Bull. Inst. Zool., Academia Sinica **25**(1): 99-104 (1986)

DIAMONDBACK MOTH RESISTANCE AND CROSS RESISTANCE TO FOUR COMMONLY USED INSECTICIDES IN TAIWAN[1]

T. C. WANG

Institute of Zoology, Academia Sinica
Taipei 115, Republic of China

and

H. T. FENG

Taiwan Agricultural Chemicals and Toxicant Research Institute
Wufeng, Taichung Hsien, Taiwan 431, Republic of China

(Accepted, November 15, 1986)

T. C. Wang and H. T. Feng (1985) Diamondback moth resistance and cross resistance to four commonly used insecticides in Taiwan. *Bull. Inst. Zool., Academia Sinica* **25**(1): 99-104. Investigations on diamondback moth resistance and cross resistance to Phosdrin, Furadan, Sumicidin and Kestrel are reported. Development of resistance to Furadan is the fast among all. However, decrease of resistance to Furadan was observed after the insecticide selection had been removed for 5 generations. Development of cross resistance to Furadan and Sumicidin were found most significant in these experiment when selected respectively with Phosdrin and Kestrel. In selection with Kestrel, cross resistance to Furadan did not occur before 20th generation. However, the resistance to Furadan increased 5 folds as the selection proceeded to 35th generation. In those diamondback moth selected with Phosdrin or Furadan, the cross resistance to Sumicidin decreased. Alternative use of these 4 insecticides to control the diamondback moth was proposed in order to retard the development of resistance in this insect.

Investigations on resistance of diamondback moth, *Plutella xylostella* (L.), to insecticide in Taiwan have been started from mid 1970's. Papers published included studies on organophosphorous insecticides (Chang, 1975; Sun *et al.*, 1978; Lee and Lee, 1979 and Cheng, 1981), carbamates (Sun *et al.*, 1978 and Cheng, 1981), synthetic pyrethroids (Cheng, 1981 and Liu *et al.*, 1981) and organo-nitrogen compound (Cheng, 1981). Variations of susceptibilities to the test insecticide among the diamondback moth collected from different localities were considered as the results of the development of the resistance in those reports.

Since then, research on insecticide resistance in diamondback moth as well as in other pest insects has been very active in this country. However, no countermeasures have been proposed so far. In this paper, we report the resistance and cross resistance of diamondback moth to 4 of the commonest insecticides for diamondback moth control in Taiwan. Efforts have been made on proposing the ideas about the alternative use of insecticides to retard the development of resistance in diamondback moth.

---

[1] Paper No. 272 of the Journal Sevies of the Institute of Zoology, Academia Sinica.

MATERIALS AND METHODS

Insecticides

One organophosphate, Phosdrin 25.3 EC (Mevinphos, Hwa Nung Chem. Co. Taiwan, R. O. C.), one carbamate, Furadan 40.64% (Carbonfuran, Cheng Feng Chem. Co. Taiwan, R. O. C.) and two synthetic pyrethroids, Sumicidin 20% EC (Fenvalerate, Sumitomo Chem. Co. Ltd.) and Kestrel 10% EC (Permethrin, Shell Netherland Chem. B. V.) were used.

Insect

Pupae of diamondback moth were collected from Taichung District Agricultural Improvement Station in April, 1982. Methods described by Koshihara and Yamada (1976) were used to maintain the insect in laboratory. Offsprings of those pupae were categorized as original generation (G-0). The offsprings of the G-0 were F-1. Similar method was used to mark the generations coming after as F-2, F-3 and so on.

Insecticide-Selecting Strategies

Third-instar larvae of G-0 were bioassayed with the methods described by Feng and Wang (1984). LC-50 then was calculated by probit analysis. Survivals in those treatments with which mortality were higher than 70% were used as the parents of the next generation. Selection was performed in every generation with the does that killed 70% of the test insect. Up to 35 generations have been consecutively selected in this experiment. Four insecticides were used to establish the selecting strategies, i. e., Phosdrin-, Furadan-, Sumicidin- and Kestrel-selecting strategies.

