CROP PROTECTION PROGRAMME

Project Title: An evaluation of the promotion and uptake of microbial pesticides in developing countries by resource-poor farmers.

R7299 (ZA 0263)

FINAL TECHNICAL REPORT

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Abbreviations

Bs	*Bacillus subtilis*
Bt	*Bacillus thuringiensis*
BV	*Baculoviruses*
CBO	Community based organisation
CFU	colony forming unit
DFID	Department for International Development, UK
DoA	Department of Agriculture, Thailand
DoAE	Department of Agricultural Extension, Thailand
EIA	Environmental impact assessment.
HearNPV	*Helicoverpa armigera* Nucleopolyhedrovirus
HzNPV	*Helicoverpa zea* Nucleopolyhedrovirus
IPM	Integrated Pest Management
NGO	Non governmental organisation
NPV	Nucleopolyhedrovirus
NRI	Natural Resources Institute, UK
OB	Oclusion body (infective particle of BV or NPV)
PIB	Polyhedral inclusion bodies (infective particle of NPV)
SpexNPV	*Spodoptera exigua* Nucleopolyhedrovirus
WHO	World Health Organisation

Conversion

£1 = 60 baht

Executive Summary

A very brief summary of the purpose of the project, the research activities, the outputs of the project, and the contribution of the project towards DFID's development goals. (Up to 500 words).

This project was a short one-year project to study the promotion and uptake of microbial pesticides in Thailand and derive lessons that could be of use to other CPP projects. This study was linked to a similar parallel study in India but due to delays in getting approval from the Indian authorities that phase has been delayed. The project carried out probably the largest ever survey of the use of microbial pesticides in a developing country including producers, dealers and farmers. It also completed literature based environmental impact assessment (EIA) studies on two major microbial pesticides Bacillus thuringiensis (Bt) and nucleopolyhedrovirus.

Thailand developed and implemented a number of different models of microbial pesticides supply including state sector production, private company local production, and importation and farmer own production. State and private production have developed as local and sustainable solutions though not without problems concerning quality and distribution. Private sector has been prominent both in supplying and educating farmers about new technologies but has had problems establishing production of some of the more technically demanding products. Importation was effective but sustainability is a problem in the face of macro-economic problems. Farmer own production has shown relatively little progress.

Thailand has developed a flexible and effective registration system but quality control is still a problem with locally produced Trichoderma products with some state sector and local production initiatives. Suppliers generally see a positive future for Bt, Trichoderma and NPV but are less certain of future growth in entomopathogenic fungi and nematodes.

Microbial pesticides have been successfully promoted to small farmers, mainly in systems where pest/disease resistance has made chemical alternatives increasingly expensive and or unreliable. Farmers in Thailand generally show a high level of satisfaction with the new microbial pesticides and would use again especially the Bt (83%), fungal antagonists (Trichoderma spp. 80%) and NPV (60%). A minority of users though also recognise technical shortcomings with the current generation of microbial pesticides that will require further technical development to overcome. Bt is undoubtedly the most successful microbial pesticide reflecting its longer history of development, greater private sector investment, inherently faster action and good storage characteristics. NPV and Trichoderma though promising still have significant shortcomings in storage stability (NPV & Trichoderma) and speed of action (NPV).

This survey contains a detailed data on both producer and user attitudes to new microbial pesticides their uptake and promotion. This data will be of relavence to any aid projects or researchers attempting to introduce new environmentally friendly crop protection technologies to resource poor farmers developing countries.

The EIAs concluded that both Bt and NPV are safe crop protection technologies whose use poses none of the environmental and health problems often associated with the use (and abuse) of chemical pesticides in developing countries.

Lessons are drawn from this study to assist other developing countries in their programmes to develop safer more sustainable crop production, though the eventual

completion of the planned study in India is expected to significantly increase their scope and reliability.

Background

The use of chemical pesticides by resource-poor farmers in developing countries is widespread, particularly on vegetables, fruit and fibre crops (Harris 2000, Oruko and Ndun'gu 2000). The common overuse and misuse of chemical insecticides while providing a short term solution to pest problems has over time led to very significant problems of pest resurgence and resistance. Thus farmers in developing countries face growing difficulties in controlling pests such as cotton bollworm and diamond-back moth which have become resistant to existing chemical control. The increasing costs and unreliability of chemical control, as well as increasing concern about crop residues, threatens the sustainability of agricultural production in many countries of Asian and Sub Saharan Africa.

In addition, the hazards to human health of applying toxic chemicals, though widely underreported, are very significant for rural workers in developing countries. Poorly enforced safety legislation, inability to afford protective equipment and lack of training expose the poorest farmers and farm workers to the dangers of pesticides. In some areas 80% of such workers have reported experiencing pesticide poisoning symptoms (Harris 2000). In addition, massive overuse of pesticide in intensive farming systems is a major cause of watershed pollution and environmental degradation.

It has been recognised that there is clear need to provide farmers with crop protection tools that are less hazardous to their health and to the environment and are less likely to cause pest resurgence and insecticide resistance problems.

Microbial pesticides (or biopesticides), those pesticides based upon an active ingredient that is a micro-organism (bacteria, virus, fungi or nematode) have for many years been considered as promising alternatives to synthetic chemical pesticides especially for developing country use (Prior 1989).

Aid donors including DFID have invested significant sums in the development of microbial pesticides. Examples include fungal agents for grasshopper control (LUBILOSA), insect viruses for cotton and vegetable pest control, bacteria for pest and disease control. The CPP and CPHP has also supported the technical development of a number of MPs including granulovirus for control of diamond back moth in East Africa (R6615), bacteria for root knot nematode control (R7472) ,NPV for bollworm and podborer control in India (R5540) and Nepal (R7885), and fungi for stored pest control in Africa (R6773). While these sums are very small compared to the investment of private industry in synthetic chemicals they do represent a significant investment by these programmes.

In recent years technical progress in a number of these CPP projects has brought a number of these technologies to a " near market" state. However while research on the technical aspects of MPs has been advancing there has been relatively little work on the socio-economic understanding how best such technologies should be promoted, produced and delivered to target groups of resource poor farmers. There have also been few studies of farmer's attitudes to and acceptance of new microbial pesticides.

An earlier DFID-funded review of the literature on use of microbials in developing countries identified that little information was available on farmers' use of microbials or of their demand for these products (Warburton 1995). It was also noted that generally microbials are not identical substitutes for chemical pesticides as their mode of action and conditions of use differ. Uptake is therefore more complex than just substituting one formulation for another and may involve a need to change approaches to application and to the perceptions of efficacy by the farmers, extension services and pesticide suppilers. The need to develop special marketing strategies involving improved education and information for microbial and other biological pesticides in order to focus users on their advantages has also been pointed out (Straus & Knight 1997)

Research on developing microbial pesticides as alternatives to chemical pesticides and targeted at developing country pests has a long history. Burges (1981) comprehensively reviewed the earlier scientific progress of microbial pesticides and more recent review articles by Jones et al. (1993), Whitten and Oakenshot (1991) and Hunter-Fuijita et al. (1998) specifically focus on microbial pesticides developments in Asia, South America and Africa. However while much research effort has been directed at the agents themselves and the technicalities of how they may be used for pest control, much less has been concentrated on the mechanics of how to develop these discoveries into practical products and promote their use by farmers. Indeed lack of information on the essential downstream steps to developing microbial pesticides has been recognised as a global problem in developing alternative biological controls (Harris and Dent 1999)

Important questions about what developing country crop systems microbial pesticides are most effective in, what type of agents are acceptable to farmers and which types of pests and diseases they best control are crucial to decisions on where, if and how to support the promotion of microbial pesticides.

The production of microbial pesticides in developing countries was seen as a major advantage of these agents as it would provide developing countries with local sources of crop production inputs at reduced cost and stimulate local agribusiness (Prior 1989). Most microbial pesticides can be produced in low technology systems very different to the capital-intensive synthetic chemical production that is generally beyond the resources of developing countries.

However there was no recent review of the actual success in establishing such local production of microbial pesticides that would draw lessons on the viability in practice of setting up local production. Or that would suggest appropriate mechanisms for production that would best enhance the access of resource poor farmers to these new technologies. There have been reviews of some recent success stories with microbial pesticides (Moscardi 1999). Microbial pesticides themselves have been the subject of reviews on their role in contemporary crop protection (Jarvis 2001, Lisansky 2000), though this concentrated on commercial products produced in developed countries. The production of a new British Crop Protection Council “The Biopesticides Manual” exclusively devoted to Biopesticide products is an indication of the increasing commercial interest in such products. There has also been discussion on the relative merits of promotion of microbial pesticides through private sector, state sector, NGOs, CBOs and farmer own production (Waage 1997, Lisansky 1997, Tripp and Ali 2001). However data on existing promotion programmes and the success or otherwise of different agents and approaches to promotion in developing countries was lacking.

Given the CPP focus on promotion of new non chemical technologies, it was felt that a case study of developing countries were microbial pesticides were being actively developed would be extremely valuable in providing information to guide future donor policies on developing and promoting MPs and other biological control technologies. This study would be based on extensive survey of users, producers and suppliers of microbial pesticides as an example of how a new technology has been promoted. It would also look at promotion policies and mechanisms to identify cases of good practice that could be transferred to other promotion projects in the future. However in evaluating the acceptance of different biopesticides it was recognised that quality was a significant problem particularly for locally produced products (Grzywacz 1995, Kennedy *et al*. 1998, Jenkins and Grzywacz 2000). Therefore a survey of product quality would also need to be included in the study in order to interpret the survey findings.

