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Positioning of Biopesticides in Thailand

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Thailand is one of the ASEAN countries that intensively uses synthetic pesticides in agriculture. Frequently, Thai farmers misuse these pesticides, leading to the contamination of agricultural products with toxic residues. Because of these problems, the government, through the Pesticides Reduction Program, has made a national policy to produce "Hygienic Food and Agricultural Products" both for internal consumption and export. The government strongly encourages the use of biopesticides in control strategies. This resulted in the registration of three *Bt* varieties i.e., var. ***kurstaki***, var. ***aizawai*** and var. *israelensis*, and application technology was developed for them. The results show that *Bt* provides remarkably effective control of many species of *Spodoptera* and some other economically important insect pests. Records show that the use of *Bt* varies from year to year. It is reported that from 2003 – 2005 use of *Bt* in Thailand doubled, from 80 to 160 tons. However, the total *Bt* use is still low (less than 1%), compared to synthetic pesticides, due to the slow action of *Bt* in causing pest mortality. The Hygienic Food and Agriculture Policy promotes the use of *Bt* in Integrated Pest Management program for vegetables, including: asparagus, okra, baby corn, cruciferous crops, chili and some other "spicy" vegetables. This has lead to increased *Bt* production in Thailand, and at least five local private companies each produce about 20 tons of *Bt* a year, while the rest is imported.

Introduction

In any crop production system, crop loss from damaging pests is still the major economic concern. Food production has increased remarkably due to the successes in plant breeding, soil management and use of fertilizers, effective synthetic chemicals and improved pesticide application technology. It is estimated that the total value of synthetic chemicals used is worth more than 30,000 million US$. Of this, herbicides make up 47%, insecticides 30%, fungicides 22%, and biopesticides less than 1%, representing an estimated value of 125 million US$ (5).

The successful economic development in Thailand over the past decades ensures the country plays an important role in food production among its neighbours. At present, Thailand is one of the biggest users of synthetic pesticides in the South Asia region and the government is working on developing and implementing a more effective use of pesticides. Agriculture is a significant, though it is in a decreasing proportion, of the Thai economy, contributing about 11% of the gross domestic product (GDP). It remains the main employer in the country, and employs 64% of the total labour force. The areas planted with major crops such as rice, cassava, rubber, coconut, cotton, sugar cane and oil palm, have all increased since 1970 and remained relatively stable since 1980.

Thailand is a major market for pesticides, with an annual growth rate of 8.8% between 1982 - 1992, with a lower growth rate since then. Thailand uses a lot of chemical pesticides in agriculture, and the trend is the same globally (5). The herbicide market has grown rapidly in recent years and now represents about 63.3% share of sales, while insecticides hold 20.0%, fungicides 13.0% and biopesticides less than 1%. Most pesticides are imported, and foreign companies hold the biggest market shares: Monsanto, followed by Ciba Geigy (now Novartis), Du Pont, Cyanamid, Bayer, and Rhône Poulenc (5). Of the imported pesticides, 70% fall into the WHO hazard categories class Ia, i.e., extremely hazardous, and class Ib, highly hazardous, and a further 30% are in category class II, moderately hazardous (16). All are considered particularly hazardous under the conditions they are used in developing countries. Without a major change in government policy, pesticide imports are expected to continue to increase in the future, as more crop land is turned into the production of higher value crops, like fruits and vegetables, where pesticide use is influenced by consumer demand for uniform and unblemished produce.

Health hazards

The rate of pesticide use in Thailand inevitably has consequences for human health, though identifying the true extent of these is difficult. Many cases of pesticide

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TABLE 1. Percentage of crop loss due to the pest infestation in difference geographic regions between 1988 – 1990.