Measurement of Resistance and Cross Resistance

Development of resistance in diamondback moth of each selecting strategy to the selecting insecticide was measured by bioassaying the 3rd-instar laevae in generations of G-0, F-1, F-2 (except Phosdrin), F-5, F-10, F-20 and F-35. Levels and cross resistance to other 3 non-selecting insecticides in the diamodback moth of each selecting strategy were measured in the generations of G-0, F-5, F-10, F-20 and F-35 with the same method mentioned above.

Part of the offsprings of F-30 in each selecting strategy were isolated from the colony and maintained in conditions without any purposive contact of insecticide for five more generations. The larvae then were bioassayed to see any conversion of susceptibility in those diamondback moth after the removal of insecticide selection.

RESULTS

Development of Resistance

The results were listed in Table 1. For

TABLE 1
Development of resistance in diamondback moth in 4 insecticide-selecting strategies

Generation	Selection Strategies LC-50*			
	Phosdrin	Furadan	Sumicidin	Kestrel
G-0	0.35	0.79	1.08	0.31
F-1	0.38	2.18	0.70	0.14
F-2	—	1.76	0.58	0.24
F-5	0.40	6.28	1.45	0.21
F-10	0.70	>40	1.85	0.52
F-20	1.14	>40	2.82	1.05
F-35	1.69	>40	5.30	0.81

* Concentration in mg/ml.

just one-generation selection with Furadan, the resistance developed to a level almost 3 times that of G-0. After consecutively selecting for 10 generations, the resistance jumped to a level more than 50 times higher than that of G-0. The dose which would kill 70% of the test population thus was unable to reach after then.

Development of resistance in other 3 selecting strategies also occurred, however, were much less significant when compared with that in Furadan-selecting strategy. Furthermore, in first 5 generations in Phosdrin- and Kestrel-selecting strategies and first 2 generations in Sumicidin-selecting strategy, the resistance level declined in spite of the presence of the insecticide selection pressure.

At the end of this experiment, i. e., after 35-generation consecutive selection, diamondback moth in Phosdrin-selecting strategy developed a 3.2-time resistance. In Sumicidin-selecting strategy, the insect of F-35 became 4.9 times higher than the G-0 in resistance. Kestrel selection created a resistance level 2.6 times higher than that in G-0 when experiment was finished.

The decrease or fluctuation of resistance level in early period of selection is not uncommon for the development of insecticide resistance in most of the insect. It is the phenomenon found in Furadan-selecting strategy that was rare. Improper use of Furadan in this island probably would tell parts of the story.

Conversions of Susceptibility

When insecticide selection pressure was removed for 5 generations from those populations which had been selected formerly with selecting insecticide in each selecting strategy consecutively for 30 generations, significant conversions of susceptibility, i. e., the decrease of resistance, were found in Furadan-selecting strategy (Table 2). The resistance which had reached to a level more than 50 times higher than G-0 before the removal of the insecticide selection pressure became only 6.2 times. Conversions of susceptibility were also found in other 3 selecting strategies, however, were not as significant (Table 2). They were only about 87.5%-, 38.7%- and 80.8%-off from the levels in F-35 of Phosdrin-, Sumicidin-, and Kestrel-selected diamondback moth, respectively.

Cross Resistance

Development of cross resistance in each selecting strategy to other 3 non-selecting insecticide which expressed as resistance ratio (RR) is listed in Fig. 1. Resistance ratio was calculated as follow:

$$RR=\frac{(\text{LC-50 of population other than G-0})}{(\text{LC-50 of G-0 population})}$$

Diamondback moth in Phosdrin-selecting strategy steadily developed the cross resistance to Furdan as the generation under Phosdrin selection proceeded. Highest RR values of 8 was found in the insect of F-35. Levels of cross resistance to Kestrel were not apparent before the F-20, however, obtained 3.6 in RR when the selection ended in this experiment. The level of cross resistance to Sumicidin decreased as selection moved toward the

TABLE 2
Conversions of susceptibilities in diamondback moth

Treatment	Selection Strategies			
	LC-50*			
	Phosdrin	Furadan	Sumicidin	Kestrel
Selected cosecutively for 30 generations	1.69	>40	5.30	0.81
Selection stopped at 30th generation and bioassayed at 35th generation	1.47	4.86	2.08	0.78

* Concentration in mg/ml.

