

Effect of Insecticides on Various Field Strains of Diamondback Moth and Its Parasitoid in Indonesia

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Abstract

The susceptibility of four field strains (Tawangmangu, Pacet, Kopeng and Lembang) of diamondback moth to the synthetic pyrethroids, carbaryl and *Bacillus thuringiensis* was assessed in the laboratory as well as in the field. Results indicated that there were differences in insect susceptibility depending upon their origin. In general, Lembang and Kopeng strains were more resistant than Pacet and Tawangmangu strains to all insecticides tested except *B. thuringiensis*. The susceptibility of the diamondback moth parasitoid, *Diadegma eucero-phaga*, from two major cabbage centers (Lembang and Pacet) was also tested. Results indicated that Lembang strain has developed resistance to fenvalerate. The efficacy of *B. thuringiensis* was lower compared to the synthetic pyrethroids and carbaryl. However, field assessment in West Sumatra indicated that *B. thuringiensis* applied singly or in combination with synthetic pyrethroids gave significantly higher yields than quinalphos as a standard insecticide. *B. thuringiensis* was less toxic to *D. eucero-phaga*.

Introduction

Cruciferous vegetables are economically very important to farmers in the highlands and in specialized production areas of Indonesia. These farmers use input intensive agronomic practices because the sale of these vegetables provides an important source of ready cash income. However, crucifer production in recent years has been seriously affected by a steady increase in the incidence of insect pests.

Two major insect pests, diamondback moth (DBM), *Plutella xylostella* L. (Lepidoptera: Yponomeutidae), and *Crociodolomia binotalis* Zell (Lepidoptera: Pyralidae) feed on the leaves of cruciferous plants from seedling stage to harvest and greatly reduce both yield and quality of the produce. During the dry season, heavy infestation of DBM can cause 100% yield loss if no insecticides are used (Sudarwohadi 1975). During the wet season, the yield loss still can be 30% (Sudarwohadi and Eveleens 1977). Oka (1976) reported that the yield loss from this insect ranged from 46 to 90%.

Insecticides are considered the most effective means of protecting crops against insect damage as they provide rapid control of whole pest complexes of major cruciferous pests. Usually farmers use large quantities of chemicals, often spraying a 'cocktail' of compounds. Woodford et al (1981) reported that the farmers of West Java used about 16 kinds of insecticides to control pests of cruciferous vegetables. The most popular insecticides now are the synthetic pyrethroids fenvalerate, permethrin, and deltamethrin.

In North Sumatra, the most popular insecticides are permethrin and chlorpyrifos. As a consequence of frequent insecticide use, DBM has developed resistance to practically all categories of insecticides, and minor insect pests have become major problems in some areas.

In 1953, the development of insecticide resistance to DDT was first noted in Lembang by Ankersmit (1953). In the 1960s, organophosphorus insecticides were used intensively in the Lembang area. Since then, resistance to most of the commonly used insecticides has been observed in this insect. In 1977, farmers started to use synthetic pyrethroids such as permethrin and deltamethrin. Permethrin at a rate of 7.5 to 15 g AI/ha could then effectively control DBM at Pujon in East Java and Kabanjahe in North Sumatra (Sitanggang 1977). But in 1982, the DBM population from West Sumatra and West Java could only be controlled when the dosage of permethrin was increased to 40 g AI/ha. Likewise, deltamethrin at a rate of 7.5 to 12.5 g AI/ha could initially control DBM at Margahayu and Segunung, however, since 1982 a dose of at least 30 g AI/ha has been required to control DBM at these locations (Sudarwohadi 1983).

These observations suggested that the DBM population is becoming resistant to this new group of compounds. Studies were initiated in 1982 to determine DBM's response to pyrethroids, carbamates, and microbial insecticides. The results reported here represent the data obtained in 1982 and 1983.

Materials and Methods

Two laboratory studies and three field experiments were conducted in 1982 and 1983.

Laboratory Study I (1982)

This experiment was conducted at Segunung, in West Java.

Insecticides Permethrin 2EC, cypermethrin 5EC, fenvalerate 5EC, and deltamethrin 2.5EC were obtained locally.

Insects Pupae of the DBM were collected from three locations and reared on cabbage in the laboratory. A population from Selo in Central Java was identified as a susceptible (S) strain. Populations from the other two locations, Kopeng in Central Java and Lembang in West Java, were reported to be resistant (R) to the synthetic pyrethroids.

