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# Insecticide Resistance Study in *Spodoptera exigua* (Hübner)

## I. Detecting the Resistance in a General Survey[1]

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ABSTRACT : Following the establish of a susceptible strain of beet armyworm ( BAW, *Spodoptera exigua*) in Taiwan Agricultural Research Institute, the insecticide resistance of field-collected BAW had been determined. In the susceptible strain, methomyl and synthetic pyrethroid were the most effective insecticides followed by organophosphorus insecticides, while carbofuran and cartap were not effective. Wild BAWs collected from north, central and south of Taiwan were resistant to various insecticides in similar ranges. The resistance ratios were 10-20, 20-40 and 40-75 folds to synthetic pyrethroids, organophosphorus insecticides and methomyl, respectively. Synthetic pyrethroids are still useful for BAW control and bifenthrin is the most effective one. The development of insecticide resistance is obviously an important reason for the outbreak of BAW in green onion field in Taiwan. The resistance characters of BAW were compared with those of diamond-back moth (*Plutella xylostella*).

Key words : *Spodoptera exigua*, Insecticide, Resistance, Green onion.

## INTRODUCTION

Since the 1980s, the beet armyworm (BAW, *Spodoptera exigua*) has caused severe damage in green onion production in Taiwan, and the development of insecticide resistance has been speculated as one of the reasons for the outbreak[8]. Although bifenthrin can provide effective control for BAW[3,8,9], the real issue on insecticide resistance has not been clarified. Following the establish of a susceptible BAW strain in Taiwan Agricultural Research Institute (TARI) in 1992, the detection of insecticide resistance in field-collected BAW has been proceeded in Pesticide Research Laboratory of TARI. The BAW resistance to 3 most important insecticide groups i.e., synthetic pyrethroids, organophosphates and carbamates were investigated in this report.

## MATERIALS AND METHODS

### 1. Insect material :

A. Susceptible strain-a susceptible AL-strain BAW has been reared in TARI successfully on the artificial diet based on Biever and Boldt[1] with minor modification.

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B. Field strains-field BAWs were collected in 1993 from I-lan (north), Da-chia (central) and Yuan-chang (south) of Taiwan. All BAWs were collected from heavily infested green onion fields, and were then reared on the same artificial diet as the susceptible strain in laboratory. The F1 and F2 generations were used for testing the insecticide resistance.

**2. Insecticides :**

Commercialized insecticides were used through out the study. Ten insecticides selected for spray tower test were bifenthrin, cypermethrin, permethrin, fenvalerate, methomyl, profenofos, methamidophos, phenthoate, mevinphos and carbofuran. For leaf dipping test, bifenthrin, permethrin, methomyl, profenofos, phenthoate, mevinphos, carbofuran and cartap were studied.

**3. Bioassay methods :**

For the basic insecticide sensitivity study of susceptible BAW, organophosphorus compounds, synthetic pyrethroids and carbamates were tested in both the spray tower method and the leaf dipping method. To investigate the resistance in field-collected BAWs, only the leaf dipping method was applied.

A. Spray tower method[7] : 1 ml of insecticide solution was pipetted into the holding tube of Burkard Potter Spray Tower and sprayed on the leaf disc of 7x7 $cm^2$. After air-dried, the leaf disc was inverted and loaded with five 4th instar BAW larvae, and sprayed with another milliliter of the same insecticide solution. Treated insects and the leaf disc were transferred into a petri dish and covered with a half-folded tissue paper before putting on lid. Total of 40 BAW larvae in 8 subsets were treated in each dosage. The post-treatment holding condition was controlled at $25 \pm 1$°C in a constant temperature growth chamber.

B. Leaf dipping method : Cabbage leaf discs of 7x7 $cm^2$ were dipped for 5 seconds in insecticide solutions containing 333 ppm Triton X-100 and then left to air-dry. For control test, leaf discs were dipped in distilled water with 333 ppm Triton X-100 only and then were air-dried on a wire rack. In each petri dish, treated leaf discs were fed to five 4th instar BAW larvae, and total of 40 BAW larvae in 8 subsets were used for each dosage.

