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DIAMONDBACK MOTH CONTROL WITH *BACILLUS THURINGIENSIS* PRODUCTS IN THAILAND

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ABSTRACT

In Thailand only products based on *Bacillus thuringiensis* are registered for control of the diamondback moth and cabbage looper pests of cruciferous crops. Most of the commercial products are based on *Bacillus thuringiensis* subsp *kurstaki* (Serotype 3a, 3b). Since it was first field tested in 1972, its efficacy has been continuously assessed. More promising activity is obtained from liquid formulation than from wettable powder and good to excellent control is normally found in highlands and lowlands areas with milder climatic condition than lowland areas with warmer climatic condi- tions. Irrigation practices also influence officency. Since the diamondback moth is resistant to many chemical insecticides, *B.t.* products are of interest to growers in many areas. Their importation has increased markedly since 1985. *Bacillus thuringiensis* will also be recommended for use in the diamondback moth national-wide IPC program. However, new strains of *B. thuringienis* that are more suitable for tropical climatic conditions and pest control practices in Thailand are required.

INTRODUCTION

In Thailand, like many other Southeast Asian countries, the Diamondback Moth (DBM), *Plutella xylostella* (L.) poses a serious limiting factor for production of crucifers. Among a total planting area of 57,000 hectares, cabbage ranks highest both in quantity and hectares. The other common varieties are Chinese kale, Chinese mustard, Chinese cabbage (pet-tsai), Chinese radish and cauliflower. Apart from DBM, crucifers are subjected to damage by a number of other insects (Table 1). In Thailand there is a complex of lepidopterous pests that attack crucifers including *Trichoplusia ni, Spodoptera exigua* and *Hellular undalis.* Since insecticides play a major role in insect control on crucifers, many products are recommended including the microbial agent *Bacillus thuringiensis* (Table 2).

There are two general types of agroecosystems for commercial crucifer cultivation-lowlands and highlands. The two main types can be subdivided into a number of cultivation areas based on the differences in cropping patterns, insecticide application as well as irrigation practices, and insect species complex. All these environmental characteristics often cause insecticide resistance and reduce insecticide effectiveness. To facilitate pesticide management for DBM control a number of cruciferous cultivation practices are proposed (see Table 3).

It is widely accepted among growers and research workers, that DBM reistance to insecticides has occurred although only few studies have been carried out and reported (Rushtaprakomchai and Vattanatangum, 1986b). The first evidence of resistance was reported by Sinchaisri et al. (1980) and later by Georghiou (1981). Zoebelein (1987) recently reported historic cases of DBM resistance to more than one group of insecticide in Thailand. From intensive studies on toxicology of insecticide resistance in the DBM in Thailand, Miyata, personal communications, pointed out that DBM is capable of developing resistance to most types of insecticides. A comprehensive field screening

TABLE 1
List of insects attacking crucifers in Thailand

Common name		Scientific name
Diamondback moth	(DBM)	**Plutella xylostella* (linn.)
Beet armyworm	(BA)	**Spodoptera exigua* (Hubn.)
Cabbage looper	(CL)	*Trichoplusia ni (Hubn.)
Cabbage centre-grub	(CG)	*Hellula undalis* (Fabr.)
Cabbage webworm		
Cotton leafworm	(CL)	*Spodoptera litura* (Fabr.)
Cabbage moth	(CM)	*Crocidolomia binotalis* Zeller
Striped flea beetle	(FB)	**Phyllotreta sinuata* (Steph.)
Turnip aphid	(A)	*Lipaphis erysimi* Kalt.
Green peach aphid	(A)	*Myzus persicae* (Sulz.)
Cabbage white butterflies	(CB)	*Pieris canidia* Sparr.
		Pieris brassicae nepalensis Doub.
Vegetable bug	(VB)	*Eurydema liturifera* Walker
Cutworm	(CW)	*Agrotis ipsilon* Rott.
Cabbage leafminor	(CM)	*Lariomyza brassicae*

