Although insecticide usage in maize, tobacco and vegetables was higher than in rice, overall use of pesticides in field crops was small. The coming into operation of large irrigation schemes for double cropping of rice caused, between 1970 and 1990, a fundamental change in cropping routine as well as a serious increase in pest incidence (ch 3.6.4). This change and the government's policy to promote production of vegetables and fruits, crops requiring intensive pest control measures, stimulated a rapid growth of the pesticide market since the early 1980s.

The first market study on the domestic supply of pesticides in Malaysia was undertaken by ARSAP between 1977 and 1982. Table 7.3.1.a shows the market shares of various plant protection product categories for the years 1977-80, expressed in formulated products (f.p.) value. Over four years, the market increased 31% in value (ARSAP, 1979, 1981a).

The strong and stable demand for herbicides had attracted early investment in a domestic formulation industry. By 1976, formulation plants in Malaysia produced more than half of the herbicide products sold in the domestic market[21] (table 7.3.1.b). Local formulation of insecticides and fungicides concerned mainly production of granules and powders or dusts (aldrin, BHC, endosulfan, thiram and DDT). Local manufacture of technical grade material was limited to 6,000 t of sodium chlorate (Adam & Reddy, 1977; ARSAP, 1981a, b; Staring 1984).

7.3.2. The Malaysian pesticide market since 1980. An overview of pesticide supply in Malaysia in the 1980s and 1990s was obtained through compilation of marketing data provided by Bayer AG, Germany. Figure 7.3.2.a shows the total annual sales for 1980-96 in terms of a.i. value and weight, and in treatable area. Total procurement of pesticides, expressed as a.i. weight, fell in 1980-83 but recovered steeply thereafter and reached a peak in 1988. After 1988, procurement in terms of a.i. weight stagnated till 1992, then rose again till in 1996 it almost matched the 1988 level. The graph for all pesticide sales[22] in a.i value followed the same trend as the graph for a.i. weight.

Table 7.3.2.a represents the aggregated data for all active ingredients traded in the Malaysian market, 1980 and 1996 (Bayer AG, Germany, 1998). The figures 7.3.2.b, c and d indicate the market shares of product categories, in terms of a.i. weight and value, and treatable area, in 1980 and 1996. The share of herbicides fell

Table 7.3.1.a. Malaysia, total pesticide market, 1977-80, expressed in f.p. value (M US$). Source: ARSAP, 1981a (data from Ministry of Agriculture, Malaysia).

Category/year	1977	1978	1979	1980
Herbicides	39.5	44.5	51.8	59.1
Insecticides	6.4	6.8	7.3	7.7
Fungicides	1.8	2.0	2.2	2.3
Rodenticides & others	1.6	1.9	2.0	2.3
Total Value	49.3	55.2	63.3	71.4

Table 7.3.1.b. Malaysia, production of domestic formulation industry, 1976. Source ARSAP, 1981a (data from the Federal Industrial Development Authority).

Category	Liquid f.p. (M litres)	Solid f.p. (M kg)	Value f.p. (M US$)
Herbicides	9.7	6.3	22.2
Insecticides	2.8	1.5	9.8
Fungicides*	1.1	0.2	1.3

Note: Fungicides inclusive of wood preservatives.

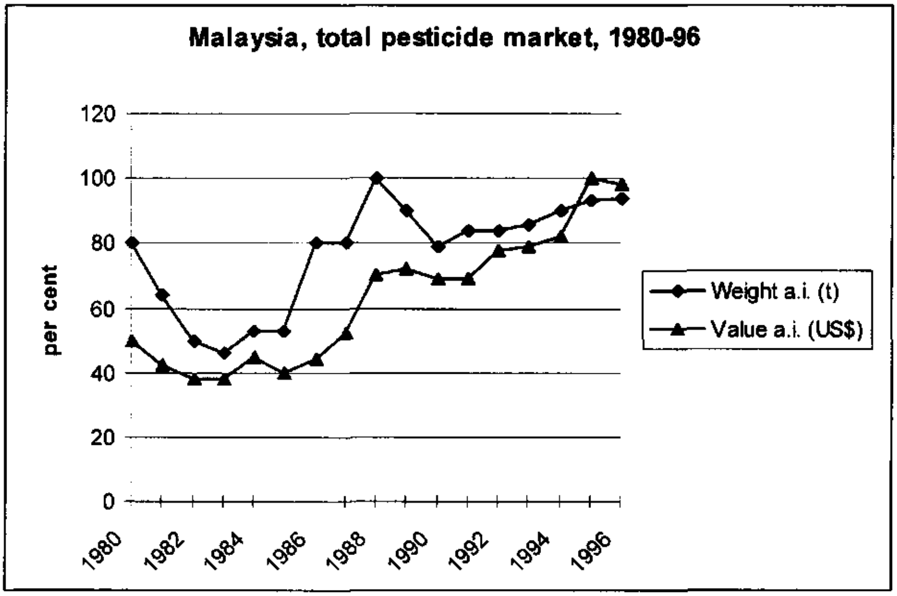


Figure 7.3.2.a. Total annual sales of pesticides in Malaysia, 1980-96, in relative values (1988 = 100% for a.i. weight; 1995 = 100% for a.i. value in US$). Source: Bayer AG, Germany, 1998.

30% between 1980 and 1996, from 87% to 57% in terms of a.i. weight (fig. 7.3.-2.c). Figures 7.3.2.b and d, however, show only a 10% reduction of the herbicide share in terms of, respectively, a.i. value and treatable area. Table 7.3.2.a confirms a shift to more expensive, post-emergence herbicides which require a lower dosage rate. The herbicides glyphosate and glufosinate (class organophosphates), with a combined sales volume of 2,922 t a.i. in 1996, almost completely replaced the former major products dalapon, MSMA and sodium chlorate, which together accounted for 4,440 t a.i. or four-fifth part of the herbicides marked 'Others' in the 1980 market. The turn-over of paraquat increased by 70%, but that of 2.4-D products fell to one third, whereas 2.4.5-T and sodium arsenite were withdrawn.

The Bayer marketing data show the distribution of total pesticide sales over various crops. Figure 7.3.2.e illustrates the change in market shares, expressed in a.i. value, in various crops during the period 1981-96. Information from various sources regarding developments in major food and estate crops enables an interpretation of the marketing data in their agricultural context. For example, the sales of, in particular, insecticides and fungicides in the horticultural sector increased from 15% to 38% in response to the government's policy of expanding vegetables and fruits at the expense of rice and other field crops outside major irrigation schemes (Agrow #26, 1996). Decreasing pesticide use in cacao corresponds with a fading of interest in the crop in W and E Malaysia because of its high costs of pest control and labour (Chee *et al.*, 1992). In rubber and oil palm, the relatively

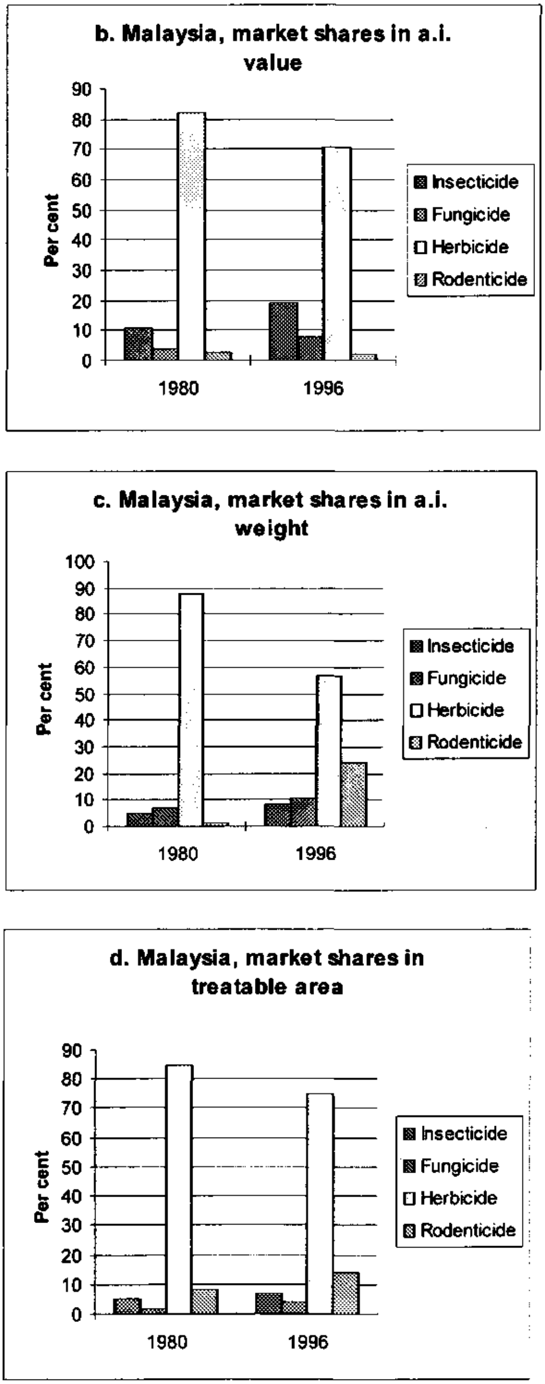


Figure 7.3.2.b, c, d. Malaysia, comparison of market shares of product categories in 1980-1996.
Source: Bayer AG, Germany 1998

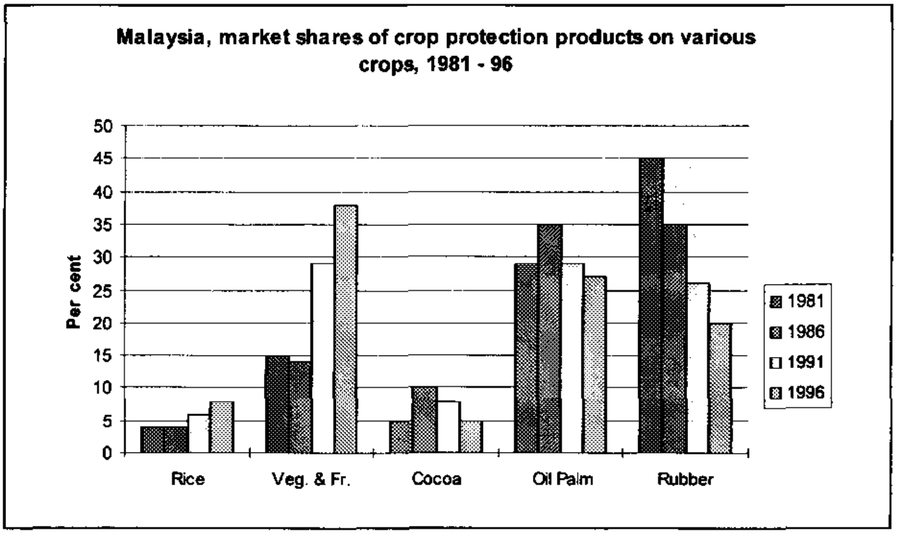


Figure 7.3.2.e. Malaysia, change in pesticide market shares (in a.i. value) in various crops between 1980-96. Source: Bayer AG, Germany.

high use of pesticides is almost entirely accounted for by herbicide applications in immature stands. Due to large scale replanting programs, herbicide use in rubber and oil palm increased in the 1970s and early 1980s. Since the mid-1980s, the herbicide sales in oil palm decreased a little whereas the area treated remained almost equal due to the use of more effective herbicides[23]. The halving in a.i. value of herbicide sales in rubber, however, is mainly attributable to an actual reduction in replanting and maintenance due to shortage of labour for tapping (Chung, 1987, 1989; Chung & Chang, 1989;Teoh, 1986).

7.3.3. The pesticide market for rice. Since 1980, the market share of pesticides for use in rice increased from only 4% to 8%, which made the sector of minor importance to the industry. But a discussion of pesticide use in rice is helpful for understanding Malaysia's approach to IPM. Since the 1960s, application of insecticides in rice was promoted by the agricultural extension service through its inclusion in the Green Revolution technology package and the accompanying *padi* credit system (ch 3.6-.4.1). The planting of non-resistant high yielding varieties and the increased application of nitrogen and insecticides led to higher pest densities. The first major outbreak of BPH and WBPH[24] occurred in the Tanjung Karang Irrigation Scheme in N Selangor State in 1977/78, and was followed by an epidemic of tungro virus disease (Balasubramaniam *et al.*, 1993). Resurgence of BPH and tungro virus transmitting green leafhoppers recurred in Tanjung Karang throughout the 1980s (fig 7.3.3.a) (Ooi & Heong, 1988). From 1977, BPH and WBPH emerged as important rice pests in the Muda area too. A green leafhopper (*Nephotettix virescens*) outbreak caused an epidemic of tungro virus disease in Muda from 1981-84 (Ho, 1994a; Heong & Ho, 1985).

Table 7.3.2.a. Malaysia. Composition of the pesticide market in 1980 and 1996, expressed in a.i. weight, a.i. value of chemical classes, and treatable area if applied following dosage recommendations. Source: Bayer AG, Germany, 1998.