Bioassay procedure The standard test for determining LD₅₀ values by topical application of insecticides was used (ESA 1970, and Heinrichs et al 1981). Insecticide in 0.05 μ l acetone was applied to the dorsal thoracic surface of 3rd instar larvae. The larvae were then transferred to 9 cm diam petri dishes containing cabbage leaves and maintained in rearing room at 25°C, 70% RH, and at a photoperiod of L:D 12:12. Ten untreated larvae were placed in a petri dish containing cabbage leaves. Each of three replicates had at least 10 larvae per insecticide concentration. A minimum of six concentrations, together with a control, were used for each bioassay. Mortality was recorded after 24 h and analyzed by probit analysis (Finney 1971).

Laboratory Study II (1983)

This experiment was conducted at Pacet in West Java.

Insecticides Permethrin 2EC, cypermethrin 5EC, fenvalerate 5EC, carbaryl 85WP, and *Bacillus thuringiensis* strain HD 1 were obtained locally.

Insects Third and/or fourth instar larvae of DBM were collected from four locations and reared on cabbage. A population from Tawangmangu in Central Java was identified as a susceptible (S) strain, and populations from Lembang and Pacet in West Java and Kopeng in Central Java were reported to be resistant (R) to the synthetic pyrethroids. Pupae of *Diadegma eucerophaga* Horstm, one of the most promising biological control agents of DBM, were also collected from Lembang and Pacet and reared separately on DBM larvae.

Bioassay procedure Toxicity measurements for synthetic pyrethroids and carbamate insecticides were made by using the procedure of Plapp and Vinson (1977).

DBM

Twenty 2nd or 3rd instar larvae were exposed to residues of insecticides on the inner surfaces of 9 cm diam petri dishes. These dishes were treated with acetone solutions of each insecticide. Acetone only was used for the control. One hour after the exposure, the larvae were transferred to untreated petri dishes containing cabbage leaves.

Diadegma eucerophaga

Ten three to five day-old adult females of *D. eucerophaga* were exposed to residues of insecticides on the inner surfaces of 25 mm od x 20 cm test tubes. These tubes were treated with acetone solutions of each insecticide. Acetone only was used in the control. One hour after exposure, the insects were transferred to untreated test tubes containing a cotton plug soaked in a 10% honey in water solution, and they were maintained in a rearing room.

All petri dishes and test tubes were maintained at 25°C, 70% RH and at a photoperiod of L:D 12:12 during the observation period.

Mortality determinations were made 48 h after initial exposure.

Toxicity measurement for *B. thuringiensis* was made by the procedure of Busvine (1971). Five week-old cabbage plants were sprayed with water solutions of *B. thuringiensis*. Water only was used for the control. Twenty 2nd or 3rd instar DBM larvae were confined on the treated plants. Mortality determinations were made 72 h after exposure. LC₅₀ and LC₉₀ and slope values for each insecticide against all field strains were calculated with maximum likelihood probit analysis (Finney 1971).

Field Experiment I, West Java (1982)

Two field experiments were conducted at Lembang and Segunung. Cabbage cultivar Gloria Osená was used at Lembang and K K Cross at Segunung. Six treatment plots including standard insecticide and control replicated four times were arranged in a randomized complete block design. The cabbage plants were transplanted at 80 x 50 cm apart in 8 x 5 m plots which contained 100 plants. Insecticidal dosage and treatments were as follows: fenvalerate 5EC (0.08 kg AI/ha), permethrin 2EC (0.04 kg AI/ha), cypermethrin 5EC (0.08 kg AI/ha), deltamethrin 2.5EC (0.03 kg AI/ha), and diethquinalphion 25EC (0.5 kg AI/ha) used as a standard check. Sprays were applied with a semi-automatic knapsack sprayer and depending on the age of the crops a spray volume of 500 to 1100 l/ha (average 800 l/ha) was used. The first application started at 14 days after planting (DAP) and was repeated once every week thereafter when the population reached the economic injury level (action threshold or control threshold). The threshold level at Lembang was 0.1 larvae/plant starting 13 DAP up to 69 DAP (Chalfant et al 1979). At Segunung the threshold level was 0.1 larvae/plant, starting 13 DAP up to 34 DAP (Chalfant et al 1979) and intermediate injury level was P=41-60%, starting

41 DAP up to 62 DAP (Sastrosiswojo et al 1981). Standard check insecticide was applied at weekly intervals starting at 14 DAP up to 70 DAP at Lembang and 63 DAP at Segunung.