Region	Percentage of crop loss from pests			**Total**
	Insects	Plant diseases	Weeds	
Africa	16.9	15.7	16.5	49.1
N. America	10.2	9.7	11.4	31.3
S. America	14.5	13.5	13.4	41.4
Asia	18.7	14.2	14.2	47.1
EU	10.3	9.8	8.2	28.3
Average	14.1	12.6	12.7	**39.4**

Source: Sinchaisri and Sirisingh. 2005.

poisoning are never reported and do not appear in the statistics. For example, a 1999 study reported that 4,169 workers with poisoning incidents contacted the Emergency Department of hospitals. Statistics from the Ministry of Public Health on occupational poisoning showed a decrease from a high of 4,169 cases in 1999 to 2,653 in 2001, although there has been no change in the type and hazard of pesticides used, or the application technology (3, 6).

Farmers are generally not aware of potential pesticide hazards, or if they are, it does not lead to modification of their actions in handling pesticides. The majority of Thai farmers generally apply higher than recommended doses of the pesticide and do not follow the instructions on the labels, wear no protective clothing, and do not observe recommended intervals between spraying and harvesting the crop (12). A partial explanation for this may be that the wages for pesticide applicators are about twice as high as for other farm workers, and the number of applicators is increasing (14).

Biopesticides, including bacteria, virus, fungi, nematode and protozoa, have been introduced as control agents on various economically important crops to control arthropod pests. Many studies on the efficacy of biopesticides have shown that biopesticides, especially *Bt* and nucleopolyhedrovirus (NPV), can be used to control several economically important pests and can be mixed or used alternatively with synthetic chemical insecticides (12). The classic example is *Spodoptera exigua* (Lepidoptera: Noctuidae), which attacks more than 30 economically important crops and is resistant to many chemical pesticides. By using *Bt* alternately with some synthetic chemicals, damaging pest levels can be easily reduced. Research on the development and use of biopesticides in Thailand is being conducted by the Department of Agriculture. The Department of Agriculture is increasing their research efforts to develop suitable biopesticide formulations and their effective use, and is encouraging farmers to use biopesticides instead of synthetic chemicals. At present, the following biopesticides are being used to control arthropod pests and rodents: bacteria, viruses, fungi, nematodes and protozoa.

Use of synthetic pesticides for controlling arthropod pests

While growing vegetables, cutflowers, fruits and other agriculture commodities, farmers suffer economic losses due to pest infestations and damage. Crop losses worldwide vary from region to region, but on the whole it has been reported that these losses represent more than a third of total production (Table 1).

Effective control measures have to be applied to minimize these losses. The use of synthetic pesticides is the traditional and most popular control method for farmers because the products act quickly, causing high pest mortality. Their usage shows a remarkable increase in recent years (Table 2). The importation of pesticides into Thailand almost doubled from 26.7 tons of active ingredient in 2002 to 53.1 in 2004, and will probably continue to increase. Of the pesticides imported in the largest quantities, the three groups, in decreasing order of amount are: herbicides, insecticides and fungicides (Table 3). The large amounts of synthetic chemicals used resulted in adverse health effects, especially among those involved with crop protection. The number of farmers getting sick or dying after using chemical pesticides is shown in Table 4.

Biopesticide suppliers in Thailand

There are two groups of companies supplying biopesticides in Thailand:

TABLE 2. The amount and Value of pesticides import to Thailand.

Year	active ingredient (tons)	Value (million $ us)
2000	-	182.3
2001	-	219.0
2002	26,689.03	227.9
2003	50,587.50	284.6
2004	53,049.80	279.4

Source: Anonymous, 2005. 1 US$ = 40 Baht

1. Non-commercial, non-profit organizations, who provide help and technical support to farmers to reduce the use of synthetic chemicals and their harmful effects to farmers and the environment, and above all to reduce the levels of toxic residues in the agricultural products. Usually, these groups are government organisations, universities and non-government organizations, including:

- Department of Agriculture (DOA): a purely technical and research organization, investigating the effectiveness of biopesticides through laboratory and field experiments. It also surveys and collects organisms that occur naturally in Thailand and looks for new ones that could be promising biocontrol agents. After finding potential organisms, intensive research is conducted on the efficacy, formulation, method of application and development of economical methods of production. After developing this production technology, DOA will produce the biopesticides in small quantities and distributes them to farmers, at no cost, to encourage farmers to avoid using toxic chemicals. Once the effectiveness of the biopesticides is demonstrated, the technology will then be transferred to interested private sector for production and sale. DOA has also established two *Bt* production units located at the Chiengmai Experiment Station and at the Entomology and Zoology group at Bangkhen, Bangkok.