**4. Response assessment :**

The assessments were made at 24 and 48 hours respectively for spray tower method and leaf dipping method. Both the dead and the seriously affected were included in percent of response (mortality). Analysis was made by correcting with the control first, and then analyzed by probit[10]. If the mortality in control were over 8%, the test was abandoned and repeated. Definition of replicates in this study is the same as that defined by Robertson and Preisler[12] : "unless each group of ten treated with any concentration is treated with a fresh formulation and (to be absolutely sure) at a different time ; it is not a separate replicate", and related discussions.

## RESULTS

The sensitivities of the susceptible BAW to various insecticides were determined by both the spray tower method and the leaf dipping method. In the spray tower determination (Table 1), synthetic pyrethroid was the most effective chemical group and bifenthrin was the most effective member of the group. For carbamates, the performance depended on compounds. The lethal action of methomyl was almost equivalent to that of synthetic pyrethroids, while carbofuran was the least effective compound in all insecticides tested. The effectiveness of organophosphorus compounds were between synthetic pyrethroids and carbofuran. The activity of tested insecticides on BAW were in the following order : bifenthrin > cypermethrin > methomyl > permethrin > fenvalerate > profenofos > methamidophos > phenthoate > mevinphos > carbofuran.

Table 1. The insecticide sensitivities of the susceptible BAW determined by spray tower method

| Insecticides | $LC_{50}$, ppm | 95% Fiducial limits | Slope±S.D. |
|---|---|---|---|
| Bifenthrin | 5.5 | 4.6～ 6.5 | 1.71±0.15 |
| Cypermethrin | 7.6 | 6.4～ 9.0 | 1.54±0.14 |
| Methomyl | 8.7 | 7.1～ 11.1 | 1.31±0.19 |
| Permethrin | 16.9 | 11.2～ 27.1 | 1.81±0.23 |
| Fenvalerate | 24.4 | 20.0～ 30.1 | 1.56±0.14 |
| Profenofos | 195.8 | 160.0～ 238.7 | 4.55±0.71 |
| Methamidophos | 226.1 | 205.9～ 246.6 | 3.45±0.27 |
| Phenthoate | 316.0 | 297.2～ 337.2 | 5.50±0.63 |
| Mevinphos | 515.1 | 484.7～ 550.0 | 5.61±0.62 |
| Carbofuran | 2,567.2 | 2,166.9～2,997.4 | 4.69±0.69 |

In the leaf dipping method, similar results were obtained (Table 2). Bifenthrin, methomyl and permethrin were the 3 most effective insecticides, and profenofos was the most active compound within the organophosphorus group, while carbofuran still stayed as the least effective insecticide. The order of effectiveness was as follows : bifenthrin > methomyl > permethrin > profenofos > phenthoate > mevinphos > carbofuran.

Table 2. The insecticide sensitivities of the susceptible BAW determined by leaf dipping method

| Insecticides | $LC_{50}$, ppm | 95% Fiducial limits | Slope±S.D. |
|---|---|---|---|
| Bifenthrin | 1.37 | 0.83～ 2.28 | 1.54±0.37 |
| Methomyl | 7.46 | 1.98～ 11.34 | 1.86±0.71 |
| Permethrin | 8.35 | 5.65～ 12.28 | 2.65±0.51 |
| Profenofos | 49.76 | 35.25～ 64.98 | 2.88±0.59 |
| Phenthoate | 214.04 | 183.21～255.76 | 5.08±1.00 |
| Mevinphos | 396.58 | 244.88～538.51 | 2.72±0.78 |
| Carbofuran | 619.68 | 521.92～879.16 | 4.89±1.25 |

