A survey of the supply, production and use of microbial pesticides in Thailand

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Abbreviations

Bs	*Bacillus subtilis*
Bt	*Bacillus thuringiensis*
CFU	colony forming unit
DFID	Department for International Development, UK
DOA	Department of Agriculture, Thailand
DOAE	Department of Agricultural Extension, Thailand
HearNPV	*Helicoverpa armigera* Nucleopolyhedrovirus
HzNPV	*Helicoverpa zea* Nucleopolyhedrovirus
IPM	Integrated Pest Management
LE	Larval Equivalents
NGO	Non governmental organisation
NPV	Nucleopolyhedrovirus
NRI	Natural Resources Institute, UK
PIB	Polyhedral inclusion bodies
SpexNPV	*Spodoptera exigua* Nucleopolyhedrovirus
SpltNPV	*Spodoptera litura* Nucleopolyhedrovirus
WHO	World Health Organisation

Conversions

1 hectare = 6.25 rai
$1 = 42 baht
£1 = 60 baht

Summary

This report presents the findings of a survey of biopesticide suppliers and farmers in Thailand. The survey forms part of a research project investigating the uptake and use of microbial pesticides by resource-poor farmers. The objectives were to identify the technical and socio-economic factors affecting biopesticide supply, distribution and use.

A total of 16 biopesticide suppliers were interviewed including government, NGO and private companies. 208 farmers were interviewed about their experiences of biopesticides and attitudes towards them in 6 different farming systems and locations throughout Thailand. The farmers were divided into those that had undergone training in the use of one or more biopesticides, and farmers chosen randomly from within the same farming system.

The biopesticide suppliers can be divided into the non-commercial suppliers – primarily the Department of Agricultural Extension (DOAE) and Department of Agriculture (DOA) who produce biopesticides in their regional Biocontrol Centers and pilot plants, the commercial suppliers who import biopesticide products, and a small number of private local producers.

The main commercial biopesticide is *Bacillus thuringiensis* (Bt), most of which is imported by companies that also sell agrochemicals. It is targeted at vegetable farmers especially those growing reduced pesticide residue vegetables. In the 1990s the government was a major customer for Bt, but now the government budgets have been reduced as a response to the downturn in Thailand’s economy since the Asian financial crisis, and many companies have seen sales fall. There is a small local production of *Bacillus subtilis* aimed at a niche market of control of fungus disease on fruit trees.

Trichoderma harzianum is the most widely produced local biopesticide. Two local companies sell Trichoderma products, but most of the production comes from the Department of Agricultural Extension (DOAE) who has developed low-cost production methods. The users are vegetable and fruit tree farmers.

Supply of viral pesticides (NPVs) is limited, so availability is a problem. The only commercial supplier imported NPV from the USA but has recently ceased to import NPV products into Thailand. This leaves the DOA as the main supplier, with small amounts also produced by the DOAE.

Small amounts of the nematode pesticide, *Steinernema carpocapsae*, are produced by both local private producers and the DOAE. These are used mainly for control of caterpillars on fruit trees.

Government organisations have a more optimistic view of the future use of biopesticides than commercial companies. Most private companies reported that their sales had decreased over the last 3 years and predicted only moderate rises or no change in future biopesticide sales. The main constraint was thought to be competition from the newer chemical pesticides. The slower action, special storage requirements, high production costs of microbial pesticides and quality issues with

some products were also thought important constraints. Government and NGO organisations thought that farmers were becoming more aware of environmental issues, and that they were beginning to accept biopesticides, so they expected an increase in demand. This is also in line with government policy to promote low-cost and environmentally sound technologies for farmers.

The farmers surveyed grew a range of crops including rice, vegetables and fruit. Many farmers did not have a clear idea of what the term “biopesticide” meant – they usually associated it with biofertilisers and botanical products. However, knowledge of microbial pesticides is good. 97% of the trained farmers and 83% of the control group had heard of one or more types or brand names of biopesticide. Among farmers 93% of trained and 32% of control farmers had used microbial pesticides. Bt products and Trichoderma were the most widely known.

Attitudes to biopesticides were generally positive, with the majority of users saying they would use them again. The advantages of biopesticides were seen particularly where chemicals were increasingly ineffective against pests such as beet armyworm (*Spodoptera exigua*) and diamond-back moth (*Plutella xylostella*). Trichoderma is widely used in the control of plant diseases such as root rots and soft rots in vegetables and fruit trees (*Phytophthora* spp.) which are difficult to control using chemical fungicides. Farmers liked the fact that biopesticides were safe to use and longer-lasting compared with chemicals. The disadvantages included the slower action, limited effect under certain environmental conditions and longer time for preparation (Trichoderma and nematodes). Insufficient supply and difficulty in finding products were a major concern, especially for viral pesticides. Although many of the trained farmers had received biopesticide free or at low cost, 40% of trained and 52% of control farmers had bought biopesticide products from shops and dealers. Farmers were, however, very critical of products which were not effective and of low quality.

A few farmers had tried producing biopesticides themselves (Trichoderma and NPV), but farmers were generally not enthusiastic about producing themselves and the majority said they would prefer to buy. Lack of time and the problems of maintaining a quality product were the main reasons given. Farmer production may be useful in certain cases, but is unlikely to be the key to increasing uptake of biopesticides amongst farmers.

Knowledge of biopesticides amongst farmers who have not participated in training courses remains limited. Government programmes can only reach a minority of farmers and the availability of biopesticides, apart from Bt, outside these programmes is minimal. The commercial companies’ pessimistic view of the demand for biopesticide is not supported by the results from the farmers’ survey which indicate that farmers are willing to buy biopesticides as a complement to other methods (including chemical pesticides) for controlling specific pest problems. The slow action of biopesticides is not sufficient to stop farmers using them, as long as they can obtain the products on time, and can observe good results of using the biopesticides over time.

The government organisations plan to expand biopesticide production but it remains doubtful that they can supply enough biopesticides to reach many farmers.

Encouraging local private companies to develop biopesticide production, especially for products such as NPVs that require specialist production, would be one step towards increasing the supply of biopesticides and reaching more farmers.

A survey of the supply, production and use of microbial pesticides in Thailand

Introduction

Microbial pesticides have been developed over many years, but have failed to make much impact on the pest control globally, accounting for less than 1% of the total pesticide market (Lisansky 2000). Despite support by donors, NGOs and some national governments, adoption by farmers in developing countries has been limited (Warburton 1995). Recent reports on the production and use of biopesticides have focused on the market in developed countries (Jarvis 2001, Likansky 2000) or on project-centred case studies of microbial pesticide use as part of an Integrated Pest Management (IPM) programme (for example, Jenkins and Vos 2000, Williamson and Ali 2000, Tripp and Ali 2001). There has been little information available on how public and private production and supply of biopesticides interact and how farmers view these pesticides and make use of them.

This study follows from a preliminary evaluation of the promotion and uptake of microbial pesticides in India and Thailand (R7299 Grzywacz and Warburton 1999). It consists of a detailed survey of biopesticide suppliers and users in Thailand. The overall aim of the study was to investigate the current supply, production and use of biopesticides and to identify the technical and socio-economic factors affecting their uptake by resource-poor farmers.

Scope
The study is based in Thailand and covers all types of biopesticide suppliers from multinationals to farmer production. It includes farmers from a range of different farming systems and includes those with extensive IPM training as well as those who rely heavily on chemical pesticides or have no IPM training.

The terms "microbial pesticides" or "biopesticides" are used interchangeably in this report. They are defined as pesticides whose active ingredient is a micro-organism. They include products based upon bacteria, fungi, virus and nematodes. Botanical pesticides and biofertilisers are not included in this definition.

Funding
The study forms part of Phase II of the project "The evaluation of the promotion and uptake of microbial pesticides in developing countries by resource-poor farmers". It is funded by the Department for International Development (DFID), UK under its Crop Protection Programme (CPP).

Collaboration
The project is a collaboration between the Natural Resources Institute (NRI), University of Greenwich, UK and the Biological Control Section, Entomology and Zoology Division, Department of Agriculture (DOA), Thailand.

The survey team were as follows:
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Ms Hilary Warburton, Socio-economist, NRI associate
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Miss Pawana Kaewdoung-ngam, interviewer, DOA
Miss Bung-On Chantigo, interviewer, DOA
Mr Chanachon Boonroam, interviewer, DOA
Mr Perm Umaim, driver, DOA

Objectives

The overall objective was to evaluate the technical and socio-economic factors affecting the sustainable use of biopesticides by resource-poor farmers. In order to do this, the study was made up of three main components: a survey of biopesticide supply, a survey of demand in terms of the perceptions and use of biopesticides by farmers, and an evaluation of the quality of selected biopesticides. The specific aims of these components were as follows:

1. Conduct surveys of suppliers of biopesticides in Thailand, characterising them in terms of:

- Ownership and size of operation
- Customers
- Product range
- Production methods
- Product quality control
- Product presentation
- Promotion/extension systems
- Supplier's reasons for starting supply or production
- Supplier's perceptions of future demand

2. Conduct case studies and surveys of farmers who are using or have used biopesticides. Investigate factors affecting their perceptions and practices in using biopesticides including:

- Socio-economic characteristics
- Farming system
- Main crop protection problems
- Why they bought/acquired biopesticides and source of supply
- How they use them
- How biopesticides fit with farmers' other crop protection methods
- Knowledge about biopesticides
- Perceptions of their efficacy and cost-effectiveness

3. Evaluation in the laboratory of biopesticides used by the farmers to check that they are likely to be effective in use.

Field Work

Plans for the study were drawn up and methods and locations agreed in December 2001. The suppliers were interviewed between January to March 2002, and the farmers interviewed in February and March 2002. Samples of biopesticides were collected during the farmers' survey for later analysis.

Methods

For the suppliers, a questionnaire survey was designed based on information from interviews with selected suppliers carried out for the preliminary study (Grzywacz and Warburton 1999). A list of all the suppliers that could be identified in Thailand was drawn up with the help of the DOA and Department of Agricultural Extension (DOAE). These were contacted and asked if they would participate. The aim was to include all suppliers of all types: private, public and NGOs who were willing to take part in order to obtain as complete a picture as possible of the biopesticide supply in Thailand.

Questionnaires were pretested with two of the suppliers, before being sent to other suppliers. Suppliers either completed the questionnaire themselves or were interviewed, depending on what they preferred.

Six different locations were chosen throughout the country for the farmers' survey. These were selected to cover a range of different farming systems and were in areas where it was known that some farmers had received training on one or more biopesticides. They were also selected in order to cover a range of variables such as the crops grown, input levels used, level of farm income, pest problems and interest in Integrated Pest Management (IPM) or hygienic[1] crop production.

In each of the locations two groups of farmers were asked to take part in the survey. The first group, the "trained group", were purposely selected from farmers who had taken part either in a training course or promotion which included the use of biopesticides. These courses were run by the DOAE, the DOA or, in one case, the Royal Project. The training courses varied in content and objectives. In some cases the training was concerned generally with IPM or with hygienic vegetable production; in other cases the training was focused more specifically on the use of one or more biopesticides. In all cases the farmers had had the opportunity to use at least one biopesticide.

The second group, the "control group", were selected randomly from within the same area and farming system. The farmers were asked to take part from randomly selected houses and fields. There was no attempt to select certain numbers based on age, gender, income or any other variable other than farming system.

All the farmers were interviewed individually using a questionnaire. In addition, discussions were held with groups of the trained farmers using semi-structured interview methods. This allowed for a wider range of views and issues on biopesticides to be aired by the farmers, and for their knowledge and perceptions about use of biopesticides to be understood in greater depth.

Four pesticide dealers were also interviewed in different locations in order to gain additional information on how biopesticides were being distributed and sold.

Information from the suppliers' and farmers' questionnaires was input into Access databases, and analysed using Access and SPSS software. Additional advice on biometrics was obtained by consulting the University of Reading Statistical Services Centre.

[1] Hygienic crop production is the term used in Thailand for crops produced with reduced use of pesticides that meet low pesticide residue criteria.

Samples of bacterial, fungal and viral pesticides were collected from suppliers during the surveys. Only locally-produced biopesticide products were analysed. Imported products were registered with the DOA so had previously undergone the standard quality checks. The samples were analysed by researchers at Kasetsart university and the DOA to check the concentration of microbial agent.

Outline of report
Following a short section on pest management in Thailand, the findings from the surveys are presented in three main sections. Firstly, an overview of the biopesticide suppliers is given, detailing the types of organisations involved, range of products and perceptions of the biopesticide markets. Secondly, information on the farmers, their farming systems and pest management problems is presented. The third section gives a breakdown of the findings by biopesticide type, with information from both suppliers and users.

Issues arising from the survey results and recommendations are discussed in the final section.

Agriculture and biopesticides in Thailand

Agriculture is of immense importance to Thailand where an estimated 80% of the population are engaged in agriculture and related industries (Falvey 2000). It is the world's largest rice exporter and an important exporter of high quality vegetables, fruits and other foodstuffs such as fish. The agricultural sector covers a wide range of farming systems from small-holder farmers growing rainfed rice in the north east of the country to large export-oriented agribusinesses. From the 1960s to the 1980s agricultural policies were geared to the intensification and modernisation of agriculture oriented towards the export and home markets. The government supported the development of agribusiness and the use of agricultural inputs such as pesticides. Although there are a number of large farmers, the majority of Thailand's agricultural produce is still produced by small-holder farmers.

There was a large increase in the importation of pesticides between 1975 and 1995 and 60% of these imports fell into the WHO categories of extremely or highly hazardous (Harris 2000). Although official pesticide poisoning cases from Thailand during 1990-95 were low at 3-5,000 per annum these were probably a significant underestimate as surveys of rural women, who do much of the agricultural labour, reported that 80% of women questioned stated they had experienced some form of pesticide poisoning (Harris 2000).

In the late 1980s, growing concerns over environmental degradation caused by over-exploitation of natural resources, and increasing disparities in income between small-holders and large, commercial farmers led to a change in emphasis in agricultural policies. Policies are now aimed at sustainable technologies that optimise production but maintain the underlying natural resource base. One aspect of this was the policy by the DOAE and DOA to develop and promote alternatives to chemical inputs such as biofertilisers, botanicals and biopesticides in the context of an Integrated Pest Management (IPM) approach. The DOAE had a budget to buy biopesticides such as *Bacillus thuringiensis* (Bt) from private companies, for distribution to farmers. In 1998 over 10 suppliers sold biopesticide products to the DOAE, who had a budget of about 50 million baht.

At the end of the 1990s, DOAE policy was modified, partly due to the recession affecting the country and partly to a change in approach. The budget for biopesticides was cut and redirected towards nine regional Biocontrol Centers. These centres are responsible for producing their own biocontrol agents and training farmers in use of biocontrol methods. In 2002 the budget was around 10 million baht to cover all the regional centres. The number of commercial biopesticide suppliers to the DOAE has halved.

In addition to government efforts there are many NGOs in Thailand actively promoting sustainable agriculture. Some of these have values drawn from Buddhist philosophies based on a concern for the natural environment. One aspect of these approaches is the increase in promotion and use of "natural" supplements for agriculture such as biofertilisers containing "effective micro-organisms" (EM). These products can be found in many pesticide dealers.

One NGO that has considerable influence in Thailand is the Royal Project Foundation. This organisation was initiated by His Majesty the King, with the aims of alleviating poverty and creating high quality, sustainable agricultural production for the hill tribes in Thailand. His Majesty's concern with environmental issues and the need for more sustainable approaches has raised the awareness of many Thai people about these issues.

Use of chemicals is still prevalent amongst farmers. 38,750 tonnes of pesticides were imported in 1995 consisting of 233 different chemicals (Falvey 2000).

The biopesticide suppliers

This section describes the types of biopesticide suppliers in Thailand and their approach to and perceptions of the supply and marketing of biopesticides. Examples of farmer production are included in the section on farmers. Details of production and marketing of individual biopesticides are contained in the sections on bacteria, fungi, viral or nematode pesticides.

Sample
Both non-commercial – government and Non-governmental organisations (NGOs) – and private, commercial organisations were included. A list of commercial suppliers was drawn up based on information about biopesticides registered in Thailand by the DOA. Information about non-commercial suppliers was sought from the DOA and DOAE. During interviews with farmers and visits to several pesticide dealers, researchers enquired about additional biopesticides and suppliers, not already included in the survey. An additional three suppliers were identified in this way.

There may be other suppliers that have not been included. These might be private companies importing products that are not yet registered in Thailand, companies selling products with a biopesticide component, but within a biofertiliser package, or agricultural colleges or universities producing biopesticides such as Trichoderma on a non-commercial basis. However, it is unlikely that these account for any significant amounts of biopesticides without the DOA, DOAE or any of the farmers interviewed hearing about them.

In total 16 biopesticide suppliers were interviewed (Table 1). Five other suppliers were identified but not interviewed.

Table 1: Biopesticide suppliers included in survey

Type of supplier		# identified	# interviewed
Non-commercial	DOAE Biocontrol Centers	10 (include head office)	5 (largest centres + head office)
	DOA	1	1
	NGO	1	1
	Colleges	1	0
	Farmer	2	2
Commercial	Multinational	3	2
	Local agent	6 (+2 given up)	5
	Local producer	3 (+1 given up)	1
Total suppliers		**26**	**16**

Industry Structure

Biopesticides are produced and supplied by public organisations – primarily the Department of Agricultural Extension (DOAE) and Department of Agriculture (DOA), and also by private companies. The range of biopesticides produced or supplied only (imported or bought from another supplier) are shown in Table 2. The most common biopesticides were *Bacillus thuringiensis* (Bt) and *Trichoderma harzianum* (Trichoderma).

Almost all Bt products are supplied through the private sector, whereas the other biopesticides are produced and supplied by both public and private organisations.

Table 2: Number of suppliers producing or supplying biopesticides

	Bacteria		Fungi		Virus		Nematode	
Biological agents	***Bacillus thuringiensis*** *B. subtilis*		***Trichoderma* spp.** *Chaetomium* spp, *Metarhizium* spp *Beauvaria* spp.		***Spodoptera exigua NPV, Helicoverpa armigera NPV, S. litura NPV***		***Steinernema* spp**.	
Supplier type	Produce	Supply only	Produce	Supply only	Produce	Supply only	Produce	Supply only
Non-commercial	1	6	6	1	6	1	6	2
Commercial	2	9	2	1	0	1	2	0
Total	3	15	8	2	6	2	8	2

Government and other non-commercial suppliers

The main non-commercial suppliers of biopesticides are shown in table 3.

Table 3: Non-commercial suppliers main business

Supplier	Main business	Budget	Importance of biopesticides	Other bio-agents
DOAE Biocontrol Centers	Plant protection using biological control	45 million baht (all centres)	Important	Macrobials Botanicals Biofertliser
DOA Biological control section	Research & development of biological control	2.3 million baht	Most important	Macrobials
Royal Project	Poverty alleviation Production, extension & marketing of hygienic vegetables	N/a	Quite important	Macrobials, biofertiliser, botanicals seeds

The Department of Agricultural Extension (DOAE)
Biopesticides are supplied and promoted by the DOAE as part of the government's strategy towards more sustainable agriculture. Current policy is focused on low-cost production of biopesticides for resource-poor farmers. There is an emphasis on self-reliance and own production wherever possible, rather than obtaining biopesticides from the private sector or elsewhere.

The DOAE has nine Biocontrol Centers located around the country, and these centres provide expertise in pest management to local DOAE offices. Staff from the DOAE head office in Bangkok and from the four largest Biocontrol Centers were interviewed.

They produce a range of biological crop production products including biofertilisers, predators and parasites, botanical pesticides and repellents, biopesticides including fungal, nematode and viral pesticides. They also run farmer field schools and other training courses on Integrated Pest Management (IPM) and production of low residue (hygienic) vegetables. The Biocontrol Centers interact directly with farmers but also supply the local DOAE field offices with biocontrol agents on request. Officially, farmers should request biocontrol agents from their local DOAE officer who then informs the Biocontrol Center. The DOAE work with farmers throughout the country, but especially farmers who have formed a farmers' group – often based round a cooperative or group marketing of their produce. The biopesticides are usually distributed free or at very low cost to farmers.

Each centre has a small number of trained staff responsible for production of all the biocontrol agents, plus labourers (Table 4). Laboratory equipment includes autoclaves, laminar flow cabinets, microscopes and fridges. Centre staff are trained from within the DOAE but also receive training from the DOA and the universities on biopesticide production.

The DOAE buy in biopesticides that they cannot produce for distribution to farmers. Their budget for biopesticides has been reduced, but Bt products are bought from private suppliers. When they have a particular need, the Biocontrol Centers will obtain other biopesticides such as nematodes and trichoderma from private suppliers and viral pesticides from the DOA to supplement their own production.

The Department of Agriculture (DOA)

The DOA Biological Control section specialise in the research and development of macrobials and microbial pesticides, especially viral pesticides and Bt. The DOA has had a pilot plant producing viral pesticides since 1986. This is a larger and more specialised plant than the DOAE Biocontrol Centers, staffed by over 30 people. The viral pesticides are distributed directly to farmers and to the DOAE. Some samples are distributed free, but most are sold to farmers at cost price. Since 2000 the DOA have also developed a pilot plant to produce Bt in Chiang Mai.

The DOA is also responsible for the quality checks required for registration of biopesticide products.

Royal Project

The Royal Project Foundation is a charitable organisation initiated by His Majesty the King with the aim of alleviating poverty and developing sustainable agriculture in the poorer areas of Thailand. The Royal Project in Chiang Mai runs projects with tribal peoples to develop production of high quality, low residue (hygienic) vegetables. As part of this project, researchers at the University of Chiang Mai who work as volunteers for the Royal Project, have been producing the fungal pesticide, Trichoderma, and supplying this at low cost to the farmers. Farmers can also obtain other inputs through the Royal Project. These include biopesticides such as Bt and nematodes, but also selected chemical pesticides.

Other NGOs
Several other NGOs were identified who promoted IPM and sustainable approaches to agriculture. Some produced their own botanical and biofertilisers, but none were found to produce biopesticides.

Universities
The universities play an indirect, but important part in biopesticide production. Researchers at Kasetsart University, Bangkok, have provided technical advice on production and quality control to at least two commercial companies, as well as the DOAE. There has been research at Khon Kaen University on biopesticides and students trained by these universities have spread the technologies for producing fungal pesticides such as Trichoderma to other agricultural colleges. For example, two of the farmers interviewed had obtained Trichoderma from the local agricultural college at Chantaburi. Researchers at Chiang Mai University introduced the Trichoderma technologies to the Royal Project, and were also investigating the potential use of other fungal pathogens.

Table 4: Non-commercial biopesticide producers: production information

Supplier type	Biopesticides produced	Year started	# trained staff	Source of advice	Laboratory facilities
DOAE Biocontrol Centers	Trichoderma, SpexNPV, HearNPV, nematodes, Metarhizium, Beauvaria	1986-1995	30 grads + 150 (all centres)	DOA, University, journals (own staff, conferences, biopesticide producers)	Airflow cabinet, autoclave, light microscope, fridge, centrifuge, bioassay consumables, moisture analyser (head office)
DOA	SpexNPV, HearNPV, SpltNPV, Bt	1990	8 grads + 26		Airflow cabinet, autoclave, light microscope, moisture analyser, DNA identification, fridge, centrifuge, spray dryer, freeze dryer, formulation equipment, bioassay consumables
Royal Project	Trichoderma	1999	2 grads + 2	University of Chiang Mai	Airflow cabinet, autoclave, light microscope, fridge, freeze dryer, formulation equipment, bioassay consumables
Agricultural College	Trichoderma		N/A	N/A	N/A

Commercial suppliers

Eight commercial companies were interviewed and 4 other companies were identified but did not wish to participate. There were also three companies that were known to have tried but given up biopesticide supply.

Of the commercial suppliers, the majority buy and distribute biopesticides, but do not produce them. Three companies, all locally-based, were identified who currently produce biopesticides. Only one participated in the survey, so information on the other local producers is incomplete.

