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Field Evaluation of Microbial and Chemical Insecticides for Diamondback Moth and Other Lepidopterous Pests Control on Cabbage[1]

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Abstract The newly introduced experimental *Bacillus thuringiensis* (BT) products and one synthetic chemical were screened in field on their efficacies to control the diamondback moth (DBM, *Plutella xylostella*), *Spodoptera litura* and *Pieris rapae*, and the long-used BT products and synthetic pyrethroids served as the comparing control agents. The results of two field experiments indicated that the newly commercialized SAN415-SC and other experimental BT products such as Florbac-FC, Florbac-XLV, TC0918 and CGA237218 provided better control on the DBM than other brands although suitable dosages still need to be determined. All BT products provided fair control for *P. rapae*. A newly developed thiourea insecticide/acaricide, Polo (diafenthiuron), performed better than any other entries in this field evaluation on both DBM and *S. litura*. Two tested synthetic pryethroids had not only lost their ability in controlling the DBM, also resulted in higher DBM counts by reducing both competition from other pests and the parasitization of natural enemies.

Key words : *Bacillus thuringiensis*, *Plutella xylostella*, *sodoptera litura*, *Pieris rapae*, diafenthiuron (Polo®)

Introduction

The diamondback moth is very efficient in developing resistance to various synthetic insecticides (Cheng, 1985; Cheng, 1988), and the control of multiple resistant DBM in field has become a difficult problem for vegetable farmers. Currently, only few insecticides registered on DBM in Taiwan (Taiwan Provincial Department of Agriculture and Forestry, 1990) show mild or no resistance problem, among those, BT is the most important one. Although suspected resistance to BT in lepidopterous species has been reported (McGaughey and Beeman, 1988; Kirsch and Schmutterer, 1988), it still remains to be clarified. On the other hand, the inconsistent control efficacy of BT is mostly linked to environmental factors (Ignoffo et al., 1982; Dunkle and Shasha, 1988; Dunkle and Shasha, 1989). In recent years, research on the improvement of BT efficacy has proceeded rapidly either by selecting mutants with higher potency or by combining

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the BT toxins to the BT formulations (Moar et al., 1986;McGaughey and Johnson, 1987; Padua et al., 1987; Gardner, 1988; Morris, 1988). For example, SAN-415 was introduced in Taiwan in 1989, and its DBM control efficacy in field was significantly better than other long-standing BT products (Chen, 1990). In order to compare the newly improved BT products and other recently developed chemicals on the control efficacy of DBM, experiments were conducted to evaluate and comment these experimental insecticides since they may be introduced for DBM control in Taiwan in the near future.

Materials and methods

1. Insecticides

A total of nine microbial and four chemical insecticides were used. The commercial formulations of three widely used BT were Thuricide WP (16,000 IU/mg, Sandoz Ltd.), Bactospeine WP (16,000 IU/mg, Duphar B. V.) and Dipel WP (16,000 IU/mg, Abbot laboratories). Six experimental BT formulations were SAN415-SC (8,000 IU/mg, Sandoz Ltd.), Florbac-FC (8,500 IU/mg, Duphar B. V.), Florbac-XLV (10,000 IU/mg, Duphar B. V.), Bactospeine-XLV (13,000 IU/mg, Duphar B. V.), TC0918 (10% a. i. in toxin, Cheng-Hong Chem. Co. Ltd.) and CGA-237218 (0.6% a. i. in toxin, CIBA-Geigy Corp.). Four synthetic chemicals used were 50% Polo SC (CIBA-Geigy Corp.), 50% Polo WP (CIBA-Geigy Corp.), decamethrin (2.8% Decis EC, Lansdowne Chem. Co. Ltd.) and flucythrinate (31.6% Pay-off EC, American Cyanamid Co.).

2. Field layouts and items inspected

Two field experiments were separately conducted from Dec., 1989 to Jan., 1990 and from Mar. to Apr., 1990, respectively to compare the efficacy of insecticides in controlling lepidopterous pests on vegetable. Field design of both experiments constituted 4 blocks, and 12 treatments were randomized into 4 blocks. Plots were separated by a protection row of cabbage. Insecticides were applied by hand-operated pressure sprayer and treated on a 7-day interval schedule. For the first field experiment, a total of 8 sprays were conducted, and insecticides were applied in 5 consecutive weeks in the second experiment.

