Proc. Fla. State Hort. Soc. 126:118–122. 2013.

Effectiveness of Biological Insecticides in Controlling the Diamondback Moth (Lepidoptera: Plutellidae) on Cabbage

Dakshina R. Seal* and Catherine M. Sabines

University of Florida, IFAS, Tropical Research and Education Center, 18905 SW 280th Street, Homestead, FL 33031

Additional index words. diamondback moth, *Bacillus thuringiensis*, new insecticides, management

Diamondback moth (DBM), *Plutella xylostella* (L.), is a major pest of cabbage (*Brassica oleracea*) that has developed resistance against most of the known classes of insecticides. Sole reliance on an insecticide or a group of insecticides is the principal cause of development of resistance. As an effort to develop a management program, we evaluated *Bacillus thuringiensis* (BT)-based biological insecticide in controlling DBM. All formulations of BT-based biological insecticide provided significant reduction of all growth stages of DBM and feeding damage on foliage was significantly reduced. Chemical insecticides showed potential for reducing DBM populations on cabbage. BT-based insecticides showed similar effectiveness as the chemical insecticides in controlling DBM. Feeding damage on foliage was significantly less on plants treated with BT or chemical insecticides than on the nontreated control. These results suggest that BT-based insecticides can be used in a management program with chemical insecticides to control DBM. This management strategy will delay the development of resistance in DBM against any specific insecticide.

Cabbage, *Brassica oleracea* var. *capitata* L., is an important crop in Florida, accounting for approximately 13% of U.S. cabbage production (Elwakil and Mossler, 2013). Out of 14 insect species feeding on crucifers, the diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), is a common pest of all Brassica crops, and the most important pest of cabbage worldwide (Talekar and Griggs, 1986). In the absence of any control measure, DBM may cause 50% to 100% crop loss (Calderan and Hare, 1986; Sagenmuller and Rose, 1986). Due to its common occurrence and significant feeding damage, this insect pest is known differently in different countries—English: diamondback moth; German: Kohl-Schabe, Kohlmotte; French: Teigne des crucifères; Dutch: Koolmotje; Spanish: Palomilla dorso de diamante. It is the most damaging pest of cabbage in Florida (Jansson and Lecrone, 1988) and most of the Caribbean countries (Salinas, 1987). Talekar et al. (1985) listed over 1000 publications on this pest through 1984.

Growers commonly use insecticides of various classes and modes of action to control this pest (Seal, 1995a, 1995b). Repeated use of same insecticides enhances development of resistance in DBM, resurgence of DBM, and elimination of beneficial biocontrol agents. DBM has developed resistance to most conventional chemical insecticides in most parts of the world (Chen and Sun, 1986; Cheng, 1986; Georghiou, 1981; Kao et al., 1989; Liu et al., 1981, 1982; Margaro and Edelson, 1990; Miyata et al., 1982; 1986; Sun et al., 1986; Tabashnik and Cushing, 1989; Tabashnik et al., 1987). Resistance of DBM to registered insecticides quickly became widespread in North America with the most severe resistance in the southern U.S. (Shelton and Wyman, 1990). Perng et al. (1988) and Kobayashi et al. (1990) reported resistance of DBM to insect growth regulator.

In 1987, control failures occurred with DBM in North America, when this insect emerged as the most destructive pest among the lepidopteran complex. The development of resistance in this pest to organophosphorous insecticides (Noppun et al., 1986a, 1986b), carbamates (Sun et al., 1978), and synthetic pyrethroids (Hama, 1986; Horikiri and Makino, 1987; Liu et al., 1981, 1982; Makino et al., 1985; Noppun et al., 1986a) has become a serious problem in managing DBM. Noppun et al. (1986b) obtained high levels of resistance to phenthoate, an organophosphate, and fenvalerate, a mixture of isomers of a pyrethroid, in DBM by selection of successive generations in the laboratory. They found that fenvalerate resistance is conferred by at least three mechanisms: 1) an efficient system of reduced cuticular permeability (Noppun et al., 1986a), 2) increased metabolic degradation (Noppun et al., 1986b), and 3) increased insensitivity of the nervous system (Noppun et al., 1986b). Tabashnik (1986) showed that the DBM develops insecticide resistance in only a few generations of selection, and therefore, it is important to extend the intervals between applications of the same insecticide as much as possible.