Ten plants within each plot were selected systematically. The numbers of DBM and *C. binotalis* larvae on each plant were recorded at weekly intervals starting 13 and 15 DAP up to 71 DAP of Lembang and 64 DAP at Segunung.

Percentage injury level was calculated as follows:

$$P = \frac{\sum (n \times v)}{5N} \times 100$$

P = percentage injury level; n = total number of leaves in an infestation class; v = numerical value of infestation class (0 to 5); where 0 = no leaf damage; 1 = 20% of the total leaf area damaged; 2 = 40% of the total leaf area damaged; 3 = 60% of the total leaf area damaged; 4 = 80% of the total leaf area damaged; and 5 = all of the leaf area damaged, and N = total number of leaves observed.

Counting was conducted every week starting 41 DAP up to 69 DAP for Lembang and 43 DAP up to 64 DAP for Segunung.

In each plot, 10 3rd or 4th instar larvae of DBM were collected at random and reared in the rearing room to determine the percentage of parasitism by *D. eucerothaga*. The insects were collected starting 16 DAP up to 65 DAP for Segunung and 37 DAP up to 72 DAP for Lembang.

Yields and ability to develop heads were observed at harvest time.

Field Experiment II, West Sumatra (1982)

The experiment was conducted at Air Anget, Tanah Datar, West Sumatra. The statistical design, plot size, planting distance, insecticidal treatments and so on were similar to those in Field Experiment I.

Field Experiment III, West Sumatra (1983)

The location of the experiment was the same as Field Experiment II. The insecticidal treatments were: *B. thuringiensis* HP 32 kg AI/ha; *B. thuringiensis* WP 32 kg AI/ha; fenvalerate 5EC 0.08 kg AI/ha; cypermethrin 5EC 0.08 kg AI/ha; *B. thuringiensis* HP 16 kg product + fenvalerate 5EC 0.04 kg AI/ha; *B. thuringiensis* WP 16 kg product + cypermethrin 5EC 0.04 kg AI/ha; *B. thuringiensis* HP 16 kg product + cypermethrin 5EC 0.04 kg AI/ha; *B. thuringiensis* WP 16 kg product + fenvalerate 5EC 0.04 kg AI/ha; quinalphos 25EC 0.5 kg AI/ha; and control.

The observations and insecticidal applications were conducted in the same way as in Field Experiments I and II.

Results and Discussion

Laboratory Study I (1982)

Among the four synthetic pyrethroid insecticides tested against the three field strains of DBM, LD₅₀ values of permethrin for the Kopeng and Lembang strains were 3 and 11 times higher compared to the Selo strain. These data indicated the possibility of development of resistance to permethrin in the Kopeng and Lembang strains. Therefore it appears wise not to use synthetic pyrethroids in Lembang area, though in Kopeng these insecticides can still be used in combination with other control practices.

Laboratory Study II (1983)

This study indicated that most of the field strains of DBM had already developed resistance to all three synthetic pyrethroids (Table 1). Resistance levels to cypermethrin were much lower than those to permethrin and fenvalerate. Tawangmangu strain was more susceptible to permethrin and cypermethrin than the other strains, but it was more resistant to fenvalerate than Pacet strain. This was at least partly due to the fact that the farmers from the Pacet area prefer to use carbamate insecticides rather than synthetic pyrethroids.

Table 1. Resistance ratios of DBM strains from four locations to selected insecticides

Location	Resistance ratios				
	Permethrin	Cypermethrin	Fenvalerate	Carbaryl	<i>B.thuringiensis</i>
Kopeng	7.5	2.5	10.4	2.5	1.7
Pacet	3.1	1.5	1.0	1.0	1.7
Lembang	3.8	2.5	18.1	1.7	1.0
Tawangmangu	1.0	1.0	5.9	1.0	1.9

Fenvalerate has been used in Kopeng, Lembang and Tawangmangu since 1981, whereas the other compounds were introduced more recently. However, levels of resistance appeared in most field strains. This finding coincided with a general observation that the effectiveness of synthetic pyrethroids in controlling DBM has declined significantly in the field. The LC_{50} values of fenvalerate for Kopeng and Lembang strains were 10 and 18 times those of to Pacet strain. The resistance ratio of Kopeng strain has increased 10 fold compared with the 1982 value.