- Department of Agriculture Extension Service: There are at least eight such centers throughout the country. These Centres provide information and technical support to farmers by demonstrating, training, and supervising the use of biopesticides. Sometimes Department of Agriculture Extension Service also produces and distributes biopesticides to farmers or occasionally sell it to farmers or private sectors at production cost.

- Universities: also search for new, promising organisms, conduct research on their efficacy, and provide some technical assistance to farmers.

- Non-governmental Organisations: These groups assist by providing either technical information or assisting with funding. The non-governmental organisations are non-profit organizations whose budgets come from donations from developed countries or from the Thai government. These non-profit organisations are the leaders in promoting the use of biopesticides and encouraging farmers to use these products by giving away the biopesticides either free of charge or by selling them at production cost.

2. Commercial organizations: These are commercial sectors which produce, import and sell for profit. Usually, these products are distributed directly to farmers by local representatives of the companies, or through local dealers who charge farmers higher prices. There are three types of companies:

- Multinational companies: these organisations import and sell both synthetic chemicals and biopesticides.

- Local agents: usually representative of the multinational companies.

- Local producers: produce and sell the products directly to farmers.

Under the national project on 'Hygienic Food and Safety', it is expected that the production and use of biopesticides will increase. All technical assistance usually comes from universities and government sectors.

TABLE 3. Importation of Pesticides to Thailand, 2002.

Category	Value (US$)	Volume (kg/L)	Value (kg active ingredient)
Acaricide	736,350	129,777	39,341
Bio-pesticide	**278,426**	**27,754**	**24,781**
Fumigants	1,892,867	787,363	721,683
Fungicide	21,760,432	4,987,369	3,131,388
Herbicide	88,857,188	26,369,286	16,557,529
Insecticide	43,407,408	8,558,137	5,535,321
Molluscicide	95,779	178,020	9,216
Plant-growth Regulator	2,789,587	1,137,805	626,636
Rodenticide	169,914	73,550	43,201

Source: Imported Pesticides into Thailand, 2002.

TABLE 4. Number of farmers affected by pesticide and herbicide use in Thailand.

Year	Number of patients	Number of dead
1992	3,599	31
1993	3,299	44
1994	3,165	39
1995	3,398	35
1996	3,168	32
1997	3,297	34

Source: Ministry of Public Health, Thailand. Department of Public Prosecution, September 1997 (http://www.anamai.moph.go.th/factsheet/occu2-12.htm)
The sickness rate was 5.71/100,000 population and death rate was 0.07/100,000 of population of agriculture workers.

TABLE 5. Some of biopesticides intensively studied and recommended for arthropod pest controlling Thailand.

Organisms used	Pests to be controlled
Bacteria *Bacillus thuringiensis* var. *kurstaki* *B. thuringiensis* var. *aizawai* *B. thuringiensis* var. *isaelensis*	Arthropod pests eg. *Spodoptera exigua, Plutella xylostella*
B. subtilis	Plant diseases eg. *Piricularia grisea, Curvularia lunata* and water treatment in shrimp industries
Viruses *NPV*	*Spodoptera exigua*
	Spodoptera litura
	Helicoverpa armigera
Fungi *Bipolaris oryzae*	*Cercospora oryzae*
Chaetomium globosum *C. cupreum*	*Piricularia oryzae, Puthium altimum, Sclerotium rolfsii, Fusarium oxysporum, Phytophthera palmivora*
Beauvaria bassiana	*Eutetranychus africanus*
Entomophthora grylli	*Patanga succinta*
Metarhizium anisopliae	*Oryctes rhinoceros*
Paecilomyces lilacinus	*Meloidogyne*
Nematodes *Steinernema carpocapsae* *S. siamkayai*	Flea beetles, *Spodoptera exigua, S. litura, Plutella xylostella*, *Cossus* sp., *Microchlora* sp.
Trichoconis padwickii	*Helmintosporium oryzae, Fusarium semitectum*
Trichoderma harzianum	*Rhizoctonia* spp., *Sclerotium* spp., *Pytium* spp.
Protozoa *Sarcocystis singaporensis*	*Rattus* sp., *Banticola* sp.