A feasibility study in 1999 funded by the CPP identified that such a study could be carried out in two Asian countries, India and Thailand (Warburton and Grzywacz 1999). In both countries DFID funding had been used previously to help develop and establish nascent microbial pesticides industries through TC programmes (Thailand T0066, 1991-93) and later CPP (India R5540CB, R5290, 1993-1997, Thailand R5290, R61611993-1995). In these countries a number of different models of promotion and development were being pursued. In India there was a larger role for local private sector producers with no importation while in Thailand importation and state production were pre-eminant. NGO and farmer production also seemed to have ahigher profile in India though also existed in Thailand. It was felt that a study of both could produce both the first truly data based studies on microbial pesticides promotion to farmers and very useful insights into the consequences of different promotion policies.

As part of this study it was also proposed to conduct an environmental impact assessment of microbial pesticides. While claims that microbial pesticides are much less environmentally damaging than synthetic chemicals are made there had been no recent studies that have reviewed the evidence. Some classes of microbials, such as baculoviruses, have been subject to extensive safety or environmental impact assessments, though not recently (Laird *et al.* 1990) however most of this has focused exclusively upon human safety aspects. There were some older studies of the side effects of microbial pesticides on non-target faunal biodiversity (Groner 1986). But the absence of recent evaluation of the environmental impact of microbial pesticides was a significant hindrance to developing policy for promoting microbial pesticides in developing countries such as those in East Africa (R7449 & R8217) and in West Africa (R 7960). Local regulatory and extension organisations lack expertise on the safety issues relating to microbial pesticides and this is a significant hindrance to them in deciding how to adopt microbial pesticides or developing appropriate regulations. The inclusion of an EIA study in this project was therefore felt to be of considerable value in implementing the uptake of key CPP projects currently underway.

An EIA of MPs such as baculoviruses is one of the most common requirements of developing country governments considering registering novel microbial pesticides (Cherry 2002). Typically developing country governments lack both the information and technical expertise to evaluate the environmental issues associated with new biological control technologies. The local companies that develop new microbial products are often small to medium enterprises that do not have the expertise and resources to alone develop EIAs for their candidate products. In the absence of appropriate guidelines and expertise developing country governments often fall back on blanket adoption of chemical registration protocols that are both inappropriate for natural biological control agents and so costly as to prohibit local development.

By producing an independent EIA on candidate microbial pesticides this would assist companies and governments to develop appropriate and cost effective registration packages for new commercial microbial pesticides currently under development by several CPP projects including R8217 (Production of baculoviruses), R8044 (Pest of potato Bolivia) and R7960 (West Africa biopesticides).

The CPP gave its approval for the current project in June 2001. Howeverthe responsible authorities in India the Indian Council of Agricultural Research (ICAR) was still processing final approval for the Indian component of the project. It was decided therefore to proceed with the Thailand phase of the project starting in mid 2001. This report covers only the work completed in Thailand. ICAR approval to extend the work to India has since been received as part of a larger study of biological control.

Project Purpose

The purpose of the project and how it addressed the identified development opportunity or identified constraint to development.

To secure and enhance the incomes and livelihoods of small rural and peri-urban farmers by developing improved policies for the promotion of safe and environmentally friendly crop protection agents' base upon natural biological control agents.

Research Activities

This section should include detailed descriptions of all the research activities (research studies, surveys etc.) conducted to achieve the outputs of the project. Information on any facilities, expertise and special resources used to implement the project should also be included. Indicate any modification to the proposed research activities, and whether planned inputs were achieved.

The main research activity was a survey of biopesticide production and use in Thailand carried out in collaboration between NRI and the Department of Agriculture (DoA) Thailand. It had been planned in the original PMF to carry out a parallel study in India at the same time. However ICAR approval for the Indian phase of the project was only obtained in summer 2002 after the Thailand component had started. The Thailand component was therefore carried out as a stand-alone study between December 2001 and March 2002.

The survey tool was developed in outline as part of the previous feasibility study but refined during the preliminary fieldwork during this project. A copy is attached in Appendix 1. It was drawn up in consultation and with Drs Ian Wilson and Savitri Abeyasekera at the Statistical Services Group Reading University. Data was collected from 16 microbial pesticides suppliers or pesticide dealers and 208 farmers were interviewed.

Its objectives were 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. To 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. To 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. To evaluate in the laboratory the biopesticide products used by the farmers to acertain quality.

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 copy of the survey tool is attached as Appendix 1. 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. Four pesticide dealers were also interviewed in different locations in order to gain additional information on how biopesticides were being distributed and sold.

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 their preferrence.

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).

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. Farm sizes of the survey participants varied between different location s and crops but tended to be smaller for the vegetable farms (1.3-2 ha) and fruit farms (1.6-3.2 ha) than for the cotton (6-7 ha) or rice (3-5 ha) farms. Therefore almost all farms were less than 10 ha and many less than 3 ha so could all be described as small farms. The majority of the farmers were men but 30% of farmers were female.

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.

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.

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. These used standard techniques for enumerating insect viruses and fungi (Jenkins and Grzywacz 2000), bacterial pesticides were counted using viable count technique to enumerate viable spores (Hunter-Fuijita et al 1998).

The project was approved in June 2001 with an original end date of 30 March 2002. However due to disruption at NRI caused by institutional restructuring that began in July 2001 (two out of the three project staff named in the PMF had left NRI by the end of the project), completion was delayed until December 2002. The socio-economic fieldwork was carried out in Thailand between December 2001 and March 2002 by a seven-person team from DoA and NRI.

The EIA was carried out as a desk study of available literature. This concentrated specifically on baculoviruses and Bt as the use of these two comprises >90% of the current use of MPs (Jarvis 2001). EIAs of other minor MPs, other insect viruses, entomopathogenic fungi and nematodes were not included in this study for reasons detailed in section 2.1.

Outputs

The research results and products achieved by the project. Were all the anticipated outputs achieved and if not what were the reasons? Research results should be *presented as tables, graphs or sketches rather than lengthy writing, and provided in as quantitative a form as far as is possible.*

The research results of this phase of this short project have been achieved, though not without significant but unavoidable delays. The survey represents the largest survey of developing country users of new microbial pesticides yet completed. A full report on the survey results is attached as appendix 2. The EIA of baculoviruses and Bt was completed and represents the first EIA of baculoviruses in general since the review by Groner (1986). These are attached as appendices 3 & 4.

It had originally been intended that this study of microbial pesticides in Thailand would be linked to a similar simultaneous study in India. However delays in getting final approval for the Indian phase prevented the Indian phase from getting underway before this phase was completed. Thus the data collected from Thailand and the results and conclusions (outputs 3 and 4) should be seen as preliminary findings that will be modified in the light of the much larger and more comprehensive study due to start in India in late 2002. The importance of the India phase was that it represented a very different model of uptake and promotion with a much larger role for the local commercial sector as producers of MPs. Thus the India survey, both because of the larger scale of microbial pesticides operation there and the greater local production element, was always considered to be the most productive component of the project.

Output 1. An evaluation of the technical, environmental and socio-economic factors which affect the sustainable use of microbial pesticides by resource-poor farmers.

The status of microbial pesticides in Thailand

The survey confirmed that microbial pesticides have seen significant adoptedion in Thailand although the scale of use is different for different classes of microbial pesticides (Table 1) and not all are produced locally. Local production of Trichoderma was established in 1986 and NPV in pilot form before1990. Some B.subtilis is produced localy but local Bt production has yet to be fully established.

Table 1 The use of microbial pesticides in Thailand

Microbial pesticides	1994	1998	2002
Bt	101 tons	90 tons	54 tons
B subtilis	NA	NA	1 ton
NPV	1.0 ton	6.0 tons	7.0 tons
Trichoderma	NA	NA	263 tons
Metarhizium	NA	NA	600 Kg
Nematodes	NA	NA	120,000 sachets (5g each)

N.A. not available

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. While originally a number of these programmes received forign donor aid all are now fully funded by the Thai Government. 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

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 (£750,000)	Important	Macrobials Botanicals Biofertliser
DoA Biological control section	Research & development of biological control	2.3 million baht (£38,000)	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 centers provide expertise in pest management to local DoAE offices. 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. The biopesticides are usually distributed free or at very low cost to farmers.
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.

The Department of Agriculture

The DoA Biological Control section specialise in the research and development of macrobials (predators and parasites) 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 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.. As part of this project, researchers at the University of Chiang Mai, 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. Researchers at Chiang Mai University introduced the Trichoderma technologies to the Royal Project.

It can be seen Table 4 that attempts to induce take up of microbial pesticides in IPM trained farmers have yielded significant results although in untrained farmers microbial pesticides use is still a minority activity.

Table 4 Farmer use of MPs in sample groups interviewed.

	Bt	NPV	Trichoderma	Nematodes
IPM trained farmers	40%	31%	66%	18%
Untrained	16%	8%	14%	1.8%

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. 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 baht	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

60 Baht = £1

All the public suppliers distribute biopesticides directly to farmers. The DoAE liaises directly with farmers identifying demand. 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 limited shelf life of current DoAE products also causes distribution problems. 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.