Since 1977, the microbial insecticide *B. thuringiensis*, has been introduced into Lembang (Sudarwohadi and Said 1977). This insecticide is still effective in controlling DBM and there is no indication of development of resistance (Table 1).

D. eucerothaga did not show any development of resistance except in the case of Lembang strain to fenvalerate, which exhibited a resistance ratio of 3 compared to Pacet Strain (Table 2). This indicated that fenvalerate has been used intensively in the Lembang area. Data on the selectivity of four insecticides to DBM vs the parasitoid are presented in Table 3. The data show that, in general, synthetic pyrethroids are more toxic to the parasite than to DBM.

The results of this study suggest that DBM has become resistant in varying degrees to synthetic pyrethroids. The LC_{50} values obtained indicate that failure in DBM control is possible if the present insecticide application practices continue. Ten to 15 insecticide

Table 2. Toxicity of four insecticides to female adult of *Diadegma eucerothaga*

Insecticide	Strain	LC_{50} ^a	RR ^b
Permethrin 2EC	Pacet	1.58	—
	Lembang	2.15	1.4
Cypermethrin 5EC	Pacet	2.83	—
	Lembang	3.64	1.1
Fenvalerate 5EC	Pacet	0.81	—
	Lembang	2.39	3.0
Carbaryl 85WP	Pacet	65.44	1.2
	Lembang	53.35	—

^a LC_{50} value, based on μ g of insecticide per test tube.

^b RR = resistance ratio.

Table 3. Selectivity of four insecticides against *D. eucerothaga*

Insecticide	Selectivity ratio ^a	
	Pacet	Lembang
Permethrin	13.5	12.2
Cypermethrin	11.9	19.7
Fenvalerate	6.4	39.2
Carbaryl	4.3	8.7

^a LC_{50} to DBM/ LC_{50} to parasitoid.

sprays are not uncommon for DBM control on cabbage in these areas. Most of the applications contain pyrethroid insecticide.

Field Experiment I, West Java (1982)

At Lembang, even at the first observation, the population of DBM had reached the threshold level of 0.1 larvae/plant except in the cypermethrin plot (13 DAP) and deltamethrin plot (20 DAP). Nine sprays of fenvalerate and diethquinalphion and eight of permethrin, cypermethrin and deltamethrin provided excellent insect control (Table 4). The synthetic pyrethroids were more or as effective as the standard check.

All synthetic pyrethroids tested were also effective in controlling the population of *C. binotalis*.

Table 4. Effectiveness of selected insecticides against DBM at Lembang 1982^a

Insecticide	Number of larvae/plant sample at DAP ^b							
	13	15	34	36	48	50	69	71
Fenvalerate 5EC	0.13a	0.08a	2.18a	1.68b	2.40abc	0.92bc	0.30a	0.20a
Permethrin 2EC	0.14a	0.00a	2.30a	0.73a	1.25a	0.36a	0.20a	0.08a
Cypermethrin 5EC	0.00a	0.00a	3.03a	1.48ab	1.55ab	0.50ab	0.30a	0.13a
Deltamethrin 2.5EC	0.10a	0.03a	2.35a	1.00ab	1.47ab	0.37a	0.35a	0.15a
Diethquinalphion 25EC	0.08a	0.08a	2.75a	1.78b	2.78bc	1.23c	0.73a	0.28a
Control	0.05a	0.30b	6.13b	7.24c	3.52c	3.18d	2.82b	2.99b

^a Insecticide was applied when the larval population reached 0.1 larvae/plant sample. ^b Average of 40 plant samples; DAP = days after planting. Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

At Segunung, the DBM population was low, and only one spray per week of each of fenvalerate, cypermethrin and deltamethrin was needed up to 36 DAP. Starting at 41 DAP, however, the percent injury level had reached at intermediate stage (above 40%), which necessitated two to three more sprays (Table 5). Synthetic pyrethroids were as effective as the standard check.