Categories and chemical classes	**A.i. weight (tonnes)**		**Trt. area (x 1,000 ha)**		**A.i. value (M US$)**	
Year	**1980**	**1996**	**1980**	**1996**	**1980**	**1996**
Insecticides						
Organophosphates	236	451	481	840	3.54	6.94
Carbamates	56	73	168	255	1.68	2.59
Organochlorines	64	50	158	137	1.09	.13
Pyrethroïds	2	20	40	1,196	0.71	5.32
Others	18	125	31	329	0.35	9.55
Total	376	718	878	2,757	7.36	25.53
Relative	5%	8%	5%	7%	11%	19%
Fungicides						
Organophosphates	1	9	2	23	0.03	0.29
Carbamates	0	<1	0	1	0	0.53
Dithiocarbamates	289	843	211	712	1.50	5.43
Organochlorines	31	18	39	541	0.30	0.26
Others	285	161	161	431	1.20	3.7
Total	606	1,031	413	1,708	3.02	10.23
Relative	7%	11%	2%	4%	4%	8%
Herbicides						
Organophosphates	215	2,922	1,043	14,678	13.53	44.79
Carbamates	0	19	0	15	0	0,53
Sulfonyl urea	0	29	0	4,765	0	12.96
Paraquat	1,336	1,847	7,485	8,378	21.39	28.49
Others	5,653	661	8,656	3,14	20.79	10.09
Total	7,204	5,478	17,184	30,980	55.71	96.86
Relative	88%	57%	85%	75%	82%	71%
Rodenticides	50	2,400	1,667	5,950	1.90	3.18
Relative	1%	24%	8%	14%	3%	2%
Grand Total	8,236	9,627	20,142	41,395	68.00	135.80
Relative	100%	100%	100%	100%	100%	100%

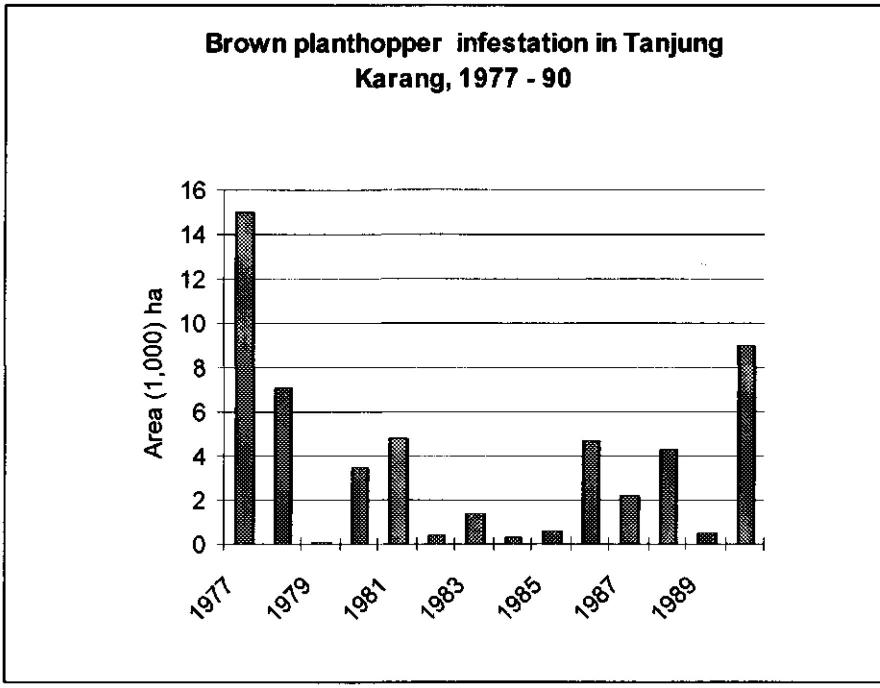


Figure 7.3.3.a. Hectareage infested by brown planthopper in Tanjung Karang Scheme, Malaysia 1977-90 Various sources.

DoA followed two lines of action in its effort to control the outbreaks. The plant breeders searched for BPH, green leafhopper and TV resistant rice varieties. DoA's Plant Protection Service and MARDI set up a surveillance system in the Tanjung Karang Scheme in 1981 to provide early warning as a guide for timing insecticide treatments. The Tanjung Karang system became the national model for monitoring of the population development of BPH and other rice pests and their natural enemies (Ooi, 1982). The economic threshold level (ETL) for BPH was determined at 7 adults or 15 nymphs/hill, and the maximum level for biological control at 50 BPH : 1 predator (Ooi & Heong, 1988; Heong, 1977).

Early in the 1980s, farmers in Tanjung Karang sprayed insecticides whenever they observed damage, generally making three to four applications per season (Kenmore, 1991b). They spent up to US$ 40 per farm on pesticides, which they bought with cash from pesticide salesmen (Heong, 1984). A survey, held in 1987, showed that Malaysian rice farmers used mostly organophosphate insecticides, which were banned in Indonesia shortly before. Almost all farmers used a lever operated knapsack sprayer[25], but had not been trained in spraying technique and sprayer maintenance (Heong *et al.*, 1992b). Tanjung Karang farmers preferred monocrotophos[26], despite its official restriction to oil palm (Kenmore, 1991b; Anang *et al.*, 1995). Another survey by IRRI in the Muda Irrigation Scheme reported that 98% of the farmers used pesti-

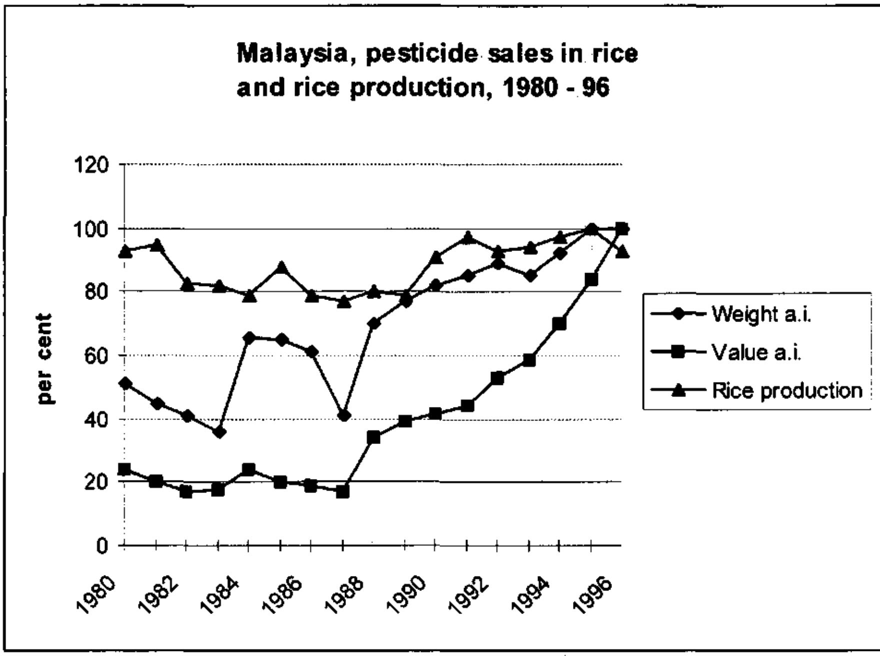


Figure 7.3.3.b. Pesticide sales in rice and rice production in Malaysia, 1980 - 96, in relative values (1996 = 100% for a.i. value and weight, 1995 = 100% for rice production). Source: Bayer AG, Germany 1998.

cides every season and that 65% of them made up to 5 applications per season. The highest number of applications recorded was fifteen times (Oka, 1996).

Figure 7.3.3.b, which plots pesticide procurement for use in rice (in a.i. weight and value) against total rice production in Malaysia, helps to determine the effect of increasing planthopper populations and tungro virus on pesticide sales. The curves for a.i. value and weight appeared to rise in respons to the BPH and tungro outbreaks of the late 1970s and late 1980s in the Muda and Tanjung Karang areas[27]. But the major virus epidemic in Muda, 1981-84, which caused an increase in use of insecticides, did not influence the downward trend of the a.i. weight and value curves.

Far more impact on the sales curves than from insect pest outbreaks resulted from the shift in method of crop establishment in the large irrigation schemes in the 1970s and 1980s from transplanting to direct seeding of rice (ch 3.6.4.3). Adoption of the direct seeding technique in the Muda Scheme early in the 1980s was stimulated by the chronic water shortage and subsequent cancellation of irrigation for the off-season rice crop beginning January 1994. This measure necessitated direct seeding of 53% of the planted area of 83,100 ha in season 1984/1 (table 3.6.4.6). The upward turn of curve for a.i. weight in 1984 indicates an increased use of herbicides necessitated by the much stronger weed competition in fields with self-sown seedlings than with transplanted rice. In 1983 and following years, the majority of farmers tried to replace direct seeding of rice by self-sown seedlings. Since the latter method aggravated the weed problem, sales of herbicides jumped in 1985-1986, when 65% of the Muda Scheme was covered by self-sown seedlings.

The continuous rise in herbicide sales since the late 1980s, is entirely attributable to the transition to direct seeding. Transplanting of rice became obsolete for the off-season and fell below 20% of the cropped area for the main season. Since developments in the Muda Scheme were copied by the other major rice schemes, direct seeding and high herbicide use are current practice in all granaries of Malaysia (table 3.6.4.3).

7.3.4. Rodenticides and control of field rats. In a 1981 survey, more than half of rice farmers in the irrigation schemes ranked field rats (*Rattus argiventer*) as the most important pest, which caused heavy losses and visual damage (Heong, 1984). Rat control by baiting and hunting with zinc phosphate and warfarin were common practice. Results were usually poor, mainly due to lack of communal approach and discipline (van de Fliert *et al.*, 1994). The integrated control of field rats on a large scale in the states of Penang and adjacent Kedah in 1985-1986 was one of the first campaigns launched by the National IPM Committee of Malaysia (Asna, pers. comm, 1986; Zadoks *et al.*, 1986).

In oil palm plantations, *Rattus tiomanicus* was a major pest, which could be effectively controlled by baiting with warfarin[28]. Resistance to warfarin developed in Malaysia since 1983 and the problem was aggravated by the build-up of *R. diardii* population as new rat plague in oil palm. Baiting with second the generation of anticoagulants, brodifacoum, bromadiolone and diflocoumafen gave good control of both species, whereas control by the acute poisons bromethalin and zinc sulphate failed (Wood *et al.*, 1972, 1990; Chung *et al.*, 1994).

Table 7.3.2.a shows sales in 1996 of about 2,400 t of rodenticides, representing a sizable market share in terms of a.i. weight and treatable area (fig. 7.3.2.c, d). Sales consisted of two thirds warfarin and one-third second generation anticoagulants. Warfarin baiting was probably mostly practiced by rice farmers.

7.3.5. Pesticide supply, distribution and application in Malaysia. In principle, the supply and distribution were handled by the private sector but various public sector agencies organized their own distribution networks. The Malaysian government, at the federal or state level, exercised control over agrochemical distribution through farmers' associations and cooperatives, operating under the umbrella of the Farmers Organization Authority (FOA), and through various land development authorities and crop production boards. The FOAs role in distribution was important as an instrument of indirect price control on pesticides because every farmer was entitled to buy from FAO outlets (ARSAP, 1981a). An estimated 60% of total herbicide supply and 50% of total insecticide supply reached the end-user through such public channels. The large private formulators had their own marketing organization and dealer network.

Pesticides were not directly subsidized by the government, but prices seemed to be reasonably well under control. The Pesticide Unit of DoA's Crop Protection Service published an annual pesticide index cum price list with retail price directives for all registered products. (Balasubramaniam *et al.*, 1993).

Pesticide management and application are still deficient, in particular in small holdings. The industry and the Malaysian Agricultural Chemicals Association (MACA) organized since the mid-1990s a 'safe use training' for applicators. The Agricultural Extension Service and other DoA divisions placed no priority on development and testing of spray equipment and training of applicators.

7.3.6. Discussion, Malaysia. The pesticide industry has a strong position in most agricultural sectors of Malaysia. The sales of herbicides to the plantation crops sector, in particular for use in oil palm and rubber estates, account for 80% of the pesticide market in terms of a.i. value. Research on biological control of weeds on estates has yielded few results.

The market share for use in horticulture, mainly insecticides and fungicides, increased from 15 to 40% in a.i. value. Research on biological control of insect pests in cole crops and solanaceous crops (Lim, 1989), and prevention of virus diseases in hot pepper (Vos, 1994) yielded practical results. Since the late 1980's, much of the IPM fervour has been lost. Chemical control is again predominant in cabbage cropping during the off-season and growers shifted to cut flowers grown for export with high pesticide use again.

Rice production in Malaysia is concentrated in large rice irrigation schemes under management of powerful Scheme Authorities. Rapid adoption of modern high yielding rice varieties, high use of inputs, credit and guidance raised rice yields from 3.3 t/ha to 5 t/ha in direct seeded rice. Outbreaks of secondary insect pests and virus epidemics were controlled through adoption of resistant rice varieties, monitoring of pest and natural enemy populations, and supervised chemical control. No major pest outbreaks occurred since the mid-1980s. In the lesser rice schemes insecticide use was allegedly increasing in the late 1990s (Oudejans, 1996).

Due to chronic shortage of irrigation water and labour the schemes have shifted from transplanting rice seedlings to direct seeding. The inherent increase in weed densities is successfully controlled by integrated weed management (IWM). Training in IWM in rice was given to farmers in Muda and other schemes through demonstration and field assistance. The shift to direct seeding, which requires an increased use of herbicides, has made the market in rice much more important for the industry.

7.4. The pesticide market in Thailand

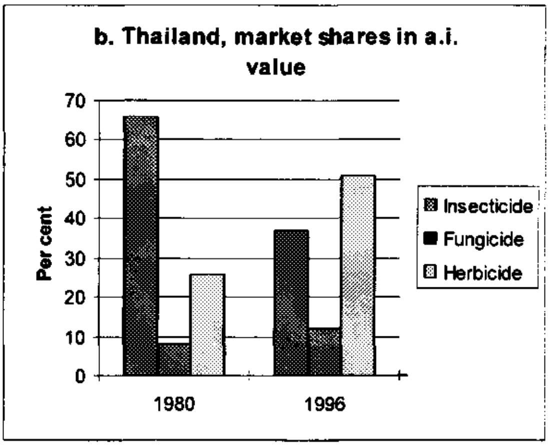
7.4.1. Thailand's pesticide market before 1980. Towards the end of the 19th century, farmers in C Thailand broke away from self-sufficiency in rice farming and began to produce a surplus for export. Foreign demand for Thai rice led to a rapid increase in production. The government improved the infrastructure, but chronic labour scarcity hampered an expansion of the hectareage (ch 4.3). Early in the 20th century, Thai farmers changed from traditional transplanting of rice to less labour intensive direct seeding. Though mechanization became available in the late 1920s, indigenous rice technology improved little before 1950 and productivity remained low. Since investment and research held off for other field and plantation crops too, Thai agriculture lagged behind in comparison to agriculture in Indonesia and Malaysia.