Table 5: Commercial biopesticide suppliers main business

Company type	Main business	# employees	Turnover	Importance of biopesticides	Other bio-agents
Multinational	Agrochemicals	11-20	N/a	Quite important	None
	Agrochemicals	101-200	800 million baht	Small < 1% turnover	None
Local supplier	Agrochemicals, seeds	101-200	N/a	Quite important	biofertiliser
	Agrochemicals	11-20	N/a	Small	None
	Agrochemicals, seeds	51-100	300 million baht	Important 8% turnover	none
	Agrichemicals	11-20	100 million baht	Small 1-2% turnover	Biofertiliser
	Agrochemicals, sprayers	21-50	80 million	Small 5-6% turnover	Pheromone (small)
Local producer	Export vegetables, seeds, agrochemicals	51-100	15-20 million baht	Quite important	biofertiliser
	Fertilisers, biopesticides	N/a	N/a	N/a	N/a
	N/a	N/a	N/a	N/a	Biofertiliser

Companies who supply biopesticides but do not produce them

The companies who supply but do not produce biopesticides are all agrochemical companies who have added imported Bt products to their list of chemicals. Only one of these companies had sold other biopesticides, namely two viral pesticides, but they had discontinued these products following take-over of the company.

The biopesticide suppliers vary in size, but only two (a multinational and a local company) employ more than 100 staff (table 5). Two companies interviewed were part of multinational groups and the other local companies have agreements with overseas producers to import and distribute their products.

Changes in this sector occur often due to both international and local factors. The spate of mergers and take-overs of biopesticide companies within the agrochemical industry globally has affected the range of products and strategy of the multinationals in Thailand. Within Thailand new companies have been set up or renamed and restructured to take advantage of import agreements with suppliers or government demand for biopesticides. Some of these are short-lived and disappear as import agreements lapse or demand slows down.

As the main business of all the commercial suppliers is agrochemicals, supply of biopesticides is a minor sideline and only regarded as a significant part of the total business by one supplier (table 5). The majority of these companies are also not in the business of supplying other bio-products, such as pheromones, botanicals, macrobials or biofertilisers. Only three companies (all local companies) reported supplying other bio-products. Of the companies that provided information on turnover, the percentage of turnover due to biopesticides varied from 0.7% to 8% of the total company turnover. The actual amounts varied from 1.5 million baht to 24 million baht ($ 0.04 – 0.57 million).

All the suppliers import brands of Bt from producers in Japan, USA, China and India.

Local biopesticide producers

Three local companies were identified who produced their own biopesticides, but detailed information was only available on one of these. One other company was identified who had started production, but not successfully brought the product to market (see *Companies who gave up* below).

Like the biopesticide suppliers, the producers do not rely only on the sales of biopesticides for their income. However, they are less closely tied to the traditional agrochemical sector: one company is involved in export vegetables and seeds as well as biopesticides; the other two companies are known to produce fertiliser and biofertiliser products and agrochemicals.

The range of biopesticides produced is greater than just Bt products. One company is known to produce Bt, Trichoderma, nematode and *Bacillus subtilis* products. The other two companies produce Trichoderma and nematodes, and *Bacillus subtilis*.

Information on the one company interviewed is shown in Box 1.

Local Producer: Uniseed

The Uniseed company is a Thai company whose main business is the production of seed and vegetables for export. Their biopesticide production started in 1995 with Trichoderma (*T. harzianum*) and was followed in 1999 with a nematode product called Unema (*Steinernema carpocapsae).* The company received grants from the government to set up biopesticide production and they also obtained technical advice from university and DOA researchers. They now have 7 science graduates and 20 other staff working on biopesticides. The graduates were trained at Kasetsart University, Bangkok.

To date, the biopesticides are only making a small profit. However, the company is planning to expand their range by adding a rodenticide based on the protozoan pathogen, *Sarcocystis singaporensis*. (This is based on research carried out by a collaborative Kasetsart University / DOA /GTZ team). They may consider production of virus pesticides in the future.

Box 1: Local Producer Uniseed

Reasons for supplying biopesticides and source of funds

Supply of biopesticides by the government agencies was driven by government policy introduced in the late 1980s and through the 1990s, to reduce pesticide use. The commercial suppliers saw a market opportunity with this new government policy and the growing concerns about health and the environment. With the exception of one company, all the other commercial companies started supplying biopesticides in the 1990s after the new government policy had been introduced.

Companies supplying biopesticides reported that funds to initiate biopesticide sales came from private funds or from the company – no venture capital was reported. At least two biopesticide producers[2] did obtain government grants or low interest loans to set up production.

Information sources

The main information sources on biopesticides were reported to be the parent company and biopesticide producers who supply these companies (Table 6). The DOA and universities were also important sources, especially for the companies producing biopesticides, whilst conferences and journals were generally of less importance. The internet was not reported as being a major source of information as yet.

Table 6: Commercial suppliers: biopesticides and source of information

Supplier type	**Biopesticides supplied or produced**	**Year started**	**Source of advice**
Multinational	Bt	1976	Biopesticide producers, parent company, DOA, (journals)
	Bt SpexNPV[3] H. zea NPV[4]	N/a	Parent company, biopesticide producers, DOA (university, conferences)
Local suppliers	Bt	1992	Biopesticide producers, parent company, DOA, journal, conferences, internet
	Bt	1995	Biopesticide producers, university, DOA, DOAE, conferences (journals, internet)
	Bt	N/a	Biopesticide producers, own staff, (university, DAO, DOAE, journals, conferences)
	Bt	2001	Own staff, biopesticide producer, university, DOA, DOAE, conferences, internet (journals)

[2] One has stopped production
[3] Discontinued in 2000
[4] Discontinued in 2000

Supplier type	Biopesticides supplied or produced	Year started	Source of advice
	Bt	N/a	Parent company, biopesticide producers, journals, conferences (own staff, DOA, university, DOAE)
Local producer	Trichoderma, Steinernema	1996	University, DOA, own staff (journals, conferences, DOAE, internet)
	Trichoderma Steinernema Bt Bacillus subtilis	N/a	University
	Bacillus subtilis	N/a	N/a

Marketing, Distribution and Promotion

Target markets

All public and commercial suppliers identified vegetable farmers as their main target customers (table 7). Export crops were thought an important area because of the stricter pesticide residue requirements for these crops. However, there were other differences in perceptions of target markets between public and commercial suppliers.

Public suppliers and local producers had a wider view of target farming systems, citing fruit trees, cotton and cut flowers in addition to vegetables. Only one of the commercial suppliers mentioned any other crop than vegetables.

Opinions about target farm size varied with most opting for small or medium farm sizes – typical of vegetable farms in Thailand. Public suppliers thought that farmers using biopesticides would have an interest in IPM or organic farming, as well as health and some environmental concerns. The commercial suppliers thought that farmers were less concerned with concepts of IPM or organic farming, but were concerned with health and environmental issues as well as farm profits. The commercial suppliers also tended to rate the education level of the farmers more highly than the public suppliers did.

Table 7: Biopesticide suppliers' view of target customers

Supplier type	Farming system (% respondents)	Farm size (% respondents)	Interest in IPM (% respondents)	Education level (% respondents)
Non-commercial 7 respondents	Vegetable (100) Fruit trees (85.7) Export crops (57.1) Cotton (42.9) Cut flowers (28.6) Legumes (14.3) Tobacco (14.3)	Small (71.4) Medium (28.6) Large (28.6)	IPM (100) Health (71.4) Organic (42.9) Environment (42.9) Profit (14.3)	Some (71.4) Medium (28.6) High (0)
Commercial 8 respondents	Vegetable (100) Export crops (37.5) Staple (12.5) Fruit tree (12.5)	Medium (62.5) Small (37.5) Large (25.0)	Health (62.5) Profits (50.0) IPM (37.5) Environment (37.5)	Medium (75.0) Some (25.0) High (25.0)

Distribution and sales

All the public suppliers distribute biopesticides directly to farmers. Within the DOAE, each Biocontrol Center covers 9 provinces. Although the Biocontrol Centers do run courses on IPM and farmer field schools with groups of farmers, the main responsibility for distributing biopesticides (and other bio-agents) lies with the local DOAE staff. They are supposed to inform the Biocontrol Centers if they know of a need for biopesticides by farmers in their local area. A request for biopesticides is then passed up the local DOAE hierarchy and on to the Biocontrol Center. The biopesticides are produced according to demand then sent out to the local areas.

There were problems reported by both DOAE and farmers with this system, due to the delays incurred between farmers initially requesting help from the local DOAE and the biopesticide finally reaching them. The DOAE cannot keep all biopesticides in stock due to their limited shelf-life and lack of storage space. Also it takes time for the request to work its way up the local DOAE hierarchy before reaching the Biocontrol Center. By the time the biopesticide reaches the farmer, it is often too late to use it successfully. Of course the Biocontrol Centers will prepare biopesticides in readiness for requests at times of the year when the staff know that they are likely to be needed, but they do have a problem matching supply and demand.

The DOA supplies biopesticides to the DOAE on request. They also work directly with selected groups of farmers and respond to requests for biopesticides from other farmers if they have sufficient supplies available. They do not have an organised distribution network.

The Royal Project distributes biopesticides through the 30 Royal Project centres, to farmers working with the Royal Project Foundation. It does not distribute outside the projects centres.

Most of the commercial suppliers sell their biopesticides through existing pesticide dealer networks. An exception is one company that sells all its biopesticides directly to the government (as the DOAE and DOA buy several Bt products). The number of outlets varies from a few selected outlets to nationwide coverage. The commercial suppliers did not report any linkages or distribution through organic or other ‘green’ networks.

The local producers have fewer, selected outlets and concentrate on locations where there is demand for their products. Two companies sell direct to the DOAE and DOA.

The resulting distribution of biopesticides means that some form of Bt product is available throughout the country, but availability of other biopesticides is extremely limited.

Table 8: Distribution outlets for biopesticides

Supplier type	**Distribution channels**	**# outlets**
DOAE Biocontrol Centers	Via local DOAE offices Direct to farmers	9 centres located nationwide + Head office

Supplier type	Distribution channels	# outlets
DOA	Via DOAE Direct to farmers	1 centre
Royal Project	Royal Project centres to participants	30 centres
Commercial suppliers 7 respondents	Pesticide dealers (85.7%) Direct to government (14.3%) Direct to farmers (42.9%)	National network (>100 dealers) (71.4%) Few outlets (28.6%)
Local producers 1 respondent	Pesticide dealers Direct to government Direct to farmers Mail order	40-50 dealers

Promotion and advertising

The DOAE promote biopesticides, particularly Trichoderma as part of their strategy on IPM and in farmer field schools. They and the DOA also run radio and TV programmes that include information on biopesticides. For example, a recent TV programme was on the topic of biopesticides as alternative control measures for insect pests. Whereas the DOAE tends to promote biopesticides as part of the wider strategy of IPM, the DOA tends to concentrate more on the specific details of particular biopesticides.

The Royal Project does not advertise or promote biopesticides outside their own centres, but they run training courses for participant farmers that include use of Trichoderma and Bt as part of hygienic vegetable production.

All the commercial suppliers and producers produced leaflets on their products and advertised their products through their dealers (table 9). Most had extension staff and ran demonstrations and field trials with farmers. Horticultural magazines were the most popular media for advertisements, although four companies also reported using radio or TV broadcasts. Only one commercial supplier said they spent more than 30% of total costs on marketing and distribution. One local producer reported spending 40 – 50% on marketing.

Only one of the local producer reported carrying out any formal market research with a questionnaire distributed to 200 farmers.

Table 9: Extension methods

Supplier type	Extension methods	Advertisements	Market Research
DOAE	Farmer field schools, demonstrations, field trials	Leaflets TV and radio programmes, newspapers	
DOA	Field trials, farmer field schools	Leaflets TV and radio programmes	
Royal Project	Farmer field schools, field trials	Leaflets	
Commercial suppliers	Via dealers (100%)	Leaflets (100%)	Investigate farmers’

Supplier type	Extension methods	Advertisements	Market Research
7 respondents	Demonstrations & field trials (85.7%)	Horticultural magazines (57.1%) Radio (42.9%)	needs (14.3%)
Local producers 1 respondent	Via dealers Demonstrations & field trials	Leaflets Horticultural magazines Radio & TV	Questionnaire to 200 farmers

Problems identified by suppliers

Suppliers were asked their opinion about a number of issues and potential problems with biopesticide uptake (table 10).

Issues connected to lack of demand by farmers were generally rated as more important than those to do with the supply side. These included the lack of knowledge by farmers and the competition from chemicals that could provide faster and sometimes cheaper pest control.

Lack of knowledge about biopesticides by farmers and lack of sufficient extension was regarded as a major problem by the public sector suppliers and local producer, but was of less concern to the commercial suppliers.

Competition, particularly with new chemicals, was the major concern of commercial suppliers. The new chemicals are generally less toxic than older chemicals and, at least initially, have no insect resistance problems. The public sector suppliers did not rate this issue quite so highly, but the high cost of biopesticides compared with chemicals was thought to be a problem by all suppliers.

The slow action of biopesticides compared with that of chemicals was thought a major problem by all suppliers. The limited shelf-life of the existing formulations of biopesticides was very important particularly to those producing biopesticides. While newer long life formulations of some pesticides, eg. entomopathogenic fungi, have been developed these are not currently used in the products produced in Thailand.

Generally issues to do with production such as technical problems, quality, production costs were thought important, but not as significant as the issues connected with demand for biopesticides. Since the commercial suppliers are not directly concerned with biopesticide production, it is not surprising that these issues are of lower priority to them.

Lack of dealers and lack of availability were rated as important especially for the public sector suppliers.

Registration and government legislation were not thought to be major problems. Non-commercial producers do not have to register products if they are not selling the products, so, for example, the DOAE products are exempt from registration. However, the commercial suppliers who did have to register did not appear to be concerned by the requirements of registration.

Table 10: Problems perceived by biopesticide suppliers

Issue	Public suppliers N= 7	Commercial suppliers N=7	Local producers N=1
Lack of demand by farmers	Important (14.3%) Some importance (28.6%) Minor importance (42.9%) Not important (14.3%)	Important (57.1%) Some importance (42.9%)	Very important
Lack of knowledge	Very important (85.7%) Minor importance (14.3%)	Very important (14.3%) Important (14.3%) Some importance (28.6%) Minor importance (14.3%)	Very important
Lack of extension	Very important (42.9%) Important (28.6%) Some importance (14.3%) Not important (14.3%)	Important (28.6%) Some importance (14.3%) Not important (14.3%)	Important
Competition with old chemicals	Very important (42.9%) Important (28.6%) Some importance (14.3%) Minor importance (14.3%)	Very important (71.4%) Important (14.3%)	Important
Competition with new chemicals	Very important (42.9%) Important (28.6%) Some importance (14.3%) Minor importance (14.3%)	Very important (100%)	Very important
High cost	Very important (57.1%) Important (42.9%)	Very important (28.6%) Important (42.9%) Some importance (14.3%)	Very important
Slow action of biopesticides	Very important (71.4%) Important (28.6%)	Very important (42.9%) Important (14.3%) Some importance (14.3%)	Some importance
Storage problems	Very important (42.9%) Important (42.9%) Not important (14.3%)	Important (57.1%) Some importance (14.3%)	Very important
Lack of quality	Important (42.9%) Some importance (42.9%) Not important (14.3%)	Very important (28.6%) Important (28.6%) Not important (14.3%)	Important
Lack of dealers	Very important (42.9%) Important (14.3%) Some importance (14.3%) Minor importance (28.6%)	Important (42.9%) Some importance (28.6%)	Very important
Lack of availability	Very important (28.6%) Important (42.9%) Some importance (28.6%)	Very important (14.3%) Important (28.6%) Some importance (42.9%)	Important
Lack of capital	Very important (14.3%) Important (14.3%) Some importance (14.3%) Minor importance (28.6%) Not important (28.6%)	Very important (14.3%) Important (14.3%) Some importance (28.6%)	Minor importance
Technical problems	Very important (14.3%) Important (47.1%) Minor importance (28.6%)	Very important (14.3%) Important (28.6%) Some importance (28.6%)	Some importance
Production costs	Important (28.6%) Some importance (14.3%) Minor importance (42.9%) No importance (14.3%)	Important (14.3%) Some importance (42.9%)	Important
Registration problems	Some importance (14.3%) Minor importance (14.3%) Not important (57.1%)	Important (14.3%) Some importance (28.6%) Minor importance (28.6%)	Not important
Government policy	Some importance (14.3%)	Important (14.3%)	Not important

Issue	Public suppliers N= 7	Commercial suppliers N=7	Local producers N=1
	Minor importance (28.6%) Not important (28.6%)	Some importance (14,3%) Minor importance (14.3%) Not important (14.3%)	
Other issues	Gap between Biocontrol Centers & farmers	Insect resistance to Bt (14.3%)	

Past and future changes in the biopesticide market

Changes in the biopesticide market

The public sector suppliers all reported an increase in their production and distribution of biopesticides, whereas the private companies mostly reported a decrease in sales over the last 3 years (1999-2001) (table 11). It is likely that this is caused primarily by the change of government policy so that the DOAE no longer have such a large budget to buy Bt products.

Table 11: Changes in biopesticide output 1998-2001

Change in sales/production over last 3 years	Public sector N=7	Private supplier N=6	Private producer N=1
Large increase (>100%)			
Increase	100%		
About the same		16.7%	
Small decrease		50.0%	100%
Large decrease		33.3%	

Three companies had stopped selling certain biopesticide products. Two of these had stopped selling Bt formulations, and one had stopped selling one Bt brand and two viral pesticides. None of the companies reported any plans to sell new biopesticides or make other major changes to their approach to biopesticides, except for the producer, Uniseed, who plan to produce and sell a new protozoan-based rodenticide and are working on new formulation methods. In contrast, the public sector suppliers have programmes to produce new biopesticides. The DOAE are working on the fungal insecticides, *Metarhizium anisopliae* and *Beauvaria bassiana* and the DOA is starting large-scale Bt production and planning a new viral NPV pesticide pilot plant. The Royal Project researchers (at Chiang Mai university) are investigating new fungal pathogens.

Companies who have given up biopesticide supply

Three private companies are known to have given up biopesticide supply completely. Their reasons are different and illustrate some of the difficulties faced by biopesticide suppliers.

- Company A was formed to provide a one-off contract to supply Bt products to the DOAE. After the DOAE budget for Bt was reduced, company A closed down.

- Company B negotiated a contract to import Bt products from India. They obtained registration for the product in Thailand. However, the Indian suppliers switched the contract to another larger Thai company, leaving company B without any Bt products.

- Company C received a low interest loan from the government to set up the production of viral NPV pesticides. They tried for three years to rear insects but had problems with the production technology that they had adopted. The product was never brought to market and the company gave up biopesticide production.

Opinions on the future of the biopesticide market

Opinions about the future success of biopesticides were mixed. The public sector suppliers were more optimistic about future uptake of biopesticides than the private sector, and generally predicted increases in all types of biopesticides except for herbicides (table 12). The reasons given were that Thai people were now more aware of the negative impact of pesticides, they were beginning to accept biopesticides like Bt and Trichoderma, and biopesticides would help in the drive towards clean, high quality export crops. Some of the private suppliers however, felt that biopesticides remained too high cost and low efficacy to compete successfully with chemicals.

The most successful biopesticides were expected to be bacteria – primarily Bt – by both public and private suppliers. Views on viral, fungal and nematode pesticides by the private suppliers were mixed, but none predicted that any of these would be very successful in the future. Fungal herbicides were not expected to be successful by any supplier.

The main markets for biopesticides were still expected to be vegetable farmers and some fruit farmers growing for export or growing high value, hygienic crops. One supplier noted that this would partly depend on the continued support by government for hygienic (low residue) vegetable production.

Table 12: Biopesticide suppliers' perceptions of change in biopesticide market

Expected change	**Public sector suppliers N=7**	**Private suppliers N=6**	**Private producers N=1**
All biopesticides	Large increase (28.6%) Increase (71.4%)	Increase (33.3%) Small increase (66.7%)	Increase
Bacteria	Large increase (57.1%) Increase (42.9%)	Large increase (16.7%) Increase (66.7%) Small increase (16.7%)	Large increase
Virus	Large increase (14.3%) Increase (42.9%) Small increase (42.9%)	Increase (50.0%) Small increase (33.3%) Decrease (16.7%)	Small increase
Fungus insecticides	Increase (14.3%) Small increase (57.1%) No change (28.6%)	Small increase (66.7%) No change (16.7%)	No change
Fungal antagonists	Large increase (57.1%) Increase (42.9%)	Increase (16.7%) Small increase (50.0%) Decrease (16.7%)	Increase
Nematodes	Increase (57.1%) Small increase (28.6%)	Increase (16.7%) Small increase (33.3%)	Increase

Expected change	Public sector suppliers N=7	Private suppliers N=6	Private producers N=1
	No change (14.3%)	No change (33.3%)	
Herbicides	Increase (14.3%) No change (57.1%) Decrease (28.6%)	Small increase (16.7%) No change (16.7%) Decrease (50.0%)	Decrease

Recommendations by suppliers

Most of the recommendations on promoting biopesticide uptake from the public sector suppliers were concerned with improving the dissemination of information about biopesticides to farmers. Suggestions included more workshops, demonstrations and field trials; better training for local extension staff and increased use of the mass media to disseminate information. One suggestion was for the number of DOAE Biocontrol Centers to be increased so that each province had its own centre. Other suggestions concentrated on making biopesticides more competitive with chemicals by either subsidising their price, or restricting pesticide imports and advertising.

Recommendations from the private suppliers were less forthcoming, but included some supply-side issues such as the need to increase research and development funding in order that producers develop better formulations, longer shelf-life and quicker acting products. One supplier thought the registration process should be made easier for biopesticide products, and two suppliers suggested price subsidies to reduce the cost of application.

It is notable that the recommendations from the public sector focus on areas where they are closely involved, such as extension, but have less to say about production and supply issues or the role of the private sector. One DOAE staff commented that he thought the DOAE would need to be involved in production and extension of biopesticides possibly for another 5 years to convince farmers of their usefulness. Once the farmers were convinced then the private sector could step in.

The private sector suppliers’ recommendations leave it to others such as government to take action. There were no suggestions that the private sector could take steps themselves such as increasing their own promotion efforts or linking up with other organisations involved with bio-agricultural products.

The farmers

This section describes the farmers interviewed in the survey in terms of the main characteristics of their farming system, their pest management practices and their perceptions of biopesticides generally.

A total of 208 farmers were interviewed. 99 farmers had been involved in training courses or promotions that included use of one or more biopesticides. Most, but not all of this training formed a component of Integrated Pest Management (IPM) training. 109 farmers were selected randomly from within the same farming system. Table 13 shows the number of trained[5] and control[6] farmers selected from each farming system.

Table 13: Number of "trained" and "control" farmers interviewed

Farming System	Location	Main crops	Mean farm size (ha)	Trained farmers	Control farmers	Total farmers
Rice	Chainat	Rice, vegetables	10.22	21	28	49
Cotton	Lopburi	Cotton, maize, vegetables	16.24	11	12	23
NE Vegetable	Nakorn Rachasima	Vegetables: salad, crucifers	4.43	12	14	26
N Vegetable	Chiang Mai, Lumpoon	Vegetable: crucifers, potato Some fruit trees	3.13	26	23	49
Grape	Samut-sakorn, Rachaburi	Grape, some vegetable	5.88	13	12	25
Fruit Trees	Chantaburi, Rayong	Durian, langsat, mangosteen Some chilli	14.77	16	20	36
Total				**99**	**109**	**208**

Farming system characteristics

1. Rice/vegetable

These farmers were from the area around the town of Chainat in central Thailand. Although irrigated rice was the major crop, many farmers also grew vegetables, soybean, groundnut or maize. Rice is farmed intensively here and farmers can obtain 2.5 crops a year. These rice farmers are generally better off than farmers in NE Thailand who rely on rainfed rice, but income from rice farming is low compared with other farming systems.

[5] "Trained farmers" is used in this report to refer to those farmers who participated in the survey and had previously been involved in some form of training on one or more biopesticides.
[6] "Control farmers" is used in this report to refer to farmers who participated in the survey after being randomly selected from the same farming system as the trained farmers.

The trained farmers were from two farmers' groups who had attended farmer field schools run by the DOAE Biocontrol Center at Chainat. One group had their own village IPM centre, built by a local farmer who was interested in IPM and a very active IPM leader. She had support from the DOAE and produced biofertiliser, botanical pesticides and Trichoderma for the local group. This group grew a mix of vegetables and rice. The second group was more concerned with rice, not vegetables. The Rice Research Centre had been conducting trials of Metarhizium with a few of these farmers. The DOAE training had covered IPM topics such as natural enemies and scouting for pests. Use of biofertilisers and botanical pesticides had been included. Trichoderma was the main biopesticide introduced, with farmers being instructed in its production, mixing and application.