For 3 field-collected BAW strains, the susceptibilities could not be determined feasibly by the spray tower method since higher doses were needed, hence the leaf dipping method was adopted. Eight compounds were tested (Table 3), and only the $LC_{50}$s of bifenthrin, permethrin, methomyl and profenofos were determined. The $LC_{50}$s could not be determined for mevinphos, phenthoate, carbofuran and cartap due to less than 10% of BAW mortality were obtained with treating doses of 1,000 ppm or higher. The result indicated that bifenthrin was still the most effective insecticide followed by permethrin, methomyl and profenofos. In field-collected BAW strains, the resistance ratios ranged from 8-28 for bifenthrin, 9-10 for permethrin, 22-43 for profenofos and 36-74 for methomyl. Actual resistance ratios could not be determined for four other insecticides due to the needed treating dosages were too high to be tested.

Table 3. Insecticide sensitivities and resistance ratios of BAWs collected from north(N), central(C) and south(S) of Taiwan

| Insecticides | $LC_{50}$ in PPM (slope) /R.R.** | | | |
|---|---|---|---|---|
| | Suscept. strain | I-lan (N) | Da-chia (C) | Yuan-chang (S) |
| Synthetic pyrethroids | | | | |
| Bifenthrin | 1.4 | 38.7(0.82) | 11.5(1.39) | 12.6(2.02) |
| | | R.R.=28.2 | R.R.=8.4 | R.R.=9.2 |
| Permethrin | 8.4 | 81.7(1.96) | 78.0(2.07) | 78.8(1.33) |
| | | R.R.=9.8 | R.R.=9.3 | R.R.=9.4 |
| Organophosphorus compds. | | | | |
| Profenofos | 49.8 | 1,600.1(2.05) | 2,136.7(2.19) | 1,112.2(2.00) |
| | | R.R.=32.1 | R.R.=42.9 | R.R.=22.3 |
| Phenthoate | 214.0 | —* | —* | —* |
| Mevinphos | 396.6 | —* | —* | —* |
| Carbamates | | | | |
| Methomyl | 7.5 | 274.0(3.03) | 553.1(2.16) | 271.6(4.73) |
| | | R.R.=36.7 | R.R.=74.1 | R.R.=36.4 |
| Carbofuran | 619.7 | —* | —* | —* |
| Organonitrogen compd. | | | | |
| Cartap | —* | —* | —* | —* |

* $LC_{10}$>1,000 ppm and $LC_{50}$ was not determined.
** R.R.=resistance ratio.

## DISCUSSION

In Taiwan, there are two *Spodoptera* spp. causing perennial damages to agricultural crops. *Spodoptera litura* is the most common occuring species, while *S. exigua* usually presents as a minor pest until the destructive damage occurred in green onion cultivation in the 1980s. TARI started investigating the proper control measure for this species in 1984. In surveying farmer's control practices, we found that various insecticides had been used in intensive sprays, and the outbreak of BAW in summer could not be controlled by existing chemical agents, hence the insecticide resistance was strongly suspected as the major reason for the control failure.

Pheromone has been used as an alternative tool for BAW control. The sex pheromone blends of BAW determined by Mitchell et al.[11] was re-confirmed for its effectiveness in

Taiwan, and the field application formulation of mixing BAW pheromone with antioxidant and oil carrier had been developed for mass trapping[6]. The mass trapping program was implemented in I-lan county green onion field since 1985 to supplement the shortfall of chemical control[3,8].

The ovicidal action of bifenthrin was discovered in 1988[8], which had also been confirmed as the most effective BAW control agent in 3 consecutive years of insecticide screening. Nevertheless, the insecticide resistance for BAW still could not be proven for lacking of a susceptible strain to compare with. From 1991-93, through numerous efforts, a susceptible BAW colony (AL-strain) has been estabished in TARI. Consistent results were obtained by both the spray tower and the leaf dipping methods for measuring the sensitivity of BAW to selected insecticides (Tables 1 and 2). Synthetic pyrethroid was found to be the most effective group with the $LC_{50}$s in the range of $10^{-5}$ to $10^{-6}$, and the order of effectiveness were bifenthrin, cypermethrin, permethrin and fenvalerate. For the organophosphorus compounds, the range of $LC_{50}$s were about $10^{-4}$, following the order of profenofos, methamidophos, phenthoate and mevinphos. For 2 selected carbamates, methomyl and carbofuran differed extremely with the $LC_{50}$s of 8.7 ppm and 2,567 ppm, respectively. The effective dosage of methomyl was similar to that of synthetic pyrethroids, while carbofuran was the least effective insecticide in the test.