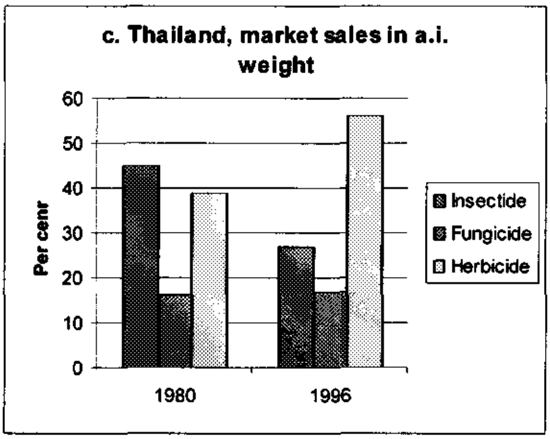
Under the National Economic and Social Development Plans since 1961, the Thai government invested heavily in land development, irrigation infrastructure and establishment of agricultural centres for research and extension (AADPC, 1984b). The farmers, however, continued to grow rice with only limited use of improved cultivars, fertilizer and pesticides, since extensive production methods brought them highest returns (ch 4.4.3) (Waibel, 1990). In an effort to alleviate poverty in backward provinces, the Thai government promoted secondary crops, such as maize, cassava, grain legumes, cotton and sugarcane through the creation of agricultural zones. The Green Revolution technology, which enhanced rice production throughout S and SE Asia, was less eagerly adopted in Thailand. It appears that only owner-farmers made full use of modern varieties and chemical imputs, whilst tenant farmers kept growing local varieties at a low input level. Due to low farm-gate prices for rice and low productivity many farmers turned to growing more profitable crops such as maize, fruits and vegetables, and to raising livestock.

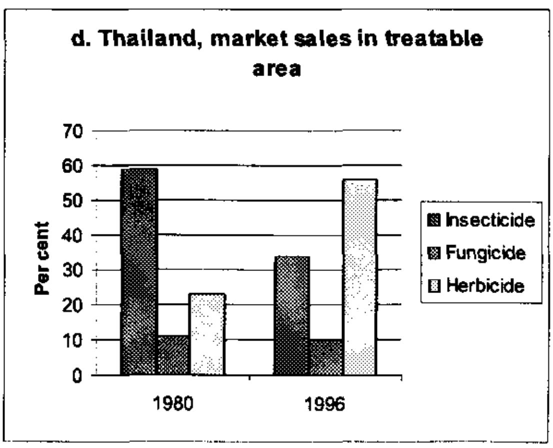
The import of pesticides, initially as finished products only, began during the 1950s. Procurement was relatively small and mostly destined for control of pests in rice, cotton and maize and of migratory locusts (James & Reddy, 1977b). The Department of Agriculture (DOA) provided the regulatory framework but left import and distribution almost entirely to the private sector. The Plant Protection Services Division (PPSD) of the Department of Agricultural Extension (DOAE) managed, in addition to its regular extension work, a national network of plant pest control units. The tasks of the Plant Protection Service Division included surveillance of insect pests and diseases in crops and the organisation of emergency control operations. DOAE provided emergency control free of charge to the farmers, and purchased the required pesticides through tenders from local formulators and distributors (James & Reddy 1977b).

For instance, over the years 1974-76, DOAE procured a total of 2,830 tonnes of f.p. costing 5.5 M US$ against a regular emergency control budget. With this supply the Plant Protection Service Division treated 2.5 M to 3 M ha/y, in particular against insects (leafhoppers and stemborers), diseases and rodents in rice (up to 90%), and locusts[29] and grasshoppers in maize and beans (10%-25%) (James & Reddy, 1977b). In the 1960s, the FAO assisted Thailand in controlling frequent outbreaks of the Bombay locust (*Patanga succincta*) which followed extensive deforestation in C Thailand (Roffey, 1969).

Several studies[30] of Thailand's pesticide market during the 1970s reveal that the total supply of formulated pesticides[31], import and domestic formulation, almost tripled from 10,000 to 28,300 tonnes over the period 1973-80 (table 7.4.1). The import of insecticides (in tonnes of a.i. and f.p.) rose rapidly between 1977 and 1980 because of pest outbreaks in rice (ch 7.4.3). Throughout the 1970s, imports consisted for 60% of formulated insecticides. Herbicides came up to almost 30% in 1980.







Figures 7.4.2.b, c, d. Thailand, comparison of market shares of product categories in 1980 and 1996. Source: Bayer AG, Germany, 1998.

Table 7.4.2. Thailand. Composition of the pesticide market in 1980 and 1996, expressed in a.i. weight, a.i. value of chemical classes, and treatable area if applied following dosage recommendations. Source: Bayer AG, Germany, 1998.

Categories and chemical classes	**A.i. weight (tonnes)**		**Trt. area (x 1,000 ha)**		**A.i. value (M US$)**	
Year	**1980**	**1996**	**1980**	**1996**	**1980**	**1996**
Insecticides						
Organophosphates	1,245	2,699	3,536	4,662	16.58	32.49
Carbamates	410	881	1,017	1,853	9.26	16.69
Organochlorines	1,009	574	1,433	1,022	5.63	9.19
Pyrethroïds	27	107	574	1,987	9.03	11.94
Others	37	450	73	702	0.61	15.81
Total	2,728	4,711	6,633	10,226	41.11	86.12
Relative	45%	27%	59%	34%	66%	37%
Fungicides						
Organophosphates	5	35	21	41	0.17	0.89
Carbamates	1	2	<1	<1	0.09	0.09
Dithiocarbamates	475	1,219	475	907	1.55	6.93
Organochlorines	5	36	11	53	0.06	0.58
Others	505	1,745	749	2,112	2.78	19.88
Total	991	3,037	1,256	3,113	4.66	28.37
Relative	16%	17%	11%	10%	8%	12%
Herbicides						
Organophosphates	14	2,468	42	7,726	0.59	42.0
Carbamates	10	203	5	319	0.17	2.73
Sulfonyl urea	0	2	0	289	0	1.43
Paraquat	420	1,363	1,108	3,079	5.33	18.64
Others	1,937	5,927	1,489	5,552	10.22	54.41
Total	2,381	9,963	2,644	16,965	16.30	119.21
Relative	39%	56%	23%	56%	26%	51%
Rodenticides	17	44	805	29	0.18	0.16
Relative	<1%	<1%	7%	<1%	<1%	<1%
Grand Total	6,117	17,755	11,338	30,333	62.25	233.86
Relative	100%	100%	100%	100%	100%	100%

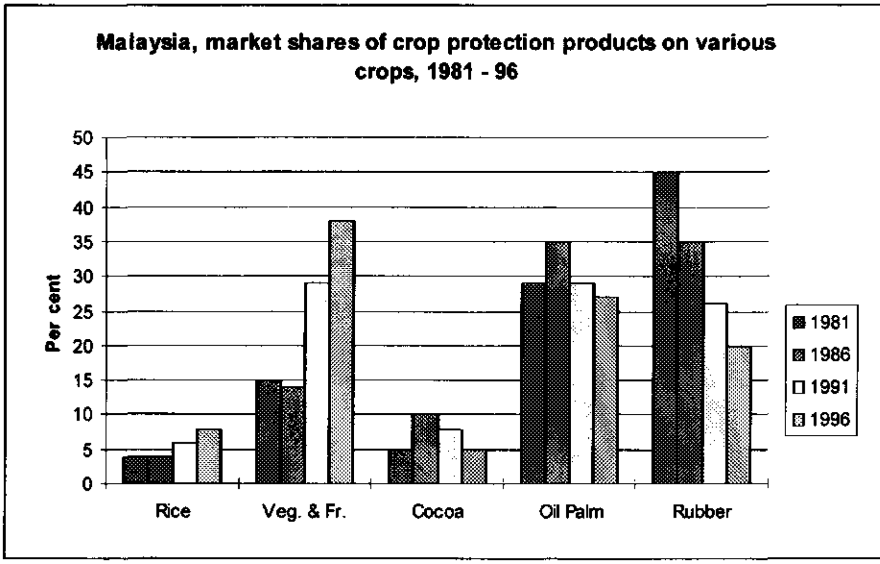


Figure 7.4.2.e. Thailand, change in pesticide market shares, expressed in a.i.value, in various crop categories between 1981 and 1996. Source: Bayer AG, Germany 1998.

In 1994, total pesticide imports amounted to 32,273 t, which consisted of 7,367 t intermediate chemicals or technical grade material for the local formulation industry valued at 37.5 M US$, and of 24,906 t of ready-for-use products for a value of 106.3 M US$. The major share of imported technical material were generic[33] pesticides. The import of ready-for-use formulations concerned primarily the new and more complex proprietary products. These new pesticides are low volume specialty products which are, in general, more effective and less hazardous[34], but far more costly.

7.4.3. The market sectors for rice, vegetables and fruits Throughout the 20th century, the Thai government promoted rice production for export since the rice trade was a major source of revenue for the treasury. Since rice production had always amply covered domestic consumption, investments were rather made to facilitate transport and trade than research for higher productivity and pest control. Reports on incidence of pests and diseases in rice seem to be rare[35]. Pesticide use in rice was low in relation to its huge area of 9 M ha. Pesticide sales in 1980 for use in rice, which amounted to 1,406 t a.i., were barely sufficient for half of that area, about 4.3 M ha if treated according to dosage recommendations (Bayer AG, 1998).

During the 1980s, sales for use in rice increased rapidly in correspondence with higher pest pressure. The curves for a.i. weight and value in figure 7.4.3.a show that sales rose early in the 1980s to a minor peak in 1984, receded a little around 1985, and then climbed steeply to a major peak in 1990. The course of the curves corresponds with the pattern of brown planthopper (BPH) outbreaks in rice which

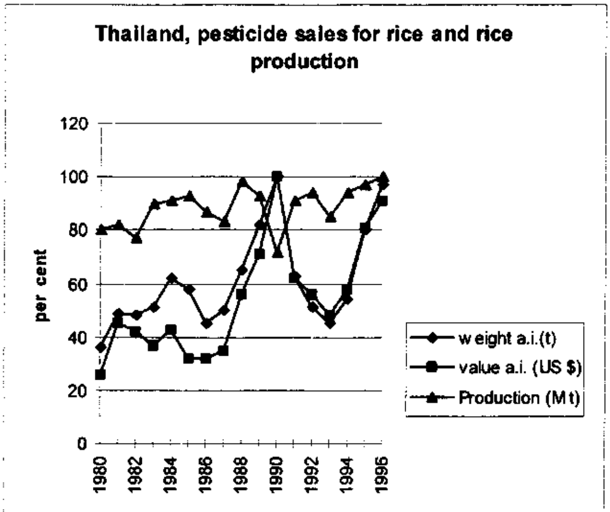


Figure 7.4.3.a. Pesticide sales in rice and rice production in Thailand, 1980-96, in relative values, (1990 = 100% for a.i. weight and value; 1996 = 100 % for rice production). Source: Bayer AG, Germany, 1998.

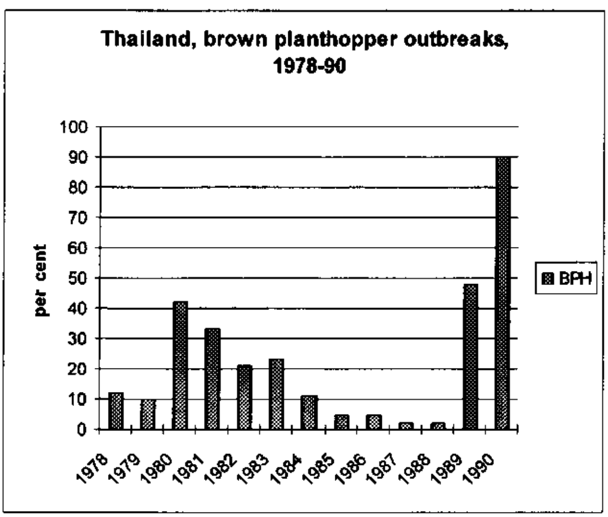


Figure 7.4.3.b. Hectareage infested by brown planthopper in Thailand, expressed in relative values, 1978-90. Various sources.

began in the late 1970s (fig 7.4.3.b). Rice production stagnated when about 109.000 ha of rice were damaged[36] by BPH and virus diseases in 1980 and a further 85.000 ha in 1981. In the crop years 1989-90, an outbreak of BPH and Ragged Stunt Virus (of which BPH is the vector) damaged an estimated 0.6 M ha of rice. This extensive damage contributed heavily to the 1.2 M ha reduction in harvested area from the record 10 M ha harvested in the previous year. The concurrent reduction in yield[37] was even greater and amounted to 3 M t of rough rice (fig 7.4.3.a). The farmers increased insecticide[38] use from the usual 1-3 early season treatments, some even up to ten sprays, every time BPH and virus infestation threatened their rice crop (IRRI, 1993). Such excessive spraying in the outbreak araes led to the dramatic BPH outbreak[39] of 1990. Only then the government undertook a major effort to introduce BPH resistant rice varies as replacement for the popular but vulnerable cultivar Suphanburi 60. By the mid-1990s, farmers in well-managed irrigation areas planted only the two resistant rice varieties issued by the Department of Agricultural Extension (DOAE).

Since 1993, pesticide sales for use in rice rose again to 90% of the 1990 record sales for rice. The chemical class marked 'Others' made the most progress, probably with the new insecticides flufenoxuron, fipronil, imidacloprid, niclosamide and chlorfluazuron as frontrunners (Bayer AG, 1998).

The traditional practice of direct seeding of rice in Thailand and high labour costs had made chemical weeding in rice a necessity already in the 1980s. Herbicides probably accounted most for the strong increase in pesticide sales for rice in Thailand since 1992 (ch 7.3.3).

Since the early 1980s, Thai agriculture has shown an unrelenting decline in rice and in upland crop production. To compensate for the loss in farmers' income, the government strongly promoted diversion of land under field crops to fruit and vegetable growing (Jungbluth, 1996). These crops are pesticide intensive since consumers demand unblemished products.

Early data from the Asian Development Bank data (ADB, 1987) showed that the horticultural sector used more pesticides than the rice sector (table 7.4.3). In 1984, the rice sector accounted for 11% of the fungicide, 22% of the insecticide and 17% for herbicide sales. The horticultural sector used, in the same year, over 75% of total fungicide and some 55 % of total insecticide supply. The use of fungicides and insecticides was particularly heavy on the citrus (pummelo and tangerine).

Concerning the use of herbicides on fruits, pineapple was the major target crop with a 12% share in 1984. The Bayer data show that pesticide sales for fruit pro-

Table 7.4.3. Thailand, market shares of pesticide categories in major crops in 1984. Source: Asian Development Bank, 1987.

Crop	Insecticide %	Fungicide %	Herbicide %
Rice	22	11	17
Vegetables	29	29	5
Fruits	13	29	18
Citrus	12	20	-
Rubber, Oil palm	-	-	24
Field crops	21	-	23
Others	3	11	13
Total	100	100	100

Note: (-) no data available

duction lead the market with a stable 36% share since 1986 (fig 7.4.2.e). Dithiocarbonate fungicides made the greatest contribution (table 7.4.2). In 1996, citrus alone accounted for 11% of the total market with sales of 2,000 t.a.i. It is likely that, under the current crop intensification policy, the use of insecticides and fungicides on fruits and vegetables will further increase in spite of residue hazards for export and domestic consumption (Jungbluth, 1996; Nanta, 1996).

