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Effective Control of Beet Armyworm, *Spodoptera exigua* (Hübner), on Green Onion by the Ovicidal Action of Bifenthrin[1]

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Abstract : The most serious insect pest of green onion in Taiwan is the beet armyworm (BAW), *Spodoptera exigua* (Hübner). For several years, using synthetic sex pheromone to mass trap the male BAW moths was the only official recommendation method for BAW control, however, sex pheromone alone cannot stand as an effective control measure when the BAW flourishing in late spring through late autumn, and the need of an effective control agent is thus urgent. Bifenthrin, a newly developed synthetic pyrethroid has been proven with strong ovicidal and insecticidal actions against BAW in both laboratory and field tests. Satisfactory control of BAW in green onion field was well demonstrated. At 42—34 ppm in field spray strength, 95.2—99.4% control of BAW infestation was accomplished and the increase in yield against the check plot is 84.1—140.9%. Good correlation between damage rating and final yield was established (R=0.9446), and $Y = 4.32X^{-0.33}$ is the best-fit model. Two synthetic pyrethroids, permethrin and fenvalerate, as well as a newly introduced insect growth regulator (IGR), chlorfluazuron, were used for comparison. Neither ovicidal nor significant lethal action on larvae was ever found on BAW for these insecticides.

Introduction

The green onion (Welsh onion) fields in Taiwan have been heavily infested by the beet armyworm (BAW), *Spodoptera exigua* (Hübner), for the past several years. The causes of the outbreak of this pest species are not clear, but the most speculated reasons are (1) the expansion of green onion cultivation acreage, and (2) the development of insecticide resistance. The plant morphology of green onion makes the chemical control very difficult, and once the BAW larvae emerge from eggs, they bore into the

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tube-shaped leaves immediately. Since the BAW larvae fed inside the green onion without eating through the outer skin of tube, they were well protected from any insecticide spray or natural enemies. For the past three years, many insecticides had been tested in the field, and none of them had ever provided satisfactory control. The synthetic sex pheromone of BAW is very powerful and has been used in a cooperated mass trapping program in the green onion field [1], but the mass trapping can only delay the outbreak of BAW in summer for 1—1½ months and reduce the density of BAW from 30—90% at most. It is insufficient to use the sex pheromone alone as a control measure, and the need of a reliable chemical control agent is still urgent. In search of useful insecticides, good ovidical action is most desirable since the egg mass is the only weak stage in BAW's life cycle in green onion field. Bifenthrin, a newly developed synthetic pyrethroid [4], is very promising for lepidopterous pests control, and hence had been investigated.

Materials and methods

Part I. The field layout

Experimental layout: the experimental field was divided into 4 blocks, and 8 different treatments were randomly arranged within each block. The Random and Complete Block Design (RCBD) was applied. Each experimental plot measured at 3.5×1.2 square meters, and total of 108 hills, 18 hills×6 rows, per plots were planted.

Insecticide treatments:

Treatment 1. Bifenthrin 2.8% EC in 666X dilution(Low).
Treatment 2. Bifenthrin 2.8% EC in 333X dilution(High).
Treatment 3. Chlorfluazuron 5% EC in 2,000X dilution.
Treatment 4. Flucythrinate 5% EC in 1,500X dilution.
Treatment 5. Sannate 45% EC in 1,000X dilution+Bayrusil 50% EC in 800X dilution (Sannate 45% EC=30% Elsan+15% Dimethoate),
Treatment 6. Orthene 75% SP in 1,000X dilution+Malathion 50% EC in 500X dilution.
Treatment 7. Evisect 50% WP in 1,500X dilution+DDVP 50% EC in 1,000X dilution.
Treatment 8. Check.

All treatments were applied by hand-operated pressure sprayer and treated in a 5-day interval spraying schedule. Total of 8 applications were conducted on May 27th, June 2nd, 7th, 12th, 17th, 22nd, 27th, and July 2nd for the complete experiment. Post-treatment inspections were conducted on June 7th, 17th, 27th and July 7th. The items inspected:

A. Damage rating and BAW larval count.

The damage rating and the BAW larval count were conducted in a sample size of 10 hills of green onion randomly selected in each plot. Total number of onion tubes, BAW damaged onion tubes, and total BAW in those damaged onion tubes were counted and calculated.