Average farm sizes for the trained and control groups were 21 rai (3.4 ha) and 30 rai (4.8 ha) respectively (table 14). Use of chemical pesticides is relatively low compared with use in the other farming systems, especially on rice. The types of products used tend to be the older and less expensive pesticides such as endosulfan and monocrotophos. Less than 5% of all the farmers reported buying a pesticide costing more than 1000 baht per litre or kilo. There was a notable difference between the trained and control farmers in their interest in IPM. Over one third of trained farmers did not report using any chemical pesticides, and only 24% were using chemicals with highly toxic active ingredients[7], compared with 77% of the control farmers.

Table 14: Rice/vegetable farming system: farm and pesticide use characteristics

RICE Farmers	Mean Farm size (std) rai	% interested in IPM, hygienic or Organic farming	% not using chemicals	% using highly toxic chemicals	% farmers buying low, medium or high price pesticide products[8]		
					Low <1000B	Medium 1000-3000B	High >3000B
Trained	20.57 (15.47)	95.7%	38.1%	23.8%	95.0%	5.0%	0
Control	30.36 (18.55)	10.7%	3.6%	78.6%	96.4%	3.6%	0

Most farmers had primary school education. 62% of the trained and 29% of the control farmers were women (table 15).

Table 15: Rice/vegetable farming system: Demographic characteristics

Rice	Farmers	Gender	Age			Education			Income sources
	Number	% women	Young < 35	Middle 35-60	Old >60	Primary	Secon-dary	Univer-sity	% non-farm income
Trained	21	61.9%	4.8%	76.2%	19.0%	85.7%	9.5%	4.8%	4.8%
Control	27	28.6%	0	88.9%	11.1%	85.2%	14.8%	0	7.1%

[7] Pesticides containing category I active ingredients defined as "highly hazardous" by the World Health Organisation

[8] Low: <1000B (<$24), Medium 1000B-3000B ($24-$71), High >3000B (>$71)

2. Cotton

The cotton farmers were from the district of Lopburi in central Thailand. Cotton was the main crop for all but three of these farmers, but most grew additional crops, commonly maize, cassava, sorghum and mungbean. The three farmers with cotton as a minor crop grew fruit trees: lime, guava and mango.

The trained farmers had been participants in a cotton IPM programme run by the DOA. This programme included the use of the viral pesticide HearNPV supplied by the DOA (DOA BioV2) to control cotton bollworm. The use of Bt was also recommended. At the time of the survey, the IPM programme was drawing to a close and would move on to other locations.

Three of the control farmers claimed to be growing "Bt cotton", and a further two control farmers mentioned they had tried growing it. Whether the cotton really contains Bt genes is debatable. Bt cotton had been trialed in this area by Monsanto, and some claim that an amount of seed 'escaped' from the trial and was multiplied up and sold to local farmers. The farmers' experience of using the "Bt cotton" was reported to be very positive for the first season when they found they did not have to spray insecticides against bollworm, but not good during the second and subsequent seasons. It is possible that the farmer-multiplied "Bt" cotton was not in fact expressing significant Bt and may have been a hybrid that did not breed true.

The farm sizes averaged 45 rai (7.2 ha) for trained and 38 rai (6.1 ha) for control farmers (table 16). Almost all the farmers used chemical pesticides. Of the 2 farmers who did not, one said she was allergic to chemicals and suffered ill effects from them; the other was very interested in IPM and organic farming. Generally, cotton farmers were prepared to spend more on a bottle or pack of pesticide than the rice farmers.

Table 16: Cotton farming system: Farm and pesticide use characteristics

COTTON	**Mean Farm size (std) rai**	**% interested in IPM, hygienic or Organic farming**	**% not using chemicals**	**% using highly toxic chemicals**	**% farmers buying low, medium or high price pesticide products**		
Farmers					**Low <1000B**	**Medium 1000-3000B**	**High >3000B**
Trained	45.45 (64.57)	81.8%	0	18.2%	0	100%	0
Control	38.00 (65.06)	66.6%	16.7%	41.7%	66.7%	33.3%	0

Most of the farmers interviewed were male, middle-aged with primary education (table 17). There was only one woman interviewed from the cotton IPM training course.

Table 17: Cotton farming system: Demographic characteristics

Cotton	**Farmers**	**Gender**	**Age**			**Education**			**Income sources**
	Number	% women	Young < 35	Middle 35-60	Old >60	Primary	Secon-dary	Univer-sity	% non-farm income
Trained	11	9.1%	9.1%	76.2%	19.0%	90.9%	9.1%	0	0
Control	12	58.3%	0	100%	0	91.7%	8.3%	0	16.7%

3. Vegetable production, North East Thailand

Vegetable farmers were located around the town of Nakorn Rachasima. The trained farmers consisted of members from two groups of farmers who had received training from the DOAE in hygienic vegetable production. One group marketed their produce together, commissioning transport to take the produce to outlets such as hotels and supermarkets in Bangkok. These outlets are prepared to pay a premium price for hygienic vegetables, especially salad crops. The control group of farmers grew similar crops and also marketed their produce directly themselves as well as through middlemen. The main crops grown were a variety of salad leaves, Chinese kale, Chinese mustard, parsley, shallots and garlic. Nine of the farmers also grew rice.

Apart from the farmers who had rice fields, farm sizes were small, averaging 13 rai (2.1 ha) for trained and 10 rai (1.6 ha) for untrained farmers (table 18). A few of the trained farmers relied only on organic products for pest management, but most still used chemicals, many of which contained highly hazardous active ingredients (table 18). Those who did rely on organic products used biofertiliser with "Effective Micro-organism", "EM". 25% of trained and 46% of control farmers had bought chemicals costing more than 3,000 baht per litre or kilo. These are the newer chemicals such as tebufenocide or chlorphenapyr used to control pests such as beet armyworm which are increasingly resistant to the older chemicals.

Table 18: NE vegetable farming system: Farm and pesticide use characteristics

NE VEGE-TABLE Farmers	**Mean Farm size (std) rai**	**% interested in IPM, hygienic or organic farming**	**% not using chemicals**	**% using highly toxic chemicals**	**% farmers buying low, medium or high price pesticide products**		
					Low <1000B	**Medium 1000-3000B**	**High >3000B**
Trained	13.17 (11.67)	91.7%	25.0%	33.3%	58.3%	16.7%	25.0%
Control	9.79 (8.63)	71.4%	21.4%	35.7%	38.5%	15.4%	46.2%

There was a slightly higher proportion of women farmers and those with secondary education than amongst the rice or cotton farmers (table 19). Farming was the main source of income for all except one farmer.

Table 19: NE Vegetable farming system: Demographic characteristics

NE Vege-table	**Farmers**	**Gender**	**Age**			**Education**			**Income sources**
	Number	% women	Young < 35	Middle 35-60	Old >60	Primary	Secon-dary	Univer-sity	% non-farm income
Trained	12	25.0%	8.3%	75.0%	16.7%	83.3%	16.7%	0	0
Control	14	42.9%	14.3%	78.6%	7.1%	64.2%	35.7%	0	7.1%

4. Vegetable Production, Northern Thailand

Vegetable producers around Chiang Mai in the north of Thailand, were chosen from three different locations: the hills just north of Chiang Mai, the lowlands near Chiang Mai and the neighbouring district of Lumpoon. The trained farmers came from three different groups. One group of farmers were participants in the Royal Project, a programme with the aim of alleviating poverty and developing sustainable agriculture for tribal people. In this area, the Royal Project was promoting the production of hygienic (low residue) vegetables. A marketing centre had been set up where farmers could bring their produce to be sorted, packed and transported to Chiang Mai and other markets. The marketing was carefully regulated with farmers receiving instructions on what to grow at a particular time. In this way, the organisers tried to maintain supplies to meet demand and maintain a good price for the farmers. The farmers also had to abide by instructions on how to grow the crops to ensure they met quality and hygienic standards. For example, many chemical pesticides were not allowed close to the harvest time, to avoid any residue problems. The system was similar to a contract farming system. Farmers were trained in hygienic vegetable production by Royal Project staff and volunteers. A project to promote the use of Trichoderma had been initiated by Royal Project and University of Chiang Mai and the farmers interviewed had been trained in its use. The vegetables grown included salad leaves, cabbage, Chinese mustard, sweet peppers, baby carrot and tomato.

Trained farmers from the lowlands around Chiang Mai and Lumpoon had been involved in IPM courses run by the DOAE and DOA respectively. They grew cabbage, Chinese kale and mustard similar to those in the Royal Project, but did not grow salad leaves. They grew garlic or shallots, chilli, potato and eggplant. The farmers did not belong to such an organised marketing outlet as those in the Royal Project and most sold their produce to middlemen.

The control farmers came from the same three areas as the trained farmers and grew similar crops (table 20). Some farmers (trained and control) grew fruit in addition to vegetables. Seven farmers from the Royal Project location grew litchi, and eleven farmers from Chiang Mai and Lumpoon grew longan.

Table 20: N Vegetable farming system: areas included in survey

Area	# trained farmers	Trainers	# control farmers	Vegetables grown	Other crops (# farmers)
Royal Project at Chaing Mai	6	Royal Project	7	Tomato, salad, cabbage, sweet pepper, crucifers, chinese mustard, carrot	Litchi (7) citrus (1)
Chaing Mai	9	DOAE	20	Egg plant, potato, baby corn, garlic, crucifers, chilli, shallot, cabbage, pakchoi, cauliflower, taro, tomato	Longan (4) Mango (1) Plum (1)
Lumpoon	12	DOAE, DOA	3	Chinese kale, Chinese mustard, garlic, shallot, chilli	Longan (7)
Total Chiang Mai	27		30		

Farm sizes were small, averaging 8 rai (1.3 ha) for both trained and control farmers. There was no significant difference in farm sizes between the three areas. All farmers used chemical pesticides although those growing hygienic vegetables restricted the use prior to harvest (table 21). A significant number used chemicals with highly toxic active ingredients. Many, particularly participants in the Royal Project also used non-chemical methods – biofertilisers, botanicals – as well. Most farmers bought the older and cheaper chemicals. None of the farmers reported spending more than 3,000 baht per litre or kilo on one of the new chemicals.

Table 21: N Vegetable farming system: Farm and pesticide use characteristics

N VEGE-TABLE Farmers	Mean Farm size (std) rai	% interested in IPM, hygienic or organic farming	% not using chemicals	% using highly toxic chemicals	% farmers buying low, medium or high price pesticide products		
					Low <1000B	Medium 1000-3000B	High >3000B
Trained	8.12 (11.51)	88.5%	0	53.8%	38.5%	61.5%	0
Control	8.13 (9.60)	39.1%	0	73.9%	56.5%	43.5%	0

15% of the trained and 17% of the control farmers interviewed were women (table 22). Most had primary education. A total of 8 (16%) farmers had other sources of income in addition to farming.

Table 22: N Vegetable farming system: Demographic characteristics

N Vege-table	Farmers	Gender	Age			Education			Income sources
	Number	% women	Young < 35	Middle 35-60	Old >60	Primary	Secon-dary	Univer-sity	% non-farm income
Trained	26	15.4%	11.5%	76.9%	11.5%	73.0%	26.9%	0	11.5%
Control	23	17.4%	13.0%	69.6%	17.4%	87.0%	8.7%	4.3%	21.7%

5. Grape

Grape is a high-value and high-input crop grown in districts to the south-west of Bangkok. With careful management the vines can be harvested every 4 months, and it is possible to obtain 5 crops in 2 years. Farmers try to control the time of harvest to meet high demand for fruit particularly round New Year. Grape production requires a large initial investment for the preparation of the plot, the vines and support framework, plus ongoing costs of hormones, fungicide, insecticide, fertiliser and labour. The vines need replanting after 3 to 4 years. If the farmer gets the management right, they can bring in an income of 14,000 baht per crop per rai (approximately $2,100 per ha). However, it is a high risk crop, and can completely fail to yield, potentially leaving a farmer with high debts.

The trained farmers were from the districts of Samut-Sakorn and Rachaburi. The DOA had given them training in the production and use of viral pesticides, SpexNPV and HearNPV. The training was focused on these pesticides rather than as part of a wider IPM training programme. The control farmers were from the same districts.

All farmers relied heavily on chemical pesticides, and were prepared to spend greater amounts than farmers from the other farming systems (table 23). Due to the intensity of chemical use, continuous production and resulting pest pressure, pest resistance to chemicals developed quickly. A new chemical might only last two to three seasons before resistance problems started, so farmers were constantly on the look out for new, effective chemicals. At the time of the survey, one of the new chemicals (spinosad) cost 6000 baht/litre. However, 88% farmers had bought and used it.

There was a large variation in farm size, especially amongst the trained farmers where it ranged from 4 to 75 rai (0.6 to 12 ha) (table 23). The majority of farmers had between 10 and 20 rai (1.6 to 3.2 ha).

Table 23: Grape farming system: Farm and pesticide use characteristics

GRAPE Farmers	Mean Farm size (std) rai	% interested in IPM, hygienic or organic farming	% not using chemicals	% using highly toxic chemicals	% farmers buying low, medium or high price pesticide products Low <1000B	 Medium 1000-3000B	 High >3000B
Trained	19.92 (17.04)	100%	0	69.2%	0	7.7%	92.3%
Control	9.75 (4.39)	41.7%	0	50.0%	0	16.7%	83.3%

The trained farmers had a higher level of education than in other areas, especially the younger people (table 24). All but one of the trained farmers were men.

Table 24: Grape farming system: Demographic characteristics

Grape	Farmers Number	Gender % women	Age Young < 35	 Middle 35-60	 Old >60	Education Primary	 Secon-dary	 Univer-sity	Income sources % non-farm income
Trained	13	7.7%	15.4%	76.9%	7.7%	46.2%	46.2%	7.7%	7.7%
Control	12	50.0%	8.3%	91.7%	0	91.7%	8.3%	0	8.3%

6. Fruit tree farmers

Fruit tree farmers were based in the districts of Chantaburi and Rayong in the south-east of Thailand. The major fruit was durian, a high value crop grown for the local and export market. Other fruit trees were mangosteen, langsat and mango. Most orchards in these areas are laid out with a network of pipes to each tree for irrigation. There was a mixture of orchards containing one type of fruit only, and those with several different fruit trees. There is a high initial investment for fruit orchards, but the income from them can be similar to that from grape production. Once established the maintenance effort is much lower than for grape.

The trained farmers were from two different farmers' groups. One group specialised in durian production and marketed high quality fruit for export and local markets. Fruit that meet the quality and residue criteria for export can be sold for twice the price of fruit going to the local market.

The other farmers' group did not appear to have the same level of organised marketing, but did provide its members with information and support. Both groups had received training from the DOAE in fruit production and quality issues, and in the use of the fungal biopesticide, Trichoderma, to control *phytopthora* on durian.

The control farmers came from the same districts; they grew similar fruit trees to the trained farmers.

Apart from fruit trees, a few farmers grew chilli, often within the fruit tree orchards. All farmers used chemical pesticides, and the majority used highly toxic chemicals (table 25). Most were interested in IPM or hygienic production especially if they were aiming for the export market.

Farm sizes were large compared with those in the other farming systems, averaging 32 rai (5.1 ha) and 43 rai (6.9 ha) for the trained and control farmers (table 25). Few people were employed on a regular basis (the investment in irrigation infrastructure decreased the need for labour).

Table 25: Fruit tree farming system: far and pesticide use characteristics

FRUIT TREE Farmers	Mean Farm size (std) rai	% interested in IPM, hygienic or organic farming	% not using chemicals	% using highly toxic Chemicals	% farmers buying low, medium or high price pesticide products		
					Low <1000B	Medium 1000-3000B	High >3000B
Trained	31.94 (50.92)	93.7%	6.3%	75.0%	12.5%	87.5%	0
Control	42.50 (48.62)	60.0%	0	80.0%	30.0%	70.0%	0

This was the one farming system where a significant number of farmers had other occupations. Over one third of farmers had other jobs, such as trading, although they said that farming was their main occupation. Fruit tree farmers were generally better educated and older than the vegetable and rice farmers (table 26).

Table 26: Fruit tree farming system: Demographic characteristics

Fruit tree	Farmers	Gender	Age			Education			Income sources
	Number	% women	Young < 35	Middle 35-60	Old >60	Primary	Secon-dary	Univer-sity	% non-farm income
Trained	16	18.8%	6.3%	75.0%	18.8%	68.8%	31.3%	0	37.5%
Control	20	25.0%	0	55.0%	45.0%	70.0%	20.0%	10.0%	35.0%

Farmers' pest management methods

The vast majority of farmers relied on chemical pesticides to control pests. The few (8.7%) people who did not report using any chemicals included those who had experienced severe health problems with chemical pesticides and those who were growing hygienic vegetables and were interested in a natural approach to agriculture. The use of "EM" and biofertiliser was a major part of their pest and crop management strategy.

Less pesticide was used on rice compared with the other crops. Mainly older and cheaper insecticides were used to try and control major pests brown plant hopper and stemborer, in addition to cultural methods such as water control. A wide range and varying amounts of chemicals, both insecticides and fungicides, were used on vegetables. If farmers were growing hygienic (low residue) vegetables, they still used a range of chemical pesticides, but limited these prior to harvesting. Diamond back moth was a major problem for those growing crucifers and some farmers experimented with new chemicals and tried rotating chemicals to slow down the development of resistance in the insects. Beet armyworm was another major problem particularly for those growing shallots and yardlong bean.

Grape farmers used the highest levels of chemical inputs: insecticides, fungicides and hormones to control the flowering and fruiting stages. With such an intensive use of chemicals, farmers found that insecticides could lose their efficacy after as little as two seasons as the insects developed resistance. Because of this and the fact that a successful grape harvest could generate high incomes, the farmers were targets for the new and more expensive chemicals. They continued to use older chemicals such as metamidophos against thrips and aphid pests, but tried new products such as spinosad to tackle problem pests such as beet armyworm and cotton bollworm. All grape farmers used chemicals, and the trained farmers' group did not think it possible to grow organic grapes.

Fruit tree farmers are also high chemical users, but with less intensive spraying than for grape. Many durian farmers grow for export, so have to limit the chemicals used prior to harvest to meet pesticide residue level requirements. Their reported pest problems were specific to particular fruit trees. For durian the main concern was *phytophtora*, a fungal disease which gradually killed the tree. Bark-eating caterpillars were a major concern on langsat trees.

Table 27: Main pest problems and pesticides used by farmers in survey

Farming system	Main pest problems reported	Pesticides commonly used
Rice	Rice: Brown plant hopper, stemborer, leaf folder, thrips, golden snail, fungus disease, rust Vegetables: Root & stem rots, cabbage looper, diamond back moth, cut worms, aphids, mildew	Furadan, imidacloprid, methamidophos, methyl parathion, chloropyriphos, monocrotophos, endosulfan, Biofertiliser, Trichoderma
Cotton	Cotton bollworm, jassids, whitefly, aphids	monocrotophos, cypermethrin, cypermethrin+phosalone, imidacloprid, neem extract
NE Vegetable	Beet armyworm, diamond back moth, flea beetle, thrips, aphids Fungus diseases	Cypermethrin, tebufenozide, monocrotophos, methomyl, abamectin, deltamethrin Carbendazim, mancozeb Biofertiliser, neem extract
N Vegetable	Diamond back moth, beet armyworm, flea beetle, leaf miner, Root & stem rots, downy mildew	Metamidophos, cypermethrin, monocrotophos, methomyl, abamectin, methyl parathion, Bt Mancozeb, carbendazim
Grape	Beet armyworm, cotton bollworm, thrips, cotton leafworm Fungus disease, downy mildew	Methamidophos, monocrotophos, methomyl, cypermethrin, abamectin, diflubenzuron, chlorphenapyr, spinosad anthracole, mancozeb, carbendazim, score
Fruit trees	Durian: thrips, red mite, fruit-boring caterpillar, psylid, root rot Langsat: Bark-eating caterpillar Rambutan: black mould Mangosteen: thrips, mealy bug	Methamidophos, cypermethrin, abamectin, dimethoate carbendazim, s-dust, omite

Sources of information

The main source of information on pest management was reported to be other farmers (table 28). Pesticide dealers and extension staff were also important sources of information. However, in discussions farmers said that advice from other farmers was often trusted more because they had learnt from experience, whereas pesticide dealers wanted to sell their products and extension staff did not always have much local experience of farming. Examples of farmers' mutual support were seen in the grape and durian farmers' groups. A farmer who had problems with his crop would invite other experienced farmers to his farm to assess the problem and offer advice.

Links with pesticide dealers were common, with 37.4% of trained and 56.9% of control farmers having received samples of new products or agreed to allow testing of new products on their farm. 90.1% of trained and 35.8% of control farmers said they had been involved with DOAE or DOA promotions.

Table 28: Farmers' information sources on pest management

Farming system	Farmer type	Information source on pest management % farmers using information source				
		Other farmers	Pesticide dealers	DOAE	DOA	Other
Rice	Trained	71.4	19.0	90.5	0	4.8
	Control	78.6	78.6	39.3	0	3.6
Cotton	Trained	72.7	27.3	72.7	100	9.1
	Control	66.7	66.7	75.0	41.7	8.3
NE Vegetable	Trained	75.0	41.7	83.3	25.0	25.0
	Control	64.3	71.4	42.9	0	21.4
N Vegetable	Trained	92.3	69.2	69.2	50.0	30.8
	Control	73.9	52.2	26.1	13.0	43.5
Grape	Trained	100	92.3	15.4	92.3	7.7
	Control	91.1	91.7	16.7	0	16.7
Fruit tree	Trained	81.3	75.0	87.5	31.3	12.5
	Control	85.0	80.0	25.0	0	10.0
Total	**Trained**	**82.8**	**54.5**	**71.7**	**44.4**	**16.2**
	Control	**77.1**	**72.5**	**35.8**	**7.3**	**17.4**

Perceptions and experience of biopesticides

All the farmers were asked about the biopesticides they had heard of or used. Many did not have a clear idea of what the terms “biopesticides” or “microbial pesticides” meant and associated the words with biofertilisers and botanical pesticides. These are products which have been strongly promoted throughout Thailand by the DOAE and many NGOs concerned with environmental and green issues. However the farmers were aware of the names of individual biopesticide products and brands.

Overall 92.9% of trained and 32.1% of control farmers had used at least one biopesticide or biopesticide brand name (table 29). 3% of trained and 17% of the control farmers had not heard of any of the biopesticide types or brand names listed. Rice farmers were the least likely to have heard of or used biopesticides.

Table 29: Farmers who have heard of or used biopesticides

Trained farmers Farming System	% farmers Never heard of any biopesticide	Heard of, but not used any biopesticide	Used a biopesticide
Rice	9.5	4.8	85.7
Cotton	0	0	100
NE Vegetable	8.3	25.0	66.7
N Vegetable	0	0	100
Grape	0	0	100
Fruit tree	0	0	100
Total	**3.0**	**4.0**	**92.9**

Control farmers	% farmers		
Farming System	**Never heard of any biopesticide**	**Heard of, but not used any biopesticide**	**Used a biopesticide**
Rice	44.4	40.7	14.8
Cotton	8.3	25.0	66.7
NE Vegetable	28.6	57.1	14.3
N Vegetable	4.5	59.1	36.4
Grape	0	63.6	36.4
Fruit tree	0	60.0	40.0
Total	**17.0**	**50.9**	**32.1**

Bt and Trichoderma were the most widely known biopesticides. Viral pesticides were not well-known outside the cotton and grape farming systems, and nematodes were only widely known amongst the fruit tree farmers. (Details of usage by type of biopesticide given in the sections below).

Information sources on biopesticides

For the trained farmers the main source of information on biopesticides, apart from their training programmes, were other farmers and dealers. The control group also obtained their information from extension staff, dealers and other farmers. Information in brochures, magazines, TV and radio only reached a minority of farmers (table 30).

Table 30: Farmers' source of information on biopesticides

Trained farmers	% farmers who obtain information on biopesticides from different sources					
Farming System	**Other farmers**	**Pesticide dealers**	**Extension / training courses**	**Brochures & magazines**	**TV & radio**	**Other**
Rice	57.1	14.3	100	0	4.8	0
Cotton	63.6	27.3	100	27.3	0	0
NE Vegetable	58.3	41.7	100	8.3	25.0	0
N Vegetable	92.3	46.2	100	3.8	30.8	34.6
Grape	92.3	92.3	100	23.1	23.1	0
Fruit tree	81.3	75.0	100	6.3	25.0	12.5
Total	**75.8**	**47.5**	**100**	**9.1**	**19.2**	**11.1**

Control farmers	% farmers who obtain information on biopesticides from different sources					
Farming System	**Other farmers**	**Pesticide dealers**	**Extension / training courses**	**Brochures & magazines**	**TV & radio**	**Other**
Rice	25.0	35.7	32.1	3.6	0	3.6
Cotton	41.7	58.3	75.0	16.7	25.0	16.7
NE Vegetable	57.1	57.1	25.7	0	7.1	14.3
N Vegetable	47.8	34.8	30.4	17.4	21.7	30.4
Grape	50.0	58.3	0	0	0	10.0
Fruit tree	80.0	65.0	15.0	15.0	35.0	12.8
Total	**48.6**	**48.6**	**30.3**	**9.2**	**16.2**	**12.8**

Source of biopesticides

Although many biopesticides came from government sources, there were a significant number of commercial products being bought and used by farmers. Ten different brand names of Bt and two each of *B. subtilis*, NPV, trichoderma and nematode were bought by farmers. The percentage of biopesticides bought from shops and dealers is shown in Table 31.