Development of an alternative method is essential to manage this pest. In the present research program, efforts were made to: 1) control the DBM using various biological insecticides; and 2) compare biological insecticides with new chemical insecticides in controlling DBM. Results from these studies will have an important bearing on the development of an effective management program by using biological and chemical insecticides.

Materials and Methods

All studies were conducted at the University of Florida–IFAS, Tropical Research and Education Center, Homestead, FL, in Krome

*Corresponding author; phone: (305) 246-7001; email: dseal@ifas.ufl.edu

gravelly loam (loamy-skeletal, carbonatic hyperthermic lithic Udorthents), which consists of about 33% soil and 67% pebbles (>2 mm). Experimental plots were randomly selected 30-ft-long segments of three adjacent raised beds, which were 3 ft wide and 0.5 ft high. The beds were separated by 6 ft between bed centers and covered with 1.5-mil-thick black polyethylene mulch. The plots were arranged in a randomized complete-block design with four replications. A 5-ft-long nontreated planted area separated each replicate. Plants were spaced 18 inches apart within each row and 36 inches apart between rows. Trifluralin (Treflan® 4EC) was incorporated into the soil of each bed 2 weeks before planting. All treatments were applied on foliage weekly or as specified in Table 1 by using a backpack sprayer with two nozzles per row delivering 70 gpa at 30 psi.

Evaluation of various biological control (VBC) insecticides. In the first study 'Gourmet' cabbage seedlings were transplanted on 12 Dec. 2012. Rate of each treatment, timing and frequency of applications are stated in Table 1. Insecticides were evaluated 48 h after each application by thoroughly checking five randomly selected plants per plot for DBM larvae. Larvae were recorded as small (1st instar), medium (2nd and 3rd instar), and large (4th instar).

Comparison of VBC insecticides with new chemical insecticides. In the second study, 'Gourmet' cabbage seedlings were set into a Rockdale soil on 5 Jan. 2013. Plants were grown following the same cultural practices as described in the first study. The insecticides used in this study are shown in Table 2. Applications of insecticides were initiated on 30 Jan. and were repeated four times at weekly intervals. Evaluations of insecticide treatments were conducted 48 h after each application by thoroughly checking five randomly selected plants per treatment plot as described for the previous study.

Statistical analysis. Data on abundance of various development stages of DBM were transformed using square-root of X + 0.25 before performing an analysis of variance (ANOVA). The transformed data were analyzed by least squares ANOVA (PROC GLM, SAS Institute 1989). However, for ease of interpretation, the means of the original data are presented.

Table 1. Treatment number, treatments, rate (lb/acre), application timing, and frequency of application

Treatment no.	Treatments	Rate (lb/acre)	Application timing and frequency
1	VBC-60342	1.0	Spray every 14 d, starting 14 d after transplant
2	VBC-60343	1.0	Spray every 14 d, starting 14 d after transplant
3	VBC-60344	1.0	Spray every 14 d, starting 14 d after transplant
4	VBC-60345	1.0	Spray every 14 d, starting 14 d after transplant
5	VBC-60346	1.0	Spray every 14 d, starting 14 d after transplant
6	VBC-60341	1.0	Spray every 14 d, starting 14 d after transplant
7	VBC-60341	1.0	Spray every 7 d, starting 14 d after transplant
8	Untreated control		