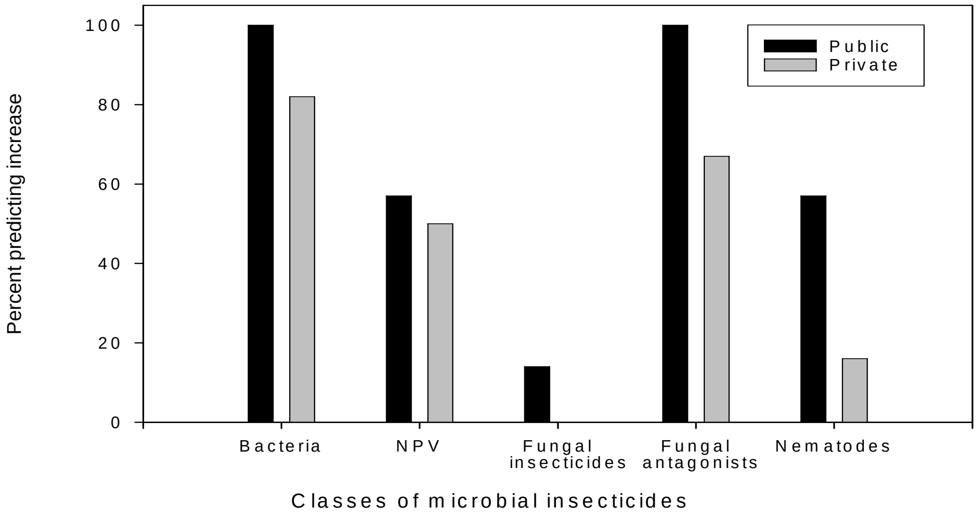
Most of the commercial suppliers sell their biopesticides through existing pesticide dealer networks. The local producers have fewer, selected outlets and concentrate on locations where there is demand for their products. Two companies sell direct to the DoAE and DoA. The resulting distribution of biopesticides means that some form of Bt product is available throughout the country, but availability of other biopesticides is extremely limited.

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. All the commercial suppliers and producers produced leaflets on their products and advertised their products through their dealers. 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.

The future of the biopesticide market in Thailand

Fig 1 respondants amongst public and private suppliers who predict a significant increase in microbial pesticides market for different classes of microbial pesticides



Opinions about the future success of biopesticides were mixed. The public sector suppliers were more optimistic about future uptake of all biopesticides than the private sector. The most successful biopesticides were expected to be bacteria, primarily Bt, fungal antagonists such as Trichoderma and NPV by both public and private suppliers. Fungal insecticides were not expected to be successful and the outlook for nematodes showed a sharp difference between private and public sector.

Supply of biopesticides 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.

Recommendations to increase uptake of microbial pesticides

Suppliers both private and public were asked the recommendations on promoting biopesticide uptake. 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.

Recommendations from the private suppliers were included the need to increase research and development funding in order that producers have better formulations, longer shelf-life and quicker acting products.

Farmer perceptions of microbial pesticides

The farmers involved in the survey had a wide variety of crop protection problems they identified as important (see table 6).

In cotton vegetables and grapes a major group of pests were the Lepidoptera including Diamond back moth (DBM, *Plutella xylostella*), Beet armyworm (*Spodoptera exigua*) and cotton bollworm (*Helicoverpa armigera*). All of these are particular targets for novel control because they show high levels of resistance to many chemical insecticides. This group have shown a capacity to rapidly develop, within 2-3 years resiatance to any newly introduced chemical insecticides. Atempts to control these often lead to farmers massively overusing chemicals and using them as mixtures at very high application rates. Indeed farmers found it necessary to spray every 2-3 days as only the earlyiest larval stages were susceptible to chemical insecticides leading to major problem of chemical residues on crops as well as environmental contamination and worker poisoning (Harris 2000). Frequently this overuse then leads to serious seconmdary outbreaks of leaf miner, mites, thrips and aphids as natural enemy control of these is disrupted by the overuse of broad spectrum insecticides.

Microbial pesticide solutions developed by the DoA and DoAE for these pests include *H.armigera NPV* (HearNPV), *S.exigua* (SpexNPV) and Bt for DBM. These have all shown themselves very promising. However DBM is still a problem as uncontrolled unplanned use of the new Bt by farmers against DBM in the late 19990's, because all chemicals had ceased to work, has resulted in DBM resistance to Bt as well.(D Wright pers comms.). Although there is evidence that resistance to some microbial pesticides such as NPV is slower than to chemicals (Moscardi 1999) this is certainly not true of others like Bt. This reinforces the need to introduce microbial pesticides as part of a conscious resistance management strategy employing a variety of controls (biological, cultural and chemical) in an integrated package to prevent resistance build up.

Table 6: Main pest & disease 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
North East Vegetable	Beet armyworm, diamond back moth, flea beetle, thrips, aphids Fungus diseases	Cypermethrin, tebufenozide, monocrotophos, methomyl, abamectin, deltamethrin Carbendazim, mancozeb Biofertiliser, neem extract
North 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

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 were interested in a natural approach to agriculture.

All the farmers were asked about the biopesticides they had heard of or used. Overall 92.9% of trained and 32.1% of control farmers had used at least one biopesticide or biopesticide brand name. Only 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.

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.

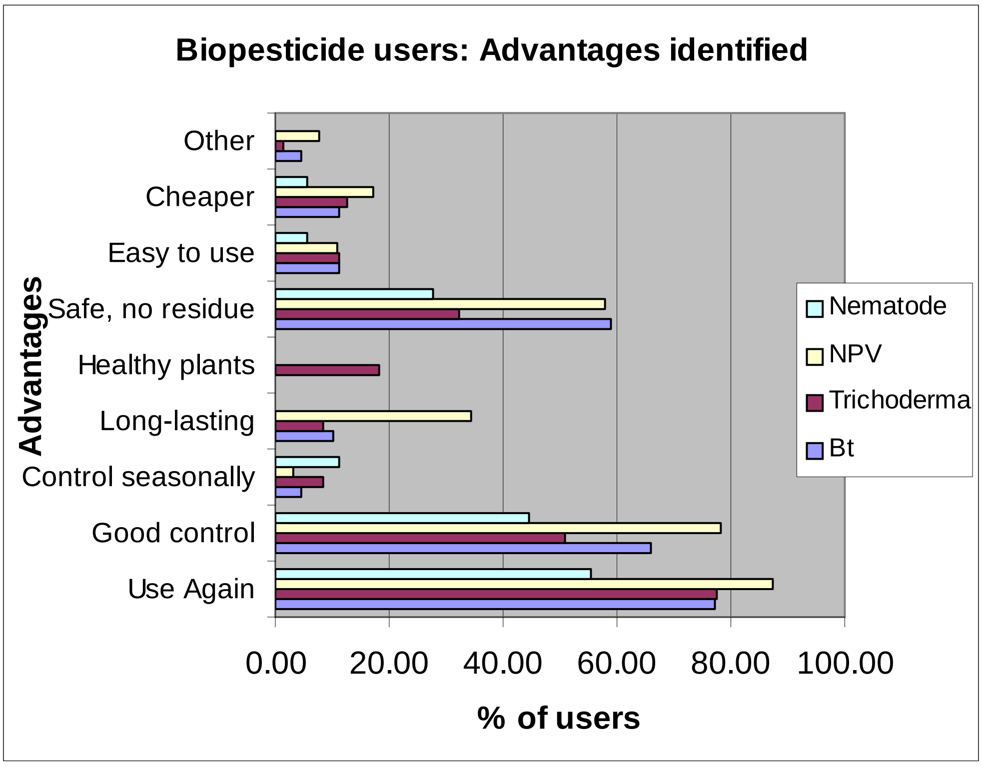
Table 7. Satisfaction of farmers who used MPs

	% satisfied with	% use again

	performance	
BT	98	83%
NPV	95	60%
Trichoderma	85	80%
Nematodes	66 (small sample n = 18)	60%

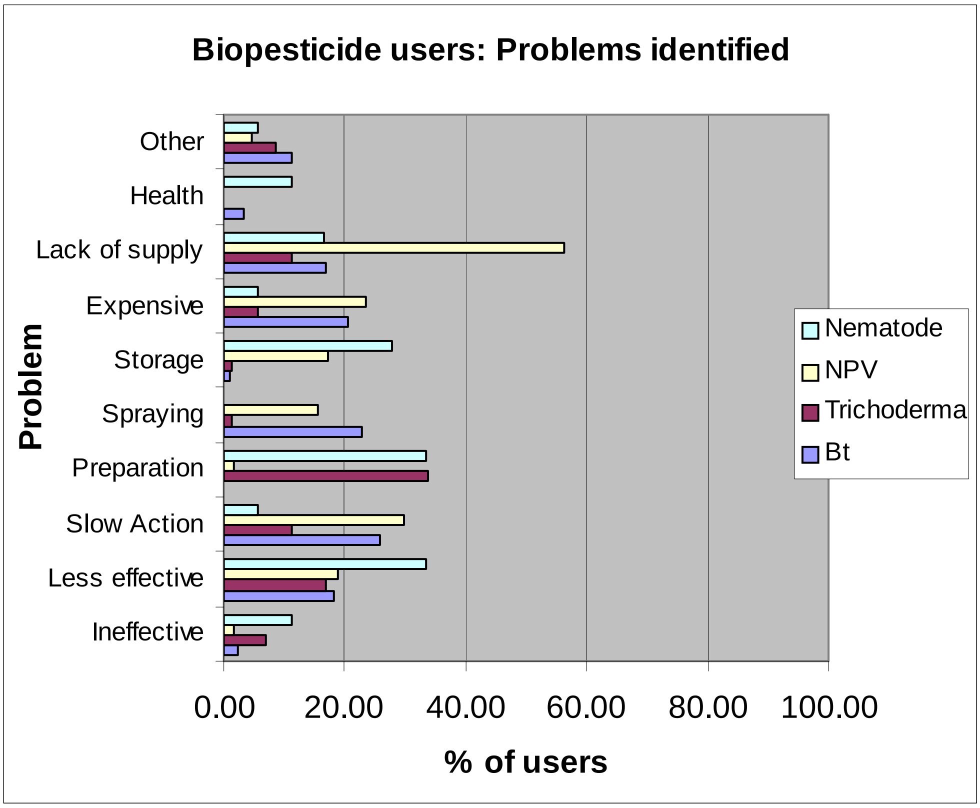
The above figures show a remarkably high satisfaction rating for Bt, NPV and Trichoderma and a willingness to use again. The results for Nematodes are perhaps less reliable as the sample size was very small (number of farmers = 18).