7.4.4. Manufacture and distribution of pesticides in Thailand. In the late 1970s, virtually 100% of the importation, formulation and manufacturing, and more than 80% of the distribution was done by private firms. There was neither government control nor intervention in the distribution chain. Due to the government's liberal attitude 51 companies were authorized to import, formulate, distribute and retail pesticides in Thailand by 1976 (James & Reddy, 1977b). By 1995, the number of parties operating in the pesticide market had further increased to 70 formulation and repackaging plants, 438 distributors and around 5,000 retailers (Jungbluth, 1996).

Early in the 1970s, several international and local companies built formulating plants in Thailand. By 1981, local formulators supplied 52% of domestic demand, mainly insecticides. Domestic manufacture[40] of the herbicide paraquat started in 1980. As domestic formulation capacity soon far exceeded local consumption, Thailand began to export pesticides within the SE Asian region. About 500 so-called 'bath tub' formulator companies existed, which generally produced a low grade product and which were difficult to control due to their irregular production pattern and high mobility (James & Reddy, 1977b).

An obstacle to government regulation of the pesticide trade in Thailand has always been its unusually large number of products and brandnames on sale. Whilst the 1980 pesticide trade in Thailand concerned 89 active ingredients, the number of a.i.s traded in 1996 had almost doubled to 172 compounds (Bayer AG, 1998). The registration procedures do not only accept pesticide formulations but also individual finished products for registration[41] (Jungbluth, 1996). In this way, monocrotophos is sold under 274 brand names, methyl parathion under 296 and paraquat under 55 (ARSAP/CIRAD, 1991). Such an exceptional number of trade names not only is highly confusing for the consumer, it also makes inspection of the market for quality and hazard under the pesticide law impossible for government inspectors.

The pesticide manufacturers and distributors of Thailand have organized themselves in two different bodies. The big producer cum distributor companies -37 by 1996- belong to the Thai Crop Protection Association, member of the Asia/Pacific Association of the Global Crop Protection Federation[42]. A group of 45 to 50 small to medium scale producers have formed the Thai Association of Pesticide Manufacturers. The remainder are non-aligned and difficult to control.

7.4.5. Discussion, Thailand. The Thai government pursued a dual policy regarding the use of pesticides. By establishing a national IPM program and through joint IPM projects, such as the Thai-German Fruit Project, the government appeared to promote judicious pesticide use by farmers. However, IPM implementation stagnated due to lack of political interest and funding. At the same time, the government aimed at increasing agricultural commodity production for export through promotion of fertiliser and pesticide use and various types of subsidies (Waibel, 1989, 1990a, b).

The rice sector in Thailand showed a relative loss of importance since the late 1970s. Government research yielded little improvement of rice growing technology and yields. Extension of modern rice technology and IPM to the farmers was limited. The effectiveness of the surveillance and early warning service in rice is little documented. Most Thai farmers still plant traditional varieties with low use of fertilizer and pesticides. These factors and high weed densities inherent to the direct seeding technique are causes of the relatively low productivity in rice farming. The serious BPH and green leafhopper outbreaks in the late 1980s followed increased insecticide application due to high rice prices. In the 1990s, the ecological balance in rice seems to be reasonably intact. There is no clear relationship between pesticide procurement and insect pest incidence in rice. The share for pesticide use in rice remained at a 20% level in the decade 1986-96.

The horticultural sector, in particular fruit growing, influenced pesticide sales more than any other crop sector. Exceptionally high use of insecticides and fungicides in fruit orchards threatened the economic viability of citrus, mango and durian production. Since 1989, the fruit tree sector has become the target of the most extensive IPM program undertaken thus far, the Thai-German IPM program for selected fruit trees. Its effect on the pesticide market is not yet recognizable in published documents.

Vegetable growing is an important and technically well developed sector. Public research and extension on pest control for vegetables were not yet sufficiently developed to reduce the high dependency on pesticide use. Agricultural development appeared to be left to private enterprise rather than to be orchestrated by public institutions.

The government of Thailand has left the supply, distribution and use of pesticides largely to the private chemical industry. The easy access to the market has resulted in the availability of a large number of pesticide products and brands (ASRAP/CIRAD, 1991; Jungbluth, 1996). The wide choice of products confuses the farmers and renders adequate control of quality and marketing tactics almost impossible. A more stringent regulation of pesticide manufacturing and use was introduced during the 1990s but implementation was slow. An increase of imports of cheaper generic pesticides has an adverse effect on the implementation of the declared policies of pesticide reduction.

7.5. Comparison of the pesticide markets in SE Asia

7.5.1. Agricultural development and pesticide markets. Agricultural development in the three countries differed considerably (chapters 2, 3, 4). In Indonesia and Malaysia, under colonial administration, the emphasis was on the production of plantation crops for export, whereas indigenous food crops remained largely neglected. Only during the Inter-bellum, 1918-41, the Departments of Agriculture in the former Netherlands East Indies and Malaya began to work on the improvement of indigenous food crops and to find ways for raising farmers' income. Independent Thailand during the 19th and early 20th century spent little scientific effort to improve rice productivity, although rice was the main export commodity. The Thai Ministry of Agriculture and Cooperatives with its executive institutions was established in 1974, later than in Indonesia (1905) and Malaysia (1905) and it benefitted less from collaboration with private estate agriculture.

After 1950, independent Indonesia gave priority to rice production in order to attain self-sufficiency in food. International and national research yielded improved rice varieties and technology which enabled the Indonesian farmers to produce a small exportable surplus over domestic consumption in the late 1980s. Through the combined effect of skilful transplanting, intensive crop care, fertile soils and adequate water management, Indonesian farmers achieved a mean *padi* yield of 4.4 t/ha by 1996. The production of vegetables and fruits, of soybean and other field crops was intensified. The plantation crops sector was largely renovated and expanded under para-statal and smallholder management.

The Thai intended to raise rice productivity as in Indonesia, but it could not bridge the gap between administration and farmers. Although research produced valuable innovations, Thai farmers were slow in adopting new rice technology, such as IRRI varieties and fertilizer (table 7.5.1), mainly because higher input costs were not set off by higher income. In the 1990s, Thai rice yields averaged a mere 2.4 t/ha. More progress was made in the secondary crops, in particular fruits, vegetables and sugarcane.

Table 7.5.1. Comparison of rice production and pesticide sales for use in rice in three SE Asian countries, 1996. Sources: FAO Production Yearbooks; Bayer AG, Germany, 1998.

	Rice production			Pesticide sales		Use in rice		
Country	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**
Indonesia	11.3	51.2	4.4	3.5	92.4	0.3	8.2	1.8
Malaysia	0.7	2.1	3.1	0.4	12.2	0.6	18.2	5.9
Thailand	9.2	21.8	2.4	3.7	45.7	0.4	5.0	2.1

Index: a. Area harvested (M ha)
b. Production of rough rice (M t)
c. Yield (kg/ha)
d. Pesticide sales for use in rice in a.i.weight (M kg)
e. Pesticide sales for use in rice in a.i.value (M US$)
f. Pesticide use in rice in kg a.i./ha
g. Costs of pesticide (a.i. value) in US$/ha in rice
h. Costs of pesticide (a.i. value) in US$/t of rough rice

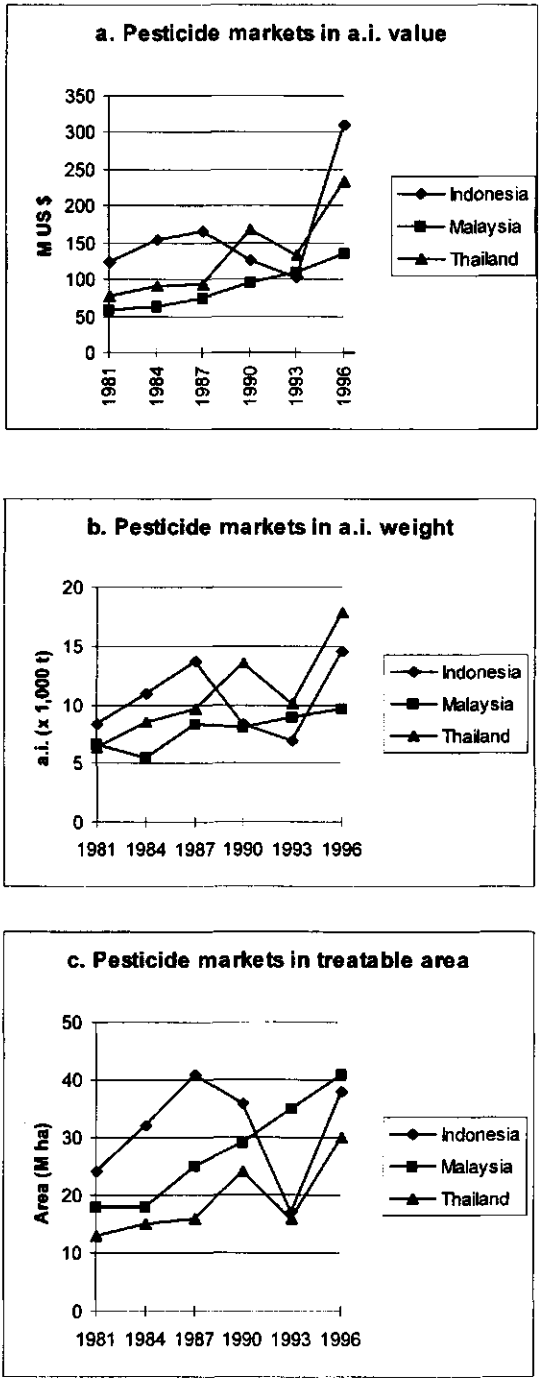


Figure 7.5.1.a,b,c. Comparison of total pesticide markets of three SE Asian countries over the period 1981 - 1996. Source: Bayer AG, Germany 1998.

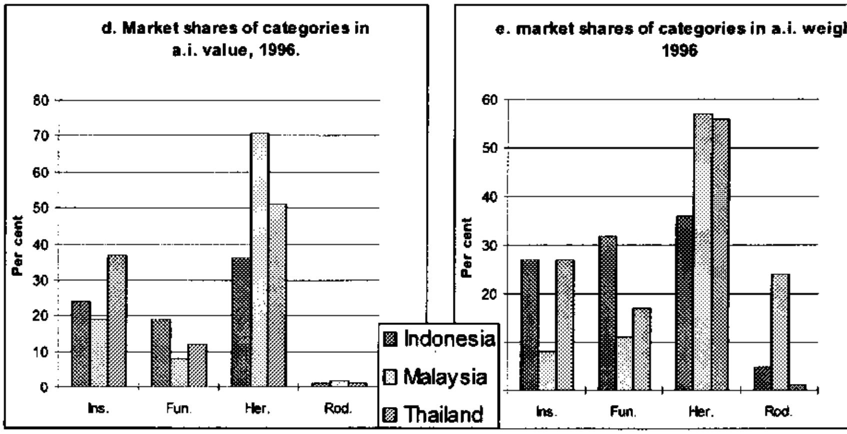


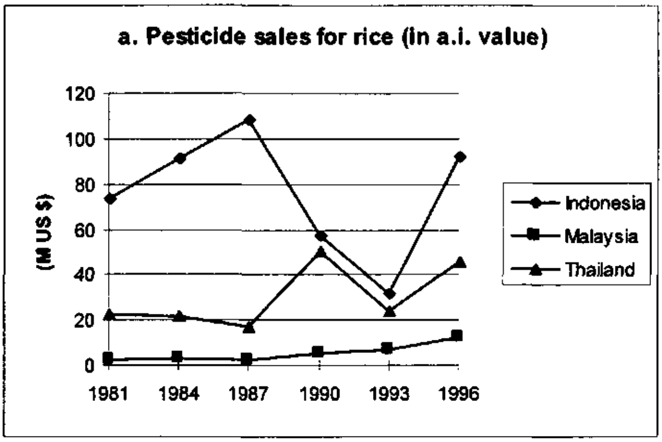
Figure 7.5.1.d,e. Comparison of market shares of product categories in the total pesticide market of three SE Asian countries, expressed in a.i. value and a.i. weight, 1996. Source: Bayer AG, Germany, 1998. Legend: Ins.=Insecticide, Fun.=Fungicide, Her.= Herbicide, Rod.= Rodenticide

In Malaysia, rice production remained a small affair in comparison to the production of export commodities. The government invested heavily in land development, irrigation and research for wet rice cultivation to alleviate the need for rice imports. Yields obtained in major irrigation schemes of Peninsular Malaysia were relatively high, 5.1 t/ha in the Muda area in the main season. The technique of direct seeding, which was common in Thailand since the beginning of 20th century, was adopted and perfected in the Muda Scheme, Malaysia, under the pressure of acute labour shortages.

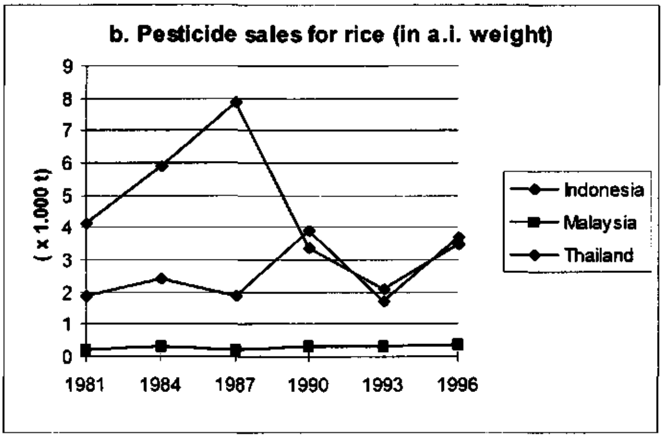
Despite the different directions in which their agricultures developed, the total pesticide markets of Indonesia, Malaysia and Thailand are of a comparable order of magnitude (figs 7.5.1.a, b and c). Each of the three markets showed an upward trend since the 1960s and reached a maximum in 1996. Measured in a.i. values, the ratio between the markets of Indonesia, Thailand and Malaysia was 2.5 : 1.7 : 1 in 1996.