Table 31: Percentage of biopesticide products bought from shops and dealers

Biopesticide	Trained farmers	Control farmers
Bt	84.2%	88.9%
Trichoderma	16.7%	45.5%
NPV	35.6%	40.0%
Nematode	7.7%	66.7%
Other	36.4%	60.0%

On farm production of biopesticides

Trained farmers using Trichoderma and NPV have been encouraged to try their own production of these products in order to reduce costs. However, farmers expressed limited enthusiasm, citing lack of time as the main reason. 36% of trained farmers using Trichoderma and only 8% of trained farmers using NPV said they preferred to produce their own biopesticides. Details of farmer production are given in the sections on Trichoderma and NPV.

Attitudes to biopesticides

Attitudes to biopesticides were generally positive, with the majority of users saying they would continue to use them. The advantages of biopesticides were seen particularly in cases where chemicals were ineffective against pests such as beet armyworm, cotton bollworm, diamond-back moth and *Phytophthora*. Farmers also liked the fact that the biopesticides were safe to use and the effects long-lasting compared with chemicals. The disadvantages included the slower action, limited effect under certain environmental conditions and time for preparation (trichoderma and nematodes). Insufficient supply and difficulty in finding products were a major concern, especially for NPVs (Figures 1 and 2).

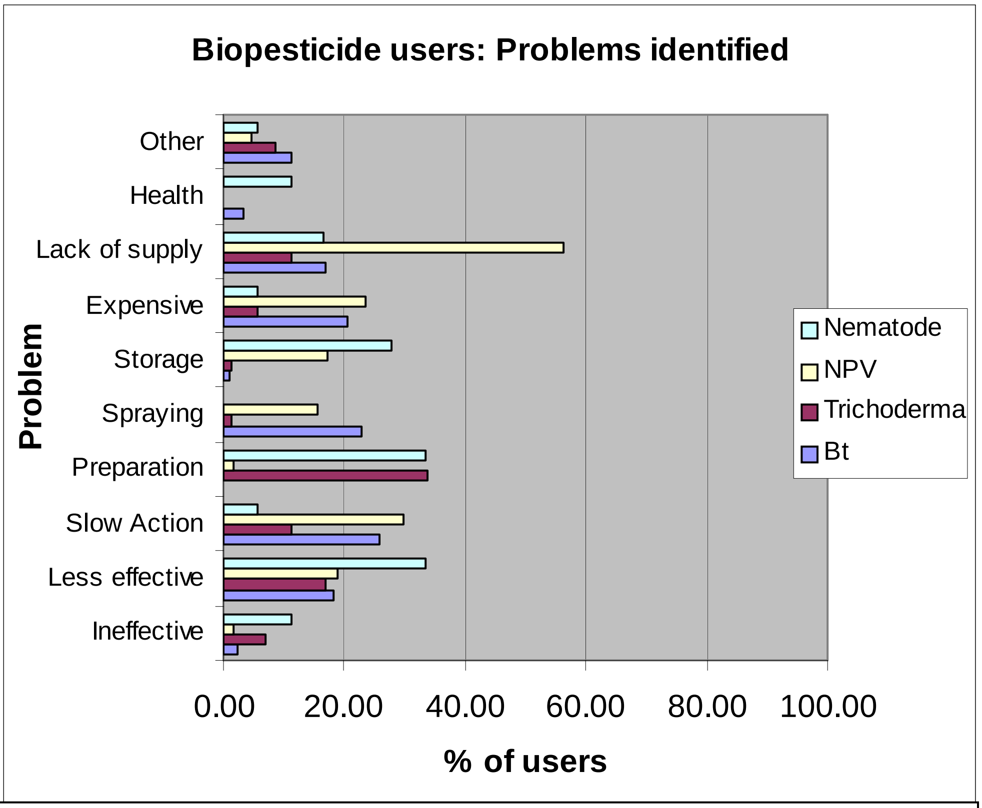

Figure 1: Problems of biopesticides identified by farmers who have used them

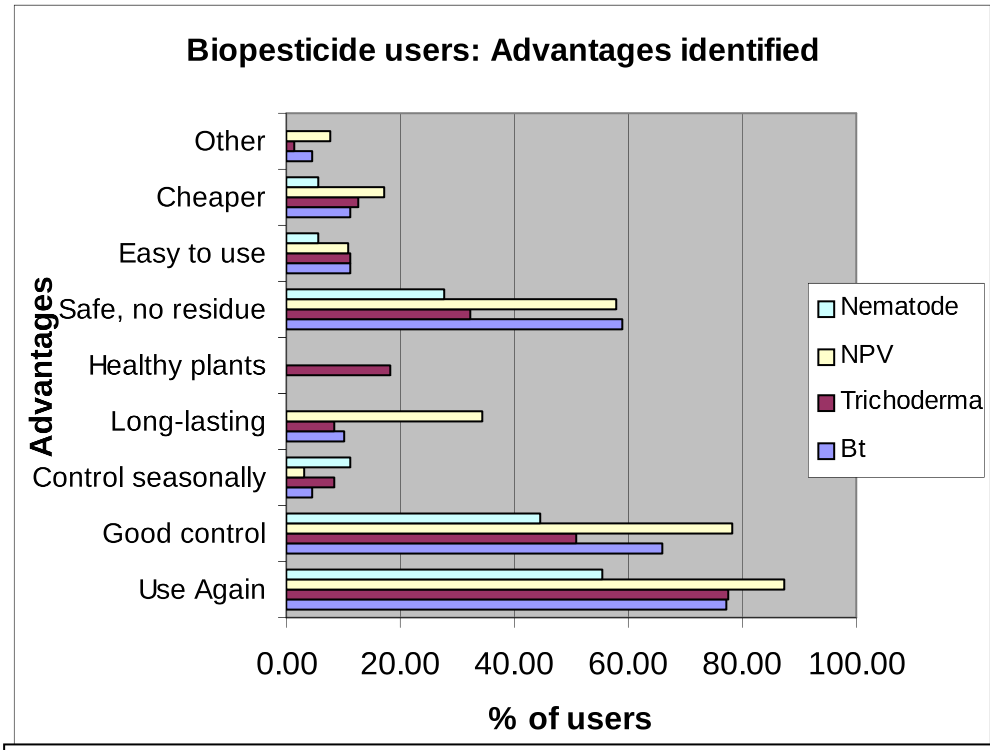

Figure 2: Advantages of biopesticides identified by farmers who have used them

Other bio-agents used by farmers

As mentioned above, many farmers associated biopesticides with biofertilisers and botanical pesticides. The DOAE run training courses in preparation and use of these products, and the use of biofertilisers with "Effective Microorganisms" (EM) is promoted by NGOs in Thailand. Farmers prepare their own biofertiliser by fermenting materials such as snails, organic wastes, rice bran for several weeks. Microorganisms are available in the shops at lower prices than those of chemical pesticides, and can be added to the brew. Detailed information on usage was not collected from all the farmers in the survey, but it is known that at least one third of the farmers were making and using biofertiliser and at least 10% using botanical pesticides. Farmers from the NE vegetable farming system were the most likely to use these products, with 91.7% of trained and 64.3% of control farmers using biofertiliser and 50% of trained and 42.9% of control farmers using botanicals.

Farmers' attitudes to biofertilisers and botanicals differ from those towards chemical pesticides and biopesticides. These are used to improve the health of the crop and help repel pests and diseases. Although some farmers said they thought biofertilisers could prevent diseases, they were unlikely to rely on biofertiliser alone if they observed a disease problem. Similarly, botanicals were thought to act as a repellent but most farmers said that additional methods in the form of pesticides would be needed if a pest problem occurred. Unlike pesticides, farmers did not expect an immediate effect from these products.

Bacteria

Bacillus thuringiensis (Bt)

Bt is a naturally occurring bacterium in soil and on plants, that produces specific toxins (δ-endotoxins) that are lethal to various pest insects but safe for humans, animals and non-target species. Many strains of bacteria are known including Bt. *kurstaki* (Btk), Bt. *aizawai* (Bta), Bt *israelensis* (Bti) and Bt. *tenebrionsis* (Btt). These are used as the basis for insecticides for specific control of Lepidoptera (Btk and Bta), leaf eating Coleoptera (Btt) and mosquitoes (Bti). Bt insecticides currently account for up to £100 million of the global insecticide market. Bt products are generally more expensive than older synthetic chemicals so tend to have a market where pest resurgence or safety are significant factors

The view from the suppliers

Bt was the most widely available biopesticide. Seven of the eight commercial suppliers interviewed supplied Bt products. In addition 4 other past or current suppliers were identified but not interviewed. These suppliers include subsidiaries of multinational companies and local companies who import Bt products. The main business of all the commercial Bt suppliers is agrochemicals (Table 32). The names and numbers of local companies are subject to frequent changes; in particular, several local companies were set up especially to supply the DOAE with Bt products during the 1980s/90s. The reduction in demand from the DOAE meant that some of these companies disappeared when the demand decreased. Two Bt suppliers identified had ceased trading, and at least 4 suppliers had been taken over or changed their name between 1999 and 2001.

Table 32: Commercial Bt suppliers and products

Company type	Main business	Status	Bt Products	Bt source
Multinational 1	Agrochemicals	Active	Thuricide HP, Delfin WG	Certis, USA [9]
2	Agrochemicals	Active	Centavi (XenTari)	Valent Biosciences, USA[10]
Local 3	Agrochemicals	Active	Relic, Quark	Valent Bioscience, USA
4	Agrochemicals	Active	DiPel	Valent Biosciences, USA
5	Agrochemicals	Active	Bactospeine HP, WP, FC, Florbac FC, Novodor FC	Valent Biosciences, USA
6	Agrochemicals	Active	Bacina	India
7	Agrochemicals	Active	Florbac WDG	Valent Biosciences, USA
8	N/a	Active – Not interviewed	Decona	N/a
9	Biopesticides & fertilisers	Active – Not interviewed	Lightening, Redcap	Own production

[9] Formally ThermoTrilogy
[10] Abbott Laboratories (biopesticide unit) are now Valent Biosciences, a wholly-owned subsidiary of Sumitomo Chemical Company, Japan

Company type	Main business	Status	Bt Products	Bt source
10	Agrochemicals	Given up – Not interviewed	Bacina	India
11	Agrochemicals	Given up – Not interviewed	Bt	N/a

Fifteen different brands of Bt were identified during the survey (Table 33). These are all registered products. The most well-known amongst the farmers surveyed were Florbac and Centari (XenTari).

The DOAE have also supplied farmers directly with Bt products that they bought from the private companies.

Table 33: Brands of Bt

Product name	Active ingredient	% survey farmers heard of it, but not used	% survey farmers used it
Florbac	Bt var aizawai	11.5	12.5
Centari (XenTari)	Bt var aizawai	7.2	9.1
Bactospeine	Bt var kurstaki	10.6	5.8
DiPel	Bt var kurstaki	4.3	3.4
Quark	Bt var aizawai	2.9	2.9
Decona	Bt	0	2.4
Delfin	Bt	0.5	2.4
Thuricide	Bt var kurstaki	0	1.9
Costar	Bt	0	1.4
Novodor	Bt var tenebrionis	5.8	1.4
Superbac	Bt	0.5	1.0
Bacina	Bt var kurstaki		
Lightening	Bt		
Redcap	Bt		
Relic	Bt var aizawai		

Production

One local company has produced Bt products, but detailed information was not available. None of the farmers interviewed reported using these products.

A Bt pilot plant has been established recently by the DOA in Chiang Mai. This pilot plant uses local strains of Bt, but is not yet supplying farmers. The DOAE Biocontrol Centers also expressed interest in expanding into Bt production, but none have yet done so.

Quality

All Bt products have to be registered in Thailand, and new products are tested to ensure they satisfy quality criteria. Two new products were tested, a commercial and a non-commercial product. The commercial product was found effective, but the other was of sub-standard concentration (table 34). Bt standard is 1.5×10^{10} CFU/ml.

There are reports of Bt products being mixed with chemical insecticides to speed up the effects, but these were not found during the survey.

Table 34: Concentration of Bt samples

Sample	Concentration	Comment
1	8.44 x 10^9 CFU/ml	Found effective in bioassay tests on *S. exigua*: 74% of 3^{rd} instar larvae killed within 3 days at 40ml/20litres and 90% killed within 3 days at 100ml/20litres
2	8.49 x 10^8 CFU/g	Low concentration, probably unreliable

Markets
The main customers targeted by Bt suppliers were the DOAE and vegetable farmers. The products are sold through pesticide dealers, although some companies had a limited number of outlets, and were concentrated in selected areas of the country. When asked to characterise their target farmers, the suppliers stated that they tended to be vegetable or fruit farmers, interested in IPM, including those producing for export.

Promotion
The suppliers promoted their products through farmers' demonstrations, advertisements and three used radio or TV programs, but none reported carrying out any market research. It appeared that much of the promotion was done by the DOAE, who recommended Bt to farmers growing hygienic and export crops. Bt can be used close to harvest time without resulting in the pesticide residue problems associated with chemical pesticides.

Sales
Four companies provided sales figures for 2001/2. Volumes ranged from 1 tonne to 35 tonnes for Bt products, giving a total of 54.8 tonnes for all four companies. The value ranged from 1.2 million to 15 million baht for Bt products, giving a total of 28.2 million baht (US $ 0.63 million) for all Bt sales by these companies. This compares with Bt imports of 101 tonnes in 1994, 80-90 tonnes in 1997 (Lisansky 2000, Agr-Evo per comm.).

Five of the 7 suppliers interviewed said sales had decreased over the last 3 years (1998-2001), only one reported sales unchanged. However, most (6) were optimistic about the future, saying that they expected Bt sales to increase in the future.

Half the Bt products were reported to be profitable, but none were considered very profitable. 20% were reported as break-even, and 33% of products resulted in a small loss for the company.

Supply problems
Suppliers thought the main problem with Bt products was the competition from chemical pesticides, especially new chemical products. The slow action of Bt compared with chemical insecticides was seen as a major deficiency. This perception is interesting as Bt is supposed to paralyse the gut within a few hours causing cessation of pest damage and death within 24-48 hours. It is possible that the observation of "slow action" might indicate some pest resistance to Bt. Registration was not seen as a problem.

The view from the farmers

Users

About 60% of trained and 40% of control farmers had heard of or used Bt or a Bt brand name (Table 35). It was most widely used amongst vegetable farmers, especially those in the Chiang Mai area and fruit farmers; less so amongst rice farmers[11]. 87.5% of the trained and all the control Bt users used other chemical pesticides and 45% of trained and 72.2% of control Bt users used hazardous chemicals[12]. Almost all Bt users expressed an interest in IPM or hygienic production (table 36).

Table 35: Percentage of farmers who have heard of or used Bt

Trained farmers **Farming system**	**% farmers never heard of Bt**	**% farmers heard of, but not used Bt**	**% farmers used Bt**
Rice	61.9	23.8	14.3
Cotton	45.5	27.3	27.3
NE vegetable	50.0	8.3	41.7
N vegetable	19.2	15.4	65.4
Grape	15.4	30.8	53.8
Fruit tree	56.3	12.5	31.3
Total	**40.4**	**19.2**	**40.4**

Control farmers **Farming system**	**% farmers never heard of Bt**	**% farmers heard of, but not used Bt**	**% farmers used Bt**
Rice	89.3	7.1	3.6
Cotton	58.3	25.0	16.7
NE vegetable	57.1	28.6	14.3
N vegetable	43.5	26.1	30.4
Grape	66.6	16.7	16.7
Fruit tree	35.0	45.0	20.0
Total	**59.6**	**23.9**	**16.5**

Table 36: Bt users: Pesticide use characteristics

Trained farmers **Farming system**	**# farmers using Bt products**	**% use other chemicals**	**% use hazard-ous chemicals**	**% interested in IPM or hygienic**	**% use fungal pesticides**	**% use viral pesticides**	**% use nematode pesticides**	**% know brand name but not "Bt"**
Rice	3	0	0	100	66.7	0	66.7	0
Cotton	3	100	33.3	100	66.7	100	33.3	33.3
NE vegetable	5	80.0	30.0	100	100	80.0	60.0	0
N vegetable	17	100	52.9	94.1	52.9	0	17.6	47.1
Grape	7	100	42.9	100	42.9	100	14.3	14.3
Fruit tree	4	80.0	80.0	100	80.0	20.0	60.0	0
Total	35	87.5	45.0	97.5	62.5	37.5	32.5	25.0

[11] This is unsurprising, as Bt can control leaf folder, a relatively minor pest of rice, but not hoppers or stem borers, the more serious rice pests.

[12] Chemicals containing an active ingredient classified as hazard category I by the WHO.

Control farmers Farming system	# farmers using Bt products	% use other chemicals	% use hazard-ous chemicals	% interested in IPM or hygienic	% use fungal pesticides	% use viral pesticides	% use nematode pesticides	% know brand name but not "Bt"
Rice	1	100	0	100	0	0	0	100
Cotton	2	100	0	100	0	100	0	50.0
NE vegetable	2	100	50.0	100	50.0	0	0	0
N vegetable	7	100	85.7	100	0	0	0	57.1
Grape	2	100	50.0	100	0	50.0	0	50.0
Fruit tree	4	100	50.0	100	75.0	0	0	100
Total	18	100	72.2	100	22.2	16.7	0	61.1

Knowledge and reasons for use

In discussions with farmers' groups most farmers knew that Bt products differed from other chemical pesticides in being less harmful to people and the environment. However not all the farmers knew nor cared that Bt was a bacteria. Some farmers recognised brands of Bt without realising that the brand contained Bt. 25% of trained and 61% of control Bt users said they had used a particular Bt product such as Florbac or Thuricide, but said they had not used Bt.

There were two main reasons why farmers used Bt products. Firstly, to reduce pesticide residues at harvest, so comply with regulations for export or hygienic produce. Secondly, to tackle diamond-back moth – a pest increasingly resistant to chemical pesticides. Also, more generally, farmers used Bt as part of a resistance strategy, alternating Bt with chemical pesticides in order to prolong the effective life of these pesticides against major pests. This was particularly true of the grape and northern vegetable farmers, whose heavy use of chemicals meant that insect resistance to chemicals could occur after only a few seasons.

Source and price

Although the DOAE did provide some Bt products for farmers (especially those in the trained groups), most Bt products (over 80%) were bought by farmers from pesticide dealers (Table 37). Prices paid for Bt products ranged from 300 baht/kg to 1500 baht/kg with most farmers paying between 550 and 700 baht per kg or litre. This is more expensive per volume than old pesticides such as methamidophos or endosulfan, but cheaper than some of the new chemicals on sale targeted at specific pest problems such as spinosad (c 6,000baht/litre).

Table 37: Source of Bt products

Trained farmers

Farming System	# Bt products	% bought from shop	% from DOAE	% from Royal Project
Rice	3	0	100	
Cotton	6	16.7	83.3	
NE vegetable	8	100	0	
N vegetable	34	91.2	0	8.8
Grape	11	100	0	
Fruit tree	4	50.0	50.0	
Total	**66**	**80.3**	**15.2**	**4.5**

Control farmers

Farming System	# Bt products	% bought from shop	% from DOAE	% from Royal Project
Rice	1	100	0	
Cotton	2	0	100	
NE vegetable	8	100	0	
N vegetable	8	100	0	
Grape	3	100	0	
Fruit tree	0	0	0	
Total	**22**	**90.9**	**9.1**	

Application

The majority of farmers found Bt products as easy or easier to use than chemical pesticides (Table 38). Those who found Bt easier to use said that it was because Bt was less toxic. Those who found it more difficult said it was because recommended spraying times were early morning or evening which was inconvenient.

Effectiveness

The majority thought Bt products were effective, although taking 3 – 7 days to work. There were complaints from four farmers that Bt worked less effectively in the rainy season, and that it could not always control the larger larvae. Several farmers used Bt with a chemical insecticide, for example, spinosad and Bt, claiming that the combined mixture was more effective than the chemical alone as it gave an immediate knock-down effect plus long-term control. A higher proportion of farmers from areas where Bt use was more common (cotton and vegetables) reported slower effectiveness of Bt (3 to 7 days) than farmers from the other areas. It is possible that what is being seen here is resistance by target pests in response to high levels of Bt use.

Table 38: Farmers' perceptions of ease of use and effectiveness of Bt products

Trained farmers

	Ease of application compared with chemical pesticides (% Bt products)			**Effectiveness (% Bt products)**			
Farming system	Easier	Same	More difficult	Immediate	Within 3 days	Within a week	Not or partly effective
Rice	66.7	33.3	0	33.3	66.7	0	0
Cotton	100	0	0	0	33.3	66.7	0
NE vegetable	37.5	25.0	37.5	0	87.5	12.5	0
N vegetable	58.8	32.4	8.8	2.9	38.2	52.9	5.9
Grape	27.3	36.4	36.4	0	90.9	0	9.1
Fruit trees	25.0	50.0	25.5	0	50.0	25.0	25.0
Total	**53.0**	**30.3**	**16.7**	**3.0**	**54.5**	**36.4**	**6.0**

Control farmers

Farming system	Ease of application compared with chemical pesticides (% Bt products)			Effectiveness (% Bt products)			
	Easier	Same	More difficult	Immediate	Within 3 days	Within a week	Not or partly effective
Rice	100	0	0	0	100	0	0
Cotton	50.0	50.0	0	0	50.0	0	50.0
NE vegetable	0	75.0	25.0	0	100	0	0
N vegetable	25.0	75.0	0	0	100	0	0
Grape	33.3	66.7	0	0	33.3	66.7	0
Fruit trees	0	0	0	0	0	0	0
Total	**22.7**	**68.2**	**9.1**	**0**	**86.4**	**9.1**	**4.5**

Problems and advantages

The majority of Bt products were thought to provide good control, and only a minority (2.3%) thought to be ineffective (tables 39 and 40). However, a significant number were perceived as being less effective than chemicals and slow to take effect. Difficulties in spraying were due to recommendations some farmers had received that Bt should be sprayed early morning or evening, and should not be mixed with fungicide. This was inconvenient for the farmers. It should be noted that Bt is described as being compatible with fungicides in the Biopesticide manual (Copping 1998), so this advice not to mix Bt with fungicides appears to be misplaced.

Attitudes to the price of Bt products varied. One particular product was generally thought to be expensive, but effective. In the N vegetable farming system where Bt was most widely used, one third of the products was perceived as expensive, and one sixth of the products thought to be cheaper than chemical insecticides.

Two products were mentioned as having a bad smell and unpleasant to use, but generally, the lack of toxicity and chemical residues was seen as an advantage, particularly by the trained farmers. This made Bt easier to apply and enabled farmers to obtain higher prices for hygienic vegetables.

Lack of availability was a problem for 17% of farmers as Bt products are not available from all pesticide dealers and supplies from the DOAE have decreased. Several brands have also been discontinued or renamed.

Other issues mentioned included phytotoxic effects on plants if Bt was overused (two farmers).

Table 39: Problems identified by Bt users

Problems identified	**Trained farmers (% of 66 Bt products)**	**Control farmers (% of 22 Bt products)**	**Total (% of 88 Bt products)**
Slow action	28.8	4.6	26.0
Difficult to spray	24.2	18.2	22.7
Expensive	22.7	13.6	20.5
Less effective than chemicals	22.7	4.6	18.2
Lack of supply	18.2	13.6	17.1

Problems identified	Trained farmers (% of 66 Bt products)	Control farmers (% of 22 Bt products)	Total (% of 88 Bt products)
Bad smell	4.6	0	3.4
Ineffective	1.5	4.6	2.3
Difficult to store	1.5	0	1.1
Lack of information	0	4.6	1.1
Difficult to prepare	0	0	0
Other	6.1	22.7	10.3

Table 40: Advantages identified by Bt users

Advantages identified	Trained farmers (% of 66 Bt products)	Control farmers (% of 22 Bt products)	Total (% of 88 Bt products)
Good control	59.1	86.4	65.9
Safe & no residues	68.2	31.8	59.1
Easy to use	10.6	13.6	11.4
Cheaper	13.6	4.6	11.4
Long-lasting control	10.6	9.1	10.2
Seasonal control	3.0	9.1	4.6
Other	6.1	0	4.6

Future Use

Most farmers (83.3% of trained and 59.1% of control) said they would use Bt again in the future (table 41). The most positive about Bt were the vegetable farmers (trained and control) from around Chiang Mai. Most had been using Bt products for several years and it was an established component of their pest management, alongside other chemicals.