Results and Discussion

Control of DBM small larvae. In the first study, DBM population abundance was medium as shown in the prespray sample (Fig. 1). Mean numbers of DBM small larvae in the pre-spray sample varied among various plots. This was due to the clumping pattern of distribution of DBM at the initiation of the study. Fourteen days after planting, after the first application of all insecticides, mean numbers of small DBM larvae were significantly fewer in all treated plants than the nontreated control. Mean number of larvae per plant in the nontreated control was 16.92. In contrast, the mean numbers of larvae per plant in all treated plots ranged from 0.12 to 0.92 larvae. Among VBC treatments, VBC 60346 performed the best in controlling DBM small larvae. On the second sampling date, 4 weeks after planting, the mean number of DBM small larvae on nontreated control plants was 6.00. On the VBC-treated plants, the mean numbers of DBM small larvae per plant were 1.40, 1.25, 0.84, 0.12, 0.10, 0, and 0 on VBC 60342, VBC 60343, VBC 60344, VBC 60345, VBC 60346, 60341 (14-d intervals), and 60341 (weekly intervals), respectively. On the third sampling date, 6 weeks after planting, mean numbers of DBM small larvae on different VBC-treated plants were 1.0 (VBC-60342), 1.45 (VBC-60343), 0 (VBC-60344), 0.30 (VBC-60345), 0 (VBC-60346), 0.10 (60341, 14-d intervals), and 0 (60341, 7-d intervals) compared to 4.50 per nontreated control plant of cabbage. On the fourth sampling date, 8 weeks after planting, mean numbers of DBM small larvae increased in all treated plants except in plants treated with VBC 60341 applied at weekly intervals. However, mean numbers of larvae on all VBC-treated plants were significantly fewer than the nontreated control (16.45 per plant).

Control of mature larvae. Mature larvae were almost absent on all VBC-treated plants (Fig. 2). On the contrary, mean number of mature larvae was 16.8 per plant in the nontreated control. Due to the effectiveness of the VBC insecticides in controlling small larvae, there were very few mature larvae on treated leaves, indicating that VBC treatment is an effective control tool against DVM.

Foliage quality. In the first study, all VBC treatments significantly increased foliage quality of cabbage plants when compared with the nontreated control (Fig. 3). This increase in foliage quality is supported by the fact that there were very few larvae on the VBC-treated plants compared with the nontreated control plants.

Evaluation of new insecticides for DBM control. In the second study, abundance of DBM was high at the beginning of

Table 2. Trade names, common names, and rate (oz/acre) of all tested insecticides in controlling diamondback moth.

Trade names	Common names	Rate (oz/acre)
Radiant SC	Spinetoram	7.0
Synapse 24 WG	Flubendiamide	3.0
Xentari	*Bacillus thuringiensis*	16.0
Rimon 10 EC	Novaluron	12.0
Avaunt 30 WG	Indoxacard	3.5
Tesoro 4 EC	Pyridalyl	6.4
Coragen	Chlorantraniliprole	5.1

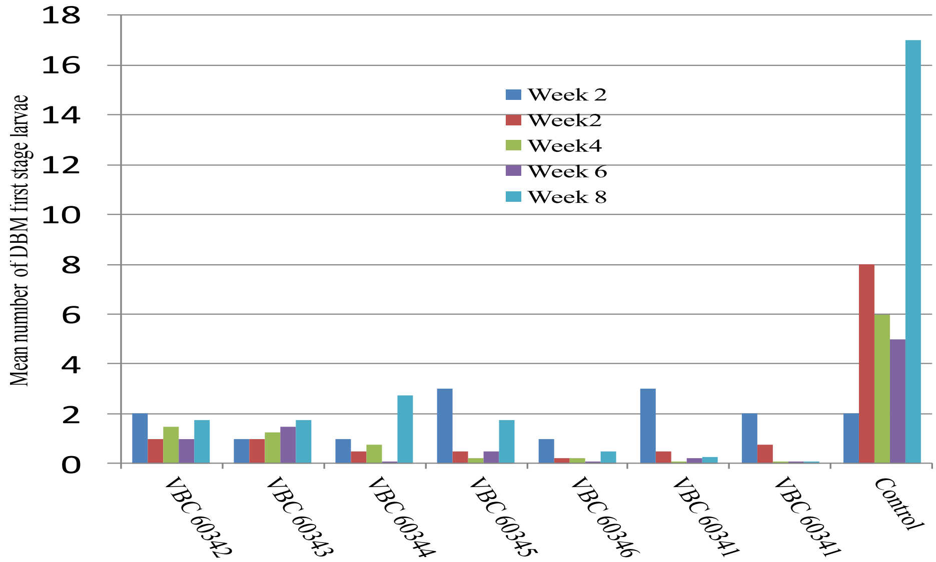

Fig. 1. Mean numbers of DBM small larvae per cabbage plant treated with various BT-based insecticides.