Table 5. Percentage injury level of the plant samples one day before spraying, Segunung, 1982

Insecticide	Percent injury level at DAP ^a			
	41	48	55	62
Fenvalerate 5EC	17.19a	44.92b	32.81b	45.31b
Permethrin 2EC	43.75cd	38.28b	48.05bc	43.00b
Cypermethrin 5EC	32.03bc	41.80b	40.23bc	49.22b
Deltamethrin 2.5EC	46.09cd	39.45b	39.45bc	43.36b
Diethquinalphion 25EC	8.20a	9.38a	9.77a	10.16a
Control	51.56d	53.91b	55.86c	57.03b

^a Average of 40 plant samples; insecticide was applied when percentage injury level had reached at an intermediate stage (41-64 dap); DAP = days after planting. Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Percent injury level In general the percent injury levels were significantly lower in insecticide-treated plots compared to the standard check and control plots. However, they were still at an intermediate stage (30-40%). This suggested that the synthetic pyrethroids had intermediate toxicity to Lembang and Segunung strains (Table 6).

Table 6. Percentage injury level of the plant samples one day before spraying

Insecticide	Injury level (%) at DAP ^a				
	Lembang			Segunung	
	41	55	69	43	57
Fenvalerate 5EC	30.84a	42.66ab	45.00a	18.75a	32.81b
Permethrin 2EC	30.89a	39.65a	39.76a	39.06b	42.19bc
Cypermethrin 5EC	31.44a	42.15a	39.82a	41.41b	40.23bc
Deltamethrin 2.5EC	31.76a	38.23a	43.09a	43.36b	43.36bc
Diethquinalphion 25EC	40.82a	51.19ab	56.00b	8.20a	10.16a
Control	65.68b	81.54c	84.19c	52.73b	55.86c

^a Average of 40 plant samples; DAP = days after planting. Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Laboratory tests had earlier shown that DBM had developed resistance to these synthetic pyrethroids.

***D. eucerothaga* parasitism of DBM larvae** In general, insecticide application did not affect the parasitism of DBM by *D. eucerothaga*, except at 44 DAP in the fenvalerate, permethrin, deltamethrin, and diethquinalphion plots (Table 7). The data also showed that cypermethrin was slightly safer for the parasite than the other synthetic pyrethroids. This finding agrees with those reported by Tonny (1982) and Pardede (1980).

Table 7. Parasitism of DBM larvae by *D. eucerothaga* in insecticide treated plots. Lembang 1982

Insecticides	Parasitism (%) at DAP ^a					
	37	44	51	58	65	72
Fenvalerate 5EC	40a	32bc	25a	23a	26a	29a
Permethrin 2EC	45a	22a	22a	30a	33a	15a
Cypermethrin 5EC	55a	35cd	22a	37a	19a	33a
Deltamethrin 2.5EC	55a	30bc	18a	37a	27a	20a
Diethquinalphion 25EC	35a	12a	18a	21a	27a	31a
Control	67a	45d	30a	35a	43a	49a

^a DAP = days after planting. Means in each vertical column followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

Field Experiment II, West Sumatra (1982)

DBM populations From the first observation (8 DAP), the larval population of DBM always exceeded the threshold level of 0.1 larvae/plant in all the experimental plots (Table 8). Therefore, insecticides were applied at weekly intervals. A total of 11 sprays were applied. The first application did not show any effect on DBM (11 DAP). At the subsequent applications, all the insecticides could effectively control the pest. All synthetic pyrethroids were more or as effective as the standard check quinalphos. These results were similar to the results at Lembang and Segunung. Fenvalerate was the most effective in controlling DBM. *C. binotalis* population was very low throughout the test.

Percent injury level All insecticides tested reduced the percent injury levels (Table 8). The synthetic pyrethroids provided excellent DBM control. The percent injury levels were lower compared to the standard check quinalphos at 49 DAP.