Table 41: Percentage of Bt users who said they would use Bt products again

Trained farmers

Farming system	# Bt products	% products used more than once	% farmers who would use Bt product in the future	
			No or not sure	Yes
Rice	3	100	0	100
Cotton	6	83.3	16.7	83.3
NE vegetable	8	87.5	12.5	87.5
N vegetable	34	91.2	5.8	94.1
Grape	11	90.9	36.4	63.6
Fruit trees	4	75.0	75.0	25.0
Total	**66**	**89.4**	**16.6**	**83.3**

Control farmers

Farming system	# Bt products	% products used more than once	% farmers who would use Bt product again	
			No or not sure	Yes
Rice	1	100	0	100
Cotton	2	0	100	0
NE vegetable	8	87.5	62.5	37.5
N vegetable	8	87.5	25.0	75.0
Grape	3	100	0	100
Fruit trees	0	0	0	0
Total	**22**	**81.8**	**40.9**	**59.1**

Bacillus subtilis (Bs)

The view of suppliers

Bacillus subtilis (Bs) was the only other bacterial pesticide identified in the survey. Two products were found, both produced by local companies. Neither company wished to be included in interviews. One product, Laminar, was marketed as a biofungicide. The other product, Bioquick, was a combination of a biofertiliser containing various microorganisms and minerals, and Bs for the control of diseases.

Production
Both products are produced locally but no details are available.

Quality
Two samples were analysed and found to have concentrations that are likely to be effective (table 42).

Table 42: Concentrations of *B. subtilis* samples

Sample	Concentration	Comment
1	1.4 x 10^{9} CFU/g	
2	1.15 x 10^{10} CFU/g	

Markets
Bs is targeted at a niche market: fungal diseases of fruit trees. The products are sold through selected pesticide dealers in fruit tree growing areas.

Promotion
The way the products are packaged indicated an interesting difference in methods of promotion. One product is presented as a specialised fungicide; the other is combined with a foliar fertiliser to provide a more general supplement for plant health. This new product (Bioquick) appears to be positioned more within the growing foliar and biofertiliser market than the pesticide market. It is not subject to pesticide registration as it is within the biofertiliser (green products) market. No farmers were interviewed who used this product, so there is no information on how this product is being used.

Sales
No sales or supply information were available, except from one of the main dealers of Bs in the fruit tree growing area. He claimed that Bs was as popular as trichoderma with farmers for control of *Phytopthora*, and he had sold 1 tonne in 2001/2.

The view from the farmers

Users
Few farmers had heard of or used Bs (table 43). The users (2 trained and 3 control farmers) were all fruit tree growers who used Bs to control fungal diseases. They used the same product (Laminar). As far as we are aware, information about Bs does not form part of the IPM and hygienic production training given by the DOAE, DOA and Royal Project, so trained farmers have not received specific training on use of Bs.

Table 43: Percentage of farmers who have heard of or used Bs

Trained farmers

Farming system	% farmers never heard of Bs	% farmers heard of, but not used Bs	% farmers used Bs
Rice	100	0	0
Cotton	100	0	0
NE vegetable	100	0	0
N vegetable	92.3	7.7	0
Grape	100	0	0
Fruit tree	81.2	6.3	12.5
Total	94.9	3.1	2.0

Control farmers

Farming system	% farmers never heard of Bs	% farmers heard of, but not used Bs	% farmers used Bs
Rice	96.9	3.1	0
Cotton	100	0	0
NE vegetable	92.9	7.1	0
N vegetable	95.7	4.3	0
Grape	91.7	8.3	0
Fruit tree	65.0	20.0	15.0
Total	**89.9**	**7.3**	**2.8**

Knowledge and reasons for use

Farmers used Bs to control stem and root rot diseases on durian and rambutan, especially after pruning, where they felt that chemical pesticides were ineffective. The Bs users had heard about the product through neighbouring farmers or recommendations from pesticide dealers. One user had previous experience of using Bs to control disease in prawn fisheries.

Source and price

All the Bs products were bought from pesticide dealers. Prices reported by farmers ranged from 600 to 650 baht per kg. In the local dealers, prices in February 2002 for Bs were 800 baht per kg and for the mixed fertiliser/BS product 440 baht per kg.

Application

One farmer said application was more difficult than chemicals as Bs needed moisture to be effective. Other users thought application was as easy as applying chemicals.

Effectiveness

Two farmers thought that Bs was effective within a week, but two other users thought Bs was very slow to take effect.

Problems and advantages

Three users said that overall they thought that Bs did provide effective control for stem and root rots, especially in the rainy season. However, the high humidity requirements of Bs meant that it was not effective in the dry season according to two farmers, and less effective than fungicide according to one farmer. Bs slow action was thought to be a problem by one farmer. Lack of toxicity was identified as an advantage compared with other fungicides.

Future Use

All farmers said they would use Bs again. However, only one of the farmers said they had already used Bs more than once.

Fungi

Trichoderma

Trichoderma harzarium and its close relative *T. viridae* are fungi of the family Deuteromycetes that have a use as biological fungicides. They act to control disease-causing fungi by competing for nutrients and thus inhibiting the growth of pathogenic fungi that damage crop plants. They are applied to soil, seed beds, cuttings or newly pruned fruit and are recognised as a highly effective control for a wide range of soil or foliar fungal pathogens (Copping 1998).

The view from the suppliers

Trichoderma supply contrasts strongly with that of Bt. The number of non-commercial suppliers outnumbered the commercial suppliers, and all products identified were locally produced (Table 44). The main outlets were the DOAE Biocontrol Centers. These have a program for producing *Trichoderma harzarium* and distributing it either free or at low cost to farmers in the form of fresh inoculum on sorghum seeds. The Biocontrol Centers also run training courses for farmers in the application of trichoderma and sometimes in its production.

The Royal Project produces trichoderma for distribution to Royal Project participant farmers who are growing hygienic vegetables. The trichoderma production is carried out in collaboration with staff from Chiang Mai University.

Trichoderma is also produced by staff in other agricultural colleges and universities. Kasetsart University is one of the main training centres in trichoderma production and the technology has been transferred to staff in other agricultural colleges. For example, two farmers reported buying trichoderma from their local agricultural college. The amount of production from these other colleges is not known but is likely to be on a small-scale only.

Through the DOAE we were able to identify one farmer who produced trichoderma for her own use and for neighbouring farmers (described below).

The two commercial suppliers identified were both local firms who produced their own products, Unigreen and Trisan. These are registered products, the first being registered in 1996. No examples of imported trichoderma products were found during the survey.

Table 44: Suppliers of Trichoderma biopesticide

Supplier	Type	Main business	Amount of Trichoderma produced per annum (tonnes)	Other biopesticides & products
Public	DOAE	Biocontrol (Head Office)	167.8 (total from all centres)	NPV, nematodes, fungal insecticides, biopesticides, botanicals
	DOAE	Biocontrol extension	10	NPV, nematodes, fungal insecticides, biofertiliser, botanicals

Supplier	Type	Main business	Amount of Trichoderma produced per annum (tonnes)	Other biopesticides & products
	DOAE	Biocontrol extension	20	NPV, nematodes, fungal insecticides, biofertiliser, botanicals
	DOAE	Biocontrol extension	21	NPV, nematodes, fungal insecticides, biofertiliser, botanicals
	DOAE	Biocontrol extension	20	NPV, nematodes, fungal insecticides, biofertiliser, botanicals
	NGO	Extension, marketing	2	
	Farmer	Farming	Produce to order	Biofertiliser, botanicals
Commercial	Local producer	Vegetable export, biopesticides	15-20	Vegetables, nematodes
	Local producer	Biopesticides fertilisers	N/a	N/a

Production
All the trichoderma produced by the DOAE, Royal Project and other agricultural colleges, was produced using a solid fermentation method with sorghum seed as the substrate. Autoclaves were used, but little other specialised equipment. The resulting product is distributed in plastic bags containing 0.5kg of the inoculated sorghum seed. Farmers are instructed to mix this with rice bran and manure before applying to their plants. The quantities produced are small, as the Biocontrol Centers have limited staff, room for storage and budgets. The amount produced by the non-commercial suppliers in one production batch ranged from 80 to 300 kg. Estimates of quantities produced per annum are shown in Table 42. Estimated costs of production per kilo of product were 40 baht for the Royal Project and DOAE.

The one private company interviewed also used a solid fermentation method based on a sorghum substrate. They could produce 3 tonnes of product per production batch and a total of 30 tonnes per month. The concentration of the product was reported as 10^8 spores/gram. The estimated cost of production was 250 baht per kilo. The commercial trichoderma products are easier for farmers to apply, in that the farmers do not have to provide the rice bran and manure in order to mix and apply trichoderma.

Suppliers, both non-commercial and commercial, received information and technical advice from the universities on Trichoderma production.

Quality
Separate rooms and sterilisation techniques (use of larminar flow, autoclave) are used by the non-commercial suppliers to minimise contamination. Efficacy tests are carried out, for example one DOAE Biocontrol Center conducts bioassay of trichoderma on phytopthora, but not on each batch of product. The main method of quality checking is the visual inspection of the green spores of the product. The internationally

recognised quality protocols do not appear to be followed for this local Trichoderma production (Jenkins and Grzywacz 2000).

Contamination of the product was identified as a major problem by these suppliers. In addition, preserving trichoderma in good condition was difficult for the DOAE Biocontrol Centers as they have limited storage facilities.

Samples of trichoderma from the suppliers were collected and analysed in the plant pathology laboratory, Kasetsart University (table 45). The spore counts were repeated twice but gave results from the non-commercial suppliers that were substantially lower than those from the commercial suppliers. The highest count for the non-commercial products was 10^9 spores/gram, whereas it was 10^{10} spores/gram for the commercial products. The standard concentration for Trichoderma is 10^{10} spores/gram so a maximum count of 10^9 spores/gram is significantly substandard and likely to result in a product that is effective sometimes but not reliable. The low results may be partly due to the length of time the trichoderma products were stored before being used.

Table 45: Number of spores of Trichoderma harzianum in samples collected from the survey

Sample Number	Spores of T. harzianum per gram
Non-commercial	
1	$> 10^6$
2	$> 10^6$
3	$> 10^6$
4	$> 10^6$
5	$> 10^7$
6	$> 10^6$
Commercial	
7	$> 10^8$

Markets

Trichoderma is used to prevent root rots and soft rots on vegetables and fruit. The main users are vegetable growers, but there is a specific market amongst durian tree growers, where trichoderma is used in control of *phytopthora*, a disease that farmers have found difficult to control using chemical fungicides.

Suppliers characterised the target farmers as vegetable or fruit farmers, usually small-scale and interested in IPM, hygienic or export production. The main markets are durian farmers in east and south Thailand, tangarine farmers in central and north Thailand, vegetable farmers around Bangkok.

The main customer for commercial products used to be the DOAE. This still remains the case although the amounts bought by the DOAE have more than halved from 1996 to 2001.

Promotion
The DOAE and Royal Project supplied trichoderma to farmers as part of an IPM or hygienic production programme, usually alongside other recommendations on cultural practices and safer use of pesticides. They ran training courses, sometimes as part of farmer field schools, on how to produce and apply trichoderma. In addition, the DOAE have used radio and TV programs to explain and promote the use of Trichoderma.

The commercial supplier interviewed said they promoted their products through farmers' demonstrations, magazine advertisements and radio spots. They have 40 to 50 dealers and a mail order service for their products.

Quantities, sales and prices
The amounts of trichoderma produced by the DOAE and Royal Project vary throughout the year, depending on the demand (as relayed back to the Biocontrol Centers from the local DOAE offices), and the availability of resources. Estimates of quantities produced from the Biocontrol Centers and Royal Project range from 2 tonnes to 21 tonnes per centre. Trichoderma products are usually provided free for farmers by the DOAE. The Royal Project charges 40 baht/kilo ($0.95) to cover costs of the raw materials, and the farmer charged 10 baht/kilo ($0.24).

The amount produced by the commercial company was reported as 15-20 tonnes. Retail prices of the two commercial brands ranged from 400 to 600 baht/kilo ($9.52-$14.29). Trichoderma was not perceived as profitable currently by one company.

Supply problems
Problems identified by suppliers included the short shelf-life of trichoderma (8 months at room temperature) and the lack of resources to produce enough when needed. Improved formulation methods were identified as an important requirement by the DOAE to lengthen the product's shelf-life. As noted above (in the paragraph on quality), several samples had low spore counts, possibly because they had been stored for a long time and in unsatisfactory conditions.

Future supply
The non-commercial suppliers are committed to maintaining and expanding Trichoderma production, and it is these suppliers that account for the majority of Trichoderma production. The one private company currently making a small loss on trichoderma is also committed to continuing production, at least in the short term. They are investigating use of liquid fermentation and improved formulation methods to prolong shelf-life. They are also applying for registration in other SE Asian countries with a view to exporting their products.

The view from the farmers

Users
Two-thirds of trained and 14% of control farmers had used Trichoderma and over 80% of trained and over 50% of control farmers had heard of it (Table 46). It was most widely used amongst vegetable and durian farmers; less so amongst cotton and grape farmers. Seven farmers said they used Trichoderma specifically on rice, however, six of these were almost certainly using Metarhizium instead (see below).

Few control farmers used Trichoderma apart from durian farmers in the fruit tree farming system.

Almost all users expressed interest in IPM or hygienic production, but most used chemical pesticides (table 47).

Table 46: Percentage of farmers who have heard of or used Trichoderma

Trained farmers

Farming system	% farmers never heard of Trichoderma	% farmers heard of, but not used Trichoderma	% farmers used Trichoderma
Rice	9.5	9.5	81.0
Cotton	36.4	27.3	36.4
NE vegetable	33.3	8.3	58.3
N vegetable	7.7	23.1	69.2
Grape	23.1	38.5	38.5
Fruit tree	0	6.3	93.8
Total	**15.2**	**18.2**	**66.7**

Control farmers

Farming system	% farmers never heard of Trichoderma	% farmers heard of, but not used Trichoderma	% farmers used Trichoderma
Rice	57.1	32.1	10.7
Cotton	50.0	25.0	25.0
NE vegetable	50.0	42.9	7.1
N vegetable	43.5	52.2	4.3
Grape	75.0	25.0	0
Fruit tree	15.0	50.0	35.0
Total	**46.8**	**39.4**	**13.8**

Table 47: Trichoderma users: pesticide use characteristics

Trained farmers

Farming system	# farmers using Trichoderma	% use other chemicals	% use hazard-ous chemicals	% interested in IPM or hygienic	% use Bt pesticides	% use viral pesticides	% use nematode pesticides
Rice	15	66.7	20.0	86.7	13.3	0	13.3
Cotton	4	100	50.0	75.0	50.0	100	25.0
NE vegetable	7	85.7	42.9	85.7	71.4	57.1	57.1
N vegetable	18	100	55.6	88.9	50.0	0	11.1
Grape	5	100	60.0	100	60.0	100	20.0
Fruit tree	15	93.3	73.3	93.3	26.7	6.7	46.7
Total	64	89.1	50.0	89.0	39.1	21.9	26.6

Control farmers

Farming system	# farmers using Trichoderma	% use other chemicals	% use hazard-ous chemicals	% interested in IPM or hygienic	% use Bt pesticides	% use viral pesticides	% use nematode pesticides
Rice	2	100	100	100	0	0	0
Cotton	2	50.0	0	100	0	50.0	0
NE vegetable	1	100	100	100	100	0	0
N vegetable	1	100	100	100	0	0	0
Grape	0	-	-	-	-	-	-
Fruit tree	6	100	83.3	100	33.3	0	16.7
Total	12	91.7	75.0	100	25.0	8.3	8.3

Knowledge and reasons for use

There was confusion amongst some rice farmers from the trained group over Trichoderma and Metarhizium. Six farmers reported using Trichoderma, but described the application method (mixing, filtering, spraying) used for Metarhizium and the target pest as brown plant hoppers (not root or soft rots). Metarhizium has been recently introduced by the DOAE and is being tested with farmers. The product looks similar to Trichoderma – plastic bags of inoculated grain. It is likely that farmers were using Trichoderma as a general name for fungal pesticides.

The fruit tree growers were the most specific about their reasons for using trichoderma. All said they used it to control root rot or *Phytopthora* on durian. Other trichoderma users said they used it to control stem rots, root rots or soil-borne fungus. Eleven of the vegetable farmers were less specific and said fungus disease in general. Only one farmer gave an unlikely target pest of mosaic virus on eggplant.

Farmer Production

As Trichoderma requires relatively little specialised equipment and uses local materials, the DOAE have also run training courses and encouraged farmers to produce their own trichoderma. However, it is unclear how many farmers are doing this. Only one farmer was identified and interviewed during the survey who actually produced trichoderma for herself and neighbouring farmers (see Box 2). In group discussions when other farmers were asked about producing trichoderma, many said they did not have the room or resources to do it. The DOAE Biocontrol Center in the fruit tree growing area had tried to transfer the technology to durian farmers' groups. However, the groups had neither the equipment nor room to produce.

33% of all the users said they would like to produce their own trichoderma products, if they were given the necessary training. However, it is not certain that all farmers realise exactly what production would entail. Some appeared to think that mixing the inoculated seeds with rice bran and manure was the production process itself. 58% of all users said they preferred to buy Trichoderma.

Farmer production of trichoderma

This farmer grows rice, vegetables and mushrooms and is very interested in IPM. She has attended vocational school in agriculture, and is leader of the local IPM group. With support from the DOAE she has built a small centre on her land for use as a meeting place for the IPM group and has a separate room dedicated to trichoderma production containing an autoclave (previously used by her for mushroom production). She received training from the DOAE in production methods and has been producing trichoderma for 8 years. Usually she produces 10 to 20 bags of trichoderma which are sold for 10 baht ($0.24) to members of the IPM group. She has also undertaken special orders from outside the group, for example, one vegetable farmer order 140 bags.

In addition to trichoderma, the farmer makes botanical pesticides from ginger, lemon grass and other plants using equipment such as solar panel and water heater bought with DOAE funds. She makes and sometimes sells biofertiliser.

Box 2: Farmer production of trichoderma

Source & price

80% of products used by trained farmers and almost half the products used by control farmers were obtained from non-commercial sources (Table 48). The DOAE was the main supplier. Most products (76% of trained and 50% of control) were obtained free of charge. The farmers would then supply their own rice bran and manure to mix with the inoculated seed. A few trained farmers (8%) paid a nominal price ranging from 20 to 70 baht for trichoderma from the DOAE or Royal Project. Those buying commercial trichoderma brands reported paying from 500 to 640 per kilo. These farmers used trichoderma for the following crops: durian (6 farmers), vegetables (5), grape (3) and cotton (2).

In discussions with the durian farmers, they pointed out that a farmers' group with access to DOAE products would pay about 300 baht per rai for trichoderma. (2 applications of 4 to 6 kg per tree). Farmers who are not members of such a group would pay about 2400 baht per rai for the commercial products.

Table 48: Source of Trichoderma products

Trained farmers

Farming System	# Trichoderma products	% bought from shop	% from DOAE or DOA	% from other source
Rice	10	0	100	
Cotton	3	33.3	33.3	33.3
NE vegetable	6	33.3	66.7	
N vegetable	18	11.1	77.8	11.1*
Grape	5	60.0	40.0	
Fruit tree	17	17.6	82.4	
Total	**59**	**18.6**	**76.3**	**5.1**

* 2 Royal Project, 1 unknown

Control farmers

Farming System	# Trichoderma products	% bought from shop	% from DOAE	% from other source
Rice	2	0	100	
Cotton	3	66.7	33.3	
NE vegetable	0	-	-	
N vegetable	1	100	0	
Grape	0	-	-	
Fruit tree	6	50.0	0	50.0*
Total	**12**	**50.0**	**25.0**	**25.0**

* 2 Chantaburi Agricultural College & 1 sample from company

Application
Over half the farmers said they found Trichoderma easier to use than chemicals (table 49). The reasons given was that it was safe to use, easy to distribute around the plant and did not need to be reapplied often. The farmers who said trichoderma was more difficult to apply than chemicals were concerned about the preparation time, as the product had to be mixed with rice bran and manure before application.

One of the commercial products was formulated so it could be sprayed and applied to the bark of the tree, whereas the other was applied round the base. In the fruit tree area, the sprayable product was reported by the main pesticide dealer to be more popular with farmers.

Effectiveness
The majority of users thought Trichoderma was effective and helped the plants recover, even thought the results were slow. One third of all users thought that it took much longer than one week – more like 1 to 3 months – to see any good effects. Over 15% of trained and control users said they could not distinguish any effects or that they were unsure because the effects were so slow. Durian farmers were the most positive about Trichoderma and compared it favourably with other fungicides. Rice, cotton and grape farmers were more ambivalent. Because Trichoderma is mixed with fertiliser, it is not always clear whether the results are due to the Trichoderma or fertiliser or both. Several farmers said it was the combination of trichoderma and biofertiliser that gave the best results.

Table 49: Farmers' perceptions of ease of use and effectiveness of Trichoderma products

Trained farmers

	Ease of application compared with chemical pesticides (% Trichoderma products)			**Effectiveness (% Trichoderma products)**				
Farming system	Easier	Same	More difficult	Immed-iate	Within 3 days	Within a week	Longer than 1 week	Not or partly effective
Rice	70.0	10.0	20.0	0	10.0	10.0	40.0	40.0
Cotton	66.7	33.7	0	33.3	33.3	33.3	0	0
NE vegetable	33.3	50.0	16.7	0	50.0	33.3	16.7	0
N vegetable	77.8	11.1	11.1	0	5.6	50.0	33.3	11.2
Grape	0	20.0	80.0	0	0	40.0	40.0	20.0
Fruit trees	23.5	17.6	52.9	0	5.9	35.3	47.1	11.8
Total	**49.2**	**18.6**	**30.5**	**1.7**	**11.9**	**35.6**	**35.6**	**15.3**

Control farmers

	Ease of application compared with chemical pesticides (% Trichoderma products)			Effectiveness (% Trichoderma products)				
Farming system	Easier	Same	More difficult	Immed-iate	Within 3 days	Within a week	Longer than 1 week	Not or partly effective
Rice	100	0	0	0	0	0	50.0	50.0
Cotton	66.7	33.3	0	0	33.3	66.7	0	0
NE vegetable	-	-	-	-	-	-	-	-
N vegetable	0	100	0	0	0	0	100	0
Grape	-	-	-	-	-	-	-	-
Fruit trees	50.0	16.7	33.3	0	0	50.0	33.3	16.7
Total	**58.3**	**25.0**	**16.7**	**0**	**8.3**	**41.7**	**33.3**	**16.7**

Problems and advantages

The main problems and advantages of Trichoderma identified by farmers are shown in tables 50 and 51. The trained farmers were generally more satisfied with the effectiveness of trichoderma than the control farmers. Over half of the control farmers thought trichoderma was less effective than chemicals or ineffective. The main complaint that the trained farmers had was over the preparation of trichoderma. Over one third of the farmers did not like having to obtain and mix the inoculated seeds with rice bran and manure; they said they would prefer a product already formulated and ready for use.

The slow action of trichoderma was only identified as a problem by a minority of users. It appeared that farmers accepted that results would not be instantaneous, and were satisfied as long as they could see the plants recovering over time. In a similar way to judging the effects of fertiliser, a significant number of farmers (18%) mentioned that trichoderma made the plants more healthy.

Lack of toxicity and residues was seen as an advantage by both trained (31%) and control (42%) farmers.

No significant differences in the farmers' perceptions could be identified between commercial brands and non-commercial products, other than related to the price of the products.