* To be classified as major important species.
Source: Div. Entomology and Zoology Dept. of Agriculture.

record of candidate products from 1972–1987 (Table 4) has demonstrated that chemical insecticides of various groups, including organophosphates, pyrethroids and insect growth regulators lost their effectiveness just a few years after their introduction. One promising approach for retarding insecticide resistance is by rotation of chemicals or using products that have a different mode of action and no cross resistance (Georghiou and Mellon, 1983). Sun et al. (1986) also suggested using *B. thuringiensis* in rotation with other insecticides. In Thailand *Bacillus thuringiensis (B.t.)* has long been regarded as a promising microbial insecticide for vegetable insect control *B.t.* products are considered safe for the environment nontarget organisms. Commercial products based on *B. thuringiensis* subsp *kurstaki* are available in Thailand.

Field efficacy of commercial products *B. thuringiensis* from tested areas in Thailand will be discussed in this report along with problems arising from field application in various cultivation areas and trends for future use.

Status of *Bacillus thuringiensis* for diamondback moth control in Thailand

Since some advantage may occur from the use of *B. thuringiensis* for vegetable insect pest control, field studies on the efficacy of commercial products based on *B.t.* were initiated in 1972 in the Northern vegetable areas by the Division of Entomology and Zoology. Field trials were continued and expanded into central areas of the country in 1974. The continuation of field tests of commercial *B.t.* products has been carried on to the present time. Most tests are carried out in farmers' fields.

Conventional sprayers were employed with an average spray volume of 1,000 litre/ha. Spray intervals were adjusted depending upon normal cultivation practices of the area. Rates of application for lowlands I (Northern) were 1.0–3.0 litre/ha., whereas in lowlands III (Central) application rates were 2.0 to 3.0 l/ha. A map of Thailand indicating testing area is shown in Fig. 1. The incidences of insect pests varies depending on seasonal and geographical distribution, a species complex of *P. xylostella, T. ni* and *H. undalis* often existed in highlands I–II and lowlands I (Northern). For lowlands II–III (central), including Bangkok suburbs, a species complex of *P. xylostella, S. exigua* and *T. ni* often occurred. In most cases the insects were more abundant during February to April A summary of field screening tests for 1972–1986 (Table 5) indicates that *B.t.* products from different sources (e.g.) Argona, Biotrol, Bactospeine, Drisidrin, Dipel and a new experimental product SAN

TABLE 2
Insecticides for major insect control on crucifers in Thailand (1986–1987)

Insecticide	Formulation	Insect (see attached list)
Organophosphorus		
Prothiophos	50 EC	DBM, GG, A,,
Malathion	83, 57 EC	A, FB,,
Pirimecarb	50 DP	FB, A
Mevinphos	24 EC	DBM, CG, CL, A
Dicrotophos	50 EC	FB
Diazinon	40, 60 EC	FB, A
Methamidophos	50 EC	CM, FB, A, CG
Carbamate		
Cabaryl	85, 50 WP	FB
Carbosulfan	50 EC	FB
BPMC	50 EC	FB
Pyrethroid		
Deltamethrin	2.5, 1.25, 3, 5 EC	DBM, CG, CL
Permethrin	10, 20, 25 EC	DBM, CG, CL
Cypermethrin	10, 15, 20, 25, 35 EC	DBM, CG, CL
Fenvalerate	5 EC	DBM, CG, CL
Insect growth regulator		
Teflubenzuron	5 SC, EC	DBM, BA, CL
Chlorfluazuron	5 EC	DBM, BA, CL
Diflubenzuron	25 WP	DBM, BA, CL
Triflumuron	25 WP, 48 SC	DBM, BA, CL
Microbial product		
Thuricide	WP (16,,000 IU per mg on *T. ni*) SC (8,,500 IU per mg)	DBM, CL
Agona	WP (16,,000 IU per mg)	
Bactospeine	FC (8,,500 IU per mg)	DBM, CL
Dipel	8 AF (14,,500 IU per mg)	

Source: Div. of Entomology and Zoology, Dept. of Agriculture, 1986–87.