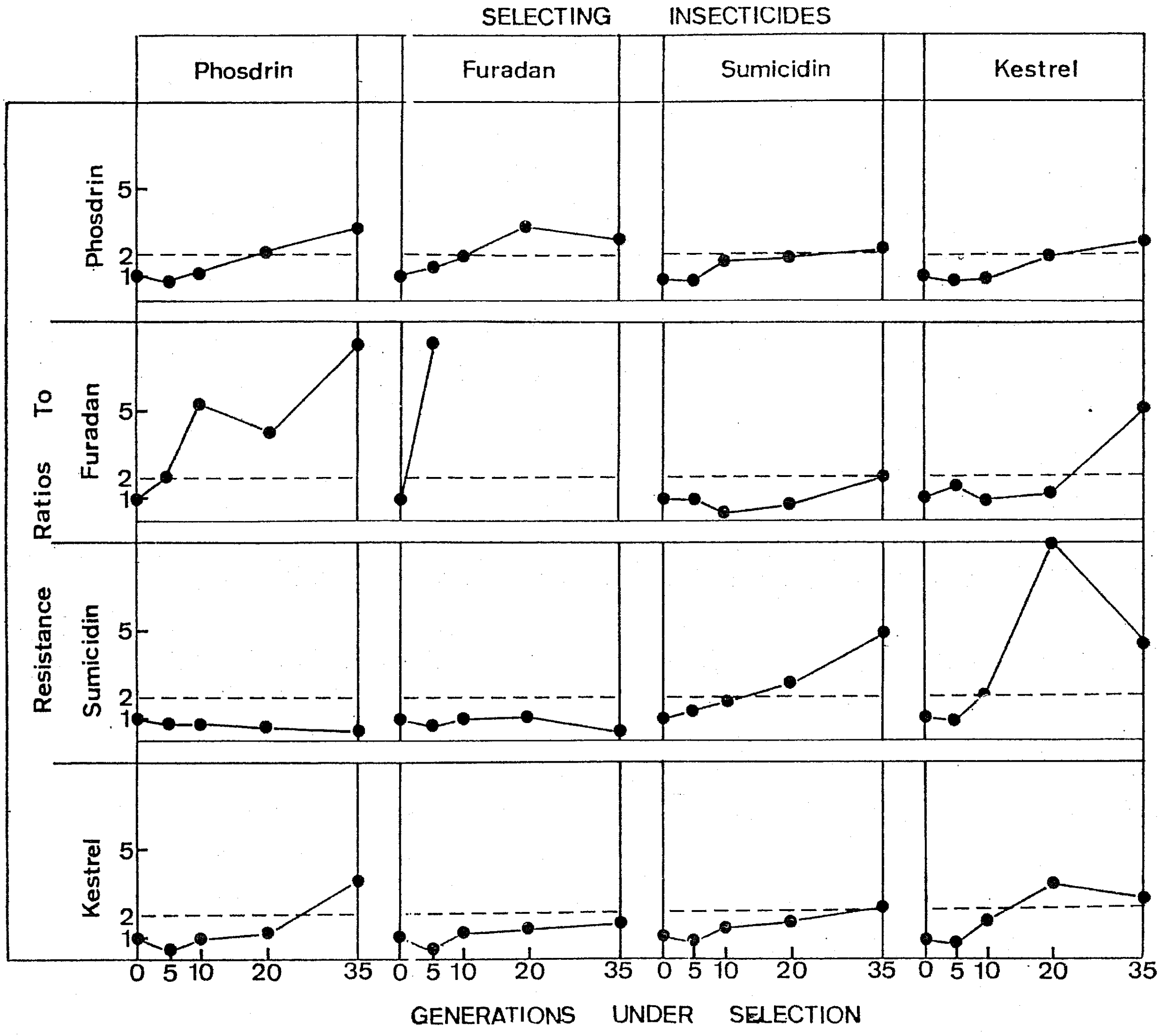

Fig. 1. Changes in resistance to each selecting insecticide and cross resistance to non-selecting insecticides in diamondback moth. (---- represents the economic resistance level [ERL] arbitrarily proposed by authors in order to make the discussion in the text possible.)

following generations and lowered to a RR value of 0.4, i. e., less than a half of RR values in G-0.