The post-treatment inspections on target insects were made on the 6th day following each spray. Total number of larvae and pupae were counted on 10 plants randomly selected in each plot, and a total of 40 plants in four blocks were inspected for each treatment. In the first experiment, *Spodoptera litura* density was high and all 8 observations were reported. The population density of DBM was low in the first 3 applications, hence only the data from the 4th to 8th week were recorded for control efficacy analysis. In the second experiment, *Pieris rapae* occurred abundantly except the last inspec-tion, thus only the first 4 observations were analyzed. The control efficacy of DBM in each treatment were recorded and analyzed.

The control efficacy in percent was calculated by comparing the target pest count in each treatment to the check plots. The control rates obtained in each experiment were analyzed by Duncan's multiple range test at $\alpha=0.05$. When the target pest count was higher than that of the check plot, the control rate was set at 0%.

3. Examine the cross resistance on diafenthiuron

A multiple resistant DBM strain was compared to the susceptible IL-strain on their sensitivity to diafenthiuron. In this part of experiment, the synergist, piperonyl butoxide (pb), in 5 : 1 ratio to diafenthiuron was incorporated in the test. The testing method was identical to that of the previous report (Cheng et al., 1988).

Results and discussions

The results of the first experiment were presented in Tables 1 and 2 for DBM and *S. litura*, respectively. Results of the second experiment were presented in Tables 3 and 4 separately for DBM and *P. rapae.*

Table 1. The control efficacies of 11 insecticides on *Plutella xylostella* in the first field experiment (Dec. 1989–Jan., 1990)

Treatment	Dilution	% control					Mean*
		5 Dec	12 Dec	19 Dec	26 Dec	3 Jan	
Polo 50%WP	1000X	95.8	96.4	94.1	93.2	93.2	94.5 a
TC0918	1000X	87.5	89.3	79.4	95.9	87.7	88.0 ab
Polo 50%SC	1000X	66.7	92.9	76.5	97.3	95.9	85.9 ab
Polo 50%SC	2000X	66.7	82.1	91.2	91.9	89.0	84.2 ab
Florbac-XLV	667X	50.0	64.3	64.7	83.8	90.4	70.6 bc
SAN415-SC	1000X	41.7	71.4	64.7	90.5	56.2	64.9 c
Florbac-FC	571X	29.2	78.6	58.8	79.7	72.6	63.8 c
Bactospeine-XLV	889X	58.3	25.0	55.9	66.2	82.2	57.5 cd
TC0918	1500X	4.2	60.7	73.5	74.3	60.3	54.6 cd
Thuricide	1000X	25.0	39.3	50.0	68.9	35.6	43.8 d
Bactospeine	1000X	0	50.0	41.2	62.2	64.4	43.6 d

*Means followed by the same letter are not significantly different ($\alpha=0.05$; Duncan's multiple range test).

Table 2. The control efficacies of 11 insecticides on *Spodoptera litura* in the first field experiment (Nov. 1989–Jan., 1990)

Treatment	Dilution	% control								Mean*
		14 Nov	21 Nov	28 Nov	5 Dec	12 Dec	19 Dec	26 Dec	3 Jan	
Florbac-FC	571X	86.2	73.6	85.3	96.1	96.2	86.7	77.3	66.7	83.5 a
Polo 50%SC	1000X	41.4	94.3	85.3	100	70.5	93.3	95.5	83.3	82.9 ab
Polo 50%SC	2000X	89.7	94.3	32.4	95.3	97.4	83.3	81.8	83.3	82.2 ab
TC0918	1500X	69.0	98.1	86.8	84.4	89.7	50.0	72.7	25.0	72.0 abc
Florbac-XLV	667X	44.8	56.6	82.4	89.1	92.3	70.0	68.2	50.0	69.2 abc
TC0918	1000X	0	96.2	55.9	89.1	79.5	63.3	77.3	83.3	68.1 abcd
Polo 50%WP	1000X	0	69.8	94.1	99.2	97.4	70.0	0	100	66.3 abcd
Thuricide	1000X	79.3	86.8	32.4	53.9	60.3	36.7	22.7	66.7	54.9 bcd
SAN415-SC	1000X	10.3	71.7	60.3	82.0	79.5	13.3	36.4	25.0	47.3 cd
Bactospeine-XLV	889X	0	43.4	30.9	64.8	74.4	20.0	22.7	66.7	40.4 de
Bactospeine	1000X	3.4	24.5	0	53.1	0	16.7	31.8	16.7	18.3 e

*Means followed by the same letter are not significantly different ($\alpha=0.05$; Duncan's multiple range test).