TABLE 6. Integrated use of SeNPV and Btk to control *S. exigua* on grape at Banpaew, Rajchaburi, Thailand, 2001 (13).

Treatment		Number of larvae (per m²)			Percent Control
			After		
NPV ($1x10^9$ PIBs) ml/20 L	*Btk* ($2x10^9$ CFU) g/20 L	Before Appl.	1st Appl.	2 nd Appl.	
20	40	156	37 ab	2 a	86.20
10	40	180	27 a	2 a	88.03
5	40	158	32 ab	1 a	93.18
20	30	243	50 b	2 a	91.14
10	30	192	19 a	4 a	77.57
20	20	192	33 ab	2 a	88.79
-	40	181	34 ab	1 a	94.05
20	-	176	27 a	3 a	81.65
Control		183	125 c	17 b	-

Means followed by a common letter are not significantly different at the 5% by DMRT

Biopesticides production in Thailand

Research and development of biopesticides in Thailand started in 1971 in order to control the diamondback moth, *Plutella xylostella* (Lepidoptera: Yponomeutidae), and cabbage looper, *Trichoplusia ni* (Lepidoptera: Noctuidae). At the beginning, all the research on biopesticides emphasized testing the efficacy for controlling various insect pests. It is reported that in the early days farmers and others involved in crop protection took little interest because biopesticides were slower acting in controlling insect pests compared to synthetic chemical insecticides. It is only after biopesticides were proven operationally to control some arthropod pests that researchers, universities, government agencies and the private sector became interested in this new, promising group of organisms. Field surveys conducted throughout the country by the Department of Agriculture revealed the presence of several promising organisms, including: *Bacillus thuringiensis, B. subtilis,* nucleopolyhedrovirus, *Metarhizium anisopliae, Beauveria bassiana, Trichoderma harsianum, Steinernema siamkayai,* and *Sarcocystis singaporensis* (Table 5). All these organisms have been intensively studied and tested, both in the laboratory and field, for efficacy. Application technology and mass production methods were also investigated. Currently, the Department of Agriculture has built a small pilot factory for producing *Bt* and NPV. The main objectives are promoting the use of biopesticides and developing an economically viable/ feasible means for mass-producing these organisms.

To promote and encourage the use of biopesticides, the Department of Agriculture has transferred the production technology of both *Btk* and nematodes to the private sector for commercialization. At present, there are five local private companies producing the three varieties of *Bt* and *S. siamkayai* (Table 5) and their combined production is about 20 tons a year. This does not cover the total demand in Thailand, and the rest has to be imported each year. The imported biopesticides (27.7 tons) represents less than 1% of all pesticide imports (42,248 tons) (2). It is estimated that local production of *Btk*, *Bti* and *Bta* will double by the year 2010.

Research on *Bacillus thuringiensis*

The first variety of *Bt* used in Thailand for insect pest control in 1969, was *Bt* var. *kurstaki* (*Btk*) (8). The main targets were lepidopterous larvae on cruciferous crops (15). Its use proved that *Btk* controlled a number of insect pests, especially those that were highly tolerant insects to synthetic pesticides, like *S. exigua* and *Heliothis armigera* (Lepidoptera: Noctuidae). These two are the key and damaging pests in many economically important crops and are very difficult to control using synthetic pesticides. It may be said that in any vegetable growing areas, farmers are going to consider turning to *Btk* or another biopesticide if they know that the target pests cannot easily be controlled using chemical insecticides. It is also generally accepted among growers and researches in Thailand that the synthetic chemicals of various groups, including organophosphates, pyrethroids and insect growth regulators, lose their effectiveness within a few years after their introduction and operational use. One promising approach for slowing the development of insecticide resistance is by alternating the use of chemicals or using products that have different modes of action. Under such conditions, growers will turn to and use biopesticides, especially *Btk,* as it is readily available in Thailand. Field tests to improve the efficacy of biopesticides, interestingly, showed that by applying *Btk* and NPV together, or either *Btk* or NPV alone, the level of control of *S. exigua* was acceptable (Table 6).