Table 50: Problems identified by Trichoderma users

Problems identified	Trained farmers (% of 59 Trichoderma products)	Control farmers (% of 12 Trichoderma products)	Total (% of 71 Trichoderma products)
Preparation	37.3	16.7	33.8
Less effective than chemicals	11.9	41.7	16.9
Slow action	11.9	8.3	11.3
Lack of supply	11.9	8.3	11.3
Ineffective	5.1	16.7	7.0
Expensive	6.8	0	5.6
Difficult to apply	1.7	0	1.4
Storage	1.7	0	1.4
Other	10.2	0	8.5

Table 51: Advantages identified by Trichoderma users

Advantages identified	Trained farmers (% of 59 Trichoderma products)	Control farmers (% of 12 Trichoderma products)	Total (% of 71 Trichoderma products)
Good control	52.5	41.7	50.7
Safe & no residues	30.5	41.7	32.4
Healthy plants	18.6	16.7	18.3
Cheap	13.6	8.3	12.7
Easy to use	10.2	16.7	11.3
Seasonal control	8.5	8.3	8.5
Long-lasting	10.2	0	8.5
Other	1.7	0	1.4

Future Use
Most farmers (81% of trained and 58% of control) said they would use Trichoderma again in the future (table 50). It should be noted that not all farmers have had much experience in using trichoderma, particularly in the rice farming system.

No significant differences could be found between the percentage of farmers who said they would use commercial brands again and those using non-commercial products.

Table 52: Percentage of Trichoderma users who said they would use Trichoderma products again

Trained farmers

Farming system	# Trichoderma products	% products used more than once	% farmers who would use Trichoderma product in the future	
			No or not sure	Yes
Rice	10	40.0	0	100
Cotton	3	66.7	33.3	66.7
NE vegetable	6	83.3	33.3	66.7
N vegetable	18	50.0	22.2	77.8
Grape	5	60.0	20.0	80.0
Fruit trees	17	76.5	17.6	82.4
Total	**59**	**59.3**	**18.6**	**81.4**

Control farmers

Farming system	# Trichoderma products	% products used more than once	% farmers who would use Trichoderma product again	
			No or not sure	Yes
Rice	2	0	50.0	50.0
Cotton	3	66.7	33.3	66.7
NE vegetable	0	-	-	-
N vegetable	1	0	100	0
Grape	0	-	-	-
Fruit trees	6	66.7	33.3	66.7
Total	**12**	**50.0**	**41.7**	**58.3**

Other fungi

Other fungal pesticides identified were Chaetomium, Metazhizium and Beauvaria. No one surveyed had heard of Verticilium.

Chaetomium

Almost 15% of all farmers had heard of Chaetomium, but only 3% said they had used it. The users consisted of four fruit tree farmers and two farmers from the cotton farming system who also grew fruit trees (table 53). They had used Chaetomium to control stem and root rot (*Phytopthora*) on durian and other fruit trees. Three farmers said they had bought the product from a pesticide dealer, paying between 500 and 700 baht ($11.90- $16.67). One had obtained it from the DOAE. It is not known how many years ago they used it, but farmers were not impressed with the efficacy. Four farmers gave details of its use and said that Cheatomium was slow acting and doubtful whether it controlled *Phytopthora*. Only one farmer said it gave good results and they would definitely use it again. Apart from doubts over its efficacy, farmers said it was now not possible to find Chaetomium in the shops. One farmer thought it had disappeared from the market about 7 years ago.

We were unable to identify any current source of Chaetomium. It appears that this biofungicide, which was researched and promoted by research institutions in Thailand in the 1980s, has faded from the market.

Table 53: Percentage of farmers who have heard of or used Chaetomium

Trained farmers

Farming system	**% farmers never heard of Chaetomium**	**% farmers heard of, but not used Chaetomium**	**% farmers used Chaetomium**
Rice	100	0	0
Cotton	81.8	18.2	0
NE vegetable	91.7	8.3	0
N vegetable	80.8	19.2	0
Grape	92.3	7.7	0
Fruit tree	56.3	25.0	18.8
Total	**83.8**	**13.1**	**3.0**

Control farmers

Farming system	**% farmers never heard of Chaetomium**	**% farmers heard of, but not used Chaetomium**	**% farmers used Chaetomium**
Rice	100	0	0
Cotton	75.0	8.3	16.7
NE vegetable	100	0	0
N vegetable	95.7	4.3	0
Grape	100	0	0
Fruit tree	50.0	45.0	4.0
Total	**87.1**	**10.1**	**2.8**

Metarhizium anisopliae

No commercial products containing Metarhizium were identified, but the DOAE is actively producing and testing *Metarhizium anisopliae* with rice farmers. It is used to control brown plant hoppers on rice and also being tested on rhinoceros beetle on coconut.

Metarhizium is produced in a similar way to Trichoderma, using a solid fermentation process with sorghum grain or maize as the substrate. It is supplied as 0.5kg plastic bags containing inoculated seed. The farmers have to mix the product with water, filter it, dilute further with water, then spray using conventional sprayers. Not surprisingly, farmers find this process more cumbersome than using chemical pesticides, plus they cannot mix it with other pesticides.

Currently, very small amounts of Metarhizium are produced. Two of the four DOAE centres interviewed said they produced Metarhizium. One of these said they produced 300kg per annum. The Metarhizium is produced when required, as the DOAE have insufficient room in the fridges to store it for long periods. It takes 2 weeks to produce, and another week to distribute and use. Three samples of Metarhizium were collected and analysed (table 54). Like the Trichoderma samples, these had deteriorated after being stored. The resulting concentration of spores was unlikely to give much effect. For comparison, commercial products have a concentration of 5×10^{10} conidia/gram.

Table 54: Number of spores of *Metarhizium anisopliae* in samples collected from the survey

Sample	Spores of M. anisopliae per gram
Non-commercial	
1	$> 10^6$
2	No growth spores
3	$> 10^6$

Less than 5% of all farmers had heard of Metarhizium and only two farmers said they had used it (table 55). However, as described above, it is highly probably that five other rice farmers who thought they were using Trichoderma, were in fact using Metarhizium.

The one cotton farmer who used Metarhizium was using it to control cotton bollworm, whereas the other rice farmers used it to control brown plant hopper. All supplies of Metarhizium came from DOAE centres, free of charge. Of the total seven farmers who used Metarhizium, six said it was effective within a week, and all said they would use it again. The main problem with it was the difficult preparation. The inoculated seed had to be mixed with water and filtered before being sprayed.

One farmer who compared Metarhizium with monocrotophos said that the monocrotophos was quicker acting, but the Metarhizium was longer-lasting and appeared to act as a repellent so that the brown plant hoppers disappeared after a time. The DOAE staff who had given Metarhizium samples to 30 farmers in total said they had received mixed reports about its effectiveness.

Table 55: Percentage of farmers who have heard of or used Metarhizium

Trained farmers

Farming system	% farmers never heard of Metarhizium	% farmers heard of, but not used Metarhizium	% farmers used Metarhizium
Rice	95.2	0	4.8
Cotton	81.2	18.2	0
NE vegetable	100	0	0
N vegetable	96.2	3.8	0
Grape	100	0	0
Fruit tree	100	0	0
Total	**95.9**	**3.0**	**1.0**

Control farmers

Farming system	% farmers never heard of Metarhizium	% farmers heard of, but not used Metarhizium	% farmers used Metarhizium
Rice	92.9	7.1	0
Cotton	75.0	16.7	8.3
NE vegetable	100	0	0
N vegetable	95.7	4.3	0
Grape	100	0	0
Fruit tree	100	0	0
Total	**93.5**	**4.6**	**0.9**

Beauvaria bassiana

Only one of the DOAE Biocontrol Centers said they produced *Beauvaria bassiana*. It is produced and applied in a similar way to Metarhizium, using corn as a substrate. It is still being tested and has not been widely distributed to farmers yet. Quantities of Beauvaria produced are very small. The DOAE hope to use Beauvaria for control of leaf folders and larvae on rice, cotton and vegetables.

Very few farmers had ever heard of Beauvaria (table 56). Only one cotton farmer said she had used it (the same farmer who used Metarhizium). She had obtained samples from the DOAE and used it for control of cotton bollworm and jassids. She was satisfied with the control (within 3 days) and said she would use it again.

Table 56: Percentage of farmers who have heard of or used Beauvaria

Trained farmers

Farming system	% farmers never heard of Beauvaria	% farmers heard of, but not used Beauvaria	% farmers used Beauvaria
Rice	95.2	4.8	0
Cotton	90.9	9.1	0
NE vegetable	100	0	0
N vegetable	100	0	0
Grape	100	0	0
Fruit tree	100	0	0
Total	**97.9**	**2.0**	**0**

Control farmers

Farming system	**% farmers never heard of Beauvaria**	**% farmers heard of, but not used Beauvaria**	**% farmers used Beauvaria**
	100	0	0
Rice			
Cotton	75.0	16.7	8.3
NE vegetable	100	0	0
N vegetable	100	0	0
Grape	100	0	0
Fruit tree	100	0	0
Total	**97.2**	**1.8**	**0.9**

Future use

None of the commercial companies interviewed reported any plans to supply new fungal pesticides. Generally, they expected a slight increase in the market for fungal pesticides but were less optimistic than the public institutions. The DOAE Biocontrol Centers plan to increase their production in the future but will not have the capability to reach more than a small percentage of farmers.

Viral Pesticides

The viral pesticides identified in Thailand were all nuclear polyhedrosis viruses (NPVs) of the Baculovirus family. These viruses are naturally occurring diseases of insects that are highly specific to one or sometimes several closely related species of insect. They are not infective to non-insect species or natural enemies such as insect predators and parasitoids, so are safe and appropriate for use in IPM programmes. Baculoviruses infect a number of important pest species, especially Lepidoptera. Commercial insecticides based upon them have been developed as biological insecticides and registered for the control of major crop pests such as *Heliothis* spp. *Helicoverpa armigera, Spodoptera exigua, S. littoralis* and *Cydia pomonella.*

The view from the suppliers

The suppliers are shown in table 57. Only one commercial supplier was identified who imported products from the USA. However, this supplier had decided to stop sales of its NPV products at the end of 2001. At the time of the survey, farmers were still using the last remaining stocks of these NPVs. It is known that two other local companies have tried to produce NPVs, but both had problems with the production process.

Unless another commercial company takes on an agreement to import viral pesticides, or set up in production, the only producers and suppliers of these pesticides are the DOA and DOAE. These produce three viral pesticides: *Spodoptera exigua* NPV (SpexNPV), for control of beet armyworm; *Helicoverpa armigera* NPV (HearNPV), for control of cotton bollworm, and *Spodoptera litura* NPV (SpltNPV), for control of cotton leafworm.

Table 57: Suppliers of viral pesticides in Thailand

Supplier type	Main business	Status of NPV products	NPV Products	NPV source
Commercial				
Multinational	Agrochemicals	Stopped sales of NPVs in 2001/2	SpodX (*Spodoptera exigua* NPV) Gemstar (*Heliothis zea* NPV)	ThermoTrilogy (Certis USA)
Local	Biopesticides & fertilisers	Stopped due to quality problems	SpexNPV	Own production
Local	Biopesticides	Stopped prior to bringing products to market, due to production problems	HearNPV	Own production
Public				
DOA	Biocontrol	Active	DOA BioV1 (SpexNPV) DOA BioV2 (HearNPV) DOA BioV3 (SpltNPV)	Own production
DOAE	Biocontrol & extension	Active	SpexNPV HearNPV SpltNPV	Own production

Production

Production of NPV pesticides has been undertaken in Thailand since the late 1980s by both the DOA and DOAE. SpexNPV was the first viral pesticide to be developed, followed by HearNPV and later SpltNPV. Although the DOAE Biocontrol Centers and DOA use similar production methods (DOAE staff are trained in NPV production by the DOA), the DOA produce on a larger scale in one specialised pilot plant whereas the DOAE produce NPV in the Biocontrol Centers along with all their other bioagents. The DOAE have a larger budget and staff overall, but it is spread over all the regional centres and there are fewer resources assigned specifically to NPV production. For example, the trained staff available in the Biocontrol Centers ranged from 3 to 9 science graduates plus 2 to 9 other staff, whereas there are 8 science graduates plus 26 staff working at the DOA pilot plant. The Biocontrol Centers do not have as much specialised laboratory equipment such as DNA identification equipment or spray and freeze dryers.

Information and training on NPV production come from within the DOA and DOAE themselves, but also from the universities, particularly Kasetsart University, and outside links with other NPV researchers.

The production process for NPVs is an *in vivo* process, that relies on the successful mass-rearing of the host insects which are then infected with the virus. It is labour-intensive and has to be managed carefully to avoid contamination with other unwanted organisms.

The source of inoculum for the DOAE Biocontrol Centers comes from the DOA, DOAE head office or Kasetsart University. The DOA inoculum is collected during surveys of natural outbreaks in Thailand. All the producers rear the insect larvae individually in the laboratory. The larvae are fed on artificial diet based on sorghum. Infected larvae are formulated into a water-based suspension that can be sprayed using conventional sprayers. The DOA are also investigating other formulations such as wettable powder. SpltNPV is the easiest NPV to produce according to the DOA, followed by HearNPV, then SpexNPV.

Quantities of NPV produced by the DOAE Biocontrol Centers are very variable and are made in small batches when the demand arises (Table 58). Three of the four DOAE Biocontrol Centers produced NPVs. The fourth Biocontrol Center had produced SpexNPV in the past, but discontinued due to lack of labour. They did plan to start production of HearNPV in the future. Overall, the DOAE estimate that they produce 4530 litres of NPV pesticides per year. The DOA pilot plant produced a total of 760 litres of NPV pesticides in 2001 – not enough to meet the demand from farmers.

Reported problems with production included lack of labour and funds to produce more; difficulties with disease of the host insects and occasional problems when the initial inoculum was not pure. Another constraint on production is that the insects cannot all be reared throughout the year.

The amounts supplied of the two commercial products, Spod-X and Gemstar, were reported to be 1.5 tonnes and 0.5 tonnes respectively in 2001.

Costs of production have been calculated by the DOA at around 1,500 baht per litre ($36) for NPV.

Table 58: Quantities of NPV produced by individual suppliers

Producer	Products	Years of production	Source of inoculum	Quantity per annum	Quantity per batch
DOAE	HearNPV SpexNPV SpltNPV	12	DOAE	25 lt 25 lt 25 lt	1 lt
DOAE	HearNPV SpexNPV	6	DOA, DOAE	60 lt 60 lt	1000 larvae 1000 larvae
DOAE	HearNPV SpltNPV	6 4	Kasetsart University	300 lt 400 lt	10 lt
DOA	HearNPV SpexNPV SpltNPV	10 14 4	Collected from natural outbreaks	260 lt 300 lt 200 lt	50 lt 70 lt 20 lt
Commercial	Gemstar (HzNPV) Spod X (SpexNPV)		USA	0.5 tonnes 1.5 tonnes	

The two private companies that are known to have set up NPV production, both had problems with the production processes. One was unable to rear sufficient insects to make the product viable and the other had difficulties with contamination and quality problems.

Quality

The concentration of viral particles (PIBs) in all the NPVs is recommended by the DOA to be 10^9 PIBs/ml. All the NPV producers reported measuring concentrations in viral particles per unit volume (PIBs/ml) rather than the larval-equivalents[13] used by some small-scale producers elsewhere. However, full quality control methods are lacking for checking the purity or concentrations of all products. Tests carried out on samples of NPV revealed that several of the products produced contained lower concentrations of PIB (table 59). The low results from some of the small-scale production facilities are not surprising as the staff are well-aware of the difficulties in producing a quality product.

One of the commercial products also failed to meet the stated concentration. The low concentration levels is unlikely to be explained by long storage of the products as prolonged storage rarely leads to the dissolution of the PIBs although it can result in loss of activity. Farmers using commercial NPV products have also noticed variations in the quality of the products before.

[13] “Larval-equivalents” is a simple but inaccurate way of measuring concentration based on the number of infected larvae used in the product. It is used by some NPV producers.

Table 59: Concentrations of PIBs/gram in samples of viral pesticides collected during the survey

Sample	Virus	Nominal count	Actual count	Assessment
Non-commercial				
1	SpltNPV	1×10^9	1.24×10^8	Low count but probably has some effect
2	SpltNPV	1×10^9	5.85×10^7	Low count, little effect
3	SpltNPV	1×10^9	4.70×10^8	Low count but would have effect
4	SpltNPV	1×10^9	1×10^9	Up to standard
5	HearNPV	1×10^9	4.91×10^9	Up to standard
6	HearNPV	1×10^9	2×10^9	Up to standard
7	SpexNPV	1×10^9	1.15×10^8	Low count but some effect
8	SpexNPV	1×10^9	1×10^9	Up to standard
Commercial				
9	HzNPV	2×10^9	2×10^9	Up to standard
10	SpexNPV	2×10^9	1.41×10^9	Below standard but would be effective

Markets

Because NPVs are specific to particular pests, the market for them depends on the current pest status of the individual pest species. The army beet worm, *Spodoptera exigua*, causes damage to high value crops such as grape and to many vegetables, particularly shallots where the pest can destroy a whole field in a few days. Grape farmers have been a particular focus of the commercial supplier and DOA as they use large amounts of pesticide and have pesticide resistance problems especially with *S. exigua*. Grape farmers are also a target market for HearNPV and Gemstar as the cotton bollworm, *Helicoverpa armigera*, is a major pest and also resistant to some of the chemical insecticides. Otherwise the main customers for HearNPV are cotton and vegetable farmers – particularly tomato and chilli. The SpltNPV is produced mainly for cut flower and orchid growers to control cotton leafworm.

With the withdrawal of the commercial importer of NPV from the market, future target markets will depend on how many farmers the DOA and DOAE can reach. To date, the DOAE have tried to reach a range of vegetable and cotton farmers as part of their IPM and hygienic production programmes. The DOA have concentrated more on particular areas and sectors such as grape farmers, cotton farmers (as part of an IPM programme) and some vegetable farmers, such as asparagus and shallot growers.

Promotion

The DOA promote NPVs through radio and television programmes as well as farmer demonstrations and trials. The DOAE include NPVs in many of their IPM and farmer field school programmes for vegetable and cotton farmers. The commercial supplier relied heavily on the DOA to recommend their products and advise on proper use. They did, however, promote NPVs amongst grape farmers and were starting some promotions with asparagus farmers.

Quantities, sales and prices

Sales of the two commercial products have declined over the last 3 years and in 2001 consisted of only 1.5 tonnes of Spod-X and 0.5 tonnes of Gemstar. The highest sales reported of Spod-X were in 1997 and of Gemstar in 1998. At that time sales of Spod-X rose to around 5 tonnes. The reason for the decline, according to the company, is the lack of demand by farmers. Farmers will use NPVs when older chemicals do not work any more, then switch back to chemicals again when a new chemical arrives on the market. For example, when the chemical Rampage (chlorphenapyr) was introduced, sales of Spod-X fell by 1.5 tonnes. However, when pest resistance starts to reoccur (as has happened with some of the newer chemicals) the farmers switch back to NPV again. Gemstar has been harder to sell than Spod-X, partly, according to the company, because farmers do not spray until they see the pest damage, which is too late for effective control. Another reason for the decline in sales might be that the company used to sell a larger proportion of their product direct to the DOAE (about 30% sales of Spod-X and 50% sales of Gemstar prior to 2001). The DOAE has cut their budget for these products as they concentrate on their own production instead.

The company reported that the NPV products are not very profitable, especially Gemstar.

The largest suppliers are now the DOA and DOAE. Unlike the private company, the quantities produced have risen over the last 3 years. However, the DOA operation is designed as a pilot plant, not to supply the whole country, and the DOAE Biocontrol Centers have only small-scale capacity at present.

Retail prices for the commercial products were 3,300 baht per litre ($79). This is more expensive than traditional chemicals such as methamidophos or endosulfan (about 500 baht per litre), and with Bt products (500 – 1,300 baht per litre). It is in line with, or less expensive than, many of the new chemicals such as chlorphenapyr or spinosad which can cost up to 6,000 baht per litre. The DOAE NPV products are distributed free to farmers, but the DOA usually charge for their products to cover their costs. Their products are sold at 2,000 baht per litre ($48).

Supply problems

Although NPVs can be produced from local, inexpensive materials and is a labour-intensive rather than capital-intensive process, it is still technically demanding to produce a consistent, effective product. It requires well-developed effective quality control procedures (Jenkins and Grzywacz 2000). Problems with insect rearing and contamination have beset all the producers at some stage, and in at least one case, forced a private, local company to give up production without bringing their product to market.

NPVs in Thailand are also more expensive to produce than some other biopesticides. The cost of one litre of NPV from the DOA is 2,000 baht ($48) – a cost calculated to break even, rather than make a profit.

Production problems were the main factors identified by the DOAE Biocontrol Centers. Lack of resources to expand production was the main factor identified by the DOA.

For the commercial company, production problems were irrelevant as they imported the products from a separate company. However, the shorter shelf-life than for chemical pesticides and the requirement to keep the product in cool conditions were seen as problems. A more important problem was the competition between the NPV products and other chemicals. Company representatives predicted that sales of NPVs would fluctuate, dipping whenever a new chemical was introduced, rising after 2 or more seasons when resistance problems emerged with the new chemicals, but then dipping again after further chemicals were introduced. The company was convinced that farmers would prefer to use a quicker-acting chemical pesticide than the slower-acting (3-7 days) NPVs wherever possible. They thought that NPVs would definitely be too slow-acting on vegetables such as crucifers.

Future supply

The future supply of NPVs from the private sector looks bleak. Currently, the import of the main commercial products (Gemstar and Spod-X) have been discontinued and it is not known of any agreements with other private companies to import them. Local companies have expressed interest in producing NPVs, but have no immediate plans to do so and are cautious of the production costs and size of market. Several companies have approached the DOA with requests for the DOA to supply them with NPVs, but the DOA does not have the capacity to do this.

The DOA and DOAE plan to continue production and increase output if resources are available.

The view from the farmers

Users

65% of trained and 31% of control farmers had heard of NPVs and 31% of trained and 8% of control farmers had used them (table 60). Overall there were 40 farmers using a total of 64 NPV products in the survey.

NPV was mainly used by cotton and grape farmers, but also by some of the vegetable farmers involved with IPM training programmes. The majority of farmers used chemical pesticides alongside the NPVs. In particular, all the cotton and grape farmers were heavy users of chemical pesticides (table 61).

Table 60: Percentage of farmers who have heard of or used viral pesticides

Trained farmers

Farming system	**% farmers never heard of viral pesticides**	**% farmers heard of, but not used viral pesticides**	**% farmers used viral pesticides**
Rice	57.1	38.1	4.8
Cotton	0	0	100
NE vegetable	33.3	25.0	41.7
N vegetable	53.8	46.2	0
Grape	0	0	100
Fruit tree	31.3	62.5	6.3
Total (99 farmers)	**35.4**	**33.3**	**31.3**

Control farmers

Farming system	% farmers never heard of viral pesticides	% farmers heard of, but not used viral pesticides	% farmers used viral pesticides
Rice	96.4	3.6	0
Cotton	8.3	41.7	50.0
NE vegetable	92.9	7.1	0
N vegetable	69.6	30.4	0
Grape	16.6	58.3	25.0
Fruit tree	80.0	20.0	0
Total (109 farmers)	**68.8**	**22.9**	**8.3**

Table 61: Viral pesticide users: pesticide use characteristics

Trained farmers

Farming system	# farmers using virus products	% use chemical pesticides	% use hazard-ous chemicals	% interested in IPM or hygienic	% buying expensive pesticides	% use Bt pesticides	% use fungal pesticides	% use nematode pesticides
Rice	1	0	0	100	0	0	100	0
Cotton	11	100	18.2	81.8	0	27.3	36.4	9.1
NE vegetable	5	80.0	20.0	100	20.0	80.0	80.0	40.0
N vegetable	0	-	-	-	-	-	-	-
Grape	13	100	69.2	100	92.3	53.8	38.5	7.7
Fruit tree	1	0	0	100	0	100	100	100
Total	**31**	**90.3**	**38.7**	**93.6**	**41.9**	**48.4**	**48.4**	**16.1**

Control farmers

Farming system	# farmers using virus products	% use chemical pesticides	% use hazard-ous chemicals	% interested in IPM or hygienic	% buying expensive pesticides	% use Bt pesticides	% use fungal pesticides	% use nematode pesticides
Rice	0	-	-	-	-	-	-	-
Cotton	6	66.7	50.0	66.7	0	33.3	16.7	0
NE vegetable	0	-	-	-	-	-	-	-
N vegetable	0	-	-	-	-	-	-	-
Grape	3	100	66.7	100	100	33.3	0	0
Fruit tree	0	-	-	-	-	-	-	-
Total	**9**	**77.8**	**55.6**	**77.8**	**33.3**	**33.3**	**11.1**	**0**

SpexNPV was the most widely used viral pesticide by grape and vegetable farmers to control beet armyworm (table 62). HearNPV or HzNPV was used by cotton farmers and also by grape farmers to control cotton bollworm. No users of SpltNPV were found during the survey. This is unsurprising as this NPV is currently produced on a smaller scale for specialised cut flower and orchid growers. There is no commercial SpltNPV product available.

