

Control of Diamondback Moth in Southeast Asia by Profenofos

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Abstract

Profenofos is a phosphoric acid ester with a broad spectrum of activity as an insecticide and acaricide. It was first developed for the control of lepidopterous pests of cotton but was found subsequently to be active against the diamondback moth, *Plutella xylostella* L. The field effectiveness of profenofos was evaluated in the Philippines, Malaysia, Thailand, and Taiwan against the diamondback moth by high volume spray applications at 7 and 10 day intervals. Results indicated that profenofos when applied at the rate of 0.25 to 0.5 kg AI/ha effectively reduced the population of diamondback moth larvae in crucifers. Yields of treated plots were increased by 41 to 100% compared to untreated plots. The effectiveness of profenofos against diamondback moth was confirmed in all countries where field tests were conducted.

Introduction

In southeast Asia crucifer vegetables are generally planted in the highlands where the climate is cool or in the lowlands during the winter season. In the Philippines, an estimated 6,000 hectares are planted annually to crucifers; in the Cameron Highlands of Malaysia, 5600 hectares; in Thailand, 57,000 hectares; and in Taiwan, 34,400 hectares.

The quality of crucifer production, however, is hampered by insect pest depredations. One of the most destructive pests is the diamondback moth (DBM), *Plutella xylostella* L (Lepidoptera: Yponomeutidae), which infests the plants from seedling stage to maturity. DBM is considered a major production constraint in this region. Losses caused by this pest, when not controlled, may be as high as 50%, and are often up to 100%.

DBM was first observed as the most destructive insect pest of crucifers in Mountain Province, Philippines, in 1960 (Magallona et al 1980). Since then other workers in the Philippines have begun extensive research work to develop an effective control program.

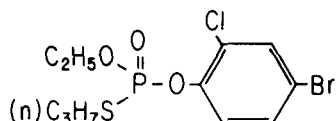
In the absence of other and more effective control measures, chemical control has been resorted to as an indispensable part of agricultural operations. Chemical control studies against cabbage pests in the Philippines were carried out by Viado et al (1957) when, amongst five insecticides tested, diazinon was found to be the most effective against the cabbage worm larvae. At that time DBM was not yet recognized as a pest. Nevertheless Ho (1965), recognizing the impending problem in Malaysia, studied the life history of the insect and conducted a screening of various insecticide candidates for its control. He found endrin, amongst others, to be effective against DBM. Later, Magallona et al (1980) established that the critical period for the protection of cabbage grown in the Philippines from DBM damage was between the fourth week and seventh week after transplanting. The first week and last three weeks of growth were less critical and required no insecticide protection.

The development of resistance by DBM was first reported in the Philippines in 1974 by Barroga (1974) when she investigated the reported reduced efficacy of commonly used insecticides such as EPN and mevinphos and confirmed the field observations. Following the discovery of resistance of DBM to presently used insecticides, various attempts have been made to over-come the resistance problem. One approach was to prepare insecticide mixtures by tank-mixing two or more insecticides with the objective of obtaining more effective treatments. In practice, many cabbage farmers in southeast Asia are already using a tank-mix of two or more different chemicals to try to obtain satisfactory control of DBM. Theoretically this is possible, but the mixtures prepared by farmers were without scientific basis. This practice had been questioned by authorities because of the high risk of residues attributed to the wrong choice of insecticide combination and farmers' practice of preparing spray mixtures two to three times the recommended dosage rates.

On the basis of the above considerations, the development of an insecticide which can be applied singly and which can be incorporated with existing pest control programs is imperative. This paper describes the physico-chemical characteristics and biological properties of profenofos together with the results of evaluations which led to the development of this insecticide as an effective chemical for DBM control.

Chemical and Toxicological Properties

Profenofos, O-(4-bromo-2 chloro-phenyl) O-ethyl S-n-propyl phosphorothioate, is an organophosphorus insecticide with the following chemical structure:



It is a nonflammable yellow liquid with a vapor pressure of 1.10^{-5} mmHg at 20°C . Its solubility in water is 20 mg/l. It is readily soluble in most organic solvents.

The acute oral LD_{50} is 916 mg/kg and acute dermal LD_{50} is more than 4600 mg/kg in rats.

The product is available under the trade name of Selecron 500EC which contains 500 g of technical profenofos per liter emulsifiable concentrate.