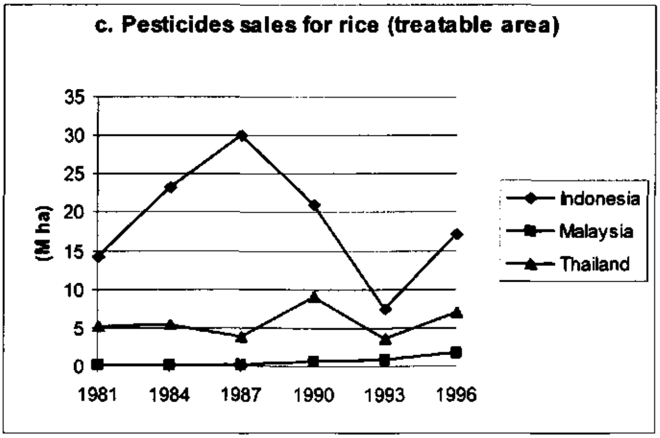
The growth of the total pesticide markets of the three countries over the period 1980-96 is plotted in the figures 7.5.1.a and b. The pesticide market of Malaysia grew steadily in value and volume without disturbance. Malaysia's market is dominated by sales of herbicides for use in oil palm and rubber. Therefore, the Malaysian total market is leading in terms of a.i. weight due to the generally lower price structure for herbicides (figs 7.5.1.d and e).

The Indonesian market peaked in 1987, and then slided into a regression that lasted till 1993. The Thai market followed a similar trend with a delay of three years, reaching a peak in 1990 and regressing until 1993. After 1993, pesticide sales in Indonesia and Thailand rose again to the maximum of 1996, the last year included in this study.



Figures 7.5.2.a,b,c. Comparison of pesticide sales for use in rice in three SE Asian countries,1981 - 1996. Source: Bayer AG, Germany, 1998.





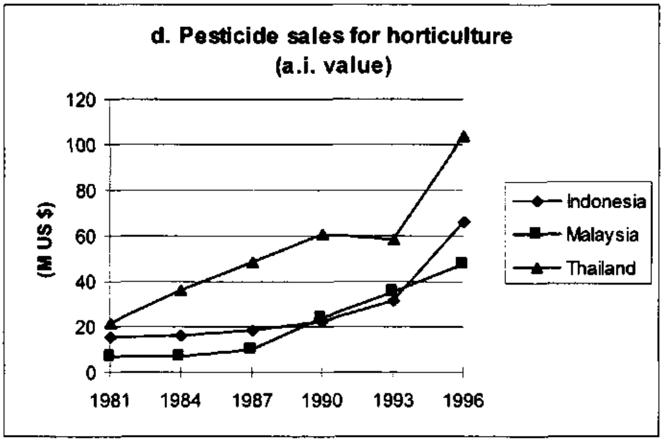
7.5.2. Crop shares in relation to total pesticide markets. The pesticide sales for use in rice, horticulture and estate crops constitute major shares in the total markets (figs 7.2.2.e, 7.3.2.e and 7.4.2.e). The influence of the shares for use in rice and horticulture on the total markets of Indonesia, Malaysia and Thailand is analysed separately.

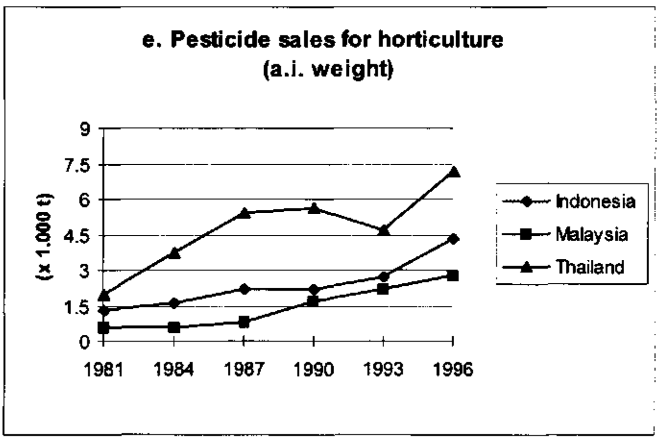
7.5.2.1. Comparison of pesticide sales for rice. The changes in the sales curves for rice in Indonesia and Thailand (figs 7.5.2.a, b and c) could be directly linked to the outbreaks of brown and whiteback planthoppers and leafhoppers and the ensuing virus epidemics. The deep recession in sales in Indonesia was the direct result of Presidential Instruction 3/1986 (ch 7.2). The ban on broad-spectrum insecticides from use in rice testified of persuasive power of the FAO Inter-country and national IPM programmes on the President of Indonesia. In Thailand, the BPH and leafhopper outbreaks of 1989 were less widespread than in Indonesia, since Thai farmers still planted traditional varieties with low sensitivity. The Thai authorities brought the BPH outbreaks rapidly under control by replacing non-resistant rice cultivars, such as Suphanburi 60. Since the Thai government did not adjust its pesticide registration nor excluded insecticides known to cause recurrence of BPH, the recession of the Thai market was minor and short-lived.

A comparison of the growth curves of the market shares for use in rice suggests that the Indonesian IPM policy had a long lasting reduction effect (fig 7.5.2.g). The Indonesian curve representing the share for use in rice fell from 66% in 1987 to 32% in 1993 and below 30% in 1996. In Thailand, however, the market share for rice fluctuated between 29% and 18%, and increased a little again after 1993. Except for a short period of increased insecticide use against BPH around 1990, there is no clear cause-effect relation between pesticide sales and pest incidence in rice or official IPM policy.

In Malaysia, the relatively small but steadily increasing share for rice in the total pesticide market reflects the government's rice intensification policy (ch 3.6.4). The total replacement of transplanting by direct seeding in the large irrigation schemes and a gradual intensification in upland rice increased herbicide use by all quarters of the rice sector. In the Muda Scheme, an Integrated Weed Management (IWM) Program, that has been implemented since 1998, appears to be effective (Ho, 1993). There was no large-scale IPM program of DoA in Malaysia addressing the issue of injudicious insecticide application by farmers in rice. The industry, however, extended its ongoing Safe Use of Pesticides campaign to include Malaysia (GCPF, 1998). DOA's surveillance and early warning system and technical assistance provided by rice scheme authorities have effectively prevented a loss of resistance against major insect pests and diseases in the currently planted rice varieties (Ho, 1993; Ooi, 1992).

A comparison of 1996 sales for use in rice and the treatable areas in Indonesia and Thailand (figs 7.5.2.a, b, c) shows that Indonesia spent double the amount in US dollars for an almost equal tonnage of a.i. as Thailand, but could treat almost 2.5 times more rice area than Thailand. The IPM policy of Indonesia has clearly resulted in a shift to procurement of more effective, more expensive insecticides





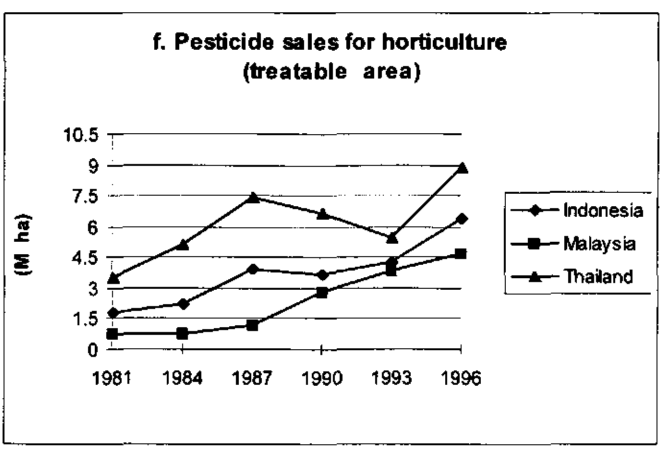


Figure 7.5.2.d, e, f. Comparison of pesticide sales for use in horticulture in three SE Asian countries. Source: Bayer AG, Germany 1998.

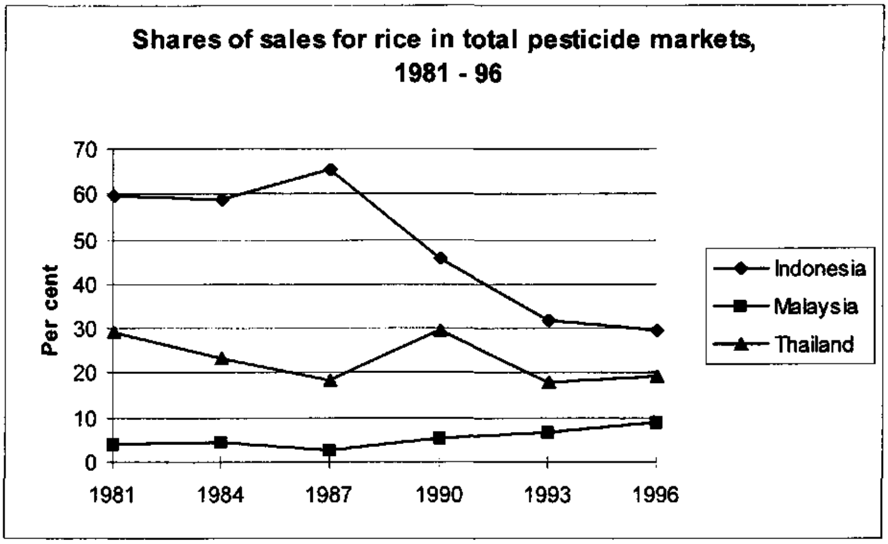


Figure 7.5.2.g. Comparison of sales (a.i. value) for use in rice, expressed as share of the total pesticide markets of three SE Asian countries, 1981-96. Source: Bayer AG, Germany, 1998.

for use in rice. A matching of the Indonesian curves in figs 7.5.2.a and c shows, furthermore, that Indonesia would have needed 5,000 t a.i. in 1982 for treating 17.5 M ha of rice, against 3,500 t a.i. in 1996 for a same hectareage.

7.5.2.2. Comparison of pesticide sales for horticulture. In each of the three countries commercial vegetable and fruit growing is expanding rapidly. The pattern of pests and diseaes is similar, pressure is high everywhere and non-judicious use of pesticides, with its inherent scala of negative effects, is common. The horticultural sector is a prime target for pesticide companies and, consequently, most in need of adequate IPM policies and programs.

The pesticide sales for use in horticulture in Indonesia, Malaysia and Thailand are plotted in the figs 7.5.2.d, e, and f. The break-up of these sales (in a.i. weight) into separate segments for vegetables and fruits (figs 7.5.2.h, i, j) show that in Indonesia more than 90% of the pesticides were purchased for use on vegetables, whilst in Thailand over 85% were applied on fruit trees and field fruit crops. Sales for use in vegetables increased strongly in Indonesia, but not in Malaysia and Thailand. In the latter two countries, sales for use in fruit crops particularly showed an over-all growth.

ket. It caused first a reduction and later a stable reduced share for rice of the total market.

4. The Indonesian Ministry of Agriculture did not entirely recall its recommendations on chemical pest control in rice, because self-sufficiency in rice remains its major objective.

5. The Presidential ban changed the choice of products used in rice. Organophosphate insecticides lost the lead and dropped to a 20% share. Carbamates substituted for organophosphate insecticides, but then yielded to pyrethroids and new insecticides from the class 'others'.

6. The newly developed insecticides enable to treat a larger hectareage with less volume of a.i., following lower dose recommendation. Thus, the reduction in a.i. quantity reached in the rice sector does not necessarily mean that Indonesian farmers treat less hectares of rice.

7. Several banned insecticides were still purchased in quantity for use in rice by 1996. This observation raises doubt about the adherence to the Presidential Instruction 3/1986.

8. The fact that, in Indonesia by 1997, not more than one million rice farmers, about 2% of the 48 million active in agriculture, had been reached by the national IPM extension, explaines its relative small impact on total pesticides sales.

9. In Malaysia, the sales of herbicides to the estate sector dominates the pesticide market by 80%. Herbicide application by large private estate companies is based on research.

10. The sales of fungicides and insecticides for use in Malaysian horticulture tripled since 1980.

11. In the 1970s, Malaysian researchers developed effective biological control, particularly of diamondback moth in cabbage crops. Due to inadequate extension, IPM was little practised and farmers continued frequent application of pesticide mixtures.

12. Allegedly due to heavy losses from insect damage, vegetable farmers in the Cameron Highlands shifted from cabbage growing to the currently more profitable production of cut flowers for export with high pesticide imput.

13. Rice production in Malaysia is a small affair compared to Indonesia and Thailand and mainly limited to six major irrigation schemes. The use of, in particular, herbicides and insecticides is generally well supervised in the larger schemes.

14. Since the large rice schemes of Malaysia have almost completely shifted from transplanting rice to direct seeding, the use of herbicides in rice increased strongly. Herbicide use in direct seeded rice in the major schemes is supervised by an empirical Integrated Weed Management system.

15. The pesticide market in Thailand showed an over-all growth since the 1970s. The market share of herbicides, in particular, doubled from 25 to over 50% since 1980, where insecticide sales lost in relative importance.

16. Sales for use in the fruit sector lead the market, whereas sales for vegetables remained at the same level.

17. The share for rice in the total pesticide market, second after cotton in 1980, receded. Most Thai farmers gave up cotton growing due to high costs of pest control.

18. In Thailand, the effect of outbreaks of secondary insect pests in rice was pronounced during 1989-91 only and related to high farm-gate prices for export rice which induced farmers to use more insecticides.
19. The pesticide markets of Malaysia and Thailand remained unaffected by the National and Inter-Country IPM Programmes in SE Asia.
20. The sales of herbicides to the rice sector is increasing in all three countries, particularly in Malaysia.
21. In the three countries the market share of pesticides for use in vegetables is growing fast, with fungicides leading, particularly in potatoes.
22. The global pesticide market expanded continuously in volume and value since the early 1960s. But for a temporarily recession in SE Asia in the late 1990s, pesticide sales are likely to increase further in the coming decades.
23. A strong growth in market share of generic pesticides is a disquieting development for IPM implementation in SE Asia.
24. Several pesticide companies operating in SE Asia use IPM idiom for promotion of their product line. Most claims on IPM applicability made by the private industry are confusing to farmers and authorities, and may cause a devaluation of the IPM concept.
25. Industrial extension on pesticide use in the framework of IPM by the staff of private chemical companies or distributors requires a thorough education in IPM principles.
26. The three countries have Pesticide Registration Boards and adequate pesticide laboratory facilities. Pesticide registration procedures are strict in Malaysia and Indonesia, but too lenient in Thailand to protect the farmers.