Table 62: Number of products used by farmers using NPVs

Trained farmers

Farming System	SpexNPV	HearNPV or HzNPV	NPV (type not specified)
Rice	0	0	1
Cotton	0	12	0
NE Vegetable	3	0	1
N Vegetable	0	0	0
Grape	25	10	1
Fruit tree	1	0	0
Total	**29**	**22**	**3**

Control farmers

Farming System	SpexNPV	HearNPV or HzNPV	NPV (type not specified)
Rice	0	0	0
Cotton	0	6	0
NE Vegetable	0	0	0
N Vegetable	0	0	0
Grape	3	1	0
Fruit tree	0	0	0
Total	**3**	**7**	**0**

Knowledge and reasons for use

All the grape farmers who used NPVs were clear about what pests were targeted, and the fact that NPVs took several days to take effect. The effects of NPVs are very visible with the infected larvae hanging from the plant. The cotton farmers were less knowledgeable with some farmers confusing NPV and Bt products. (Both products will control cotton bollworm). These farmers had less experience with NPVs, and had less precise knowledge of pesticides in general, compared with the grape farmers who spend large amounts on chemical inputs. From the grape and cotton farmer discussions, few knew that the NPVs worked like a disease, rather than like chemicals, but few cared, as long as the product was effective.

NPVs were used to control specific pests: cotton bollworm and beet armyworm, that were increasingly difficult to control with other chemical pesticides. Beet armyworm can be controlled by some of the newer chemical insecticides such as Success (spinosad), Rampage (chlorphenapyr) or Mimic (tebufenocide). However, many farmers are cautious about relying on these chemicals alone, as they know from past experience that the larvae can develop resistance to new chemicals within several seasons. Even though the chemicals can give an initial knock-down effect, farmers prefer to alternate their use with other pesticides to slow down the development of resistance problems. NPV is one of the alternative pesticides. In addition, NPV is considerably cheaper than the newest chemicals, so some farmers reserve the use of the new chemicals for situations where an immediate effect is required, such as when there is a heavy infestation of late instar larvae, and use NPVs at other times. There are certain stages in the growth cycle when NPVs are advantageous compared with chemicals. For example, cotton bollworm can be a problem for grape farmers at the flowering stage. HearNPV is useful because it does not damage the flowers. SpexNPV has advantages over chemicals because it can be used up to harvest with no damage to the fruit or residue problems. Generally NPVs were regarded as “cold” insecticides as they do not damage leaves or fruit.

From the group discussions, farmers said they knew that NPVs had to be applied early when the larvae were small in order to have an effect. If they waited until the infestation was heavy then the NPVs would not control it quickly enough. Some farmers had experimented with regular sprays of low dosage SpexNPV as a preventative measure. Farmers were also aware that NPVs were less effective in hot sunlight, so need to be sprayed early morning or evening. Some said that NPVs were less effective in the rainy season as the NPV could be washed from the leaves before being ingested by the larvae.

Farmer Production

The trained grape and cotton farmers had been shown how to collect infected larvae and make their own NPV pesticide. Five grape farmers and four cotton farmers had produced their own NPV successfully (see case study in Box 3). However, only one grape and one cotton farmer were enthusiastic about own production. The other farmers said they used to produce their own NPV, but it was difficult to collect sufficient larvae to make much pesticide and the resulting pesticide was not as effective as that from the DOA. Some also disliked storing the NPV mixture in the fridge alongside food stuffs. When all the NPV users were asked whether they preferred to produce or buy biopesticides, 71% of trained users and 67% of control users said they definitely preferred to buy. Most claimed they had insufficient time to produce themselves. This lack of interest in production was evident amongst the less well-off cotton farmers as well as the grape farmers.

Case Study: Farmer Production of SpexNPV

This farmer has 16 ha of grape, and has been growing grapes for over 30 years. He started using SpexNPV 15 years ago, alongside other chemicals. He uses NPV because the insects are not resistant to it, it is less expensive than the new chemicals and it does not damage the fruit and can be used up to harvest. After harvest he lets the larvae increase on the vines. He sprays with NPV then has 10 labourers collect all the infected larvae. He prepares and keeps the larvae in the fridge until the next season when he uses it. The collected larvae make enough NPV to spray 4 to 5 times. He has also sold some NPV to neighbours for 500 baht per gallon. The farmer thinks that making NPV himself helps to reduce his costs. However, he said that his friends do not like collecting larvae because it takes time, and they prefer to buy.

Box 3: Farmer Production of NPV

Source & price

65% of trained farmers using NPV and 60% of control farmers using NPV obtained the products from the DOA or DOAE (table 63). The DOAE give the products free to selected farmers participating in IPM programmes. The DOA usually charge farmers 2,000 baht per litre, but in the case of the trained cotton farmers, NPV was provided free of charge during the IPM training. 35% of trained and 40% of control farmers bought Gemstar or Spod-X from pesticide dealers at prices ranging from 2,800 to 3,300 baht/litre. No other source of NPVs was identified in the areas visited.

The farmers who bought NPVs were mainly grape farmers. All of these farmers have bought insecticides and fungicides costing more than 1,000 baht per litre, and 88% have spent over 3,000 baht per litre for the newer chemicals. Therefore the prices of NPVs are within the range of prices paid for chemicals. Cotton farmers spend less on chemicals: 65% of cotton farmers had paid between 1,000 baht and 3,000 baht per litre, but none reported spending more than 3,000 baht per litre on any pesticide.

Table 63: Source of NPV products for farmers

Trained farmers

Farming System	# NPV products	% bought from shop	% from DOAE	% from DOA
Rice	1	0	100	0
Cotton	12	0	0	100
NE vegetable	4	25.0	75.0	0
N vegetable	0	-	-	-
Grape	36	50.0	0	50.0
Fruit tree	1	0	100	0
Total	**54**	**35.2**	**9.3**	**55.6**

Control farmers

Farming System	# NPV products	% bought from shop	% from DOAE	% from DOA
Rice	0	-	-	-
Cotton	6	0	50.0	50.0
NE vegetable	0	-	-	-
N vegetable	0	-	-	-
Grape	4	100	0	0
Fruit tree	0	-	-	-
Total	**10**	**40.0**	**30.0**	**30.0**

Application

NPV is diluted and sprayed using conventional spraying equipment. Most users found its application similar to that of chemicals or easier, primarily because it needed less safety precautions and did not cause farmers to feel dizzy and sick (table 64). 24% of trained farmers thought NPV was more difficult to apply mainly because they had to spray early morning or evening to have most effect.

Farmers do mix NPV with other insecticides – sometimes with insecticides to control sucking pests, and sometimes with new insecticides such as spinosad to give an immediate knock-down effect on large larvae, while the NPV works longer-term on the smaller larvae.

Effectiveness

Farmers were aware that NPVs did not produce immediate effects, but the majority thought that NPVs were effective after 3 to 7 days (Table 64). Unlike some other biopesticides, the effects of NPVs are easily visible by the farmers. Several farmers reported that NPV was not as effective in the rainy season, when rain washed off the pesticide before it could be ingested by the larvae; also that NPV was not as effective later in the season or on late instars. stages of the larvae.

In comparing the effectiveness of NPVs with new chemicals such as spinosad, farmers had mixed opinions over which they would prefer to use. Most would like to like to use both. Spinosad has a quick action, but farmers say they have to spray again in 3-4 days. NPV is slower but requires fewer sprays as it lasts longer.

Farmers were sensitive to changes in the concentrations of the NPV products. In discussions several farmers said they thought that the commercial products were not always as effective as the local products, but others disagreed saying that Spod-X was more concentrated. It appeared that one batch of Spod-X and one of the local SpexNPV had been less concentrated than standard, and the farmers had noticed immediately. Farmers generally thought that Gemstar (derived from *Heliothis* NPV) was less effective than local HearNPV (isolated from the local strain of *Helicoverpa armigera*). One farmer said he had to increase the application rate and another that they had to spray several times to control the larvae.

Table 64: Farmers perceptions of ease of use and effectiveness of NPVs

Trained farmers

	Ease of application compared with chemical pesticides (% NPV products)			**Effectiveness (% NPV products)**			
Farming system	Easier	Same	More difficult	Immediate	Within 3 days	Within a week	Not or partly effective
Rice	100	0	0	0	0	0	100
Cotton	33.3	58.3	8.3	0	66.7	33.3	0
NE vegetable	25.0	50.0	25.0	0	50.0	50.0	0
N vegetable	-	-	-	-	-	-	-
Grape	36.1	33.3	30.6	0	47.2	52.8	0
Fruit trees	0	100	0	0	0	100	0
Total	**35.2**	**40.7**	**24.1**	**0**	**50.0**	**48.1**	**1.9**

Control farmers

	Ease of application compared with chemical pesticides (% NPV products)			**Effectiveness (% NPV products)**			
Farming system	Easier	Same	More difficult	Immediate	Within 3 days	Within a week	Not or partly effective
Rice	-	-	-	-	-	-	-
Cotton	66.7	33.3	0	0	50.0	33.3	16.7
NE vegetable	-	-	-	-	-	-	-
N vegetable	-	-	-	-	-	-	-
Grape	75.0	25.0	0	0	25.0	75.0	0
Fruit trees	-	-	-	-	-	-	-
Total	**70.0**	**30.0**	**0**	**0**	**40.0**	**50.0**	**10.0**

Problems and advantages

Not surprisingly several farmers identified the slow action of NPVs compared with chemical insecticides as a problem. 19% said NPVs were ineffective in certain situations such as during the rainy season or when sprayed late in the season, but very few (2%) thought that NPVs were ineffective overall (table 65). The comment about NPV being less effective late in the season is interesting, as there has not been similar reports of this phenomenon in the scientific literature. It may indicate a temporary local build-up in pest resistance in response to repeated NPV application.

Other problems included the short shelf-life of NPVs and the need to store them in the fridge. Most farmers have fridges, but some disliked the idea of storing NPV next to food items. (Some locally-produced products have a strong and disagreeable smell). 16% farmer thought NPVs were difficult to apply due to the inconvenience of spraying them in early morning or evening.

The overwhelming problem, especially for the cotton farmers, was the lack of availability and uncertainty over where they would be able to obtain NPVs in the future. This problem will be exacerbated as the last remaining supplies of commercial NPV products disappear from the shops.

78% of farmers thought that NPVs provided good control and in certain cases were advantageous as could be used at the flowering stage when chemicals were not suitable. Other advantages included the long-lasting effects of NPVs compared with chemicals, so that the farmers can spray less frequently and thus save time and money (table 66). As with the other biopesticides, the majority of farmers liked the fact that NPVs were not toxic, so safe for them and for the environment (important for farmers with fish farms, for example).

Table 65: Problems identified by NPV users

Problems identified	Trained farmers (% of 54 NPV products)	Control farmers (% of 10 NPV products)	Total (% of 64 products)
Lack of supply	51.9	80.0	56.3
Slow action	31.5	20.0	29.7
Expensive	25.9	10.0	23.4
Less effective than chemicals	20.4	10.0	18.8
Difficult to store	20.4	0	17.2
Difficult to apply	14.8	20.0	15.6
Ineffective	1.9	0	1.6
Difficult to prepare	1.9	0	1.6
Lack of information	0	0	0
Other	6.1	22.7	4.7

Table 66: Advantages identified by NPV users

Advantages identified	Trained farmers (% of 54 NPV products)	Control farmers (% of 10 NPV products)	Total (% of 64 products)
Good control	75.9	90.0	78.1
Safe, no residues	57.4	60.0	57.8
Long-lasting control	40.7	0	34.4
Cheaper	14.8	30.0	17.2
Easy to use	9.3	20.0	10.9
Seasonal control	3.7	0	3.1
Other	3.7	30.0	7.8

Future Use

Most of the farmers who had used NPVs (91% of trained and 70% of control) said they would use them again (if they were available). There was little difference between those using SpexNPV and those using HearNPV.

Table 67: Percentage of NPV users who would use NPV products again

Trained farmers

Farming system	# NPV products	% products used more than once	% farmers who would use NPV product in the future	
			No or not sure	Yes
Rice	1	100	0	100
Cotton	12	100	8.3	91.7
NE vegetable	4	50.0	25.0	75.0
N vegetable	0	-	-	-
Grape	36	100	5.6	94.4
Fruit trees	1	0	100	0
Total	**54**	**94.4**	**9.3**	**90.7**

Control farmers

Farming system	# NPV products	% products used more than once	% farmers who would use NPV product again	
			No or not sure	Yes
Rice	0	-	-	-
Cotton	6	83.4	33.3	66.7
NE vegetable	0	-	-	-
N vegetable	0	-	-	-
Grape	4	100	25.0	75.0
Fruit trees	0	-	-	-
Total	**10**	**90.0**	**30.0**	**70.0**

Nematodes

Certain entomopathogenic nematode/bacteria complexes can be used as pesticides. When the nematodes infect the insects, the symbiotic bacteria are released into the insect's blood and cause septicaemia. The nematodes used in Thailand are *Steinernema carpocapsae*. These have a broad host range and have some advantage over other types of pesticide in that they can seek out their hosts. They do require a high level of moisture to be effective. The nematodes are specific to insects, with no effects on vertebrates.

The view from the suppliers

Two of the suppliers were private, local companies and the others were the DOAE Biocontrol Centers, all of which supplied nematodes (Table 68). All the nematode products were produced locally and packaged in a similar way. Nematode products have been developed since the mid 1980s, and produced by the DOAE since the mid 1990s.

Table 68: Suppliers of nematode pesticides

Supplier	Type	Main business	Amount of Nematodes produced per annum (tonnes)	Years produced
Public	DOAE	Biocontrol (Head Office)	81,700 bags (total from all centres)	
	DOAE	Biocontrol extension	500	5
	DOAE	Biocontrol extension	na	-
	DOAE	Biocontrol extension	1,400	6
	DOAE	Biocontrol extension	Na	
Commercial	Local producer	Vegetable export, biopesticides	40,000	15
	Local producer	Biopesticides fertilisers	N/a	

Production

Nematodes are reared on larvae such as *S. exigua* or *S. litura*. They are transferred to small pieces of sponge and packaged in plastic bags. The concentration of the DOAE products was said to be 3 million nematodes per pack in some centres, 4 million nematodes in others. The commercial products are 4 million nematodes per pack. The nematodes have to be kept in cool conditions in a fridge and have limited shelf-life of a few months.

The initial source of nematodes for the Biocontrol Centers and commercial producers came mainly from the DOA. Khon Kaen University also supplied inoculum to one centre.

Quantities produced are small. Batches varying from 20 to 100 packets of nematodes can be produced by the DOAE Biocontrol Centers at one time. Costs of production were estimated by the centres as 15-20 baht per pack with a batch run of 100 packs, and 35 baht per pack with a batch run of 20 packs. Total DOAE production for all the Biocontrol Centers was reported to be 81,700 bags per annum.

One of the commercial companies reported produces 40,000 packets in 2001, and could produce up to 8,000 pack per month. Costs of production were estimated at 25 baht per pack.

Quality
Concentration of the nematode products was not measured during the survey. The producers said they carried out visual inspections and bioassay tests in the laboratory before releasing the products to the farmers.

Markets
Both the DOAE and commercial companies supply their nematode products primarily to fruit tree growers. There is a niche market for nematodes to control bark-eating caterpillars on langsat. These pests are difficult to control using chemical insecticides, whereas nematodes have an advantage in seeking out their hosts. Nematodes have also been distributed to vegetable farmers by the DOAE involved in their IPM programmes for control of lepidoptera larvae and coleoptera pests (flea beetles).

Promotion
The DOAE promote use of nematodes through their farmer field schools and IPM training programmes. The commercial companies have given out samples and held farmer demonstrations, especially in the fruit tree growing areas.

Quantities, sales and prices
There is insufficient information from the survey to estimate total quantities of nematodes distributed. One commercial company reported that they made a slight loss on sales of nematodes, and the value of sales in 2001 was about 1.2 million baht.

Nematode products are distributed free to farmers by the DOAE. Retail prices of the commercial products are around 40 baht per pack.

Supply problems

Problems with the formulation process for nematodes were reported, but there were generally fewer problems than with NPV production. Lack of host insects and lack of labour were constraints for the DOAE Biocontrol Centers.

A major supply problem reported was due to the short shelf-life of the product and need to store in cool conditions. Because the market was small it was difficult to match supply and demand and not have old products left that were no longer effective.

Future supply
The commercial biopesticide suppliers (supplying Bt) did not rate the future market for nematode products as very strong, predicting none or small increases only in the demand. None reported plans to expand into nematode products. Therefore it is likely that the future supply will be confined in the short term to the existing suppliers. The DOAE and commercial producer were more optimistic, predicting an increase in sales or distribution. The DOAE Biocontrol Centers based in areas where fruit trees are grown gave a more optimistic opinion than other centres.

The view from the farmers

Users
Fewer farmers had heard of or used nematode pesticides compared with other types of biopesticide. A total of 20 farmers had used nematodes and information was given on 15 products. 49% of trained and 29% of control farmers had heard of nematodes, but only 18% of trained and 2% of control farmers had used them (table 69). The main users were fruit tree farmers growing langsat (in the fruit tree farming system around Chantaburi and in the N vegetable farming system around Chiang Mai). The few vegetable farmers who used nematodes had received them from the DOAE.

Table 69: Percentage of farmers who have heard of or used nematode pesticides

Trained farmers

Farming system	% farmers never heard of nematode pesticides	% farmers heard of, but not used nematode pesticides	% farmers used nematode pesticides
Rice	61.9	28.6	9.5
Cotton	63.6	27.3	9.1
NE vegetable	66.7	0	33.3
N vegetable	42.3	46.2	11.5
Grape	84.6	7.7	7.7
Fruit tree	6.3	50.0	43.8
Total (99 farmers)	**51.5**	**30.3**	**18.2**

Control farmers

Farming system	% farmers never heard of nematode pesticides	% farmers heard of, but not used nematode pesticides	% farmers used nematode pesticides
Rice	92.9	7.1	0
Cotton	58.3	41.7	0
NE vegetable	92.9	7.1	0
N vegetable	78.3	21.7	0
Grape	91.7	8.3	0
Fruit tree	10.0	80.0	10.0
Total (109 farmers)	**70.7**	**27.5**	**1.8**

Knowledge
Over half the trained farmers and two-thirds of the control farmers had no idea what nematodes were. Of those who used nematodes, none said they knew the scientific name *Steinernema*. However, in discussions the farmers described them as like tiny worms, and knew that they attacked larvae. The langsat farmers knew exactly what pests the nematodes controlled, whereas the vegetable farmers were less clear about what the target pests were.

Source & price
Most farmers using nematodes had obtained the products free from the DOAE (table 70). Two of the farmers had been supplied with commercial brands by the DOAE, otherwise the products were the DOAE's own production. Only 2 farmers (one trained, one control) reported buying nematode products from a shop. Two other farmers had received samples direct from the commercial producers.

Table 70: Source of nematode products

Trained farmers

Farming System	# Nematode products	% bought from shop	% from DOAE or DOA	% from Royal Project
Rice	2	0	100	0
Cotton	0	-	-	-
NE vegetable	2	0	100	0
N vegetable	3	33.3	0	66.7
Grape	1	0	100	0
Fruit tree	7	0	100	0
Total	**15**	**6.7**	**80.0**	**13.3**

Control farmers

Farming System	# Nematode products	% bought from shop	% from DOAE	% direct from producer
Rice	0	-	-	-
Cotton	0	-	-	-
NE vegetable	0	-	-	-
N vegetable	0	-	-	-
Grape	0	-	-	-
Fruit tree	3	33.3	0	66.7
Total	**3**	**33.3**	**0**	**66.7**

Reasons for use
The majority of users (67%) were farmers growing fruit trees who used nematodes to control bark-eating caterpillar on langsat. The other farmers who had used nematodes were less precise. Some said they had just tried samples given by the DOAE, others said it was to control larvae such as beet armyworm and flea beetles on a range of crops including tomato, crucifers, soybean, grape. One vegetable farmer was confused, thinking that nematodes would control fungus disease.

Application
Sponges containing the nematodes have to be soaked in water and the nematodes squeezed out into the water so they can be sprayed. Most users (67%) said that the application was more difficult than using chemical pesticides. Apart from the time

taken to prepare the nematodes for application, this was the one biopesticide that a few farmers felt uneasy with because they feared that the nematodes might enter their skin when they were squeezing them out of the sponges.

Effectiveness

Opinions over the effectiveness of nematodes varied (table 71). A few farmers said that they found it difficult to judge whether the nematodes were working, and whether they needed to reapply. The langsat farmers were the most positive about the effectiveness as they knew exactly what pests they wanted to control with the nematodes. The farmers knew that the nematodes would not be effective in the dry season and required moisture in order to work well.

Table 71: Farmers perceptions of ease of use and effectiveness of nematode products

Trained farmers

	Ease of application compared with chemical pesticides (% Nematode products)			**Effectiveness (% Nematode products)**			
Farming system	Easier	Same	More difficult	Immediate	Within 3 days	Within a week	Not or partly effective
Rice	0	0	100	0	100	0	0
Cotton	-	-	-	-	-	-	-
NE vegetable	50.0	50.0	0	0	100	0	0
N vegetable	33.3	33.3	33.3	0	0	33.3	66.7
Grape	0	0	100	0	0	0	100
Fruit trees	0	14.3	85.7	0	14.3	57.1	28.6
Total	**13.3**	**20.0**	**66.7**	**0**	**33.3**	**33.3**	**33.3**

Control farmers

	Ease of application compared with chemical pesticides (% Nematode products)			**Effectiveness (% Nematode products)**			
Farming system	Easier	Same	More difficult	Immediate	Within 3 days	Within a week	Not or partly effective
Rice	-	-	-	-	-	-	-
Cotton	-	-	-	-	-	-	-
NE vegetable	-	-	-	-	-	-	-
N vegetable	-	-	-	-	-	-	-
Grape	-	-	-	-	-	-	-
Fruit trees	33.3	0	66.7	0	33.3	33.3	33.3
Total	**33.3**	**0**	**66.7**	**0**	**33.3**	**33.3**	**33.3**

Problems and advantages

Uncertainty over the effectiveness and the limitations of effect during the dry season were important issues (tables 72 and 73). Farmers did not always know what to look for in order to see if the nematodes were being effective. However, over half the farmers thought that nematodes could provide good control at least in the rainy season. A dislike of the preparation method was reported by one third of farmers. A few farmers (11%) had doubts over the safety of nematodes, but others (28%) liked the fact that nematodes did not have toxicity or residue problems.

Table 72: Problems identified by nematode users

Problems identified	Trained farmers (% of 15 nematode products)	Control farmers (% of 3 nematode products)	Total (% of 18 nematode products)
Less effective than chemicals	33.3	33.3	33.3
Difficult to prepare	26.7	66.7	33.3
Difficult to store	33.3	0	27.8
Lack of supply	13.3	33.3	16.7
Ineffective	13.3	0	11.1
Health risks	13.3	0	11.1
Slow action	6.7	0	5.6
Expensive	6.7	0	5.6
Other	6.7	0	5.6

Table 73: Advantages identified by nematode users

Advantages identified	Trained farmers (% of 15 nematode products)	Control farmers (% of 3 nematode products)	Total (% of 18 nematode products)
Good control	46.7	33.3	44.4
Safe, no residues	33.3	0	27.8
Seasonal control	13.3	0	11.1
Easy to use	6.7	0	5.6
Cheaper	6.7	0	5.6
Other	0	0	0

Future Use

There were mixed opinions about using nematode products again (table 74). 56% of farmers said they would use nematodes again. Those who were not keen to use nematodes again were usually farmers who had little experience of their use and had used them only once.

Table 74: Percentage of nematode users who said they would use nematode products again

Trained users

Farming system	# Nematode products	% products used more than once	% farmers who would use NPV product in the future	
			No or not sure	Yes
Rice	2	50.0	100	0
Cotton	0	-	-	-
NE vegetable	2	100	0	100
N vegetable	3	66.7	33.3	66.7
Grape	1	0	100	0
Fruit trees	7	57.1	28.6	71.4
Total	**15**	**60.0**	**40.0**	**60.0**

Control farmers

Farming system	**# Nematode products**	**% products used more than once**	**% farmers who would use Nematode product again**	
			No or not sure	Yes
Rice	0	-	-	-
Cotton	0	-	-	-
NE vegetable	0	-	-	-
N vegetable	0	-	-	-
Grape	0	-	-	-
Fruit trees	3	33.3	66.7	33.3
Total	**10**	**33.3**	**66.7**	**33.3**

Discussion

Factors affecting the uptake of biopesticides

Many reasons have been advanced to explain the slow uptake of biopesticides, ranging from technical production problems to lack of extension and adverse farmer perceptions of biopesticide efficacy (Lisansky 1997). These factors are considered below based on the findings from the surveys.