Biological Properties

Profenofos is a broad spectrum insecticide with contact and stomach poison activity against sucking, mining, and chewing insects. It is non-systemic but has excellent translaminar action. This property provides effective control of boring and mining pests because of the rapid uptake and penetration of the active ingredient into the plant tissue. Remarkable control of DBM was observed even when this product was applied shortly before heavy rainfall or when the product was used in heavy rainfall cabbage growing areas.

The insecticidal properties of profenofos were first described by Buholzer (1975) under CIBA-GEIGY code number CGA-15324. The product was originally developed for the control of lepidopterous pests of cotton. Since 1977-78, this product has been introduced commercially in cotton-growing areas. Subsequent development work has

resulted in the discovery that it is an effective insecticide for the control of DBM in crucifers.

This insecticide was evaluated in several countries in southeast Asia and the results are reported in this paper.

Materials and Methods

Field trials were started in 1977 and were continued up to 1979 until enough data on the biological efficacy of profenofos were obtained. The tests were initiated in Malaysia, Thailand, and the Philippines at official research stations to find the most effective rate of application and appropriate spray intervals. Tests were continued in 1983 to 1984 in these countries and in Taiwan. In addition to these tests, the commercially formulated product was made available to research institutions such as AVRDC for evaluation to confirm the results obtained in earlier tests.

The emulsifiable concentrate formulation, Selecron 500 EC, was used in all tests. Various rates of application were tested and were sprayed onto test plants using ordinary 10-16 liter capacity knapsack sprayers. The spray volumes ranged from 500 to 1000 l/ha, depending on the growth stage of the test plants.

The plot sizes used in the tests were 1 x 10 m or 1 x 20 m. Each treatment was replicated four times in a randomized complete block design. Depending on the plot size, the total number of plants sampled for efficacy evaluation per plot was 10 or 20.

Results and Discussion

Effect of various rates

The results of the trials conducted in Malaysia, Thailand, and the Philippines are shown in Tables 1 to 3, respectively.

Malaysia trial (1977) Profenofos was applied at different rates and these treatments were compared with prothiophos which was used as a standard.

The incidence of DBM in the untreated plots was high during the second to the third week after transplanting and declined onwards towards crop maturity. In the profenofos-treated plots at all application rates the DBM larval population was low (Table 1). Even during the peak population period of two to three weeks after transplanting, the profenofos-treated plots were relatively free from DBM larvae, with only 1 to 5 larvae/10 plants compared to 114 to 229 larvae/10 plants in untreated plots. This observation showed that profenofos from 0.3 to 0.6 kg AI/ha when sprayed at weekly intervals controlled DBM effectively and was equal to the standard prothiophos treatment.

The damage indices observed in all profenofos-treated plots, as well as the standard, were very low compared to the untreated plots. At five weeks after transplanting, the leaves of plants in the untreated plots were already skeletonized (damage rating 3.25) whereas the profenofos treated plots were relatively clean (damage ratings of 0.25). Yields of cabbage from profenofos-treated plots, regardless of the rate tested, ranged from 107 to 118 t/ha and were equal to the yields of plots treated with the standard insecticide, prothiophos.

Thailand trial (1978) Profenofos was compared to several promising compounds for the control of DBM on Chinese kale.

The larval populations of DBM in the profenofos-treated plots sprayed 750 ppm AI were the lowest (Table 2). Mean larval counts in the profenofos treated plots taken

Table 1. Effects of profenofos application on DBM infestation of cabbage at the Cameron Highlands, Malaysia

Insecticides ^b	Rate ppm AI spray	No. of DBM larvae /10 plants at WAT ^c			Damage rating ^a at WAT		Yield t/ha
		3	5	8	5	8	
Profenofos	425	5	0	0	0.25	0.5	112.3
Profenofos	850	1	0	0	0.25	0.5	118.3
Profenofos	1275	4	0	0	0.25	0.5	107.8
Prothiophos	550	11	0	0	0.25	0.5	119.6
Control	—	229	14	13	3.25	3.0	99.8

^a Damage rating: 0 = no damage to leaves, 1 = slight damage or 1 to 3 leaves skeletonized, 2 = moderate damage or 2 to 4 leaves skeletonized, 3 = heavy damage or most leaves skeletonized, and 4 = severe damage or all leaves skeletonized. ^b Both insecticides were formulated as 50EC. ^c WAT = weeks after transplanting. Spray volume 600 ml/plot (10 sq m) for 1st, 750 ml for 2nd, and 1000 ml for 3rd through 8th weekly sprays.