Although the DBM density occurred in the two experiments differed due to variation in seasonal abundance, the outcome of treatments have similarity for a particular insecticide. Most of the entries of both field test were BT, but the control efficacy differed significantly from one product to another. Three currently available commercial BT products, Thuricide, Bactospeine and Dipel, did not perform as well as expected for DBM control. Among them, the long-used Bactospeine gave the worest performance in both field tests, and the control rate were 43.6 and 24.3% only. Another long-used BT, Thuricide, provided only 43.8 and 49.5% control.

On the contrary, new experimental BT products gernerally gave better DBM control at adequate application dosage. SAN415-SC, a new BT product on the market, provided 34—65% control, however another WG formulation with potency of 32,000 IU/mg provided better DBM control compared to other entries (Chen, 1990). For DBM, Florbac-FC and Florbac-XLV showed 64% and 60—70% control efficiencies, respectively, than the check plots, while TC0918 and CGA237218 gave 60—80% control (Tables 1 and 3). Although Bactospeine-XLV is a new BT formulation, only minimum improvement in its DBM control efficacy appeared.

Higher dosage of TC0918 and CGA237218 resulted in better DBM control. The dosage difference affected the control rate as the results varied between the two dosage treatments in TC0918 and CGA237218. It seems that for DBM, efficacies of Florbac-FC, Florbac-XLV, TC0918 (1000X) and CGA237218 (1000X) in field application were equal to or better than that of SAN415-SC (Table 1) .

Table 3. The control efficacies of 11 insecticides on *Plutella xylostella* in the second field experiment (Mar. Apr., 1990)

Treatment	Dilution	% control					Mean*
		27 Mar	3 Apr	10 Apr	17 Apr	25 Apr	
Florbac-FC	571X	46.4	64.5	64.2	70.7	68.1	62.8 a
CGA237218	1000X	57.1	60.9	55.6	57.1	73.9	61.0 ab
Florbac-XLV	667X	57.1	65.9	63.0	56.1	53.6	59.1 ab
Thuricide	1000X	42.9	60.1	33.3	44.7	66.7	49.5 bc
Bactospeine-XLV	889X	25.0	47.8	49.4	36.8	44.9	41.4 cd
CGA237218	2000X	27.4	46.4	46.9	43.9	14.5	35.8 de
SAN415-SC	1000X	22.6	28.3	22.2	47.2	47.8	33.6 de
Bactospeine	1000X	16.7	36.2	24.7	25.2	18.8	24.3 e
Dipel	1000X	29.8	22.5	19.8	36.6	8.7	23.5 e
Decamethrin	1000X	0	0	0	0	0	0 f
Flucythrinate	8500X	0	0	0	0	0	0 f

*Means followed by the same letter are not significantly different ($\alpha=0.05$; Duncan's multiple range test).

Similar results were found for *S. litura*, which showed that Florbac-FC, Florbac-XLV and TC0918 were the better choice among BT tested in the experiment (Table 2). For *P. rapae*, all BT products gave similar and fair control which ranged from 57—78% (Table 4).