Notes

1. In 1996, world's largest agrochemical multinational Novartis (meaning "new skills") was formed by a merger of the Swiss companies Ciba and Sandoz. Novartis' sales breakdown in 1996 showed weed control 52%, disease control 27%, insect control 18%. With seed sales valued at 872 M US$, Novartis ranked as second largest seed company in the world (Agrow, #261, 1996).
2. The Agricultural Requisite Scheme for Asia and the Pacific (ARSAP) was a Netherlands financed, semi-autonomous project of the UN Economic and Social Commission for Asia and the Pacific established in 1975 for the study of supply, distribution and use of fertilizers and pesticides the region. The project was part of the United Nations strategy to improve food security in S.and S.E. Asia through establishment of data collection systems and training. ARSAP's fertilizer work was continued as Fertilizer Development Network for Asia and the Pacific (FADINAP). In 1983, the work on pesticides was taken over by UNEP/RENPAP (supply and industry) and CIRAD, France, (development of a Pesticide Index and IPHYTROP Data Bank for S and S.E.Asia)(Wynn *et al.*, 1997).
3. At the time, rumours persisted that a lot of subsidized, imported pesticides were right away exported again. The data of table 7.2.1 may therefore overstate the quantities that were actually built up in the Indonsian stores. Much government money might have been misappropriated (various personal communications).

4. Emergency spraying by DoA's servicable aircraft (3 Cessna's and 1 Pilatus Porter) remained a limited affair. For example, in 1976/77, DoA's aerial unit treated 7,650 ha during the dry season and 38,000 ha during the wet season (James & Reddy, 1977a).

5. During the 1978/79 wet season the mobile brigades sprayed 337 t insecticides (chlorpyriphos, diazinon) and applied 34 t of rodenticides (almost all anti-coagulants). The Aerial Unit sprayed 110 t insecticides in the same season (ARSAP, 1980).

6. In 1978, damage from BPH was far less than in previous years due to introduction of the resistant IR36 cultivar and to exceptionally heavy rainfall during the wet season. DoA's Surveillance and Forecasting Service reported insects (in particular brown and white-backed planthoppers) and diseases on 20% of the Bimas rice area in the 1978/79 season (ARSAP, 1980).

7. ARSAP (1980) calculated the 1976-78 average insecticide use by Bimas credit farmers at 0.8 kg a.i./ha in the dry season and 1.5 kg a.i./ha in the wet season. The corresponding average use by Inmas cash-paying farmers was 0.5 kg a.i./ha and 0.75 kg a.i./ha (ARSAP, 1980). The recommended annual rate was 4 kg a.i./ha.

8. Some non-subsidized prices in E Java included fenitrothion (Sumithion^R 50EC) Rp 3,750, fenthion (Lebaycide^R 50EC) Rp 1,500, and mancozeb (Dithane^R M-45 WP) Rp 2,200 (ARSAP, 1980).

9. Synthetic pesticides are manufactured as technical grade material (TC), which contains the intended active ingredient (a.i.) together with associated impurities and, usually, small amounts of necessary additives. TCs are manufactured in various forms as chrystals, flakes, viscous oils and so on, which must be diluted with solvents or inert materials to concentrated formulations before they can enter distribution channels (Oudejans, 1992).

10. Yield losses, caused by brown planthopper, rice leaffolder, stemborer and gall midge were said to threaten food security in Indonesia.

11. Resistance of BPH to various organophosphates, carbamates and pyrethroids was detected in W and C Java (Soejitno, 1991; van de Fliert, 1993).

12. The data for a.i. weight and a.i. value (in US$) are recorded under the year 1987. It is assumed that annual data refer to actual sales transactions, and not to delivery of goods.

13. Fig. 7.2.4.b was depicted in project documents of the FAO Inter-country IPM in Rice Programme, third phase, as a justification for continued investment in IPM extension by participating governments and donors.

14. In the Bayer data series, the a.i. value was expressed in German marks (DM) and US$. Between 1985 and 1995 the rate of exchange varied between DM 3.07 and DM 1.43 for US$ 1. Fig. 7.2.2a demonstrates that exchange rate fluctuations may greatly distort the information. In chapter 7, all values are expressed in US$.

15. An agro-economic survey, 1981, in several main rice-growing areas in Java reported that almost all farmers used HY-rice varieties and fertilizers, except for a small percentage planting traditional varieties for a special clientele (van de Fliert, 1993).

16. For example, the Bayer Indonesia plant, formulating 715 tonnes of fenthion technical into LebaycidR 50EC in 1982, was closed after 1986. To date, Bayer Indonesia has only minor formulation of fenobucarb, propineb and cyfluthrin (Dollacker, pers. comm., 1998).

17. Price differences might be a reason because a calculation of costs of recommended a.i. dose/ha worked out at $9.24 for carbofuran and $7.24 and $5.07 for phentoate and monocrotophos. If this cost differential between carbamates and organophosphates would be the real reason, then the market forces were stronger than government control.

18. The retail prices of cypermethrin and endosulfan formulations for farmers were not available and

might show a price ratio <1.9, because of sales taxes and high profit margins on small packages of pyrethroids.

19. The Bayer data series, 1998, mention use in potatoes separately for Indonesia, but not for Malaysia and Thailand.

20. Heavy weed infestation in oil palm plantings may cause up to 20% reduction in yield. During the 3-year immature phase, 13-18 rounds of chemical weeding are required costing up to US$ 530/ha or 28% of total costs of crop establishment (Chung, 1993)

21. In 1978, almost 85% of a.i. imports consisted of technical material for the formulation of herbicides (mainly dalapon, 2,4-D, sodium arsenite, glyphosate and paraquat)(ARSAP, 1981b).

22. Local pesticide sales by the members of the Malysian Agricultural Chemicals Association account for over 90 % of the Malaysian market (Agrow #261, 1996).

23. The major herbicides used in oil palm include: 2,4-D amine in the pre-felling phase; paraquat and glyphosate in land preparation before replanting to suppress regrowth and to protect soil against erosion. In nurseries and young plantings paraquat, glyphosate and glufosinate-ammonium for control of soft grasses and broadleaf weeds, metsulfuron-methyl for broadleaf weeds and fluazipop-butyl perennial grasses (*Eleusine indica* and *Paspalum* spp) (Chung, 1993).

24. The Tanjung Karang outbreak followed the 1975-1976 outbreaks in N Sumatera, which is a typical BPH outbreak centre.

25. A 1985 survey reported that 80% of the Muda rice farmers (n = 915) owned a lever operated knapsack sprayer, generally 3-6 years old and priced between US$ 20-35. Equipment maintenance was deficient and nozzles were seldom replaced (Heong *et al.*, 1992b).

26. Monocrotophos was marketed in small containers for application as trunck injection in oil palm against borers. The product was largely diverted for use in rice and vegetables as the handsome container size suited small holders better than larger oil palm estates (Newsletter Malaysian Plant Protection Society, 1990).

27. The Tanjung Karang Scheme, measuring only 20,000 ha, represents about 10% of total irrigated rice area in Peninsular Malaysia. The data on the 1977-80, 1986-88 and 1990 outbreaks in Tanjung Karang serve, therefore, as a *pars pro toto* indication rather than giving the full picture for Malaysia.

28. For rat control in oil palm one standard warfarin bait, cubes containing broken maize and 15% warfarin embedded in parafin wax and costing US$ 1/kg, was placed per tree. Problems in controlling rats by anti-coagulent use are described by Wood, Chung & Sim (1990).

29. In the 1960s and 1970s, the migratory Bombay locust (*Patanga succincta*) was regarded a major pest. Several DoAs in S and SE Asia (India, Pakistan, Thailand) maintained a small fleet of aircraft for locust control. In Thailand, 1973, a major locust outbreak infested about 233,000 ha of which 140,000 ha were sprayed by air and 93,000 by ground application (James & Reddy, 1977b).

30. Studies made in Thailand by *i.a.* James & Reddy (1977b), ARSAP (1981), Rijk & Van der Meer (1984) and Jungbluth (1996) contain data on pesticide imports, local production and estimated use per ha, expressed in a.i. and f.p. equivalents of weight and value. Since the data relationship between the rather diverse data is not clear, table 7.4.1.a has been drafted as an estimate.

31. Data on supply of active ingredients in Thailand during the 1970s (ARSAP, 1981) conflict with data obtained from the industry and are therefore not included.

32. Paraquat is usually applied as post-planting, pre-emergence, inter-row spray in maize and cassava, as blanket spray for weeds in fruit trees, and as strip or circle spray in rubber and oil palm (Whitaker *et al.*, 1991).

33. Generic pesticides are first and second generation, off-patent and relatively low price compounds.

Generally, generic products require higher dosage, are more toxic and contain more impurities than patented products.

34. Sometimes, new products appear to receive registration for use in rice and vegetables when the claim of lower hazard seems not to be fully justified. For instance, the a.i. fipronil is registered for control of migratory locust because of long residual activity, a questionable feature for use in food crops.

35. In 1966, a rice tungro infection reportedly affected 0.6 M ha of rice.

36. No report was found, that described the 'hectareage damaged' on basis of ETLs for rice pests, monitoring results and actual yield loss assessments. Thus, it is not possible to judge whether injury figures were inflated for political reasons.

37. The financial loss from BPH and RSV damage in 1990 was estimated at 308 M US$ (8 billion bahts; US$ 1 = 26 bht, 1991) (Rumakom *et al.*, 1991).

38. Favoured products were monocrotophos, methyl parathion, deltamethrin, endosulfan and carbamates. In 1990, about twice as much carbamate insecticides were sold (1,180 t a.i.) as in 1989 or 1991. The popular carbamates methomyl, carbofuran, fenobucarb and isoprocarb were all locally formulated as granules (Bayer AG, 1998).

39. The massive BHP outbreak in C Thailand in the 1990s was attributed to excessive use of pesticides. Damage from BPH infestation was estimated at about 70%, and from rats at 12 % (Rumakom *et al.*, 1991).

40. In 1980, production of paraquat was started from the imported intermediate chemicals bipyridine and methylchloride. When natural gas became available from gasfields in S Thailand the intermediates were also manufactured in Thailand. Since 1990, two factories manufacture 5,500 t of paraquate per year.

41. In the 1970s, the sole criterion for granting or refusing permission for import of any pesticide was whether the pesticide in question had been entered on the list of poisonous articles published in the Royal Gazette of Thailand. If not, the material was regarded not to be covered by any regulation.

42. Before the 1995 decision to decentralise GIFAP, the organisations were called Thai Pesticide Association and International Group of National Pesticide Associations (GIFAP), Brussels, respectively. GIFAP was renamed Global Crop Protection Federation (GCPF) in 1996.

Chapter 8

Epilogue

The aim of this study was to describe the history and the achievements of Integrated Pest Management (IPM) in SE Asia. As IPM encompasses more than a technical answer to injudicious use of pesticides, the author studied two periods, agriculture before and after the introduction of synthetic pesticides. My incentive was curiosity about the impact of FAO's Inter-Country Integrated Pest Control Programme in Rice in S and SE Asia and the ensuing National IPM Programmes, in which I became tangentially involved. The historical part came in with the question 'How did the colonial planters manage without pesticides?'

A first question 'why, how and when did the protection of crops become an issue for research and institutionalisation' was answered by a brief description of agricultural development in three SE Asian countries. Before 1870, the European trading companies and the colonial administrations demonstrated the agricultural potential of Indonesia and Peninsular Malaya through a successful exploitation of their national resources. At the end of the 19th century, the promise of high returns attracted European investment in commodity crop production. Owing to a fortunate combination of capable men, money and crops of great potential in unexploited, fertile lands, agriculture prospered. When pests and diseases became production constraints, the Botanical Gardens Departments had the expertise and means to organize adequate research. Early in the 20th century, the colonial Departments of Agriculture and private research stations made valuable contributions to estate and indigenous agriculture both. Inventive solutions were found to pest and disease problems, in particular through selection and breeding for resistance, vegetative propagation and grafting, and biological control.

After World War II, synthetic pesticides, which, as a panacea against injurious organisms, attracted almost all attention and funding, soon began to create problems of their own. Scientist detected the new phenomena of pesticide-induced pests and pesticide resistance in pests. Once the feasibility of integrated pest control with reduced use of pesticides was proven in N America and in Europe, international institutions and donors had an instrument to address the deteriorating pest situation in developing countries. The FAO obtained the support of donors for major IPM programmes a.o. in cotton, rice and maize in Asia and C America.

A second question refers to the impact of the IPM efforts in SE Asia. Study of program reports and of the literature suggested a considerable success for IPM implementation in Indonesia, and some progress in Malaysia and Thailand. An impartial answer was sought through the analysis of records on pesticides marketing from the three countries over 1980-96. These records show a real impact of IPM policy on insecticide sales in rice in Indonesia, but not in the other two countries. In particular, the 1986 Presidential ban on insecticide use in rice in Indonesia had a lasting effect on the volume (in a.i. weight) of pesticides sold for rice. The

FAO Inter-Country Programme deserves credit for that achievement. In Indonesia, the change in attitude concerning use of insecticides in rice is evident with many civil servants, researchers and farmers. It is difficult to judge if that attitude can be sustained.

In Malaysia, the intensification of rice production had a clear effect on the pesticide market. Malaysian researchers were leading in bringing IPM to SE Asia and, in particular, to the granaries of the peninsula. Two major constraints, shortage of irrigation water and of labour, led to direct seeding, which became possible through an effective Integrated Weed Management. Sales of herbicides in direct seeded rice increased rapidly. The task of IPM extension in rice appears to be undertaken by the powerful Irrigation Scheme Authorities.

In Thailand, IPM in rice received little attention beyond research. Rice was a traditional export commodity and not subject to intensification programs driven by concerns about food security. As in Malaysia, herbicide use in direct seeded rice is increasing, but IWM receives little attention yet.

The second target of IPM implementation in SE Asia, excessive pesticide use in vegetables, left no mark on pesticide sales. In all three countries the sales of fungicides and insecticides for vegetables is increasing continuously. In Indonesia and Thailand the IPM for vegetables movement is yet too small to show, in Malaysia the initial achievement in highland vegetables was lost.