B. Yields.

Upon harvesting, 10 hills of green onions in each plot were randomly collected and the weights in kilogram were recorded. For each treatment, 4 replicates were gathered for statistical analysis.

Part II. The laboratory investigation of bifenthrin

Insect materials : the 4th instar I-lan BAW were used for insecticide sensitivity test. BAW egg masses laid on the filter paper, cabbage leaves and aluminum foil were used in the ovicidal test.

Insecticides : Bifenthrin 2.8% EC, fenvalerate 20% EC, permethrin 10% EC, and chlorfluazuron 5% EC made of different concentrations which were equivalent to or lower than the strength for field spray were used.

Testing procedures : in BAW larval sensitivity test, the spray tower method used for testing the insecticide resistance was adopted [3]. After a preliminary test, 5—7 dosages within LC_{10} and LC_{95} were tested on BAW larvae and the mortality response was analyzed in probits. For the ovicide test, BAW egg masses laid on filter paper were used as the standard test, while egg masses laid on cabbage leaves and aluminum foil were used to simulate the green onion surface and the non-absorption surface respectively. The length of dipping treatment was compared on 10 seconds vs. 5 seconds, and eventually 5 seconds dipping treatment was chosen as the standard testing procedure for evaluating the ovicidal action of different insecticides.

Results and discussions

Part I. The BAW control efficacy test in green onion field

Both the BAW damage rating and the final yield of different treatments are presented in Table 1. The time sequence of BAW infestation in the green onion field

Table 1. The rate of beet armyworm damage and the yield of green onion by 7 different insecticide treatments

Treatment	Rate of BAW damage (%)				Yield
	Jun. 7	Jun. 17	Jun. 27	July 7	(kg per 4 hills)
Bifenthrin (Low)	0	0.75	0.72ab*	4.80b	0.81b
Bifenthrin (High)	0	0.99	0.10a	0.57a	1.06a
Chlorfluazuron	0.15	0.39	1.60ab	9.40b	0.80b
Flucythrinate	0.27	2.40	5.80c	28.50d	0.53cd
Sannate+Bayrusil	0	0.75	1.30ab	11.50bc	0.78b
Orthene+Malathion	0.29	0.12	2.10bc	13.70bc	0.68bc
Evisect+DDVP	0.14	0.67	1.20ab	21.10cd	0.55cd
Check	0	1.70	9.30c	89.80e	0.44d
			$P<0.01$	$P<0.001$	$P<0.001$

*Means within columns followed by the same letter are not significantly different (Duncan's multiple range test) almost followed an exponential pattern as the damage suffered in the check plots indicated, from 0 to 1.7, to 9.3 and eventually at 89.8% in 4 consecutive field inspections. The insufficient infestation in the first two inspections can not demonstrate any difference among treatments . Nevertheless, the difference became more obvious after the 3rd inspection, and was extremely significant at the end of test. The analysis of both the damage rate (X) and the yield (Y) were highly significant at $P<0.001$ level with well-fit correlation ($R=0.9446$), and the most-fit model is $Y=4.32X^{-0.33}$. The larval density is not a good parameter to measure the control effect (Table 2), which is due to (1) BAM egg masses usually varied in their eggs numbers and (2) the migration of BAW larvae within the onion field for short distance.

Table 2. The density of beet armyworm in different treatments.

Treatment	BAW density, insects per hill			
	Jun. 7	Jun. 17	Jun. 27	July 7
Bifenthrin (L)	0	0.175	0.150a*	5.475abc
Bifenthrin (H)	0	0.375	0.025a	0.300a
Chlorfluazuron	0	0.525	3.775b	5.300abc
Flucythrinate	0.3	0.975	0.725a	13.675d
Sannate+Bayrusil	0	0.025	0.250a	2.600ab
Orthene+Malathion	0	0.100	0.725a	6.850abc
Evisect+DDVP	0	0.100	0.275a	9.250bcd
Check	0	0.225	3.175b	10.075cd
			$P<0.01$	$P<0.01$

*Means within columns followed by the same letter are not significantly different (Duncan's multiple range test)

Both high and low dosages of bifenthrin were sufficient for BAW control in the field as the BAW damage rate were 0.57 and 4.70% respectively (Table 1). The yield increased 84.1—140.9% compared to the check plots. Chlorfluazuron and the mixture of sannate and bayrusil also provided certain degree of BAW control. Three other treatments were not satisfactory.