Fig 2 Biopesticide users advantages identified



The advantages farmers identified for using microbial pesticides are very interesting and are shown in Figure 2 and include good control, no worry about chemical residues and for NPV recognition by some users that they are long lasting compared to chemicals. Overall willingness to reuse was over 70% for all groups with the exception of the entomopathogenic nematodes.

Fig 3 Biopesticide user's problems identified



The problems identified were slower action, extra preparation time (nematodes and Trichoderma) and difficulty in supply (NPV). The supply problem with NPV is that as importation agreement for the commercial NPVs has lapsed local supply is now inadequate for demand.

This list of perceived problems does identify several areas where the technical capabilities of the current generation of microbial pesticides available in Thailand are a limitation. The current NPV formulations in production need refrigeration for long term storage, are slower in action than chemical alternatives. A major expansion of their market will probably not be possible until products that overcome these limitations are developed and available in Thailand.

Table 7 Use of MPs by IPM farmers in different cropping systems % who had used different classes of agents by cropping system

	Bt	NPV	Trichoderma	Nematodes
Rice	4.8%	14%	80%	9.5%
Cotton	100%	27%	36%	9%
Vegetables	40%	53%	65%	22%
Fruit	100%	44%	93%	43%

Thai farmers showed significant rates of microbial pesticide use in most crops. This is not because they lack access to conventional alternatives as only 8.7% overall reported not using chemicals and some of these were because they had experienced chemical pesticide poisoning and deliberately given up chemical insecticides as a result.

Knowledge of biopesticides varied with crop system. Among rice farmers, who have poor uptake of MPs, 44% interviewed had never heard about microbial pesticides whereas only 8% of cotton farmers and between 8-28% of vegetable farmers had not heard of microbial pesticides. This pattern undoubtedly reflects the impact of official IPM promotion campaigns by the DoAE, which are well developed for cotton and vegetable production but less active in rice.

Rice farmers show little propensity to use microbial pesticides except for Trichoderma. The reasons given are

- Specificity: NPV and Bt are not targeted at major rice pests
- Cost: input costs are low for rice reflecting lower value of crop (95% of farmers but only the cheapest pesticides<1000 Baht litre).
- Resistance to cheap chemical insecticides is not a problem so older cheaper chemicals are still effective (perhaps a reflection of low historical use of insecticides on rice).
- Residues on crop are not yet an issue

Cotton farmers Cotton farmers show quite high levels of microbial pesticides use especially of Bt and NPV. The reasons for this are

- Cotton is a sector showing very heavy pesticide usage and has been targeted by the DoAE as a priority for IPM including NPV & Bt.
- Some major cotton pests *H.armigera* were among those with most pronounced resistance to conventional chemicals thus encouraging farmers to use alternative microbial pesticides.
- Cotton farmers are prepared to spend more than rice farmers (100% buy pesticides costing 1000-3000Baht litre)

However microbial pesticides based IPM strategy is difficult to support, as cotton prices are too low to pay for heavy reliance on microbial pesticides (Jones 1993).

Vegetable farmers are also significant adopters of microbial pesticides.

- Vegetables are attacked by a number of pests that are most resistant to conventional insecticides e.g. *H.armigera, S.exigua* and *P.xylostella*. Cheap older chemicals are no longer effective. The new generation of insecticides (Spinosad,) that are effective are very costly at up to 6000 Baht litre.
- Input costs are high and but so are incomes per unit area so farmers can afford the higher priced microbial pesticides (46% spend >3000Baht litre on pesticides).
- Residues are a definite problem for vegetables for export and are increasingly a factor in vegetables for local consumption.

Fruit farmers appear to be the most enthusiastic adopters of microbial pesticides. This is influenced by a number of factors

- This is a high value and high input crop 90% of farmers use pesticides costing >3000 Baht litre.
- Resistance is a serious factor and farmers reported new insecticides last only 2-3 seasons before a loss of efficacy.
- Fruit farmers have particular problems such as bark eating caterpillars on langsat trees and root rot on durian for which the specific microbial pesticides (nematodes and Trichoderma) seem very effective.
- Phytotoxicity of conventional chemicals particularly at flowering seems to push many farmers away from using conventional chemicals.

Although some biopesticides came from government sources either free, subsidised or at cost, there were a significant number of commercial products being bought and used by farmers. In the sample of farmers who had not previously received IPM training between 40-90% of those who had used microbial pesticides obtained them from commercial sources. The low purchase of some microbials by IPM trained farmers (nematodes and Trichoderma) may reflect the adequacy of the supply distributed during the IPM programmes for these agents. Ten different brand names of Bt and two each of *B. subtilis*, NPV, Trichoderma and nematode were bought by the farmers. The percentage of biopesticides bought from shops and dealers is shown in Table 8.

Table 8: Percentage of biopesticide products bought from shops and dealers

Biopesticide	IPM Trained farmers	Untrained control farmers
Bt	88.9%	88.9%
Trichoderma	16.7%	45.5%
NPV	35.6%	40.0%
Nematode	7.7%	66.7%
Other	36.4.%	60.0%

Individual microbial pesticides

Bacillus thuringiensis

Bt is one of the most widely available MPs and seven out of eight suppliers interviewed sold Bt products and 15 different brands were identified. These are mainly sourced from the USA though one product from India was briefly on the market. One local company did report producing Bt but no users of this were identified in this survey. The DoA has a programme to develop local production of Bt and a pilot plant with two 500 litre fermenters has been established in Chang Mai. The plan is to produce products based upon local strains of Bt but full-scale production is not yet underway.

The reliance on the importation of Bt has had significant consequences for Bt adoption. The use of Bt rose rapidly from its introduction but has fallen back in recent years. This could be because the Asian financial crisis after 1997 caused a fall in the value of the Baht making imported Bt less competitive. Bt is more expensive at 300-1500 Baht per litre than the older chemicals such as endosulfan or methidophos that cost less than 300 baht per litre, though the latter are no longer effective against resistant pests such as cotton bollworm and DBM. Though also the appearance of Bt resistance in some areas following uncontrolled overuse of Bt may also be a factor in its declining use.

Imported products are are generally produced to internationally recognised standards and The DoA registration procedure ensures they meet these standards. Thus a policy of relying on imported registered products has removed some of the quality problems that can be a feature of locally produced products (Jenkins & Grzywacz 2000). However in Thailand and other South East Asian countries in recent years there is extensive smuggling of cheap unregistered “bootleg” crop protection products often produced in China to no international standards (D .Wright & N.Jenkins pers comms.). These can include chemical insecticides and microbials such as Bt and baculoviruses NPV and granulovirus (GV) and so real use may not be reflected in official figures.

Satisfaction of farmers with Bt appears high with 95% of farmers both IPM trained and untrained reporting that they were effective. The significant criticism seemed to be that they were slower acting than chemicals (26%) and more difficult to apply (22%). The farmers have been recommended to apply either morning or evening and not to mix with fungicide. Interestingly this recommendation may be incorrect as the BCPC manual on biopesticides states they are “compatible with a wide range of fungicides” (Copping 1998).

The driving forces for farmers to adopt Bt appear to be chemical insecticide resistance in key pests like DBM and the need to meet low chemical residue requirements for export and local crops. These two factors are probably strongly linked as increasing resistance is a major cause of pesticide overuse as farmers seek to overcome declining effectiveness due to resistance by increasing application rates and frequency.

However microbial pesticides are not immune to resistance and there are reports of Bt resistance in vegetable pests in Thailand. DBM is indeed the only pest in the world where Bt resistance in the field has been widely confirmed including South Asia. The two strains of Bt *kurstaki* and Bt *aizawai* contain different toxins and resistance by DBM to one confers no cross resistance to the other. However there has been no system implemented for using these two different strains as part of a planned resistance management strategy in Thailand so that multiple resistance can develop. Bt products have in recent years faced competition from the new generation of chemical insecticides such as Spinosad. However these new insecticides cost even more than Bt at up to 6000 Baht per litre so Bt still retains market share in the face of these newer and highly effective chemical insecticides. Indeed some farmers seem to have learned how to alternate Bt with newer more expensive chemicals as part of an ad hoc resistance management system.

Bt is perceived by the pesticide suppliers in Thailand as a product with an expanding role in Thai agriculture, albeit one largely confined to vegetable farmers, fruit farmers and those producers growing for export.

B.subtilis (Bs) is produced locally on a very limited scale as a control agent for fungal diseases of fruit trees. However its use as yet too limited for this study to pick up any statistically useful data.