I conclude that the introduction of IPM to SE Asia has been beneficial. Sustainability of IPM cannot be taken for granted, as the Malaysian highland vegetable example shows. Success can be expected only when farmers feel empowered and when a positive attitude towards IPM pervades the whole governmental administration from top to bottom, as a comparison of Indonesia and Thailand shows. Donors should apply this insight when negotiating with recipient governments.

A last question `Did I serve two masters?' is answered with an ambiguous `yes and no'. The answer is `Yes', if the chemical industry and the IPM protagonists take an absolute stand in the promotion or rejection of pesticide use in agriculture. I was educated with a belief in pesticides and had, like my industry master, a blind eye for the ecological consequences. I have seen dedicated scientists and good research in that world. I was not always happy with his blunt eye, rather insensitive to other issues than high return on investment, necessary as it may be to run a company. The second master, IPM, also appears to suffer occasionally from impaired eyesight, when the advantages of judicious pesticide use are denied. The `no intervention' message in rice is helpful in extension, but statistics show that 1 to 1.5 application may be needed in rice towards the end of the season. In vegetables and fruits, `informed intervention' as elaborated by V. Stern *cum suis* is the corner stone for an effective IPM. The answer is `No' if both sides agree to collaborate in research for and need-based application of specific synthetic pesticides of low toxicity in a true IPM fashion.

Chapter 9
Summary

This book deals with the history and achievements of Integrated Pest Management (IPM) in SE Asia. Chapter 1 explains the author's motives and the research questions. What is IPM? How were pests and diseases of tropical agriculture controlled before synthetic pesticides became available? Why and by whom were IPM programs in SE Asia developed and what is their impact? The chapters 2-4 describe agricultural developments from 1800 to the present in Indonesia, Malaysia and Thailand. In Indonesia and Malaysia, development began with the investment of foreign expertise and capital. In Thailand, where foreign influences were barred, development began from within.

Early in the 16th century European trading companies began to control the centuries old East-West trade lanes of S and SE Asia. The Dutch East Indies Company (*VOC*) obtained a monopoly in the spice trade which had its production centre in the Maluku Islands. The Napoleonic Wars in Europe upset the balance of power in the Malay-Indonesian archipelago. The English, who in the late 18th century had settled in Penang on the W coast of Malaya, confiscated the Dutch possessions in Indonesia and Melaka. In 1816, the Dutch returned and ruled the country as the Dutch East Indies under a colonial administration until 1949.

During 1830-80, the Dutch colonial government, under the obligation of meeting its own expenses, imposed a system of enforced production of agricultural export commodities on Java and Sumatera. The extensive plantings of coffee, sugarcane, indigo and spices brought the Dutch huge profit but in the end caused food shortages and poverty to the Indonesian farmers. This period of monopolistic exploitation demonstrated the agricultural potential of the Dutch East Indies and made European capitalists eager to share in the opportunity. In the 1870s, an Agrarian Law and a Sugar Law were issued on the basis of two motives. First, to secure the Indonesian farmers' rights to the soil and to grow sufficient rice. Second, to open the country for foreign private investment in plantation agriculture through long lease constructions.

In Malaya during the 19th century, Chinese immigrants established a smallholder production of spices, coconut and sugar. Increasing civil turmoil resulting from feuding sultans and fighting factions of Chinese immigrants had destabilized Malaya to the extent that the English had to restore order. From 1875 onwards, the English succeeded in establishing a colonial administration and in unifying the country. Only then, Western merchant firms began to plant commodity crops in Malaya on estate scale with full support from the government which provided land titles and planting material.

Agricultural development in Thailand had a rather different start. In the 18th and 19th century Thailand remained an independent Kingdom and did not encourage foreign investment. Thai farmers largely produced rice and other crops for self-sufficiency, since the country lacked a transport infrastructure and all trade was monopolized by the royal court. After 1860, increasing opportunities to export rice induced farmers of the C Plain to produce a surplus. When revenues from exporting rice increased rapidly, the Thai government began to strengthen the infrastructure a.o. through the digging of canals and to liberalize trade. The build-up of estate agriculture remained limited to S Thailand and it was hardly encouraged.

In the Dutch East Indies (DEI) and Malaya the growing of estate crops, such as sugar, coffee, rubber, and cacao was severely hampered by pest and disease problems and by a lack of resistant planting material. The *Coffea arabica* culture was destroyed by the Coffee Leaf Rust Disease and the growing of sugarcane became almost uneconomical due to *Sereh* Disease. The planters turned to the Botanical Gardens' Departments, which were the early centres of expertise on commodity crops. The *Plantentuin* institutions at Bogor, Java, became the centre for public and private research on the improvement of commodity crops and on control of pests and diseases. Agriculture in Thailand was mainly directed at rice production and did not share in the development of agricultural research elsewhere.

Whilst in the DEI and Malaya commodity agriculture developed rapidly, indigenous agriculture remained neglected for a long time. A Department of Agriculture was established in both the DEI and Malaya in the same year, 1905. The departments had the dual function to represent the interests of estate agriculture with the government and to improve indigenous agriculture and farmers' income. Special divisions were established for rice cultivation and extension to smallholder farmers. Between 1910 and 1940, estate agriculture flourished, smallholder production of rubber, cacao and coffee became important and the production of rice and *palawija* crops rose substantially through the construction of irrigation facilities and the breeding of improved varieties. Rice production in Thailand increased too through an expansion of the rice area and better irrigation, but research for improvement of productivity received less attention.

In the DEI and Malaya, great progress in pest and disease control was made through the selection and breeding for higher productivity, habitus and resistance, through clonal propagation and through grafting. Entomological research of pests and their natural enemies resulted in effective biological control *e.g.* of pests in coconut, oil palm and cacao. Some early entomological studies are still regarded as standard works today.

The 1930s and 1940s were unfortunate decades due to the world-wide economic recession and to World War II. The export of commodities from the DEI and Malaya and of rice from Thailand decreased due to low world market prices and trade restrictions. The Japanese occupation, 1942-45, created great damage to people, institutions and the estate industry. After the war, Malaysia and Thailand recovered rapidly. In the DEI, the struggle for Indonesia's independence caused additional damage and postponed the restoration of agriculture. After Independence, in 1949, a shortage of human and financial resources hampered agricultural development for many years.

During the 1960s, the governments of Indonesia and Malaysia launched rice production intensification programs to improve their national food security and to keep up with the rapid population growth. They invested large World Bank loans in the irrigation infrastructure and adopted the Green Revolution technology for rice production. In Indonesia, the intensification programs were aimed at the farmers of the main rice provinces of Java and the Outer Islands, in Malaysia at the Malay farmers in the large Rice Irrigation Schemes. In Indonesia, the farmers were strongly urged, through social pressure and the provision of credit and subsidies, to adopt the high yielding IRRI rice varieties, and to use fertilizers and pesticides. The Departments of Agriculture in the three countries established a Surveillance and Early Warning System with economic threshold levels for major insect pests of rice and operated an Emergency Control Service to assist farmers at the time of outbreaks. The Thai government also introduced high yielding rice varieties but did not strengthen the agricultural extension nor did it stimulate higher use of fertilizer and pesticides. Thai farmers, generally, continued to grow favoured local rice varieties.

In Indonesia and Malaysia, the recommended calender application of insecticides over large rice areas caused outbreaks of secondary insect pests, in particular brown planthopper and leafhoppers, with subsequent virus epidemics. Around 1970, IRRI scientists proved the pesticide-induced nature of the outbreaks and began to develop an Integrated Pest Management strategy.

The principles of Integrated Pests Management (IPM) were elaborated by researchers in the West (chapter 5). Many effective methods of integrated control of pests and diseases had been elaborated by researchers and planters during colonial days before synthetic pesticides were available. The new challenge after World War II was to integrate need-based pesticide use with other control techniques. Once the principles were well researched and formulated, international organisations and donors showed interest to develop and implement regional IPM programs in cotton, maize and rice.

To solve the brown planthopper and virus problems in rice in S and SE Asia, the FAO established an Inter-Country Programme (ICP) for IPM in Rice in 1979 in seven countries including Indonesia, Malaysia and Thailand. The three countries organized National IPM Programs. Many activities were undertaken with support of FAO's ICP for IPM field studies and training of trainers and farmers. These activities prepared the road to the Presidential Instruction 1986/3 in Indonesia which declared IPM as national policy, banned most insecticide for use in rice and withdrew the subsidies on pesticides. In Malaysia, the Minister of Agriculture issued an official statement in favour of IPM.

In Indonesia and Malaysia, the continuous replacement of sensitive rice varieties by cultivars with a higher resistance against planthoppers, leafhoppers and viruses and the ban on insecticide use in rice brought the serious pest outbreaks to a halt. Since the area planted to high yielding rice cultivars and the fertilizer use continued to increase, Indonesia achieved self-sufficiency in rice in the 1980s. In Malaysia too, research on rice production and pest control in rice yielded good results, but the research findings were *de facto* only applied in the large rice schemes. Malaysia gained an advantage in Integrated Weed Management in direct seeded rice. IPM in non-rice field crops and in plantation did not gain much visibility.

In Thailand, the development of agricultural institutions and research was delayed until the 1950s. A probable reason is that the government was more concerned about the revenues of rice exports than about possible food shortages. The Ministers of Finance and Commerce managed the agricultural sector through price controls with little interest for scientific development. Because of an ample availability of land and low rice prices, the Thai farmers had little incentive to improve rice production in kg/ha. Adoption of improved rice varieties, fertiliser use and mechanisation remained low.

Throughout the 1990s, the government of Indonesia was consistent in implementing its IPM policy and contributed considerable manpower and funds at the federal and provincial levels. Adopting FAO's Farmer Field School model of extension about one million Indonesian farmers attended a season-long IPM training. In Malaysia, the National IPM Program received little political support. However, in the major rice irrigation schemes, the Scheme Authorities provided the necessary guidance to the farmers on improved production and pest control technology. In Thailand, IPM remained a matter of research because of inadequate impact of extension on the farmers.

In Indonesia, Malaysia and Thailand, the production of estate and smallholder crops increased considerably after 1970. In Indonesia and Malaysia, the estate production of palm oil is still expanding. In Malaysia, rubber and cacao decreased due to a shortage of labour for tapping and pest control. In Indonesia, the production of sugar is stimulated by a heavily subsidized nucleus estate-smallholder system, whereas in Thailand sugar production has increased by private investment. IPM in estate crops is practised by estates to some degree. In Indonesia, where cacao increased in Sulawesi, IPM in cacao is sponsored by an international consortium.

Because of a growing concern about the high use of pesticides by vegetable and fruit growers and the serious pest and disease problems in horticulture (chapter 6), the Indonesian National IPM Program began to include vegetables in FFS training for rice-based cropping systems since 1994. In 1995, a new FAO Inter-Country IPM for Vegetables Programme was launched which was recently extended to Indonesia.

We tried to measure the impact of the international and national IPM programs for rice and vegetables through an analysis of the pesticide markets in the three countries over the period 1980-1996 (chapter 7). The pesticide markets of Indonesia, Malaysia and Thailand remained largely unaffected by national and international IPM efforts in SE Asia. A clear impact of the Inter-Country and national IPM programs on the sales of insecticides for use in rice is visible in Indonesia, but not in Malaysia and Thailand.

The sales of herbicides to the rice sector is increasing in all three countries, particularly in Peninsular Malaysia. Only in the large Rice Irrigation Schemes, the herbicide use in direct seeded rice is supervised by an empirical Integrated Weed Management system.

The sales of pesticides for use in horticulture increased in correspondence with the rapid expansion of the sector. In Indonesia, extension of IPM for vegetables has become part of the National Program for IPM. IPM efforts did not, however, impact sales for use in horticulture. In Malaysia, biological control of insect pests in vegetables has been intensively researched, but no evidence was found that the IPM for vegetables program reduced pesticide sales.

The pesticide companies, in general, have taken over the IPM ideology, however, with the explicit inclusion of pesticides as indispensable means for effective control of injurious organisms. The advance of generic pesticides, which took over 50% of the global pesticide market in 1996, is a cause of considerable concern because these products are often beyond adequate regulatory control on quality and application.

In the epilogue (chapter 8) the author answers the questions posed in chapter 1 and concludes that IPM implementation in SE Asia met with considerable success in rice in Indonesia, but not in the other two countries. The introduction of IPM to SE Asia has been beneficial. To advance IPM in horticulture, the IPM programs and the pesticide industry should collaborate in research for and need-based application of specific synthetic pesticides of low toxicity in a true IPM fashion.

Hoofdstuk 10

Samenvatting

Dit boek beschrijft de geschiedenis en de resultaten van Geïntegreerde Bestrijding van Plagen (IPM) in ZO Azië. Hoofdstuk 1 licht het motief van de schrijver toe en poneert de onderzoeksvragen. Wat is IPM ? Hoe werden de ziekten en plagen in de tropische landbouw bedwongen voordat er synthetische bestrijdingsmiddelen waren? Waarom en door wie werden IPM programma's ontwikkeld in ZO Azië en wat voor een effect sorteren ze. De hoofdstukken 2-4 beschrijven de ontwikkeling van de landbouw in Indonesië, Malaysia en Thailand tussen 1800 en heden. In Indonesië en Maleisië brachten de investering van buitenlandse kennis and kapitaal deze ontwikkeling op gang. In Thailand, waar buitenlandse invloeden geweerd werden, begon de ontwikkeling van binnen uit.

Vroeg in de 16e eeuw kregen Europese handelmaatschappijen de macht over de eeuwenoude handelswegen tussen Oost en West door Z en ZO Azië. De Nederlandse Verenigde Oost Indische Compagnie (VOC) verwierf het monopolie over de specerijenhandel, waarvan het produktie centrum op de Molukse eilanden lag. Toen de Napoleontische oorlogen in Europa ook het machtsevenwicht in de Maleis-Indonesische archipel verstoorden, namen de Engelsen, die zich laat in de 18e eeuw gevestigd hadden op Penang voor de W kust van Maleisië, de Nederlandse bezittingen in Indonesië en Melaka in beslag. De Nederlanders keerden in 1816 terug en beheersten het land als Nederlands Oost-Indië (NOI) onder koloniaal bestuur tot 1949.

Van 1830-80 dwong het Nederlandse koloniale bestuur, dat zijn eigen onkosten moest dekken, de boeren van Java en Sumatera om export gewassen te telen. De uitgestrekte aanplantingen van koffie, suiker, indigo en specerijen brachten Nederland grote winsten op, maar veroorzaakten op den duur voedseltekorten en armoede onder de Indonesische boeren. Deze periode van monopolistische uitbuiting (het Cultuurstelsel) toonde de landbouwkundige mogelijkheden van NOI aan en stimuleerde Europese investeerders om daarvan te profiteren.