***D. eucerothaga* parasitism of DBM larvae** In contrast to the Lembang and Segunung experiments, in West Sumatra, only during the first three observations (35, 39 and 43 DAP) did insecticides fail to adversely affect the parasitoids. However,

Table 8. Effect of insecticide spray at one day before and three days after spraying on DBM population, injury level, and yield at Air Angat, West Sumatra, 1982^a

Insecticides ^b	Number of larva/plant sample at DAP ^c								Percent injury ^d level	Yield t/ha
	7	11	31	35	47	51	63	67		
Fenvalerate	0.38a	0.38a	0.15b	0.43b	0.43c	1.05c	0.68c	1.28c	8.61c	36.8a
Permethrin	0.28a	0.25a	0.55b	0.88b	0.68c	2.45c	1.80c	3.18c	16.10c	26.1b
Cypermethrin	0.48a	0.40a	0.73b	0.48b	0.78c	2.95c	1.83c	2.63c	12.70c	25.7b
Deltamethrin	0.45a	0.43a	0.93b	1.05b	2.75bc	6.93b	3.80c	4.93c	16.69c	33.4a
Quinalphos	0.45a	0.35a	0.83b	1.28b	3.33b	7.98b	9.78b	12.15b	33.63b	11.3c
Control	0.30a	0.35a	1.85a	3.03a	5.58a	12.63a	17.40a	17.80a	50.63a	8.4c

^a Insecticide was applied when the larval population reached 0.1 larvae/plant sample. ^b See text for insecticide formulation and AI used. ^c Average of 40 plant samples: DAP = days after planting. ^d At 40 DAP. Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

beginning at 47 DAP, the insecticide application did have some adverse affect on the parasitism of DBM larvae (Table 9). Only the standard check, quinalphos, showed no significant difference in the percent parasitism compare to insecticide-free control plots. **Head development and yields** The numbers of heads developed in the synthetic pyrethroid plots were higher than in the standard check quinalphos and control plots. Consequently the yields in pyrethroid-treated plots were significantly higher than in the standard check and control plots. The highest yield of 36.8 t/ha was obtained in the fenvalerate plot (Table 8).

Table 9. Parasitism of DBM larvae by *D. eucerothaga* in insecticide treated plots at Air Angat, West Sumatra, 1982^a

Insecticides ^b	Parasitism (%) at DAP ^c						
	47	51	55	59	63	67	71
Fenvalerate 5EC	17bc	15bc	23ab	25bc	18b	18d	20c
Permethrin 2EC	19bc	33abc	13b	18c	30c	25b	60a
Cypermethrin 5EC	24bc	38ab	28a	15c	20d	13b	38bc
Deltamethrin 2.5EC	10c	15bc	25ab	23bc	13d	25b	33bc
Quinalphos 25EC	45a	50a	33a	38a	48a	45a	63a
Control	33ab	33abc	35a	30ab	38b	48a	50ab

^a Observations were conducted at two days after spraying. ^b See text for AI used. ^c DAP = days after planting. Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Field Experiment III, West Sumatra (1983)

Based on the previous laboratory and field experiments, the results suggested that DBM had developed resistance to synthetic pyrethroids and that these chemicals had an adverse affect on the parasitoid of DBM. However, synthetic pyrethroids were still preferred by farmers for controlling DBM. Therefore, in this experiment, we looked for alternative control method by using a microbial insecticide and mixing it with synthetic pyrethroids.

DBM population From the first observation (13 DAP), the larval population of DBM was already above the threshold level of 0.1 larvae/sample plant in all the plots (Table 10). The insecticides were sprayed at weekly intervals, because each individual insecticide spray failed to reduce the larval population to below the threshold level. Microbial

Table 10. Effect of insecticide mixtures on DBM larval population at one day before and two days after application, on injury level, and yield of cabbage at Air Angat, West Sumatra. 1983^a

Insecticide ^b	No. of larvae/plant at DAP ^c						Injury % at 48 DAP ^d	Yield t/ha
	13	16	34	37	55	58		
<i>Bt</i> ^e HP	5.57ab	1.80b	1.33c	1.30c	4.53cd	2.47b	27.78c	36.78ab
<i>Bt</i> WP	3.63b	1.73b	0.57c	0.53c	2.03cd	1.07b	26.15c	37.78ab
Fenvalerate	5.10ab	1.90ab	1.70c	0.90c	4.27cd	3.60b	29.61bc	29.31b
Cypermethrin	7.37a	2.13ab	1.80c	1.40c	3.37cd	4.33b	33.21ab	30.46b
<i>Bt</i> HP + Fen ^f	3.42b	1.53b	1.13c	1.13c	4.50cd	3.77b	27.46c	37.78ab
<i>Bt</i> WP + Cyper ^g	4.23ab	1.80b	1.20c	1.27c	2.30cd	2.00b	26.32c	34.87ab
<i>Bt</i> HP + Cyper	4.27ab	1.97ab	1.93bc	1.23c	4.90bc	4.07b	27.09c	37.21ab
<i>Bt</i> WP + Fen	6.33ab	1.73b	0.60c	0.80c	1.53d	1.67b	26.95c	42.76a
Quinalphos	5.20ab	2.43ab	3.17ab	3.80a	14.87a	10.40a	35.91a	16.30c
Control	5.50ab	4.47a	3.43a	2.63b	7.73b	8.83a	34.98a	15.97c