415 I gave fair to excellent control for *P. xylostella* and *T. ni* on common cabbage in lowlands I (Northern), but gave only fair control against DBM on Chinese kale in lowlands III (see Tables 6 and 7).

More recent field evaluations of *B.t.* products were carried out in lowlands I (Table 8). A Bactospeine FC formulation applied at rates 1.0–1.5 litre/ha. gave excellent control on DBM populations, whereas other commercial products such as Dipel 4L, Toarow CT and experimental SAN 415 I, B 5014/15 and B 4010 gave promising results.

In the field tests recorded so far, Bactospein FC formulation has shown more consistant effect than did other *B.t.* preparations. Thus in 1986 Bactospein FC applied at the rate of 2 liter/hectare was selected for an experimental trial as integrated control of DBM on common cabbage. The results from the treated areas confirmed the work of Rusttaprakornchai (1987a). At the present time the recommended rates of products based on *B.t.* for vegetable growers in Thailand are 1.5–2.0 liters or 1.5–2.0 kilograms of product per hectare for highlands and lowlands I, and 2.5–3.0 liters or 2.5–3.0 kilograms product per hectare for lowlands II + III.

TABLE 3
Crucifer cultivation pattern in Thailand*

Cultivation	Major crop varieties	DBM incidence
HIGHLANDS I		
Newly open forest areas, rainy season crop only, one crop/year	Common cabbage, chinese cabbage	light
HIGHLANDS II		
more than 5 years of continuous cropping up to two crop/year	Similar to I	light to moderate
LOWLANDS I		
rice based cropping system, one crop/year after rice	Mixed varieties	light to moderate
LOWLANDS II		
areas close to lowlands III, more than one crop/year	Common cabbage, chinese cabbage, chinese mustard, chinese radish	moderate to heavy
LOWLANDS III		
lowlands cultivation chinese method year-round cropping	Chinese kale, mustard Green, chinese mustard, chinese radish, chinese cabbage	moderate to heavy

*Proposed for DBM Management Program

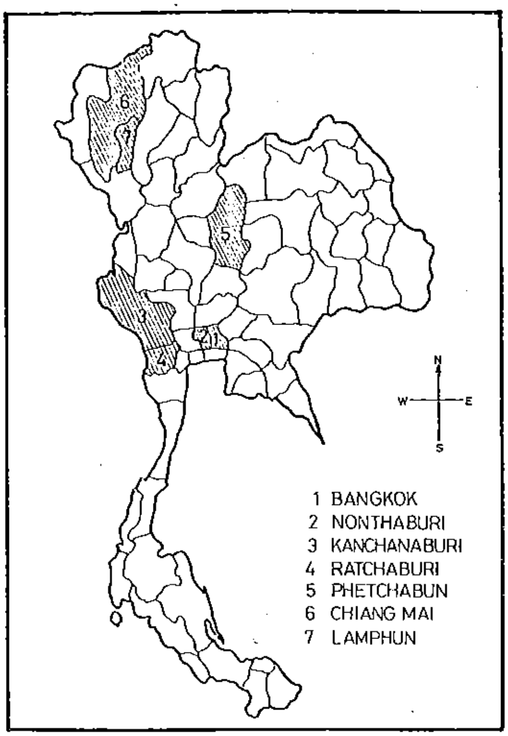

Fig. 1. Map of Thailand showing field evaluation areas of *B.t.* products.