In conclusion Bt is clearly one of the most acceptable and successful MPs for farmer adoption though its cost confines its use to crops such as fruit and vegetables that can support high input costs. Reliance on imported commercial products from developed countries ensures a high quality product, but exposes farmers to the effects of currency fluctuations. Local production is an option but as Thailand has not yet moved its programme into commercial scale the potential sustainability of local Bt production remains unproven.

Fungal pesticides

As can be seen in Table 1 the main fungal microbial pesticides is *Trichoderma harzium* used to control various fungal plant diseases including Phytopthera spp. Pythium spp and Fusarium spp.

All of the Trichoderma used is produced in Thailand mostly by the DoAE but some also by commercial producers (20,000 Kg) and an NGO (2000 Kg). The work in Thailand shows that large-scale local production of fungal MPs is possible and the figures for Thai local production are impressive. A majority (60%) of farmers who had used these products found them effective though preparation time needed for application was a significant drawback mentioned by 30% of users. However quality tests show there is a serious problem of low viable spore counts particularly in non-commercial production. It cannot be determined if this is a problem in production or in storage. It is likely that unless this problem is addressed by improved quality control procedures the sustainability of Trichoderma must be considered questionable.

NPV

Thailand was one of the first countries in Asia in 1995 to register commercial NPVs for control of *H.armigera* and *S.exigua* and continues to be very active in NPV promotion. Its development of substantial local production of HearNPV and SpexNPV is probably second in Asia only to China and India (Jones et al 1998). NRI first became involved in 1988 with training under FAO auspices. DFID was an important donor that assisted in the development with TC project (T0066) of technical assistance between 1991-93 and research projects to support the development of NPV and Bt (R5290 & R6161) between 1993-95. In 1996 the DoA with its own funds built a dedicated plant in Bangkok with 27 staff to produce HearNPV and SpexNPV. Attempts were made to commercialise NPV production with a local company between 199-97 but these failed due to problems scaling up production. In particular mass producing insects in which the NPV are propagated was not successfully established. A problem contributing to this was that the plant was physically distant from the main source of technical expertise at the DoA in Bangkok making technical liaison difficult. Close proximity of new biotechnology companies to established sources of expertise is often an important feature of successful biotechnology companies in Indian (Grzywacz et al. 2000).

Much of the NPV supply to farmers before 2001 came as imported products SpexNPV (Spod-X) and HearNPV (Gemstar) but importation has fallen off in recent years and had lapsed completely by the time of this study. This may partly be due to the decline of the Baht making sales to Thailand less profitable. Another factor is the rapid expansion of an alternative market for NPV in Australia where new markets and larger farm units make sales more profitable (Murray et al 2000).

Nematodes

The nematode work is an interesting example of microbial pesticides promotion. Nematode commercial products have been produced in developed countries but tend to be expensive and restricted to niche markets (Smitt 1997). The nematode products using *S.carpocapsae* produced in Thailand are a relatively recent arrival and their development was assisted by donor funding from ACIAR (G. Rothschilds pers. comms.). They seem to be well received and may have a significant future though it is rather early to make an informed judgement as yet.

Microbial pesticides production and supply

Thailand is interesting as it has developed or adopted a number of different mechanisms for producing and supplying microbial pesticides to local farmers.

1. Importation of products from developed countries (NPV & Bt)
2. Local production by DoA and DoAE (NPV, Bt, Nematodes, fungi)
3. Purchase of local production by Department of agriculture (NPV, Bt, Nematodes
4. Farmers own production (NPV & fungi)
5. Local commercial supply direct to farmers (NPV, Bt, Fungi)

Importation from developed countries has worked well in ensuring a supply a good high quality NPV and Bt to farmers but the cost is high and subject to currency fluctuations. Thus for microbial pesticides to be affordable to poorer farmers some form of local production does seem essential.

Local production by government bodies has been successfully established but as it was not run on a cost recovery basis it was not self-financing and the scale of operations has reduced following governmental budget cuts. While government production can provide a basis for introduction it may be doubted that it can ever meet mass demand unless run on a self-financing basis. Another problem was that quality in some of the government products was poor. It has been observed elsewhere (Kennedy et al 1998) that state organisations often lack the scale up, manufacturing, quality control skills that are at the core of successful private sector biotechnology companies (Harris and Dent 1999).

Trichoderma production in particular had achieved very significant growth (Table 1). This is based upon very simple solid substrate fermentation system that uses a local grain and this methodology seems eminently suited to developing country needs. The quality though left much to be desired and suggested an urgent need to review production storage and distribution chain to avoid distributing ineffective or out of date products.

Farmer own production of microbial or botanical pesticides has been considered a possible option as a means by which resource poor farmers can access safe crop protection technologies including microbial pesticides. However attaining and maintaining a sufficient quality product to be effective can be a major problem (Tripp & Ali 2000). Very few farmers here indicated much interest in producing microbial pesticides though some production of both Trichoderma and NPV was found.

Purchase of microbial pesticides from local suppliers by government bodies can be an interesting advance on production by government as it can marry private production skills with central planning. This has stimulated local producers of Trichoderma; Nematodes in Thailand and their products were of good quality. However as yet Thailand had not managed to establish either Bt or NPV local production, which may reflect the higher technical demands of manufacturing these products. In contrast to the findings from Thailand the feasibility study for this current project found at least six companies producing NPV though not Bt in India (Warburton and Grzywacz 1999) and many more have been reported (Puri et al 1997). Several companies in India therefore appear to have successfully moved into NPV production having built new production facilities (N Jenkins pers. comms.) and producing products for the home market and for export (Jayanth and Manjunath 2000).

Quality control

The question of the production of MPs and the most appropriate model for developing countries cannot be divorced from the question of quality control. It is a major drawback of some schemes to promote biological control agents as crop protection agents in developing countries that they have failed adequately to address the problem of poor product quality (Jenkins & Grzywacz 2000). It was for this reason that this survey was designed to not only gather survey data on the production and use of biopesticides but also test samples so that the results of farmer surveys of satisfaction could be interpreted correctly.

There are serious quality concerns about some microbial pesticides in Thailand. *Trichoderma harzium* non-commercial products that should have been 10^9 viable spores per g were all found to have less than 10^7 viable propagules per g. There was a similar discrepancy in commercial *T.harzium* product. It was not possible to determine if the problem lies in poor production or poor product stabilisation but as producers reported serious contamination problems there is a suggestion that production was certainly a problem.

With the bacterial products commercial imported Bts were found to be effective. There were two locally produced Bts tested, the commercial product was effective with a good count of Bt and was effective in the bioassay. The non commercial product however had a low count of Bt. Both the *B.subtilis* locally produced products were found to have an adequate viable colony count and were judged effective.

Counts of NPV products showed that imported commercial products were up to standard (2x 10^9 OB per ml). Most locally produced non-commercial products were also up to the prescribed standard. However some of the products from the DoAE regional production centres did show seriously low counts. Currently the DoAE do not implement a full quality control system to international standards (Jenkins & Grzywacz 2000). It was noticeable that farmers had commented upon apparent variations in NPV product efficacy.

Nematode products were not checked for quality in this survey. The team did not know prior to the survey that these products were already in production and there was no nematode quality expertise included in the project team. Thus no conclusions on the quality of these nematode products could be drawn.

The general lessons about quality control from this survey appear to be

- Bt and NPV have much less of a quality control problem than fungi.
- Processes are simpler for Bt and technical infrastructure exists
- Need to improve QC processes in DoAE or there will be a danger farmer loss of confidence.
- Wider context good QC can be established but may need access to improved technical capacity

Registration and regulation of microbial pesticides

One important facet of promoting microbial pesticides or any alternative to chemical pesticide is the regulatory environment. There is a widespread and some would say well founded feeling that conventional chemical style regulatory packages are not appropriate for MPs (Waage 1997, Lisansky 1997). That the excessive burden of unnecessary testing merely prevents new non-traditional biological controls entering the market place and acts as a barrier to innovation and reduces competition to established chemical pesticides. Here in recent years the US EPA has introduced fast tracking for MPs and this has had a stimulating effect on getting new MPs registered. In contrast the more bureaucratic EU model with high registration costs and approval times may discourage of both MPs and minor use chemicals.

In this context the finding that commercial companies find no problem with the registration system developed in Thailand is very interesting. In Thailand all non-commercial production of microbial pesticides by government, farmers and NGO's do not require registration. This system has facilitated the rapid adoption of local production of microbial pesticides. However, as seen in the samples tested here, such a complete absence of quality tests has produced undesirable consequences in terms of quality of product.