Table 4. The control efficacies of 11 insecticides on *Pieris rapae* in the second field experiment (Mar. Apr., 1990)

Treatment	Dilution	% control				Mean*
		27 Mar	3 Apr	10 Apr	17 Apr	
Thuricide	1000X	81.4	70.3	73.2	86.3	77.8 a
Decamethrin	1000X	88.5	75.5	70.4	72.5	76.7 a
Bactospeine-XLV	889X	64.6	70.3	88.7	76.5	75.0 ab
Florbac-XLV	667X	67.2	68.8	85.9	70.6	73.1 abc
Bactospeine	1000X	74.3	70.8	47.9	78.4	67.9 abc
CGA237218	1000X	61.9	75.0	59.2	74.5	67.7 abc
SAN415-SC	1000X	67.3	70.3	57.7	70.6	66.5 abc
Florbac-FC	571X	69.9	58.3	73.2	62.7	66.0 abc
Flucythrinate	8500X	68.1	53.1	69.0	64.7	63.7 abc
CGA237218	2000X	73.5	68.2	42.3	49.0	58.3 bc
Dipel	1000X	53.1	79.7	56.3	37.3	56.6 c

*Means followed by the same letter are not significantly different ($\alpha=0.05$; Duncan's multiple range test).

A new synthetic chemical, diafenthiuron, showed extremely effective control on both DBM and *S. litura.* The SC formulation performed equally well for both pest species, while the WP formulation was better on DBM than on *S. litura.* Diafenthiuron provided better and consistant control when compared to BT products(Tables 3 and 4).

As was reported by Cheng (1985), the DBM counts for both deltamethrin and flucythrinate treatments were higher than that for check plots, which demonstrated again that the synthetic pyrethroids had totally lost their ability to control the resistant DBM in Taiwan. The elimination in competition from other pests and the reduction of DBM mortality due to reduce natural enemies were presumed to be the reasons. This has been a common phenomenon in TARI's experimental farm in recent years(unpublished data of field evaluation tests in 1988 and 1989), although synthetic pyrethroids are still effective against other insect pests on cabbage (Chou et al.,1984).

Since diafenthiuron performed extremely well against DBM, it sensitivities of both the susceptible and the resistant DBMs were compared in the laboratory (Table 5). The results showed that the multiple resistant SC-strain (Cheng et al., 1990) had the same susceptibility to diafenthiuron as the susceptible strain i.e., LC_{50} at 245ppm, therefore, cross resistance from other insecticide does not exist. The addition of pb to diafenthiuron showed no difference in the resistant strain's sensitivity, which indicated that diafenthiuron may not be affected by the inherited oxidative metabolism in DBM.

Table 5. The laboratory test of diafenthiuron on *Plutella xylostella* for possible cross resistance from other insecticides

Insecticide or combination	LC_{50} in ppm		R. R. and S. R.**
	Suscep. strain	Resist. strain*	
Diafenthiuron	245.9	245.5	R. R. = 1
Diafenthiuron+5pb	—	240.8	S. R. = 1

*resistant SC-strain (Cheng et al., 1990)
**resistance ratio and synergistic ratio

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新型微生物及化學製劑防治抗性小菜蛾及其他鱗翅目害蟲之研究[1]

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摘　要

針對本省抗藥性嚴重之小菜蛾及蔬菜上其他有關之鱗翅目害蟲，以新發展出之試驗性蘇力菌（*Bacillus thuringiensis*）製劑及殺蟲殺蟎劑硫化尿素（thiourea），進行田間藥效測定。結果發現，新發展之成品的確較以往之商品效果爲佳，對小菜蛾、斜紋夜盜蛾之防治率均較固有之蘇力菌商品提高 50—100 %；而所有供試藥劑對白粉蝶之防治效果則略遜。蘇力菌製劑中，以 Florbac-FC、Florbac-XLV、TC0918、CGA237218 及 SAN415 之效果較以往使用之 Thuricide、Dipel及 Bactospeine 更佳。硫化尿素類之新藥 Polo (diafenthiuron) 所表現之藥效更超過蘇力菌，惟此一化學藥劑未來可能遭遇抗性問題。Polo 之兩種劑型中，Polo-SC 對小菜蛾及斜紋夜盜蛾效果均佳，而可濕性粉劑配方對小菜蛾之防治效果則優於斜紋夜盜蛾。本試驗中再度證明，合成除蟲菊精類已對抗性小菜蛾完全失去防治效果，其試驗區內之小菜蛾密度甚至超過對照區，原因可能係該類藥劑不但未能造成小菜蛾之死亡，同時也減少其他害蟲與天敵對小菜蛾之競爭及寄生能力。

關鍵詞：蘇力菌、小菜蛾、斜紋夜盜蛾、紋白蝶、硫化尿素。

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