TABLE 4
Summary of results of field screening of various insecticides for diamondback moth DBM control in Thailand during 1972–1987

Insecticides	Year of introduction and use[#]															
	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Kavinphos	4N	–	2N	3N	–	–	–	–	–	–	–	–	1C	–	–	1N
Naled	2N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Quinalphos	–	–	4C	–	–	–	–	–	–	–	–	–	–	–	–	–
Methomyl	2N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Methsaidophos	3N	–	3N	2N	–	–	–	–	–	–	–	–	–	–	–	–
Acephate	3N	–	–	2N	–	–	–	–	–	–	–	–	–	–	–	–
Biotrol	3N	3N	3N, 2C+	–	–	–	–	–	–	–	–	–	–	–	–	–
Disidrin		2N	2N+, 2C	–	–	–	–	–	–	–	–	–	–	–	–	–
Dipel		2N	2N	–	–	–	–	–	–	–	–	–	–	–	3N	3N
Cartap			3N, 3C	–	1C	–	–	–	–	–	–	–	–	–	–	1N
Triazophos			3N	3N	3C	4C	4N	–	–	–	–	–	–	–	–	1N
Prothiophos				4C	4N	–	4C	–	–	–	4N	–	1C	–	1C	1N
Fenvalerate					4C	3C	4N,	–	–	–	3N	–	–	–	–	1N
Permethrin					4C	–	2C	–	–	–	–	1C	–	–	1N, 1C	1N
Cyanofenphos						3C	2C	–	–	–	–	–	–	–	–	–
Cypermethrin						3C	3C+	–	–	–	–	2C	–	–	–	–
Deltamethrin							3C	–	–	–	–	1C	–	–	–	–
Thuricide							2C	–	–	–	–	2C	1C	–	–	1N
Bactospeine WP							2C	2C	–	–	3N	2C	–	–	3N, 2C	3N
Bactospeine FC											3N	2N	2C	–	–	–
Argona															4N, 2C	4N
Diflubenzuron											2N	2C	–	–	3N, 2C	–
Trifluouron											3N	3C	–	–	1N, 1C	–
Teflubenzuron											3N	2C	1C	–	1N, 1C	–
Chlorfluazuron												3C	4C	–	4N, 2C	4N, 1C
												4C	–	–	4N, 2C	4N, 1C

[#]1 = poor control, 2 = fair control, 3 = good control, 4 = excellent control. C = central region including Bangkok suburbs, N = northern region.
*Mixed with other insecticides.
Source: (Rushtaprakornchai, 1986a, 1986b and 1987b)

TABLE 5
Summary of results from field screening of *Bacillus thuringiensis* for control of diamondback moth in Thailand during 1972–1987

Insecticides	Year of introduction and use[#]															
	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Biotrol	3N	3N	3N, 2C	–	–	–	–	–	–	–	–	–	–	–	–	–
Disidrin		2N	2N+, 2C	–	–	–	–	–	–	–	–	–	–	–	–	–
Dipel		2N	2N	–	–	–	–	–	–	–	–	–	–	–	–	3N
Thuricide HP								2C	–	–	3N	2C	–	–	3N, 2C	3N, 2C
Thuricide SC											3N	2C	–	–	–	–
Bactospeine WP											3N	2N	2C	–	–	–
Bactospeine FC															4N, 2C	4N
Argona											2N	2C	–	–	3H, 2C	–

[#] 1 = poor control, 2 = fair control, 3 = good control, 4 = excellent control C = central region including Bangkok suburbs, N = northern region. + = mixed with other insecticides.

TABLE 6
Results of field evaluation of *Bacillus thuringiensis* products for control of diamondback moth on *Chinese kale* at Nonthaburi Province (C) 1986[a]

Insecticides	Rate (kg, litre) of product/ha	No. of DBM larvae & pupae/10 plants after treatment	Yield (kg) 25 plants
Thuricide HP	2.0 kg	3.0 abc	0.94
Thuricide HP	3.0 kg	0.7 cd	0.96
Argona WP	2.0 kg	1.3 bcd	0.93
Argona WP	3.0 kg	1.7 bcd	1.00
SAN 415 I	1.0 kg	2.7 abcd	1.02
SAN 415 I	1.5 kg	1.3 bcd	1.11
Dipel 4F	3.0 litre	2.7 abcd	1.05
Dipel 4F	4.0 litre	1.3 bcd	0.83
Bactospeine FC	3.0 litre	1.0 cd	1.13
Bactospeine FC	4.0 litre	0.0 d	1.30
Control		6.0 ab	0.81

Source: Rushtaprakornchai, 1987A
a = Cultivar: Local Kim Jeng, Sowing date 19/2/86. harvesting date 16/4/86. Spray interval 4 days. Average sprayed mixture 1,000 litre/ha.