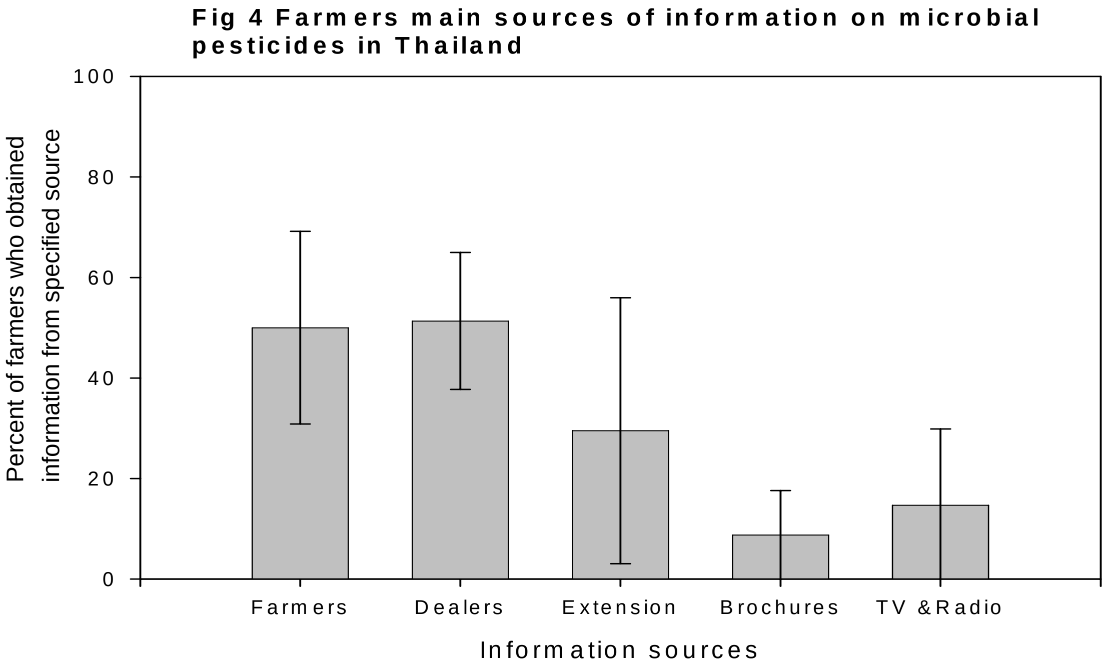
For commercially produced Bt, NPV and Trichoderma these are considered to be generically safe (see EIA below) and producers need only submit samples for efficacy tests. Another factor in the smooth functioning of the system is the excellent technical skill base in the DoA registration group that allows them to deal with registration issues with confidence.

In conclusion the simple efficacy based registration system adopted in Thailand appears an excellent model for the development of microbial pesticides but consideration should be given to extending it also to cover to all government and NGO produced microbial pesticides.

Microbial pesticides promotion

The sources of information used to inform farmers in the survey were interesting. In figure 4 the source of information that farmers used are presented. The data for this group of farmers excluded those who had been trained in IPM by the extension services.

Fig 4 Farmer sources of Information on microbial pesticides



The findings point to the central role of farmer to farmer and pesticide dealers in informing farmers. Extension services in Thailand also play an important role and have impact but this is no longer true of many developing countries. Media can play a role but while TV and radio are significant there is little evidence that brochures and magazines, often a favoured route of promotion for publicly funded development projects, have a serious impact on farmers.

Role of microbial pesticides in smallholder farmers

A key question for development research programmes such as the CPP is can novel agricultural technologies be promoted successfully in developing countries and to reduce the poverty and improve the health of the poorest groups of rural householders. It has commonly been observed that agricultural technologies are first adopted by the better off farmers or by agribusinesses. These groups have the education to appreciate the advantages of new technology, the knowledge to implement the new technology successfully and the resources to pay for them.

Most of the farmers involved in this study would certainly be considered small scale farmers as farm sizes varied from 3-7 ha for rice and cotton farmers to 1.6-3.2 ha farms for the vegetable and fruit farmers.

Table 9 :Biopesticide suppliers' view of target customers

Supplier type	Farming system (% respondents)	Farm size (% 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)
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)

From table 9 it can be seen that the suppliers identify small farmers as 60-70% of their customer base. It also confirms the leading role of vegetable, fruit and export farmers as customers for MPs.

The study here from Thailand suggests that small-scale farmers can successfully adopt new microbial pesticides technologies including Bt, NPV and fungal biocontrol agents. However such adoption is largely confined to crop systems where the new technology has a clear competitive advantage over existing synthetic chemical pesticides and the farmers have the resources to afford the new technologies. Factors in determining this are many but two key ones are (a) where existing chemical pesticides are no longer effective or economic i.e. have become more expensive because frequent or higher application rates are needed to overcome resistance, (b) where the cropping system has the resources to support the often higher costs associated with adoption of a microbial pesticides (in terms of cost of product, higher cost of application or more labour). Thus, high value crops such as vegetables can support the higher costs of microbial pesticides or safer chemical pesticidesbecause the very high value of the crop (up to $2,000 per ha) means cost is not a limitation to the adoption of crop protection technology.

A linked factor, which makes farmer's more disposed to adopting microbial pesticides-based strategies of crop protection, is that vegetable systems are intensive and often have a history of intensive chemical use. In these situations resistance to chemical insecticides is often already a serious problem. Consequently:

- The older cheaper chemical insecticides are no longer effective at original rates
- High rate applications and frequent applications have already raised pest control costs
- The farmers are used to paying high costs for new more expensive chemicals
- Farmers have experienced failures of chemical only control
- Farmers have often encountered health problems arising from overuse and abuse of chemicals.

All of these factors make farmers more disposed to adopt novel microbial pesticides based strategies of crop protection.

A recent new phenomema is a situation where specific chemical insecticides are banned for safety reasons creating a new niche for alternatives. Safety legislation is notoriously ill enforced in many developing countries and so legislation has often little impact in changing farming practices. Through increasing globalisatin this is beginning to impact on developing country practices. An example is the important vegetable export market in Thailand to Japan and Europe where avoidance of residues is crucial to the acceptance of horticultural produce. Here vegetables export firms enforce bans on many chemical insecticides through comprehensive monitoring and severe penalties on errant farmers. Such trade mechanisms are probably much more effective at reducing insecticide residues on produce and misuse of insecticides than any legal instruments.

Thus general findings of this survey are:

- Farmers in the vegetable and fruit sector are the most likely to take up new microbial pesticides technology

- Rice and cotton farmers are much less likely to adopt newer technologies

- Farmers whose crop protection costs (both raw materials and application costs) are high are also more likely to adopt microbial pesticides new technology

- The most effective promotion pathways are through existing pesticide dealer networks and farmer to farmer with extension type training, TV & radio and brochures being progressively less effective.

Output 2. A report evaluating the environmental impact where microbial pesticides are adopted in place of chemicals.

In determining the scope of this EIA it was decided to confine the data to that covering Baculoviruses (BV, a term covering NPVs and closely related granuloviruses or GV) and Bt. It was felt that only in these two groups was there an extensive body of literature reviewing actual widespread use over at least 20 years. This reflected the fact that these two groups of entomopathogens account for >90% of the commercial use of biological insecticides according to informed industry sources (Jarvis 2002). It is true that in the last decade new insecticide products utilising fungi and nematodes have appeared. However as yet their field use has been restricted so that environmental impact data is as yet not as abundant as with baculoviruses and Bt that have been in widespread use for over 20 years. It was also known that expert reviews of the environmental impact of several groups of entomopathogenic fungi and nematodes were in preparation and should be published in 2003 (Hokkanen and Hajek 2003).

Another reason for restricting the EIA to these two groups is that they are relatively homogeneous and clearly distinct with a high degree of common biology. It is therefore possible to make generally applicable statements about environmental impact of these two groups on the basis of existing data. Fungal entomopathogens under development as biocontrol agents are drawn from a variety of major taxonomic groups (Orders Entomothorales, Hyphomycetes, Oomycetes, and Chytridiomecetes). They are as such diverse organisms of uncertain taxonomic relationship and very different biology about which it is difficult to make general statements.

There have been major reviews of the safety and environmental impact of entomopathogenic fungi (Goettel et al 1990). However apart from data derived from the use of entomopathogens in glasshouses, where several entomopathogenic fungi have been successfully commercialised this review has been based small-scale trials of fungi at the research stage rather than commercial products. The only major use of large-scale applications of fungal entomopathogens in crops in the tropics has been the experience with Metarhizium anisopliae (flavoridae) var. acridium (Green muscle,). This product was developed under funding from a donor consortium for control of locusts and grasshoppers under the LUBILOSA programme.

As part of this programme field studies were conducted in Africa comparing the impact of Green muscle to the Organophosphate Fenitrothion for control of grasshoppers (Peveling et al 1999). These were applied at rates sufficient to obtain similar measure of target pest control (75-86%). Impact of effect on non-target arthropods was monitored for 31 days post application. Fenitrothion reduced populations in four families by 69-33%. There was no evidence of adverse effect of Green muscle on non-target arthropods. This supported earlier host rage tests of studies that also showed that a variety of non target insets were not susceptible to Ma and in contrast to the situation with a selection chemical insecticides drawn from several major groups of insecticides including Pyrethroids, IGRs and OPs (Peveling and Demba 1997). Similar recent studies on another fungal entomopathogen Beauvaria bassiana also under development as a grasshopper control product in the USA found a similar absence of any significant impact on non target arthropods two weeks after application though brief post application declines were seen (Brinkman and Fuller 1999).

The EIAs prepared as outputs for this project are attached to this report (Appendix 3 & 4). The conclusions of these EIA may be summarised as follows.

Natural (wild type) BV

The evidence on the environmental impact of wild type BV is among the most comprehensive we have for any microbial pesticides dating back over 50 years and a number of BV (at least six) are registered as commercial products in the USA South America, Asia and Europe (Jarvis 2001).

The key findings are

- There is a great deal of evidence to support the view that BV are safe to vertebrates
- BV are not infective to vertebrates or plants
- There is no evidence of adverse effects on the environment through the application of wild type BV.
- There are no findings of deleterious side effects of BV application recorded from the field.
- They are naturally occurring, being found widely on harvested crops and ubiquitous in crop and forest ecosystems.
- Extensive safety tests on vertebrates and non-target invertebrates have shown no harmful effect.