Table 2. Effects of profenofos application on the DBM infestation of Chinese kale in Thailand

Insecticides	Rate ppm AI spray	No. DBM larvae/10 plants at days after transplanting			Yield t/ha
		15	35	55	
Permethrin 10EC	100.0	17.50	48.00	45.50	2.9
Fenvalerate 20EC	100.0	18.50	41.00	43.25	2.9
Cypermethrin 15EC	100.0	19.50	39.00	41.25	3.2
Deltamethrin 2.5EC	12.5	16.75	51.50	54.50	2.8
Prothiophos 50EC	750.0	4.50	10.75	8.75	3.4
RH-0994 48EC	750.0	14.50	20.00	43.00	2.3
Control	—	18.50	35.75	15.50	2.3

at 15, 35, and 55 days after transplanting were 4.5, 10.7, and 8.75, respectively, which were much lower than those observed in the untreated plots which were 18.5, 35.75, and 15 respectively. In this trial, profenofos showed pronounced activity against DBM and apparently had a longer residual effect compared to deltamethrin and cypermethrin which were applied at concentrations of 12.5 and 100 ppm AI, respectively.

Plants treated with 750 ppm AI profenofos were relatively free from DBM larval feeding when they were examined at 55 days after transplanting. Twenty-nine percent of the observed plants belonged to damage categories 3 and 5, while those treated with deltamethrin, cypermethrin and permethrin belonged mostly to damage categories 5 and 7. The average yield of the profenofos treated plot was 3.4 t/ha compared to 2.3 t/ha in the untreated plot.

Philippine trial (1978) In the advanced evaluation test conducted at the Baguio Experiment Station under the Bureau of Plant Industry, profenofos was tested at rates of 0.25, 0.5, and 0.75 kg AI/ha as against 0.50 AI of the standard chemical, methamidophos. Insecticides were sprayed at weekly intervals. The results are shown in Table 3.

The population of DBM larvae in the plots treated with profenofos was the lowest when counts were made at 20, 36, and 50 days after transplanting. There was either no damage or only slight damage, to the plants. The standard insecticide treated plants had considerably more damage.

Yields of profenofos-treated plots, at any tested rates, ranged from 73 to 78 t/ha compared to the standard, which yielded 55 t/ha. The lower yields obtained from the methamidophos-treated plots were attributed to the larger number of outer leaves which had to be removed prior to weighing.

Table 3. Effects of profenofos application on the DBM infestation of cabbage at Baguio, Philippines

Insecticide ^a	Rate kg AI /ha	No. of DBM larvae /20 plants at DAT ^b			Damage rating ^c	Yield t/ha
		20	36	50		
Profenofos	0.25	0.05	0.37	0.37	0.74	73.0
Profenofos	0.50	0.00	0.20	0.02	0.64	78.5
Profenofos	0.75	0.05	0.25	0.10	0.63	74.0
Methamidophos	0.50	0.05	3.42	1.20	1.06	55.0
Control	—	0.97	72.72	21.95	2.19	00.0

^aAll insecticides were formulated as 50EC. ^bDAT = days after transplanting. ^cDamage rating: 0 = no damage, 1 = slight damage or 1 to 3 leaves with holes, 2 = moderate damage or 4 to 6 leaves with holes, 3 = heavy damage or most of the leaves with holes, 4 = serious damage or all leaves with holes and skeletonized. Damage rating figures are mean of 10 damage assessments. Plants were sprayed at weekly intervals starting 10 days after transplanting.

Effect of application intervals

To test the efficacy of profenofos when applied at various spray intervals, a trial was initiated by the Baguio Experiment Station of the Bureau of Plant Industry in the Philippines. Profenofos was sprayed at various rates and applied at intervals of either 7 or 10 days. The results of this trial are shown in Table 4.