In 1980 werden een Landbouwwet en een Suikerwet uitgevaardigd die op twee beginselen steunden. Zij beoogden, ten eerste, de vastlegging van de rechten van Indonesische boeren op eigen land en de teelt van voldoende rijst. Ten tweede, om het land toegankelijk te maken voor buitenlandse investeringen van privaat kapitaal in de plantage-landbouw middels langjarige pachtregelingen.

In Maleisië gedurende de 19e eeuw zetten Chinese immigranten kleine landbouwbedrijven op waarop zij specerijen, kokosnoten en suikerriet produceerden. Burgelijke onrust, veroorzaakt door machtsstrijd tussen sultans en elkaar bevechtende groepen van Chinese immigranten, maakte de situatie in Maleisië dermate instabiel dat de Engelsen de orde moesten herstellen. Vanaf 1875 slaagden de Engelsen erin om een koloniaal bestuur te vestigen en de staten geleidelijk in een unie samen te brengen. Toen pas durfden grote westerse handelsmaatschappijen plantages aan te leggen voor exportgewassen. De regering verleende daaraan volle medewerking door landrechten en plantgoed te verschaffen.

De landbouwontwikkeling in Thailand begon op een andere manier. Tijdens de 18e en 19e eeuw bleef Thailand een onafhankelijk koninkrijk dat buitenlandse investeringen buiten de deur hield. De Thaise boeren produceerden rijst en andere voedselgewassen voor zelfvoorziening, omdat het land geen infrastructuur voor transport bezat en het koninklijk hof het monopolie hield over alle handel. Na 1860 ontstonden er mogelijkheden om rijst te exporteren, hetgeen de boeren in de centrale vlakte er toe aanzette om meer rijst te telen dan nodig voor lokaal gebruik. Toen de staatsinkomsten uit de rijstexport snel toenamen, verbeterde de Thaise regering de infrastructuur door het graven van kanalen en verruimde zij de handelsbepalingen. Plantagelandbouw bleef beperkt tot Z Thailand en werd niet aangemoedigd.

In NOI en Malaya hadden cultures, zoals suikerriet, koffie, rubber en cacao, zwaar te lijden van ziekten en plagen, waartegen nog geen resistent plantmateriaal beschikbaar was. De *Coffea arabica* cultuur werd vernietigd door een roest ziekte en de teelt van suikerriet werd bijna verliesgevend door de *Sereh*-ziekte. De planters zochten steun bij de Botanische Tuinen, die de meeste kennis inzake exportgewassen hadden. De Plantentuin-instellingen in Buitenzorg werden de bakermat van publiek en privaat onderzoek voor de verbetering van exportgewassen en de gewasbescherming. De landbouw in Thailand bleef gericht op rijst en nam niet deel aan de ontwikkeling van het onderzoek elders.

Terwijl in NOI en Malaya de handelslandbouw een snelle ontwikkeling doormaakte, werd er aan de inheemse landbouw nauwelijks aandacht geschonken. In NOI en Malaya werd in hetzelfde jaar, 1905, een Departement van Landbouw opgericht. De departementen hadden een dubbele taak, namelijk om de belangen van de handelslandbouw te vertegenwoordigen bij de regering, en om de inheemse landbouw op hoger peil te brengen en het boereninkomen te verbeteren. Speciale afdelingen werden opgericht voor de rijstteelt en voor de landbouwvoorlichting voor kleine boeren. Tussen 1910 en 1940 maakte de plantage landbouw een bloeitijd door, nam het aandeel van de kleine boeren in de productie van rubber, cacao en koffie toe en steeg ook de productie van rijst en tweede gewassen. De rijstproductie verbeterde door de aanleg van irrigatiewerken en het veredelen van rassen. In Thailand nam de rijstproductie toe door een uitbreiding van het rijstareaal en verbeterde irrigatie, maar aan onderzoek voor verbetering van de productiviteit werd nauwelijks aandacht besteed.

In NOI en Malaya, werd grote vooruitgang geboekt in de beheersing van ziekten en plagen door selectie en veredeling voor hogere opbrengst, plantvorm en resistentie, door clonale vermeerdering and door enting. Entomologisch onderzoek van plaaginsecten en hun natuurlijke vijanden leverden doeltreffende biologische bestrijdingswijzen op, zoals van insektenplagen in kokospalm, oliepalm en cacao. Enkele vroege entomologische studies worden heden ten dage nog als standaardwerk beschouwd.

De jaren 1930-50 waren moeilijk ten gevolge van de economische recessie en de Tweede Wereldoorlog. De export van handelsgewassen uit NOI en Maleisië en van rijst uit Thailand leden onder de lage wereld markt prijzen en handelsrestricties. De Japanse bezetting, 1942-45, bracht grote schade toe aan mensen, instellingen en de plantage-landbouw. Na de oorlog herstelden Maleisië en Thailand snel. In NOI veroorzaakte de strijd voor Indonesië's onafhankelijkheid nog meer schade en duurde het langer voordat de landbouw kon herstellen. Na de Onafhankelijkheid, in 1949, kwam de ontwikkeling laat op gang ten gevolge van een langjarig tekort aan mensen en middelen.

In de jaren '60 organiseerden de regeringen van Indonesië en Maleisië programma's gericht op de verhoging van de rijstproduktie in verband met de nationale voedselzekerheid en de snelle bevolkingsgroei. Zij investeerden grote leningen van de Wereld Bank in irrigatiewerken en pasten de Groene Revolutie technologie toe in de rijstteelt. In Indonesië werden de programma's gericht op de boeren in de belangrijkste rijstprovincies van Java en de buitengewesten, in Maleisië op de Maleise boeren in de grote geïrrigeerde rijstpolders. In Indonesië werden de boeren onder druk gezet, door sociale dwang en door het verschaffen van krediet en subsidies, om de hoogproductieve IRRI-rassen te planten en kunstmest en pesticiden te gebruiken. De Departementen van Landbouw van de drie landen zetten een bewakings- en waarschuwingsdienst op met toepassing van economische schadedrempels voor de belangrijkste plagen in rijst en organiseerden een Bestrijdingsdienst voor Noodsituaties om de boeren bij te staan in ernstige plaagsituaties. De Thaise regering bevorderde eveneens het planten van hoogproductieve rijstrassen maar liet na om de voorlichting te versterken en het gebruik van kunstmest en pesticiden te stimuleren. De Thaise boeren, bleven de voorkeur geven aan het planten van lokale rijstrassen.

In Indonesië en Maleisië veroorzaakten de kalendermatige insecticidenbespuitingen op grote rijstarealen het uitbreken van secundaire insectenplagen, vooral van de 'brown planthopper' en 'leafhoppers' met de erop volgende virusepidemieën. Rond 1970 bewezen onderzoekers bij het IRRI dat de massale plaaguitbarstingen door insecticiden werden veroorzaakt. Met die kennis begonnen zij een strategie voor Geïntegreerde Bestrijding van Plagen (IPM) te ontwikkelen.

De beginselen van IPM werden door Westerse onderzoekers uitgewerkt (hoofdstuk 5). Vele doeltreffende methoden van geïntegreerde bestrijding van ziekten en plagen waren al bedacht door onderzoekers en planters in de koloniale tijd voordat synthetische pesticiden beschikbaar waren. De nieuwe uitdaging na de Tweede Wereldoorlog was het integreren van noodzakelijk geacht gebruik van pesticiden met andere bestrijdingsmethoden. Nadat de beginselen eenmaal goed onderzocht en geformuleerd waren, kregen internationale organisaties en donoren belangstelling voor het ontwikkelen en uitvoeren van regionale IPM programma's voor katoen, maïs en rijst.

Om een oplossing te vinden voor de 'brown planthopper'- en virusproblemen in Z en ZO Azië begon FAO in 1979 een 'Inter-Country Programme (ICP) for IPM in Rice' in zeven landen, waaronder Indonesië, Maleisië en Thailand. De drie landen organiseerden nationale IPM programma's. Met steun van FAO's ICP for IPM Rice werd begonnen met veldstudies en het trainen van trainers en boeren. Deze activiteiten maakten de weg vrij voor de Presidentiële Instructie 1986/3 in

Indonesië, waarin IPM werd uitroepen tot nationaal beleid, het gebruik van de meeste insecticiden in rijst werd verboden en de subsidies op pesticiden werden ingetrokken. In Maleisië legde de Federale Minister van Landbouw een officiële verklaring af ten gunste van IPM.

In Indonesië en Maleisië werden de bedreigende plaagsituaties beteugeld door geregeld vatbare rijstrassen te vervangen door rassen met een grotere resistentie tegen planthoppers, leafhoppers en virussen, en door een beperking van het insekticidengebruik. Door een voortdurende uitbreiding van het areaal, waarop hoogproductieve rassen en kunstmest werden gebruikt, werd Indonesië in de jaren 1980 zelfvoorzienend in rijst. Ook in Maleisië leverde het onderzoek inzake productieverbetering en plaagbestrijding in rijst goede resultaten op maar deze werden *de facto* alleen toegepast in de grote rijstpolders. Maleisië verwierf een voorsprong in geïntegreerde onkruidbestrijding (IWM) in breedwerpig gezaaide (direct seeded) rijst. IPM in niet-rijst veldgewassen en in plantagegewassen kreeg geen grote bekendheid.

In Thailand begon de ontwikkeling van landbouwinstellingen en het onderzoek pas rond 1950. De regering had waarschijnlijk meer aandacht voor de staatsinkomsten uit het exporteren van rijst dan voor een mogelijk voedseltekort. De Ministers van Financiën en Handel stuurden de agrarische sector door middel van prijsbeheersing en hadden weinig belangstelling voor de wetenschappelijke ondersteuning. De ruime beschikbaarheid van land en de lage prijzen hielden de Thaise boeren af van verhoging van de rijstproductie in kg/ha. Zij maakten weinig gebruik van verbeterde rassen en kunstmest.

Gedurende de jaren 1990 hield de regering van Indonesië vast aan het uitvoeren van de IPM politiek door een ruime toewijzing van mankracht en fondsen op het federale en provinciale vlak van bestuur. Ongeveer een miljoen boeren namen gedurende een vol seizoen deel aan de FFS IPM training.

Het Nationale IPM Programma in Maleisië kreeg weinig politieke steun. Maar in de grote rijstpolders gaven de autoriteiten de noodzakelijke begeleiding aan de boeren inzake productieverhoging en gewasbescherming. In Thailand bleef IPM in de onderzoeksfase steken omdat de voorlichters de boeren onvoldoende bereikten.

In Indonesië, Maleisië en Thailand nam de productie van handelsgewassen door plantages en kleine boeren na 1970 flink toe. In Indonesië en Maleisië neemt de productie van palmolie op plantages verder toe. De productie van rubber in Maleisië nam af vanwege een tekort aan tappers. In Indonesië werd de productie van suiker bevorderd door het zwaar gesubsidieerde systeem van productie door kleine boeren rondom een kernbedrijf met verwerkingscapaciteit, terwijl in Thailand de suikerproductie door private investeringen wordt gedreven. Sommige plantages passen IPM toe, maar geven hier weinig bekendheid aan. In Indonesië wordt de toepassing van IPM in cacao betaald door een internationaal consortium.

Vanwege een toenemende bezorgdheid over het hoge gebruik van pesticiden door groenten- en fruittelers en de aanzienlijke ziekten- en plagendruk in de tuinbouw (hoofdstuk 6), begon het Indonesische Nationale IPM Programma vanaf 1994 groenten op te nemen in de FFS training voor de rotatieteelten met rijst. In 1995 ging een nieuw FAO Inter-Country IPM Programma voor de Groententeelt van start, waaraan ook Indonesië sinds kort deelneemt.

Wij probeerden de invloed van het internationale en de nationale IPM programma's voor rijst te meten door het analyseren van de pesticidenmarkten in de drie landen over de periode 1980-96 (hoofdstuk 7). De pesticidenmarkten van Indonesië, Maleisië en Thailand werden nauwelijks beïnvloed door de internationale en de nationale IPM inspanningen in ZO Azië. Een duidelijke invloed van de internationale en nationale IPM programma's is slechts aantoonbaar in Indonesië, maar niet in Maleisië en Thailand.

De verkoop van herbiciden voor de rijstsector neem toe in alle drie de landen, vooral in Maleisië. Alleen in de grote rijstpolders wordt het herbicidengebruik ondersteund door een empirisch systeem van geïntegreerde onkruidbestrijding.

De verkoop van pesticiden voor gebruik in de tuinbouw loopt parallel met de snelle uitbreiding van de sector. In Indonesië werd de voorlichting over IPM in groententeelt een onderdeel van het Nationale IPM Programma, maar de IPM inspanningen brachten de verkoop van pesticiden niet omlaag. De pesticidenfirma's hebben zich, over het algemeen, de IPM-ideologie eigen gemaakt, maar wel met inbegrip van het gebruik van pesticiden als onmisbare hulpmiddelen bij het doeltreffend bestrijden van schadelijke organismen. De opmars van generieke bestrijdingsmiddelen, die in 1996 al een marktaandeel van 50% opeisten, is een bedenkelijke zaak, omdat deze producten vaak moeilijk op kwaliteit en toepassing kunnen worden gecontroleerd.

In de epiloog (hoofdstuk 8) geeft de schrijver antwoord op de in hoofdstuk 1 gestelde vragen en komt tot de conclusie dat de toepassing van IPM in ZO Azië succesvol verliep in Indonesië, maar niet in de twee andere landen. Het introduceren van IPM in ZO Azië was een goede zaak. Om IPM in de tuinbouw en fruitteelt te bevorderen zouden de IPM programma's en de bestrijdingsmiddelenindustrie moeten samenwerken in het onderzoek naar en de toepassing van synthetische pesticiden met specifieke werking en lage toxiciteit.

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Curriculum vitae

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From 1985 to 1996, the author worked at the Ministry of Agriculture, Nature Management and Agriculture, the Netherlands, as senior officer in the Division for International Co-operation. The function involved liaison with the UN Food and Agriculture Organisation, Rome, the European Commission, Brussels, ODA Institutions in donor countries and NGOs, on Plant Protection and Pesticide Management related issues.
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