Although the selection pressure of insecticide in Furadan-selecting strategy was unable to get higher after the F-10, the level of cross resistance to Phosdrin continued to increase in the generations coming after. In F-10, the RR value was 1.9 and they became 3.3 and 2.7 in F-20 and F-35, respectively. Cross resistance to Sumicidin and Kestrel did not develope significantly. In F-35, RR to Kestrel was only 1.6. To Sumicidin, RR in F-35 was found only 0.4, i. e., 40% of that in G-0.

Levels of cross resistance in the Sumicidin-selecting strategy were the least apparent among all 4 selecting strategies. In F-35, highest RR value, 2.3, was found in the selecting strategy with Kestrel. Resistance ratios to Phosdrin and Furadan were 2.2 and 2.0, respectively.

In Kestrel-selecting strategy, cross resistance to Sumicidin, another synthetic pyrethroid, was found the most significant. The

RR value in F-20 was as high as 8.9, although decreased to 4.3 in the F-35. The cross resistance to Phosdrin was about the same level as its resistance to the selecting insecticide, the Kestrel. The RR value in F-35 was 2.6. Not until the generation of F-35 did the cross resistance to Furdan become significant. The RR value in the last generation of this experiment was 5.

DISCUSSION

How high the resistance level developed would show the impactness on the control of the pest insect varies from case to case. Many factors are needed to be considered collectively. It is by no means to recommend the candidate insecticide for chemical control simply by comparing the different resistance levels developed in each selecting strategy. However, to make the discussion in this paper possible, we arbitrarily assign RR=2 as the economic resistance level (ERL) in equivalent to the idea of economic injury level (EIL) frequently used by economic entomologist as well as many entomologists in other fields (Fig. 2). In other words, it is considered as a control failure in question for the application of a certain insecticide if the diamondback moth develops to a level of this insecticide two times or higher than that of G-0.

With the assumptions made above, the Furadan should not be included in the list to control the diamondback moth as far as the resistance development is concerned. However, the resistance of diamondback moth to Furadan decreased significantly after the use of this insecticide had been terminated for only 5 generations. This indicated that the efficacy of Furadan application against the diamondback moth probably could be preserved by prolonging its application interval.

Continuously use of both Sumicidin and Kestrel for 10 generations are satisfactory from the resistance points of view. RR for diamondback moth of F-20 in Phosdrin-selecting strategy was equal to ERL, i.e., 2. For those insect in Sumicidin- and Kestrel-selecting strategies, they were still lower than ERL in F-10.

The results in Phosdrin-selecting strategy indicated that the Sumicidin could be used to replace the Phosdrin when the ERL is reached. The replacement with Sumicidin will enjoy 10 to 20 more generations in the control strategy since the development of resistance to Sumicidin did not become higher than ERL until then. The replacement with Furadan is not desirable due to the fast development of cross resistance to this insecticide.

For the control of diamondback moth with high resistance level to Furadan, Sumicidin and Kestrel are ideal alternatives. This recommendation was based on the fact that, in our results, the resistance levels to these 2 synthetic pyrethroids in Furadan-selected diamondback moth have never been higher than the ERL we had proposed. After the selections with Furadan, they even became less resistant to Sumicidin than the insect in G-0. Whether there is negative correlation existed in between the development of Furadan- and Sumicidin resistance is needed investigated furtherly on diamondback moth.

Once the resistance to Sumicidin has reached to or become higher tha the ERL, Furadan is suggested to replace the insecticide, however, should not be used for more than one generation. Phosdrin and Kestrel with much slower increasing rates in resistance development are recommended for the replacement and probably could be used for another 20 and 10 generations, respectively, before the ERL's are reached.