- No confirmed findings that wild type BV replicate in any vertebrate cell lines.

- Have no impact on agriculturally important invertebrates such as pollinating bees or silkworms, where that is the BV is not specifically infective to the silkworm species.

In conclusion it would appear that wild type BV are a safe microbial pesticides whose use in pest control in place of synthetic chemicals would thus confer significant environmental benefits where appropriate.

Genetically modified BVs

The safety of genetically modified BV is potentially much more contentious than for natural BV. GM is a powerful technology that can drastically modify an microbial pesticides host range, efficacy and mode of action potentially altering its impact on the environment. The impact of GM technology on developing country crop production has been the subject of a special CPP funded study much more comprehensive and exhaustive than possible here and which should be referred to in the context of this report (Thwaites and Seal 2000)

The EIA concludes

- The safety of BV should not change where the modification of consists of the addition of a gene(s) for insect specific toxins, enzymes or hormones.

- Most modifications have been restricted to Lepidopteran isolates so that the species most at risk here are only the non-target lepidoptera.

- Those lepidoptera recombinant BV so far tested have shown no effects on predators of BV infected larvae in either laboratory or field tests. BV infections by recombinant BV may effect the success of individual parasitoids that co-infect hosts but there is no evidence of significant population effects.

- Recombinant BV may show expression in some human cell lines if heterologous vertebrate genes are involved in the transformation.

Thus in conclusion with GM BV much more caution is justified in recommending the adoption of GM BV as pest control technologies, especially where vertebrate genes and promoters are used in the GM BV. Safety testing of recombinant BV is therefore still highly desirable preferably using internationally recognised and agreed protocols (EPA 1996). Its conclusion that “In the long history of baculoviruses there have been no documented negative ecological effects from their wide-scale release” is an important statement that should encourage the adoption of microbial pesticides based upon baculoviruses in place of chemical insecticides. Where of course the microbial pesticides can be shown to be effective as crop protection agents.

Immediately prior to the completion of this FTR a draft copy of a review of the ecological impact of virus insecticides was kindly made available by the author (Cory 2003). This review focuses on the ecological role of BVs in relation to other arthropods in crop and forest ecosystems rather than general safety issues addressed in the BV EIA report. Its conclusions are entirely consistent with the findings of the EIA report produced for this project. It clearly states that BV have no recorded effects on vertebrates and that much of the (safety) testing is repetitive expensive and unnecessary. The main ecological effects of BV are on non-target susceptible species. These, as a result of the high specificity of BV are normally closely related to the target pest. Another conclusion is that BV from Lepidoptera are not infective to insects outside the order from which the BV was isolated. Neither are BV infective for predatory insects, parasitoids, cockroaches, lacewings, honeybees or other non-phytophagous insects. This would suggest that much of the environmental impact dossier requirements for non-target testing of vertebrates, arthropods and invertebrates for a new BV registration could be waivered. This approach is increasingly that taken by regulatory bodies such as the US EPA who routinely now fast track BV registration.

Bacillus thuringiensis

Bt is the most widely used biopesticide in the world and has accounted for 90% of microbial pesticides use over the last decade (Lisansky 1997, Jarvis 2001). It is also one with an extensive history, the first Bt product was produced in 1938. Major expansion in use only developed however after the discovery of highly active Lepidopteran (Bt *kurstaki*), Dipteran (Bt *israelensis*) and Coleopteran (Bt *tenebrionis*) isolates after 1960's when increasing environmental concerns and resistance in key pests created an increased market opportunity for Bt products. The advent of new molecular techniques has in recent years vastly increased the range of known Bt toxins some with activity against new classes of pests including nematodes and mites (Travis and O'Callaghan 2000). Thus it is likely that in future the importance of Bt in crop protection can only increase as new products appear that export this wealth of newly discovered biological activity.

Since the early 1990's a major new direction for Bt research was in connection with GM technology. This has enabled the construction of new novel Bt toxin genes and their incorporation into plants to create insecticide resistant strains. A few new recombinant products for sprayable Bt have been developed but these did not involve transfer of genes between species so should perhaps not be considered as new GM products in the currently understood sense (Jarvis 2001).

The use of Bt genes, wild type or recombinant, in plant breeding is in itself a major topic both of scientific and public concern. Again will not be dealt with here but the reader is referred to the recent CPP commissioned report on GM technology and its impact on crop production in developing countries (Seal & Thwaites 2000).

The EIA of sprayable wild type Bt's key conclusions were

- Wild type Bt sprayable products have been used over four decades without harm.

- They have been safe to use with minimal non-target impact, little residual toxicity and a lack of mammalian toxicity.

- Apart from odd wound infections by one strain there is a history of safe use for over 40 years

- USA EPA (1996) concluded the toxicity of the delta endo-toxins (the primary insecticidal toxins) of Bt was minimal to non-existent

- No significant toxicity to birds and indirect effects in the field posed little risk to bird populations.

- WHO (1992) concluded Bt use in aquatic systems had produced no records of adverse effects.

- In non-target lepidoptera negative effects are reported but tend to be temporary and only where there are isolate populations are permanent changes

- Use of Bt has ecological advantages

In conclusion the EIA concludes, “Bt has proved to be a very safe, particularly in comparison with synthetic chemical pesticides”. However it urges continuing monitoring of non-target impacts in the field following applications more extensive studies of Bt in natural ecosystems.

It may be concluded that both of the microbial pesticides (Bt & BV) looked at here have very significant environmental advantages over their synthetic chemical alternatives. The evidence to date for one other groups the entomopathogenic fungi, though more limited, points at present to a similar conclusion. Therefore the continued development and promotion of microbial pesticides therefore, providing these can achieve acceptable levels of efficacy and cost, is likely to confer considerable environmental benefits for developing countries.

The health, environmental and ecological negative effects of inappropriate use of chemical insecticides are well known. However it is likely that in many developing countries the full adverse impact of chemical pesticides on health is seriously underestimated. In Thailand the farmer survey confirmed that 75% of farmers over all cropping systems (100% in vegetables and rice) used chemical insecticides that were in FAO's most hazardous category. Harris (2000) reported a survey in Thailand that found 80% of rural women, who do much of the low paid fieldwork, reported symptoms of chemical pesticide poisoning. This report also highlighted the small official incidences of insecticide poisoning reported in Thailand suggesting huge under reporting of pesticide related health problems is common. A similar situation is likely in all poor developing countries where health care is limited and pesticide monitoring weak.

Substitution of safe crop protection agents is likely to have an enormous positive effect on the health of rural workers. Most of these are drawn from the poorest groups and contain a high proportion of women whose lack of skills leave then few alternative sources of income.

Output 3. Guidelines for biopesticide producers, the CPP, NARS, NGOs and CGIARs on improved methods for promoting biopesticide uptake by farmers.

This output was intended as the product of both the Thailand and the planned Indian biopesticides survey (still under consideration by CPP). The conclusions to this output must therefore be considered partial and provisional pending completion of the Indian survey. The importance of the India survey was that it would study a very different model of uptake and promotion, with a much larger role for the local commercial sector as producers of MPs. The India survey because of the larger scale of microbial pesticides activity in India and its greater local production element was always considered to be a crucial element of the project.

In considering how best to promote a new microbial pesticide the first stage is to assess that the microbial pesticide is suitable for promotion and this process is discussed below under Output 4. It cannot be overemphasised that unless the new technology meets a real farmer need, it will not have a successful or sustainable future.

The sustainability of supply is an important consideration in a new microbial pesticides promotion project. Options for supplying microbial pesticides include (1) importation (2) local production by private company (3) local production by state body (University, research institute, extension service) (4) Local production by NGO (5) Local production by farmers themselves. In our survey if Thailand we found that a number of these routes had been used and the findings may therefore through light on the feasibility of the different options.

Importation was an initially good option for Bt and NPV as importing products developed and registered in OECD ensured good quality product (NPV and Bt). However it also meant they were expensive so not a viable option for the poorest farmers. It is unlikely that importing such products will ever meet the constraints of resource poor farmers. Even to high input farmers, currency fluctuations can be a major risk to sustainability. This risk could be reduced if the source were in another developing country and in the survey cases of microbial pesticides from India being registered in Thailand were found. In countries in sub Saharan Africa, where the manufacturing base is very limited, setting up microbial pesticides production in one country may only be sustainable if export markets to other countries in the region can be used to create a large enough market to support the new product.

That local production of microbial pesticides is viable is shown because in this survey local production of Trichoderma, Nematodes and NPV was successfully established. Production by private local companies in Thailand was as yet limited with only with Trichoderma and nematodes being produced. As yet there was no commercial production of NPV or Bt. Here the data from India would have been a real bonus as private company production is widespread (Puri 1997) with many companies producing NPV and Trichoderma alongside predators parasitoids and sometimes botanical pesticides (Jayanth & Manjunath 2000).

The involvement of private companies in microbial pesticides development is highly desirable even during the early research stages of a new agent. The success of a new microbial pesticide is dependent on many factors. Crucial among these is product formulation, mass production, marketing and supply (Lisansky 1997). All of these are skills that are often weak or lacking in the public sector research (Dent and Harris 2000). However they are the skills which are paramount in successful private company manufacturing companies. Indeed the best private agrochemical companies often have a clearer vision of farmer needs and constraints than are found in socio-economists from public sector agricultural research organisations. In addition agrochemical companies often have effective promotion and marketing pathways that are experienced at promoting new products and have established networks for doing so.