The quality of bifenthrin-protected green onion is also much superior to that of other treatments. The intact green onion in the bifenthrin treated plots indicated a possible ovicidal action since the reasonable explanation for intact onion tube is that the larvae never emerged from eggs or they died soon after hatching. The investigation to verify whether bifenthrin possesses the unique ovicidal action compared to other insecticides was therefore conducted.

Part II Efficacy test of bifenthrin as the insecticide and ovicide for BAW.

The potency of bifenthrin in controlling the BAW larvae was first tested against two other commonly used synthetic pyrethroids, fenvalerate and permethrin (Table 3).

Table 3. The comparison of needed control dosages of three synthetic pyrethroids for the 4th instar beet armyworm larvae, *Spodoptera exigua* (Hübner).

Insecticide	Needed dosages (48 hour observation), PPM		
	LC_{50}	LC_{95}	Slope
Bifenthrin	23.5	93.8	2.74
Fenvalerate	718.5	3,230.9	3.46
Permethrin	70.9	371.2	2.89

The slopes of all three synthetic pyrethroids were similar may indicate that they have the same mode of action. After comparing the LC_{50} and LC_{95} readings of these tested compounds, bifenthrin is 4 and 30 times more potent than permethrin and fenvalerate, respectively.

Besides the insecticidal action, bifenthrin is more capable of killing the BAW eggs than other synthetic pyrethroids. It only takes three days for BAW larvae to emerge from the egg mass, and the physiological condition may vary from day to day in BAW's embryo, therefore different day-old egg masses were tested for the possible different response. In Table 4, the effect of treated time was checked. Both the 10 seconds and 5 seconds treatments exerted 100% lethal effect on 1-day-old

Table 4. The effect of different dipping time on the ovicidal action of bifenthrin on beet armyworm, *Spodoptera exigua* (Hübner) .

Insecticide	Concentration (PPM)	Dipping time (second)	% Mortality of BAW egg (larvae)*		
			1-day old	2-day old	3-day old
Bifenthrin	84	10	100	100	68(32)
	42	10	100	100	67(33)
	28	10	100	100	69(31)
Bifenthrin	84	5	100	100	38(62)
	42	5	100	100	49(51)
	28	5	100	100	31(69)
	14	5	42(58)	—	—
Check	0	10	0	0	0

*Mortality as BAW larvae in parentheses

and 2-day-old BAW eggs. For the 3-day-old BAW eggs, 10 seconds treatment resulted in 68% egg mortality and subsequently killed all newly hatched larvae, while the 5 seconds treatment only resulted in 30 —50% egg mortality but still killed all hatched larvae. The strong action of bifenthrin again had been demonstrated at even lower concentration of 14 ppm.

For further comparison, bifenthrin, fenvalerate, permethrin and chlorfluazron were diluted to 14—84ppm, and the BAW egg masses were dipped into those concentrations for a standard 5 seconds treatment (Table 5). The results showed that bifenthrin

Table 5. The ovicidal action of bifenthrin, fenvalerate, permethrin and chlorfluazuron on beet armyworm, *Spodoptera exigua* (Hübner)*.

Insecticide	Concentration (PPM)	% Mortality of BAW eggs (larvae)		
		1-day old	2-day old	3-day old
Bifenthrin	84	100	100	38.2(61.8)
	42	100	100	48.8(51.2)
	28	100	100	31.2(68.8)
	14	42.2(57.8)**	—	—
Fenvalerate	84	7.0(0)	3.9(0)	5.9 (6.9)
	42	2.3(0)	4.5(0)	0 (0)
	28	0.3(0)	0 (0)	0 (0)
Permethrin	84	4.1(2.8)	11.6(4.2)	10.6 (9.8)
	42	2.2(0)	0 (0)	1.3 (3.1)
	28	0 (0)	0 (0)	0.7 (0)
Chlorfluazuron	33	9.4(2.2)	4.4(2.8)	6.5 (2.4)
	25	0.8(0)	0.8(0.4)	0.7 (2.1)
	17	0 (0)	0 (0)	3.2 (0)

*BAW egg masses were laid on common filter paper.
**Mortality as BAW larvae in parentheses.

is the only insecticide that possess ovicidal action against BAW and exerts complete control over the newly emerged BAW larvae in almost all test concentrations. Despite fenvalerate and permethrin both belong to the synthetic pyrethroids, they showed neither ovicidal action nor killing ability on the newly hatched larvae. Chlorfluazuron, a newly developed benzoylarylurea with excellent insect growth regulator action against lepidopterous species [4], showed no ovicidal or significant lethal activity against the BAW larvae.