TABLE 7
Results of field evaluation of *Bacillus thuringiensis* for control of diamondback moth on *common cabbage* of Lumphun Province (N) 1986a

Insecticides	Rate (kg, litre) of product/ha	No. of DBM larvae/pupae/10 plants			Yield (kg) 20 marketable heads
		1st check	2nd check	3rd check	
Thuricide HP	1.0 kg	17.0 bcde	42.3 cdef	65.7 bcdef	4.4 a
Thuricide HP	1.5 kg	13.0 cdef	57.7 cdef	80.3 abcde	4.7 a
Argona WP	1.0 kg	21.0 bc	75.7 bcd	82.7 abcd	4.2 a
Argona WP	1.5 kg	16.0 bcde	49.7 bcde	104.3 a	6.6 a
SAN 415 I	0.5 kg	13.3 cdef	27.3 efg	99.0 ab	4.7 a
SAN 415 I	0.75 kg	3.6 f	13.3 fg	52.3 defg	5.8 a
Dipel 4 F	2.0 litre	8.0 cdef	42.7 cdef	77.3 abcdef	5.4 a
Dipel 4 F	2.0 litre	6.3 ef	21.0 efg	44.0 fghi	4.4 a
Bactospeine FC	3.0 litre	8.6 cdef	23.3 efg	15.3 hi	6.2 a
Bactospeine FC		7.0 cdef	12.0 fg	12.0 i	6.2 a
Control		45.3 e	281.3 a	54.0 defg	0.0

Source: Rushtaprakornchai, 1984a.
a = Cultivar: Tropical queen. Transplanting date 25/2/86. Spray interval 7 days.
Average sprayed mixture 1,000 litre/ha.

TABLE 8
Results on field screening of *Bacillus thuringiensis* products for control of DBM on common cabbage at Lampoon (N) 1987

Insecticides	Rate/ha	No. of DBM larvae + pupae/10 plants on					Yield t/ha
		87/02/09	87/02/16	87/02/23	87/03/02	87/03/15	
B 4010	1.0	9.7 ab	8.3 ab	4.7 a	10.0 abc	4.3 ab	29.1 ab
B 4010	1.5	6.0 ab	10.3 abc	7.7 ab	7.0 a	2.7 a	25.0 bc
B 5014/15	1.0	14.7 bc	10.0 abc	7.3 ab	17.0 bc	3.3 ab	30.5 ab
B 5014/15	1.5	19.0 cd	12.0 abc	8.7 ab	14.7 abc	4.3 ab	25.0 bc
S 415 I SC	1.0	11.3 ab	13.0 abc	7.7 ab	8.0 a	4.3 ab	29.1 ab
S 415 I SC	1.5	7.7 ab	9.3 abc	7.0 ab	11.0 abc	3.0 ab	29.1 ab
Toarow CT, WP	0.5	11.7 abc	16.0 cd	9.0 b	14.0 abc	7.7 c	25.0 bc
Toarow CT, WP	1.0	8.3 ab	13.7 bc	8.7 ab	15.7 abc	6.0 bc	30.5 ab
Bactospeine FC	1.0	9.7 ab	9.0 abc	5.7 ab	7.7 a	4.3 ab	34.7 a
Bactospeine FC	1.5	4.0 a	6.3 a	5.7 ab	9.0 ab	3.7 ab	23.6 bc
Dipel 4L	1.5	22.7 d	15.3 abc	9.3 b	18.3 c	5.7 abc	24.3 bc
Control	–	32.7 e	21.7 d	22.3 c	27.7 d	15.0 d	17.9 c

(a) Cultivar: Tropical queen. (b) Transplanting date: 87/01/11. (c) Insecticide applied 87/01/27, 02/03/10, 02/17.,02/24, 03/03, 03/10, 03/17. (d) Harvest date: 87/03/27. (e) Data shown are means of three replicates. Mean in each vertical column followed by the same letter are not significantly different at 5% level according to Duncan's Multiple Range Test. (f) Plot size: 10 sq. m.
Source: Rushtaprakornchai, 1986a.