^a Insecticide was applied when the larval population reached 0.1 larva/plant. ^b See text for insecticide formulation and AI used. ^c Average of 40 plants. ^d Average of 30 plants. DAP = days after planting. ^e *Bt* = *Bacillus thuringiensis*. ^f Fen = Fenvalerate. ^g Cyper = Cypermethrin. Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test. See text for the formulation and rate of application of the insecticides.

insecticides applied alone or as mixtures with fenvalerate or cypermethrin gave a better control than either fenvalerate or cypermethrin alone or the standard check, quinalphos. A mixture of *B. thuringiensis* WP with fenvalerate or cypermethrin performed better than a mixture of *B. thuringiensis* HP with fenvalerate or cypermethrin. The synthetic pyrethroids alone were less effective.

Percent injury level The microbial insecticide applied alone or as a mixture could reduce the percent injury level of DBM. Of the two synthetic pyrethroids tested, cypermethrin was less effective.

Parasitism DBM larvae by *D. eucerothaga* The parasitism level of DBM in the microbial insecticide-treated plots was similar to the parasitism level in the control plot. In contrast to the second field experiment, the synthetic pyrethroid applied alone or as a mixture did not show adverse effects on the parasitoid (Table 11).

Head development and yields The head development in all the insecticidal plots was higher than the control plot. The total number of plants which did not develop

Table 11. Parasitism of DBM larvae by *D. eucerothaga* in insecticide treated plots. Air Angat, West Sumatra. 1983^a

Insecticides ^b	Parasitism (%) at DAP ^c						
	16	23	30	37	44	51	58
<i>Bt</i> ^d HP	10a	0d	25a	13b	12a	0b	27a
<i>Bt</i> WP	17a	33abcd	17a	36ab	13a	19ab	17a
Fenvalerate	25a	60ab	32a	30ab	20a	10ab	22a
Cypermethrin	50a	43abc	26a	38a	17a	23a	30a
<i>Bt</i> HP + fenvalerate	29a	31abcd	7a	21ab	21a	3ab	23a
<i>Bt</i> WP + cypermethrin	43a	67ab	8a	10b	19a	10ab	17a
<i>Bt</i> HP + cypermethrin	22a	54ab	22a	26ab	17a	4ab	35a
<i>Bt</i> WP + fenvalerate	19a	17cd	18a	33ab	11a	9ab	32a
Quinalphos	32a	58ab	25a	39a	21a	4ab	23a
Control	21a	71a	19a	24ab	24a	14ab	37a

^a Observations were conducted at two days after spraying. ^b See text for formulation and AI applied. ^c DAP = days after planting. Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test. ^d *Bt*: *Bacillus thuringiensis*.

heads in the cypermethrin plot was quite high. However, it was still significantly lower than in the standard check quinalphos plots and in control plots. The yields when microbial insecticide was applied alone or as a mixture with synthetic pyrethroids were better than when pyrethroids were applied alone and in the standard check quinalphos plots (Table 10). The highest yield of 42.76 t/ha was obtained with a mixture of *B. thuringiensis* WP with fenvalerate.

The results obtained in these three field experiments indicated that synthetic pyrethroids had intermediate to low toxicity to the various field strains of DBM. These insecticides are toxic to the parasitoid. Mixture with a microbial insecticide gave better control and a less adverse effect on parasitoid. However, our studies show that there can be a wide variation in the toxicity of individual insecticides or their mixtures, to both DBM and to the parasitoid. Therefore, comparative field evaluation of the possible candidate insecticides within the class and their mixtures with microbial insecticides or other kinds of chemicals may be necessary to ascertain their effects on the whole natural enemy complex and to evaluate their relative usefulness in integrated pest management programs.

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