Generally, to induce mortality in field-collected BAWs required significantly higher doses when compared to that of the susceptible BAW. This confirmed the suspicion that insecticide resistance was a factor for the failure of BAW control. A commonly used insecticide in Taiwan, cartap, was also subjected to the dipping test, but no BAW mortality had been observed even in the susceptible strain (Table 3).

In viewing of the results, the insecticide resistance of BAW has characters differed from another notorious lepidopterous pest, diamondback moth (DBM, *Plutella xylostella*)[2,4] in Taiwan. For example, in carbamates, methomyl was more effective than carbofuran for BAW, while opposite was true in DBM[5]. Another difference is the synthetic pyrethroids resistance. The extremely high mfo (mixed function oxidases) in resistant DBM almost immuned the insect from the lethal action of synthetic pyrethroids, while BAW only encountered moderate synthetic pyrethroid resistance, and bifenthrin still is the most effective insecticide for BAW control in Taiwan.

For the organophosphorus compounds, the BAW resistance was similar to that of DBM, but the effectiveness of individual compound differed, for example, mevinphos is a better choice than profenofos in DBM control[5], and vise versa in BAW. Organophosphorus insecticides suffered 20 to 40 folds resistance. Comparatively, synthetic pyrethroid suffered only mild resistance at 10 to 20 folds, while methomyl met a high resistance at 40 to 75 folds.

By comparing insecticide chemical groups for BAW resistance, we concluded that：

1. BAW populations in cultivated fields of Taiwan are universally resistant to synthetic pyrethroids, carbamates and organophosphorus insecticides.
2. Synthetic pyrethroids suffered only mild resistance and are still useful in the control of BAW with bifenthrin stays the most effective compound.

3. Organophosphorus compounds emerged resistance problem and would not be a good choice for BAW control for the moment.
4. Although methomyl is an effective control agent for BAW, the 40 folds high resistance will cause problem in control.
5. The characters of insecticide resistance in BAW are significantly different from those of DBM.

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# 甜菜夜蛾抗藥性之研究

## I. 本省甜菜夜蛾族群抗藥性之檢定[1]

鄭　允　高靜華[2]


### 摘　要

由本省北、中及南部地區青葱上所採集之甜菜夜蛾與省農試所培養之感性品系，比較三類主要殺蟲劑之敏感度發現，甜菜夜蛾對合成除蟲菊精劑最爲敏感，而對納乃得之感度也極高，有機磷劑之藥效落於其後，與納乃得同屬氨基甲酸鹽之加保扶效果更次之，而本省蔬菜上常用之培丹則完全無藥效。偵測田間採得之甜菜夜蛾抗藥性時發現，北、中、南三區所採集之甜菜夜蛾族群間並無明顯差異，對合成除蟲菊精之抗性均在10-20倍之間，對有機磷劑抗性均爲20-40倍，對納乃得之抗性則爲40-75倍之間。就抗藥性之特質而言，甜菜夜蛾與小菜蛾迥然不同。綜合田間現用藥劑之防治效果，仍以合成除蟲菊精劑較佳，尤以畢芬寧之藥效最好。


**關鍵詞**：甜菜夜蛾、殺蟲劑、抗藥性、青葱。

1. 臺灣省農業試驗所　研究報告第 1693 號。本計畫部份承國科會經費補助（計畫編號 NSC81-0409-B-055-506 及 NSC82-0409-B-055-20），洪秀芬及簡淑貝協助工作，謹此一併致謝。
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