DISCUSSION

We have reported here that *B. thuringiensis* subsp *kustaki* (Serotype 3a, 3b) can be used effectively for DBM control in Thailand. Importation of *B.t.* products has increased since 1980 when the use of pyrethroids began to decrease. Importation reached a record of 71.0 tons in 1986 at the time when insect growth regulators (IGRs) showed decreasing effectiveness in the field (Figure 2). *B.t.* products are applied more frequently in lowland I and II in order to replace the pyrethroids and IGRs. Records from field surveys made between 1985 and 1987 in lowlands II and III showed that the percentage of *B.t.* applications increased sharply from 0.52 % to 9.74 % (Tondeetae, 1988). Even though studies are being carried out on DBM resistance to insecticides, it should be noted that the DBM in Thailand is developing resistance to many insecticide groups in addition to pyretroids and IGRs. Should further application of *B.t.* substantially increase, the incidence of DBM resistance to *B.t.* could become a problem (Miyata, 1988). Thus under the IPC program for DBM, rotation of insecticides is a suggested tactic. It is anticipated that vegetable growers will be able to test the newly launched product Abamectin in Thailand. Possible problems of decreasing efficiency of *B.t.* products in the lowland III area of Thailand may be the result of a number of factors such as extremely high temperature, more frequent and heavier overhead sprinkler application using the chinese method of cultivation, and decreased sprays coverage particularly to under-leaf surfaces. One of the limiting factors on the efficacy of *B.t.* products in Thailand is at the time when DBM co-exists with other lepidopterous pests. More potent and broader spectra *B.t.* strains are required. Investigations addressing their area are being carried out at our plantation.

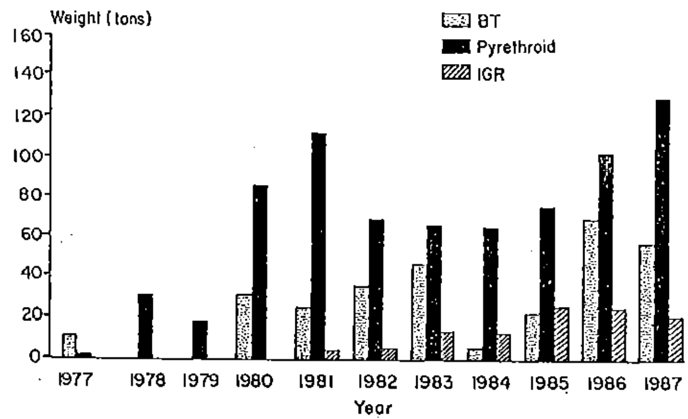

Fig. 2. Importation of *B.t.*, pyrethroid and IGR products to Thailand for agricultural use during 1977 to 1987. Source: Agricultural Regulatory Division Department of Agriculture.

CONCLUSION

Bacillus thuringiensis formulations are being used effectively and widely for controlling *P. xylostella* and *T. ni* in Thailand. Promising control of these pests have been achieved when *B.t.* is applied on common cabbage that grows in highlands and some lowland areas, but *B.t.* formulations fail to show consistant effectiveness when sprayed on chinese kale and other crucifers in central lowlands, including Bangkok surburbs where a Chinese method of cultivation is employed. Factors needing additional research are application techniques, heavy overhead irrigation, and influence of extreme climatic conditions. The rise and fall of products based on *B.t.* demand for Thailand market depends on the development of insecticide resistance by the DBM. Rotation of *B.t.* products with other insecticides is strongly recommended. This practice is advocated not only to retard the development of insecticide resistance on registered products, but also to prolong the present efficacy of *B.t.* products. More potent strains of *B.t.* with broader spectra of activity are also required.

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