In Thailand, the amount of biopesticides used often varies from year to year, and the use of *Btk* is in inverse proportion to when the efficiency of the synthetic chemicals decreases. If a new, effective synthetic chemical is introduced, the use of biopesticides decreases. The importation of biopesticides into Thailand doubled in 1986 compared to 1985. However, the amount of *Btk* imported decreased in 1987 compared to that of 1986 due to the introduction of a new and effective group of pyrethroid insecticides. It has been reported that the percentage of *Btk* applications sharply increased by at least 15-fold between 1985 – 1987.

At present, there are more than 30 pest species in Thailand that can be controlled by *Btk*. In the past decade, DOA researchers have discovered over 100 new isolates of *Bt*. To promote the use of *Bt*, DOA has built a pilot plant with a production capacity of at least 1,000 litres per year to serve the northern vegetable growing areas and hopefully to reduce the dependency on the use of highly toxic chemical insecticides in the northern part of Thailand. Research on formulation of *Btk* has also been carried out to prolong the efficacy and stability in the environment. Furthermore, the private sector has also developed *Bt* strains (*Btk* and *Bta)* which can control the important pest of cruciferous crops.

Research on nucleopolyhedrovirus (NPV)

Nucleopolyhedrovirus (NPV) is recognized as the most effective virus for controlling several insect pests. Three NPVs can be produced by Department of Agriculture researchers i.e., *H. armigera* NPV, *S. exigua* NPV and *S. litura* NPV. Due to the problem of insecticide resistance of the cotton bollworm, the beet armyworm and the common cutworm, viruses can be used instead of the chemical insecticides and viruses can also play an important role in IPM programs. HaNPV provides effective control of the cotton bollworm on cotton, mungbean, sorghum, okra, asparagus, tomato, tobacco, grape vine, tangerine, rose and marigold. SeNPV is a promising agent to control the beet armyworm on onion, shallot, okra, asparagus, grape vine, rose, marigold and orchids. SlNPV is produced for the control of common cutworm on some vegetables such as cabbage, yard long bean and orchids. The Department of Agriculture has built and has been operating a nucleopolyhedrovirus pilot plant since 1994. The total production capacity for the three viruses, HaNPV, SeNPV and SlNPV, is 1000 litres (1-2 x 10^9 PIBs/ml) per year.

Research on entomopathogenic fungi

Metarhizium anisopliae (class Hypocreales: Clavicipitaceae) and *Beauveria bassiana* (Deuteromycotina: Hypomycetes or Moniliales: class Hyphomycetes) are two of the fungi that can be used as a microbial insecticides in Thailand at present. In Thailand, most of the research focuses on the use of green muscardine fungus, *M. anisopliae*, for the control of rhinoceros beetle, *Oryctes rhinoceros* (Coleoptera: Scarabaeidae), which causes considerable economic damage to both coconut and oil palms. Large scale applications of this fungus have been conducted in the coconut plantation in the southern part of Thailand.

Research on entomopathogenic nematode

Research on entomopathogenic nematodes for controlling insect pests in Thailand started in 1986. The first field trials were conducted to determine the effectiveness of *Steinernema carpocapsae* against such bark-boring caterpillars as: *Cossus* sp. (Lepidoptera: Cossidae) and *Microchlora* sp. (Lepidoptera: Pyralidae), both serious insect pests of Longkong, *Lansium domesticum* (Sapindales: Meliaceae). When suspensions containing 2,000 nematodes/ml were sprayed on the stems and twigs of Longkong tree in the evening, 80% of the bark-feeding caterpillars died within 24 hours of the application. Further field trials were conducted, suggesting that this nematode can also be used to control the larvae of striped flea beetle, *Phyllotreta sinuata* (Coleoptera: Chrysomellidae), sweet potato weevil, *Cylas formicarius* (Coleoptera: Curculionidae) and beet armyworm, *S. exigua*. In 1999, the nematode production technology was transferred to a private company for marketing and distribution (11).