The use of NGO’s is often considered an important promotion mechanism to promote new IPM technology. Their use to promote microbial pesticides as part of a raft of non chemical IPM interventions has been recorded elsewhere in Asia though not without problems (Tripp and Ali 2000). NGOs were recorded in the survey as promoting IPM that contained microbial pesticide technology but none were found to be producing any microbial pesticide. Overall therefore there was little new data from this survey to increase our understanding of how such NGOs can be used to promote new technology.

Getting farmers to produce their own microbial pesticides is a strategy promoted by certain researchers in international centres promoting non chemical IPM (Tripp and Ali 2000). This has been seen by some as a potentially important means of providing resource poor farmers with new crop production technologies. Farmer production has been promoted in Thailand with Trichoderma and NPVs but this survey found that only a minority of farmers, 36 % using Trichoderma and no more than 8% with NPV said in the survey they would actually preferred to produce their own. Even fewer farmers had actually practised it. Time constraints and competing priorities in crop agronomy were the main reasons sited. It seems therefore that the concept of getting farmers to produce their own inputs is one that is on the evidence of this survey not a major promotion route for microbial pesticides.

In considering possible promotion pathways the survey did produce some interesting data. Extension training was most effective in informing farmers. Where developing countries have adequate state sector institutions this is an obvious mechanism. In many developing countries however such national extension services are in serious decline and may not be appropriate to bear a major role in promotion. In these cases the extension role may be taken by international organisations FAO FFS or NGO rural IPM programmes such as have been run by CARE.

The role of commercial sector in promotion should also not be neglected most farmers still reply on pesticide dealers for information. If the extension system has limited or little capacity to support new microbial pesticides introduction then using the pesticide dealers is probably the only other effective option. If the supply chain already involves a private pesticide supplier then the existing pesticide dealer chain can be used as a very potent pathway for promoting information on new microbial pesticides. The results of the survey here indicate that methods often favoured by donor aid projects, newspapers, TV, Radio and leaflets have much less impact than the extension training or existing pesticide dealer network and should only be considered as supplementing those two main routes of information.

Output 4. Guidelines to aid IPM practitioners in assessing the suitability and sustainable viability of microbial pesticides for resource-poor farmers.

As this output had been intended as the product of both the Thailand and the planned Indian biopesticides survey (still under consideration by CPP) the conclusions to this output should be considered partial and provisional pending the completion of the planned India survey.

The first major decision in evaluating the suitability of new microbial pesticides assessing the technical performance of the candidate microbial pesticides. This is often carried out on the basis of on station trials however it is questionable that this is sufficient without a programme of on farm trials. A major flaw in developing microbial pesticides to commercialisation under public funding has been the failure to conduct realistic on farm trials early to determine if the agent can reasonably meet user's expectations on performance and cost of application. A usable microbial pesticide must be effective when used under the conditions and with the constraints that apply to the farmer. Many candidate agents can be effective when tested in trials by highly qualified scientists who have the time and skill to apply then correctly. However they prove either ineffective or too time consuming to be practicable when used on farm. The DoA programme of developing NPVs and other agents in Thailand has included an extensive series of on farm trials over many years (Jones et al 1998). These are used to evaluate the agent, refine application rates, validate its use on particular crops and develop farmer acceptable recommendations for the agent's use.

Besides assessing the efficacy of a candidate microbial pesticides there also needs to be a realistic determination of its reliability under realistic end user conditions. It has been pointed out that many candidates MPs while proving highly effective in many instances but that their control is neither reliable nor predictable. Reliability is crucial to farmers and they can often accept a less than total degree control or a more expensive product but not a product that is unreliable (Lisansky 1997). Here the issue involves not only the inherent reliability of the microbial pesticides but also the reliability of the formulation as used by the farmer. In this survey there was a problem with Trichoderma products, probably due to the poor stability of the current formulation. Farmers also reported reliability problems with some batches of early NPV products.

In this quality control is crucial to the sustainability of a new technology such as microbial pesticides. This project identified serious problems with some microbial pesticides in Thailand that are quality control problems. The relative successes with Bt and NPV were related to the well-established technical capacity of the DoA to register and ensure that these products met good quality standards. New technologies such as microbial pesticides are often unfamiliar to registration authorities used only to dealing with commercial chemical insecticides. Thus they will frequently need access to expertise and skills they do not possess to adequately complete registration. Where a new technology such as a microbial pesticide has been developed as part of a donor funded research project, the donor must expect not merely to fund the product R & D but will also need to help the recipient country's registration authority.

Another stage is determining that the microbial pesticides are appropriate is to profile the cropping system, pest or disease and farmers. MPs are most successful where:

1. The pest/disease has shown resistance to conventional pest control technologies. MPs may be introduced as either an alternative or as a specific component of an insect resistance management (IRM) strategy.
2. The costs of conventional control are high (a result of (1) above).
3. Insecticide residues on edible crop products (Vegetables or Fruit) are an important consideration.
4. The crop itself has sufficient earning capacity to support the often higher costs of microbial pesticides based IPM.

Output 5. Publication of results in a refereed international journal, as well as local agricultural journals, newsletters and national fora.

This output has not been completed at the time the FTR was completed. A series of publications though are planned including.

(1) The survey report (Appendix 2) to be published as part of the CABI Biopesticides series of books or a paper on the findings will be written for an international agricultural journal (Late 2002)
(2) A paper on the survey will be published for an Asian agricultural journal (Late 2002).
(3) A publication based upon the combined EIAs of Bt and NPV is also under consideration.

Contribution of Outputs to developmental impact

Include how the outputs will contribute towards DFID's developmental goals. The identified promotion pathways to target institutions and beneficiaries. What follow up action/research is necessary to promote the findings of the work to achieve their development benefit? This should include a list of publications, plans for further dissemination, as appropriate. For projects aimed at developing a device, material or process specify:

a. What further market studies need to be done?
b. How the outputs will be made available to intended users?
c. What further stages will be needed to develop, test and establish manufacture of a product?
d. How and by whom, will the further stages be carried out and paid for?

This biopesticide survey of Thailand is the first detailed picture of the microbial pesticides programme in a developing country. It contains detailed data on producer and user attitudes to microbial pesticides. As such it should prove a valuable guide for a number of CPP projects and other developing country IPM programmes that are seeking to develop and promote microbial pesticides as part of safe and more sustainable crop production.

The survey data and findings will be especially valuable to policy makers in developing country NARS, CGIAR centres and the Development donor community in informing their choices about:

(a) What microbial pesticides to promote to small farmers and to which cropping systems they are most appropriate
(b) How to best promote new microbial pesticides or other new crop protection technologies
(c) How best to set up sustainable locally sourced supply of new technologies and
(d) The quality control problems associated with local production and supply of microbial pesticides.

However the data from Thailand did not include many examples of successful private sector adoption and promotion. This is something that has been more successful developed in India (Puri et al 1997, Warburton and Grzywacz 1999) and so it is still important to complete the planned survey of India to improve our understanding of how successful private sector involvement can be promoted. After some delay ICAR has now agreed participation as part of a survey of microbial pesticides and macrobial pesticides (predators and parasitoids) involving ICAR, Directorate of Biocontrol Bangalore, CABI and NRI. Thus it is hoped that this survey can be expanded to include data from India so that an updated report can be prepared by early 2004.

The EIAs are documents that can be used by researchers, NARS, International research centres and interested companies to support obtaining official clearance to conduct fieldwork on NPV and Bts that are candidates for development into crop protection products. The EIAs could also be used as part of a registration dossier. The results comprehensively support the approach that NPV and Bts should not have to undergo standard mammalian or toxicity testing or the testing of non-target invertebrates from outside the order of the pest species. Acceptance of this would have significant savings in registration costs for any institution or company seeking to develop and commercialise new NPV or Bt strains.

Results and report will be forwarded to project leaders of all CPP projects currently involved in developing or commercialising microbial pesticides. These include R8044 (Pest of potato Bolivia), R7960 (West Africa biopesticides), R8217 (Production of baculoviruses in Kenya), R8218 (Production of Pasteuria in Kenya), R7954 (Armyworm outbreaks Tanzania) and R7885 (On farm Chickpea IPM). Results will also go to interested NARS and international development and research bodies including: Indian Council Agricultural research, Kenya Agricultural research Council, Nepal Agricultural Research Council, Tanzania Ministry of Agriculture, Bangladesh Agricultural Research Institute, ICRISAT, ICIPE, IITA, USAID. FAO, International Biopesticide Consortium for Development, CAB International UK and ARC centres.

List of planned publications

1. The survey report (Appendix 2) to be published either (a) as part of the CABI Biopesticides series of books entitled “Survey of the biopesticides industry in Thailand :supply production and use”
2. Or (b) A paper will be written for an international agricultural journal

3. In addition a paper will be published for an Asian agricultural journal on the same topic to ensure local dissemination.

4. A presentation on the survey results will be made in a paper at a forthcoming international conference on biological pesticides probably the society of invertebrate pathology conference in August 2003.

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List of Appendices

Appendix 1. Survey questionaire

Appendix 2. Report A survey of the supply, production and use of microbial pesticides in Thailand

Appendix 3. Report Environmental impact of baculoviruse

Appendix 4. Report Environmental impact of Bacillus thuringiensis