Production

Production problems were not a major issue affecting Bt supplies in Thailand, but were important factors for Trichoderma, in terms of quality, and for NPV in terms of costs and quality.

Trichoderma production uses local inputs and requires little specialised laboratory equipment for solid fermentation processes. It can be produced by small, local units, although the resources required are still beyond that of most individual small-holder farmers. However, the quality of samples was variable, indicating a need for improvements in quality control methods that are straightforward to use. Such control methods have been developed (Jenkins and Grzywacz 2000). It is possible that many of the quality problems were due to leaving the Trichoderma too long in inadequate storage facilities. Better storage control procedures are required so that out-of-date, ineffective products are not distributed to farmers. There is a trade-off between cost and quality as implementing quality checks will involve at least additional staff time. However, producing unreliable products will undermine farmers' confidence in the products.

NPV production is a totally different affair from that of Trichoderma, and not something to be entered into lightly, as local producers have found. Although the inputs are low-cost, local products, the production process requires expertise in the mass rearing of insects and rigorous procedures to avoid contamination by unwanted micro-organisms and the associated reductions in NPV yield. It is questionable whether any institution, public or private, should diversify into NPV production without fully appreciating the specialised nature of the production process.

Costs of producing NPVs are higher than simple fungal fermentation products: estimates from producers indicated that one litre of NPV cost 8 times that of one kilo of Trichoderma[14]. It is also more than twice as expensive as the retail prices of older synthethetic chemical insecticides such as methamidophos or endosulfan. The high costs of NPV production have inhibited at least one local producer from entering into local production. There are ongoing improvements in production techniques and formulation that can help potential producers, but as yet, the production costs are likely to remain higher than those of older chemical insecticides and fungal insecticides. The cost of locally produced NPVs may however remain lower than the new generation of insecticides with novel modes of action such as spinosad and chlorfenapyr. While these new chemicals are highly effective their costs are likely to be many times that of the older easily synthesised chemicals (Sparks 2001).

[14] Based on commercial cost of production for Trichoderma

A low-cost version based on collecting insects from the field is unlikely to add much to uptake of NPVs (see *Farmer Production* below).

Quality control remains an issue as the samples collected showed variable and often sub-standard concentrations. Quality problems are not confined to small-scale production and have occurred in commercial products, but are frequent in units that have few staff dedicated to NPV production and lack quality control checks. Sacrificing quality to cut costs is unlikely to work: farmers appear to be very sensitive to changes in quality and will stop using sub-standard products.

Given that the production processes for biopesticides are very different, it is not obvious that producing as many as possible in one centre is the only or best approach. The production of NPVs by every Biocontrol Center or NGO may be over-ambitious, as in practice it is difficult to provide the specialised environment and staff required to produce NPVs as well as all the other macrobials, botanics, biofertilisers and biopesticides. An alternative option would be to concentrate NPV production in fewer, more specialised centres or to obtain NPV from outside sources (as is done for Bt products), while focusing resources on other biocontrol production.

Shelf-life
Short shelf-life is a problem perceived mainly by suppliers, not farmers. If farmers use a product that is out-of-date, they may think it is ineffective and not use it again. They are less likely to worry about why it was ineffective.

The shelf-life of Bt products was not a major concern to Bt suppliers, but the short shelf-life of all the other biopesticides did cause concern to suppliers. Improvements in formulation to prolong shelf-life would be advantageous, but so would improving the distribution pathways to enable biopesticides to reach the farmers more quickly (see *Distribution* below). For the low-cost Trichoderma, NPV and nematode products clear labelling of expiry dates and storage instructions on each biopesticide would be one step towards helping farmers and local DOAE officers avoid using out-of-date, ineffective products.

The short shelf-life of current NPV formulations mean that imported brands have to be brought in by air if made in the USA. This adds further to the products' costs.

Environmental instability
All biopesticide products are less effective in certain conditions such as strong sunlight, dry conditions or heavy rain, and farmers would prefer products that are usable in all conditions. Improving the formulation by, for example, improving the "stickability" of NPVs so they were not washed off in the rain would increase the demand for these products in the rainy season. However, farmers are used to switching between pesticides depending on the season and growth stage of the crop, and this is how many are using biopesticides. Also factors such as rainfastness are also problems for many chemical pesticides, they are not unique to biopesticides. The important issue is that farmers are clear under what set of conditions biopesticides will work successfully. If they know this, they can choose the appropriate time to use them.

Formulation and ease of use

Biopesticides were generally thought as easy to use as chemicals. The one aspect that many farmers complained about was the preparation required for Trichoderma and, to a lesser extent, nematodes. If commercial brands of Trichoderma are to compete with the low-cost packets of inoculated grain, then they would need to be similarly priced or formulated to be significantly easier to apply than the packets of grain. One commercial Trichoderma product is available that can be sprayed, and required no mixing, and there are certainly technologies already developed elsewhere to improve Trichoderma formulations (Jarvis 2001, chapter 6). The durian farmers were particularly interested in a sprayable Trichoderma product, but many vegetable farmers were happy with a product that they could place round the plants..

Farmer Production

For resource-poor farmers, making their own biopesticides from local materials has been suggested as a way to promote biopesticides that are affordable, and enable farmers to take advantage of safe, low-cost and self-reliant methods of pest management (Prior 1989). This approach is in line with government policy and the DOAE and DOA have taught farmers Trichoderma and NPV production as part of their promotion of biopesticides. Some, however, have questioned whether farmer production is always the best option for small-scale farmers (Trip and Ali 2001). Findings from this survey suggest that farmer production might be a useful additional source of biopesticides, but is not the key to uptake of biopesticides generally.

Many Thai farmers are prepared to produce their own inputs, as shown by the number of farmers in the survey who produced their own biofertiliser using fermentation methods. But although farmers said they were interested in producing biopesticides, very few actually did it, and many complained even about the mixing required for Trichoderma. Of those farmers that had been trained and used Trichoderma and NPV, only 36% of Trichoderma users and 8% of NPV users expressed an interest in producing their own products. It should be noted that the two farmers who did produce Trichoderma and SpexNPV had resources not available to all their neighbours such as the space to build a special room for Trichoderma production, or the resources to employ 10 labourers to collect infected insects for NPV.

It would be possible to set up farmers’ groups to produce Trichoderma, if farmers were sufficiently interested and prepared to set a room aside for production. But despite their efforts, the DOAE have not yet convinced many farmers to do this. The amount of support required from the DOAE or other NGOs for these village groups may not be cost-effective compared with the DOAE producing products themselves or obtaining products from the private sector.

In the case of NPVs, a few farmers have successfully made and used their own NPV. However, farmer production is likely to be marginal for a number of reasons. First, farmers may collect infected larvae to extend the use of NPVs, but are unlikely to collect enough to make sufficient NPV for the following season without obtaining additional NPV from other sources. Farmers need to have a suitable area after harvest where the insects can accumulate and be collected – easier with cotton than with grape. Second, farmers may not be as enthusiastic to produce their own pesticide as some would like, despite the savings in cash. Their reluctance may be due mainly to lack of time, but also to doubts whether their product will be as effective as a packaged product, reluctance to allow larvae to accumulate in any area of their land, and possibly distaste at making and storing the NPV. Since the shelf-life is short, it is preferable to buy NPV fresh when it is needed rather then used NPV stored from previous seasons.

Registration
Registration has not emerged as a major issue in Thailand. Commercial companies have not complained of problems in registering their products. The registration process includes testing the concentration of the products and carrying out bioassays, which the companies appear to accept as standard practice as they would with other chemical pesticides. Products that are distributed free through government and NGOs or fall within the micro-nutrients category are not subject to registration, and therefore are not bound to conform to the same quality standards.

Marketing and promotion
Commercial suppliers' views of the market for biopesticides tended to be limited to farmers who grew hygienic or export crops and needed products with no chemical residue problems. Public and NGO suppliers tend to view biopesticides as part of an IPM programme and of interest to IPM-trained farmers. If the promotion of biopesticides is confined to certain groups of farmers with interests in export, hygienic or IPM production, then the market for them will be limited. However, the results of the survey show that other farmers can and will make use of biopesticides. The grape farmers, for example, are heavy users of chemicals and sell into the local market, so are not too concerned with pesticide residues. They use NPVs because they are effective, not because they are compatible with an IPM approach. Durian farmers use Trichoderma because it is effective in controlling *Phytopthora*, not because it has any effect on residue levels on the fruit.

Because of the government's policy of buying biopesticides (mainly Bt) in the 1990s, commercial suppliers initially had an easy time. Their largest customer was the DOAE, who took responsibility for distributing the products to the farmers. With the recent reductions in budget, commercial suppliers have had to work harder to sell their products. Although they do sell to farmers through pesticide dealers the sales have fallen as companies have not fully replaced the loss of DOAE sales with new sales to farmers. Little information was obtained on their marketing strategy for biopesticides, and it appeared that the DOAE and DOA were effectively doing much of the marketing of biopesticides for them. Commercial companies would like the DOAE and DOA to do more in terms of biopesticide promotion, but there appears to be a lack of enthusiasm on the part of most biopesticide suppliers to take the initiative themselves. Local biopesticide producers appear more enthusiastic and have been active in promotion activities such as farmers' demonstrations.

The growth in green products such as biofertilisers and micro-nutrients in Thailand is very noticeable. However, biopesticide suppliers do not seem to have developed links with that market or engaged much with the popular green movement. One exception is the new Bs product, Bioquick, which illustrates a different approach to the biopesticide market. Instead of being packaged as an alternative to chemical fungicides with the aim of disease control, it is packaged as an alternative to fertiliser with the aim of improving plant health. This was the only biopesticide product identified in the survey that was marketed in this way. Possibly because most commercial suppliers sell agrochemicals, they have tended to treat biopesticides as just other types of chemicals. Bioquick illustrates that there are alternative ways of positioning and promoting biopesticides in the market that could be further exploited.

Distribution

Distribution of DOAE biopesticides is cumbersome as the requests from farmers for biopesticides are supposed to be sent via district and provincial DOAE offices before reaching the Biocontrol Centers. This generates delays and means that the DOAE Biocontrol Centers find it difficult to match demand with supply. This leads to shortages of products when they are needed, and oversupply then wastage when they are not. Farmers complain of products arriving too late to be of use to them. For example, requests from rice farmers for help in controlling brown plant hopper can take several days to reach the Biocontrol Center. It then takes 2 weeks to produce the Metarhizium. By the time the product is distributed to farmers it is too late to control the pest. If the Biocontrol Centers anticipate the situation and make up quantities of biopesticides in advance, they risk being left with products that do not store well and have to be thrown away. Unless the distribution network can be improved, farmers will not be able to rely on biopesticides from the DOAE, especially those insecticides required to tackle an urgent pest outbreak.

Perceived effectiveness of biopesticides

Many suppliers are convinced that biopesticides, however carefully produced, cannot match chemical pesticides in controlling pests effectively. The only time when biopesticides can out-perform chemicals is when certain pests become resistant to older chemicals, and the next generation of chemicals are not yet on the market. In this situation biopesticides may fill the gap for a short while. Otherwise, biopesticides are perceived as too slow acting for farmers to prefer them to chemicals. The suppliers appear to take a narrow and short-term view of effectiveness in terms of instant knockdown effects.

Farmers' views were rather different. Although they would prefer a quick-acting pesticide, the immediate effects were not the only criteria important to them. Many took a longer-term view, considering factors such as how long-lasting the control was, how soon they would need to spray again, and what damage might be caused to the flowers and fruit by the pesticide. Using this wider set of criteria for effectiveness, then it is possible for biopesticides to compete with chemical products.

Competition with chemical pesticides

Following on from above, many commercial suppliers think that new chemicals will displace any biopesticides being used. Conversely, many proponents of IPM aim to promote biopesticides as replacements for chemical pesticides.

Farmers who used biopesticides appear to take a more pragmatic view. They see biopesticides as compatible with and complementary to chemical pesticides. The choice is not between biopesticides and chemicals, but is about choosing the best product for the particular circumstances. For example, a vegetable farmer may regularly use Bt to control larvae, but occasionally use spinosad on his crucifer crop if the infestation is great enough to damage the quality of the leaves. A fruit tree farmer may use nematodes on langsat in the rainy season but switch to other chemicals in the dry season.

Cost
Cost is likely to be of most concern for NPV users and producers, since, as mentioned above, the underlying costs of production are high compared with other products. This may restrict the market to vegetable and fruit farmers and exclude many cotton farmers, for example. This still leaves a large potential market, but could exclude the poorer farmers. (The rice farmers who are amongst the poorest are unlikely to use NPVs on rice as it is not a target crop). From the survey findings, 53% of all NE and N vegetable farmers and 65% of all cotton farmers have been prepared to pay over 1,000 baht per kg ($24) for pesticides, but only 12% of vegetable farmers and none of the cotton farmers have paid more than 3,000 baht per kilo ($72). (This is a very rough indication only of farmers' willingness to pay for pesticides) There is no easy way to tackle this, as producing a lower-cost, but ineffective product is of no help at all to the resource-poor farmer.

For the other biopesticides, the costs of production are lower and are within the range of prices paid by the majority of farmers for pesticides. Bt products are more expensive than most pesticides bought by rice farmers, but again, Bt is not of much use against the most important rice pests.

If the DOAE production of Trichoderma and nematode expand further there is a possibility of the DOAE products competing against the more expensive commercial products and undermining the private sector's entry into the market. This is unlikely to be the case currently with such a small level of production, but may become an issue if production expands.

Safety and environmental concerns
The lack of toxicity of biopesticides compared with chemicals was seen as a major advantage by farmers, but it is not clear that safety considerations alone would make farmers choose biopesticides. Most farmers who used biopesticides continued to use highly toxic chemicals, implying that they place other considerations above that of safety. The lack of toxicity make the biopesticides easier to apply from the farmers' point of view.

Environmental concerns were not voiced by many farmers. The few farmers with fish farms were concerned that chemicals could affect the fish and thought biopesticides were preferable in this respect.

Information and training for farmers
Lack of information on biopesticides has been cited as one reason for low uptake of biopesticides. This was a problem identified by suppliers, although not by many farmers themselves. It was clear that those farmers who had had the opportunity to use biopesticides over a number of seasons were more knowledgeable and usually more enthusiastic about using biopesticides, than those who had been participants on a course but not yet had much opportunity to try them for themselves. Both trained and control farmers talked frequently about testing out new products, and it is important to many to observe a new product first (a demonstration on a course, or on a neighbour's field), then try it themselves. Only after farmers have tried the products in different situations, times and dosages on their fields will they decide whether the product is worth using. A course or TV programme is a useful introduction, but not

enough in itself to convince farmers without hands-on experience. If farmers are left without an accessible source of biopesticide and source of advice following an IPM course then they are unlikely to continue to use biopesticides.

It is also important that information given about the biopesticide is specific about the target pest and the effects so farmers are clear about why they are using the product and how to judge its effectiveness. If several biopesticides are introduced as part of an IPM programme there is a danger that farmers may become confused between the different products. For example some cotton farmers did not know the difference between NPV and Bt, and many of the rice farmers were unclear about the effects of fungal pesticides and the difference between Trichoderma and Metarhizium. Also some farmers were confused about how to produce these products, thinking that both Bt and NPV could be made by collecting insects from the field, mixing with manure and then fermenting them. (A mixture of NPV, Trichoderma and biofertiliser production processes).

The most successful extension programmes in terms of uptake were specific and long-term. For example, durian farmers knew exactly why they were using Trichoderma and had support available over several years from the DOAE. Once farmers are familiar with using biopesticides, they are often the best people to promote the technology to surrounding farmers. Since farmers obtain a large amount of information on crop protection from their neighbours, the technology will spread if it is seen to be successful and the products are available.

Farmers did not appear interested in the biology behind the biopesticides. This implies that information should be focused on practical questions of why, when and how a biopesticide should be used, rather than the focusing in detail on the scientific background.

Overall, the fact that over 80% of the control farmers had heard of one or more biopesticides indicates that promotion efforts, primarily by the DOAE and DOA, has raised awareness of biopesticides. However, training farmers is not a short-term affair. Sustained support over several seasons focusing on one particular biopesticide and its use is likely to be more effective than short, more general courses covering a range of biopesticides and other bio-agents.

Type of farmer
The suppliers had varied views over the type of farmer they expected to use biopesticides, but agreed that vegetable farmers were a major target for marketing. Certainly, vegetable farmers can make use of all the different types of biopesticide. Bt and Trichoderma are being promoted, but there is also scope for use of NPVs if the supply could be expanded. Nematodes have yet to be fully proved as effective on vegetable farms. Rice farmers are the least likely to use biopesticides, partly because commercial products are too expensive, but mainly because the current set of biopesticides have little to add to a rice farmer’s pest management. Bt, Trichoderma, NPVs and nematodes do not control pests of great economic importance to rice farmers. The one exception might be Metarhizium if it can be shown to be effective against brown plant hopper. Rice farmers would require a low-cost product and it is vital that the supplies are timely if they are to be of any use to the farmers.

If Bt-cotton were to be successfully introduced, this would negate the need for Bt and change the market for NPVs amongst cotton farmers. This possibility is remote though, and these farmers are potential biopesticide users[15]. However, unless farmers are able to obtain further supplies of biopesticides, and to have access to advice, the training that some of them have received on biopesticides may be wasted.

In terms of demographic characteristics, there was little to distinguish the farmers using biopesticides from those who did not. It is true that those more likely to receive training from the DOAE were farmers who had organised themselves into farmer groups. However, no significant differences in age, education, gender or size of farm could be identified between users and non-users.

The role of government

In Thailand the public sector through the DOAE, DOA and universities have provided considerable support for biopesticides in terms of research, production, promotion and training. There have been linkages between public and private companies in terms of advice and government loans. The uptake of biopesticides so far has been due more to the efforts of the public sector than the private sector.

The current policy is focused on low-cost production of as wide a range of biopesticides as possible through the Biocontrol Centers. However, even with increased facilities, it is unlikely that these centres would be able to supply enough biopesticides to reach the majority of farmers. If use of biopesticides is to expand, then more private producers need to be encouraged to enter into production of biopesticides. Out-sourcing some biopesticides to the private sector, rather than trying to produce everything within the public sector, plus providing information and advice on production methods, potential markets and farmers' attitudes to different biopesticides could be a useful step in encouraging private producers.

Continuing training of farmers is an important role for the public sector, but as noted above, longer-term, specific training on individual biopesticides may be more effective than trying to introduce many new ideas and products over a limited time.

Characteristics of successful uptake of biopesticides

From the survey results, three examples of uptake of biopesticides can be identified as particularly successful in that a) a significant number of trained farmers continue to use these biopesticides and b) the technology has spread to some of the surrounding farmers. These examples are: use of Bt by farmers growing vegetables around Chaing Mai; use of SpexNPV by grape farmers and use of Trichoderma by durian farmers. Although the biopesticides used are different in each case, there are a number of common factors that are likely to have contributed to the success.

1. Inadequacy of chemical pesticides

In each case, chemical pesticides were not effective or did not meet the farmers' requirements. For the vegetable farmers, chemicals were increasingly ineffective against diamondback moth and beet armyworm. Also farmers growing hygienic

[15] In Australia the introduction of Bt cotton has facilitated an expansion of NPV use as HzNPV is used in the resistance management strategy to reduce selective pressure on Bt and prevent resistance build-up.

vegetables required methods which left no pesticide residues prior to harvest. Alternatives, in the form of new chemicals were more expensive than Bt. Similar considerations were true for grape farmers, who were finding it difficult to control beet armyworm. Durian farmers had tried and often failed to control *Phytopthora* with fungicides.

2. Clear target pests and reasons for use

Farmers in all three examples knew exactly what they wanted to control and therefore, what to look for in assessing the results.

3. Long-term supplies, support and experience

Farmers were able to obtain supplies of the biopesticide over several years, either from dealers (Bt for vegetable farmers) or the DOA (SpexNPV for grape farmers) or the DOAE (Trichoderma for durian farmers). They could turn for advice from the same sources as well as experiment themselves over a period of time.

4. Long-term view

Farmers were under no illusions that biopesticides were the quickest way of controlling pests. They were prepared to use them for a variety of reasons: to extend the useful life of other chemicals by alternating them and delaying development of resistance (vegetable farmers); to provide longer-term control so reduce the spray frequency (grape farmers), or to wait for several weeks to see signs of new root development (durian farmers).

5. Complements to chemicals

All the farmers used chemicals and, with very few exceptions, were not looking to replace chemicals by biopesticides. Biopesticides were an additional tool in their pest management strategy: a way of adding a longer-term, more sustainable method to the quicker, more immediate chemical control.

These characteristics indicate that, from the farmers' point of view, uptake of biopesticides does not depend on whether they are supplied by private or public organisations, nor whether they are promoted as part of an IPM approach. It depends on whether individual biopesticides can add significantly to long-term pest management methods.

Issues

What type of organisation is the most effective in producing biopesticides?

With so few local, commercial producers of biopesticides it is difficult to draw many conclusions about the most effective type of production, other than noting that the answers will differ for the different types of biopesticides. It should not be expected that one type or size of producer would be appropriate for all biopesticides. Since the production processes for each biopesticide require very different skills and equipment (fermentation methods for Bacteria and fungi, mass rearing of insects for NPVs and nematodes), it cannot be assumed that the same producer can produce any biopesticide with equal success.

In general, the more sources of biopesticides and the wider the range of products and producers, the better for the farmers. Current policy in Thailand places the emphasis on local, low-cost production through the Biocontrol Centers and farmer production. This approach has many benefits in allowing resource-poor farmers to try biopesticides. However, the very small-scale, low-cost route is not necessarily the only or best option for every type of biopesticide. If quality is compromised in an effort to keep costs down then this will undermine the uptake of biopesticides in the long term. Farmers, particularly resource-poor farmers, cannot afford to buy biopesticides that are not effective, however cheap they are.

A pragmatic policy towards biopesticide production may be the most useful for farmers, promoting specialised plants for biopesticides where economies of scale or specialised procedures are required (Bt, NPV, some Trichoderma products and possibly nematodes) and small-scale low-cost production where appropriate (Trichoderma, Metarhizium, possibly nematodes).

Is IPM the only approach?
Biopesticides are often promoted as part of an overall IPM programme. Of course, biopesticides fit with IPM objectives of sustainable agriculture, but the promotion of biopesticides can be pursued separately as well as with IPM for two reasons. Firstly, biopesticides can be of interest to farmers who do not consider themselves interested in IPM, because they are heavy users of chemicals. Secondly, if biopesticides are presented within a package of other bio-agents and crop protection methods, there can be a problem where farmers are not sure of exactly what the biopesticide is supposed to do, cannot distinguish its effects, and confuse the different biopesticides.

What is the future for biopesticides in Thailand?
Future views of the biopesticide market in Thailand have been mixed, with the public sector taking a much more optimistic view of growth than the commercial companies. Apart from Bt products, the large agrochemical companies are unlikely to diversify into other biopesticides in the near future, especially when they are facing mergers and a downturn in sales globally. There are opportunities for local producers to enter the market with technical advice and support from the public sector. If the public sector through the DOAE continue to promote biopesticides, but also encourage private production (possibly through out-sourcing some biopesticides to the private sector), then uptake amongst farmers may continue to increase.

Biopesticides are unlikely to be used amongst rice farmers (unless Metarhizium proves very effective against brown plant hopper), but there is a potential market amongst the large numbers of vegetable and fruit farmers.

Conclusion

This study has covered both public sector and private biopesticide suppliers and a range of farmers from different farming systems. There is evidence that farmers will choose to use biopesticides where these products provide farmers with effective long-term pest control. Use of biopesticides is viewed by most farmers as complementary to the use of chemical pesticides rather than as replacements for them.

The supply of biopesticides is currently problematical, as the private sector has been less than enthusiastic about strongly promoting biopesticide products, preferring to follow the public sector rather than take the initiative. There are few local producers. The public sector through the regional Biocontrol Centers are seeking to expand and promote low-cost biopesticide production, but there is also a need to encourage private producers to supply those biopesticides that require more specialised production.

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