Research on coccidian protozoa for rodent control

Due to resistance of rodents to chemicals, new rodenticides must also be developed. It has been reported that *Sarcocystis singaporensis* caused mortality in the native *Rattus* species (4, 7). *S. singaporensis* is a coccidian protozoan with a life cycle between a python and rats (*Rattus* spp. and *Bandicota* spp.). Cooperative research conducted by the University of Hohenheim, Bayer A.G. and the Agricultural Zoology Research Group, DOA, Thailand, showed that this parasite is highly effective in controlling rats in rice fields, oil palm plantations and chicken farms. Further research on *Sarcocystis* will include studying the virulence of the parasites, viability, immunological selection, and mass production techniques of this organism. The research group currently has a cooperative project with Uniseeds Co., Ltd. to develop this parasite as a commercial product. The Department of Agriculture and TGZ-project (German Technical Cooperation Agency) are pushing and encouraging the ASEAN countries to use such poison baits against rats, both in the fields and in households. So far, considerable success using this organism to control rats has been confirmed in both Thailand and the People's Democratic Republic of Laos (9).

Biopesticides can be used as an IPM control component and can replace synthetic chemicals in most vegetable production programs. To minimize the impact of chemical pesticides, especially pesticide residues on food products, the cooperating agencies, including the Department of Agriculture, universities, National Science and Technology Development and the Thai Research Fund, have transferred the technical knowledge for the production and use of biopesticides to local, private companies. According to the Thai Government's policy promoting Thailand as "the world's kitchen", *Btk*, *Bta* and other biopesticides are emphasized as being one of the major control components in IPM programs for the production of vegetables, both for local consumption and export, on such crops as asparagus, baby corn, okra, etc. Even so, considerable effort still has to be exerted to increase the use of *Btk*, as the use of this biopesticide is still very low compared to those synthetic chemicals.

There are several of reasons why farmers are reluctant to adopt *Btk* or other biopesticides to replace synthetic chemicals:

1. Comparative efficacy: Biopesticides generally act slower than synthetic pesticides, killing arthropod pests over a longer time rather than having an immediately apparent "knock-down" effect, so the pests can still damage the crops after application. Because of this, farmers still prefer to use and rely on the quick acting synthetic pesticides, causing high pest mortality shortly after application, which farmers got used to expect over the last 30 years. Furthermore, biopesticides are more expensive than synthetic pesticides, consequently farmers unhesitatingly always choose the cheaper and faster acting synthetic pesticides. In addition, biopesticides are highly specific compared to broad spectrum synthetic chemical pesticides. This disadvantage makes farmers reluctant to adopt biopesticides as a control component of IPM.

2. Application technology: Technical knowledge on the proper application methods, both number and size of spray droplets per m^2 foliage, is very important for enhancing the efficacy of biopesticides. Applying too much spray volume causes loss of product, while applying too little spray volume can cause uneven coverage of the target crops and lower pest mortality. Research proved that conventional applications of *Btk* (high spray volume, ca. 750 L/ha) are less effective than the reduced volume application (of less than 250 L/ha with droplet density 198-209 droplets/cm^2) in controlling *S. exigua* (13).

3. Availability of biopesticides in Thailand: As mentioned earlier, biopesticides represents less than 1% of overall pesticides imported and used. They are quite specific to insect pests, sometimes they are hard to get and cannot be used as broad-spectrum applications to control various pests, as can synthetic pesticides.

4. Technical knowledge and training: Farmers need training, not only in the knowledge of how biopesticides and synthetic pesticides work, but also in the application technology and health hazards associated with the use of these products. Such training will lead to the proper use of both biopesticides and synthetic pesticides.

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