Table 4. Effect of profenofos application at various rates and intervals on infestation of cabbage by DBM

Insecticide ^a	Rate kg AI spray	Spray interval (days)	No. DBM larvae per 10 plants		Damage rating ^b at 55 DAT ^c	Yield t/ha
			Before spray	After spray		
Profenofos	0.250	7	1.9	0.5	0.8	104
Profenofos	0.250	10	2.9	0.9	0.9	107
Profenofos	0.500	7	1.6	0.5	0.7	108
Profenofos	0.500	10	3.0	0.6	0.8	99
Profenofos	0.750	7	1.8	0.4	0.7	95
Profenofos	0.750	10	2.8	0.8	0.8	102
Methamidophos	0.750	7	2.9	1.4	0.9	99
Methamidophos	0.750	10	5.9	2.1	1.0	101
Control	—	—	47.5	53.2	1.7	47

^aBoth insecticides were formulated as 50EC. ^bDamage rating: 0 = no damage, 1 = slight damage or 1 to 3 leaves with holes, 2 = moderate damage or 4 to 6 leaves with holes, 3 = heavy damage or most leaves with holes, 4 = serious damage or all leaves with holes and skeletonized. Damage rating figures are mean of four replicates and 9 (7 day interval) and 13 (10 day interval) sampling occasions. ^cDAT = days after transplanting.

Profenofos efficacy did not vary whether it was sprayed at 7 or 10 days intervals. The larval populations in the profenofos treated plots were much lower compared to the untreated plots. The mean number of larvae per 10 plants was not more than two at any of the rates tested when the treated plots were examined 55 days after transplanting. There was, however, a slight increase in the number of larvae observed in the plots which were sprayed every 10 days compared to those sprayed every seven days. The effect of profenofos on larval population at all rates tested and at both spray intervals was equal to or better than that of the standard methamidophos.

Marketable head yields obtained from profenofos-treated plots at all rates and timings were significantly higher than the untreated plots and were equal to or higher than the yields obtained from plots treated with standard insecticide.

Post introduction experience

After careful study of the results obtained in this region, the product was registered and commercially introduced for cabbage under the trade name Selecron 500EC in Thailand, Malaysia, Taiwan, and Philippines from 1978 to 1982. The product has since then been used successfully on cabbage for DBM control. Although DBM is known to develop resistance to chemicals quite rapidly, in the case of profenofos there has been no official report so far of resistance development by the insect. This was despite continuing trials conducted to monitor the response of DBM to profenofos in this region.

The trial reports shown in Tables 5 and 6 clearly demonstrate that profenofos was highly effective against DBM in Taiwan three years after the commercial product was introduced. When applied at the rate of 0.5 kg AI/ha, profenofos reduced the number of DBM larvae and pupae, more effectively than the *Bacillus thuringiensis* (AVRDC 1984). As a result, the profenofos-treated plots yielded 92% more than untreated plots, and 28% more than *B. thuringiensis*-treated plots (Table 5). When tested under farmer's field conditions from April to July 1984, profenofos at the rate of 0.5 kg AI/ha reduced the DBM population more effectively than a tank-mix combination of metamidophos + deltamethrin at 0.5 kg AI and 28 g AI/ha (Table 6).

Table 5. Effect of profenofos application on the DBM infestation of cabbage in Taiwan

Insecticide	Rate kg AI/ha	No. of DBM larvae and pupae/10 plants at DAT ^a				Yield t/ha
		44	56	65	72	
Profenofos 50EC	0.5	14.5	30.0	30.5	99.5	85.6
Bactospeine	0.5 ^b	62.5	129.0	157.0	229.7	66.5
Control	—	139.0	208.3	374.5	529.0	44.5

^a DAT = days after transplanting. Data are mean of four replicates. ^b *Bacillus thuringiensis*, actual product.

Table 6. Effect of profenofos alone and in combination with other insecticides on the DBM infestation of cabbage in Taiwan

Insecticides	Rate kg AI/ha	No of DBM larvae /leaf at 98 DAT ^a
Profenofos 50EC + Cypermethrin 5EC	0.500	1.05
Profenofos	0.500	1.14
Methamidophos 50EC + Deltamethrin 2.8EC	0.500	3.65
Mevinphos 25.3EC	0.506	5.54
Control	—	11.69

^a DAT = days after transplanting. Data are means of four replicates of 40 leaves each; insecticides sprayed at 80, 84, and 91 DAT.

These results indicate the potential of profenofos for the control of DBM infesting crucifers in southeast Asia. The availability of profenofos in these countries will offer an opportunity for farmers to obtain higher yields.

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