Furadan and Sumicidin are not suggested to use as alternatives for Kestrel. It is because the high level of cross resistance to those 2 insecticides were found associated with the development of resistance to Kestrel. If the replacement is needed, Phosdrin is recommended in case there is no other candidate available.

The chemical control strategy against diamondback moth with alternative use of different insecticides proposed above is based on the results originated from the experiments performed in laboratory. To materilize its feasibility in the field, further works is needed in the future.

REFERENCES

CHANG, L.C. (1975) A study of resistance of Plutella xylostella L. to several organophosphorous insecticides. *Plant Prot. Bull.* **17**: 431-432.

CHENG, E.Y. (1981) Insecticide resistance study in *Plutella xylostella* L. II. A general survey (1980-81). *J. Agric. Res. China* **30**: 285-293.

FENG, H.T. and T.C. WANG (1984) Selectivity of insecticide to *Plutella xylostella* (L.) and Apanteles plutellae Kurd. *Plant Prot. Bull.* **26**: 275-284.

KOSHIHARA, T. and H. YAMADA (1976) A simple mass-rearing technique of the diamondback moth, *Plutella xylostella* (L.), on germinating rape seeds. *Jap J. Appl. Entomol. Zool.* **20**: 110-114.

LEE, S.L. and W.T. LEE (1979) Studies on the resistance of diamondback moth, *Plutella xylostella* to commonly used insecticides. *J. Agric. Res. China* **28**: 225-236.

LIU, M.Y., Y.J. TGZENG and C.N. SUN (1981) Insecticide resistance in the diamondback moth. *J. Econ. Entomol.* **75**: 153-155.

SUN, C.N., H. CHI and H.T. FENG (1978) Diamondback moth resistance to diazinon and methomyl in Taiwan. *J. Econ. Entomol.* **71**: 551-554.

小菜蛾對本省四種常用農藥之抗性與交互抗性

王清澄　馮海東

本研究採用四種本省最常用於小菜蛾防治的殺蟲劑，包括美文松（phosdrin）、加保扶（furadan）、芬化利（sumicidin）及百滅寧（kestrel），作爲探討小菜蛾之抗性與交互抗性。

小菜蛾系採自臺中改良場之蛹所建立，以上述四種農藥自第一代起分別選汰。以殺死70%以上之處理濃度下存活之個體作爲繁殖下一代之親代，選汰之工作連續進行35代。在親代，第一、二、五、十、二十及三十五子代測出各選汰農藥對其族羣之致死半數濃度，作爲抗性發展之依據。同時除第一及二子代外，依上述代數，測量其餘三個非選汰農藥對各族羣之致死半數濃度，作爲交互抗性發展之衡量標準。

各選汰系列，在第三十子代時，移出部份族羣，在不接觸農藥狀況下飼育五代，然後測其抗性，並與原族羣者比較，以探討抗性在農藥停用後之情形。報告中同時假設抗性或交互抗性達到親代之2倍時爲抗性忍受界限，超過此一水平卽假設爲防治失效。

結果顯示，加保扶的選汰下，小菜蛾之抗性發展最快。但一旦停用加保扶時，經過五代，抗性卽急劇降低10倍以上。此結果顯示，加保扶在小菜蛾的防治上，不宜連續使用。

經加保扶和芬化利選汰後，小菜蛾分別對美文松和百滅寧產生極顯著的交互抗性，可見加保扶與美文松或芬化利與百滅寧不適合交互使用。在百滅寧的選汰下，小菜蛾對加保扶之交互抗性在第二十代後才急劇上升。而以美文松和加保扶連續選汰後，小菜蛾對芬化利之交互抗性，非但沒有增加反而降低，這個結果指出，當前二殺蟲劑防治小菜蛾失效時，似應可以用芬化利取代。

本實驗的結果顯示，舊有的農藥可以在適當的輪用下，延緩抗性所造成的困擾，一味引進新藥並非萬靈丹。