The strong absorption power of filter paper may uptake extra insecticide solution and contaminate the under-surface of egg masses, which then results artifact in mortality counts. Hence, the BAW egg masses laid on cabbage leaves and aluminum foil were again tested in the same procedure as that on the filter paper (Table 6). The result is identical, since only bifenthrin showed ovicidal action. The unique ovicidal action against BAW and the strong killing ability on the newly emerged BAW larvae obtained in the laboratory investigation is sufficient to explain the satisfactory performance of bifenthrin against the BAW in green onion field.

Table 6. The ovicidal action of bifenthrin, fenvalerate, permethrin and chlorfluazuron on beet armyworm, *Spodoptera exigua* (Hübner) when egg masses were laid on different substrates.

Insecticide	Concentration (PPM)	% Mortality of BAW eggs (larvae)*		
		1-day old	2-day old	3-day old
On cabbage leaves				
Bifenthrin	28	85.0(15.0)	100	—
	14	91.8(8.2)	58.5 (41.5)	—
Fenvalerate	84	—	0 (0)	0 (2.3)
Permethrin	84	8.5(6.0)	7.9 (6.0)	9.8(17.0)
	42	10.2(10.2)	0 (2.9)	—
	28	0 (1.8)	0 (0)	—
Chlorfluazuron	33	2.2 (3.0)	0 (4.2)	2.2 (5.9)
	25	0 (1.6)	0 (2.2)	—
	17	0 (0)	0 (0)	—
On aluminum foil				
Bifenthrin	42	100	—	—
	28	100	—	—
	14	86.4(13.6)	96.1 (3.9)	—
Fenvalerate	84	—	8.9 (0)	—
	28	—	0 (0)	—
Permethrin	42	0 (0)	4.4 (0)	—

*Mortality as BAW larvae in parentheses.

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畢芬寧 (Bifenthrin) 對甜菜夜蛾之殺卵效應及其葱田應用技術[1]

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摘 要：

數年來本省青葱受甜菜夜蛾，*Spodoptera exigua* (Hübner)，嚴重爲害。甜菜夜蛾之卵塊產於葱管上，幼蟲孵出後立刻咬破表皮潛入葱管內取食，以致化學藥劑或天敵均難有效防治。本試驗共七處理，分別爲：不施藥之對照區；畢芬寧 84ppm 及 42ppm；克福隆 25ppm；護賽寧 33ppm；賽滅松與拜裕松之混合劑；歐殺松與馬拉松之混合劑；及硫賜安與二氯松之混合劑。測試結果發現，高劑量之畢芬寧處理，葱管受害率僅0.6%，每叢青葱平均甜菜夜蛾幼蟲之密度低於0.4隻，產量較對照區高出 140%以上。即使是低劑量之畢芬寧處理，葱管受害率也低於 5 %，其產量亦較對照區高出84%。其他處理中，僅克福隆以及賽滅松與拜裕松之混合劑處理有較佳之表現。但克福隆處理之葱管受害率可達 9 %以上，而賽滅松與拜裕松之混合劑均爲劇毒農藥，其葱管受害率亦超過10%以上，兩者之產量均較畢芬寧處理低。爲明瞭畢芬寧對甜菜夜蛾之防治原理，再進行室內殺蟲及殺卵比較試驗，結果發現，畢芬寧對甜菜夜蛾幼蟲之毒效超過百滅寧 3 ～ 4 倍，超過芬化利達30倍。此外浸漬處理28～84ppm之畢芬寧對甜菜夜蛾 1 日～ 2 日齡之卵塊有 100%殺除效果；對 3 日齡之卵塊亦有 30～50%之殺除效果，而且孵化之幼蟲也立即全部死亡。供測試殺卵效應的其他殺蟲劑，如芬化利、百滅寧與克福隆，均無明顯的殺卵及殺蟲效果。

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