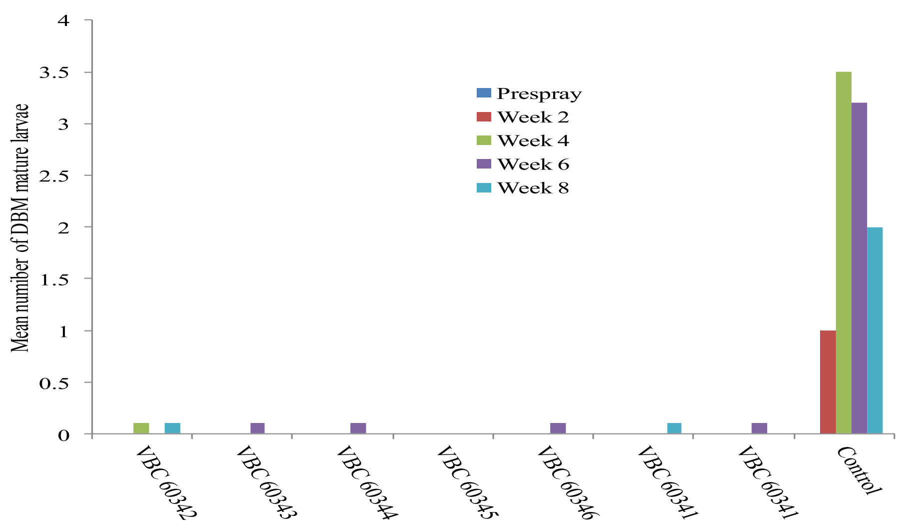

Fig. 2. Mean numbers of DBM mature larvae per cabbage plant treated with various BT-based insecticides.

the observation period. Mean number of DBM larvae was 15.99 per plant in nontreated control plots after the first application of insecticides (Fig. 4). Mean numbers of larvae per plant were 2, 4, 5, and 4 on Synapse-, Xentari-, Rimon-, and Tesoro-treated plants, respectively. No larvae of any development stages were recorded on the plants treated with Radiant, Avaunt, or Coragen. On the second sampling date, mean number of larvae per plant in the nontreated control was 8.96 (5–13). Mean numbers of larvae per plant were 1, 1, and 2.0 on plants treated with Xentari, Rimon, or Tesoro, respectively. No larvae were recorded on plants treated with Radiant, Avaunt, Coragen, or Synapse. On the third sampling date, mean number of DBM larvae per nontreated control plant was 5.89. In contrast, no DBM larvae were recorded on any of the treated plants. All treatments provided significant reduction of DBM larvae. Xentari, a BT- based insecticide, provided significant control of DBM larvae when compared with the nontreated control and did not differ from the new insecticides in the present study. DBM feeding damage ratings also indicated that all chemical and biological treatments effectively reduced DBM populations on cabbage when compared with the nontreated control (Fig. 5).

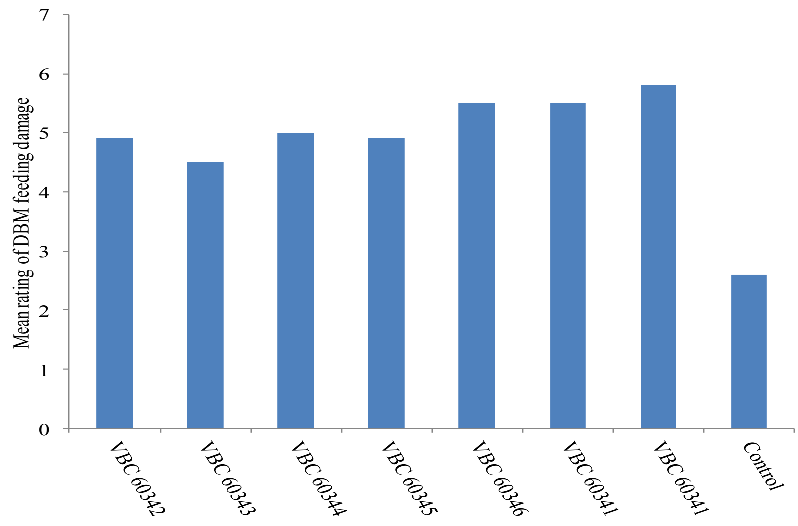

Fig. 3. Mean rating of DBM feeding damage on cabbage foliage treated with various BT-based insecticides.

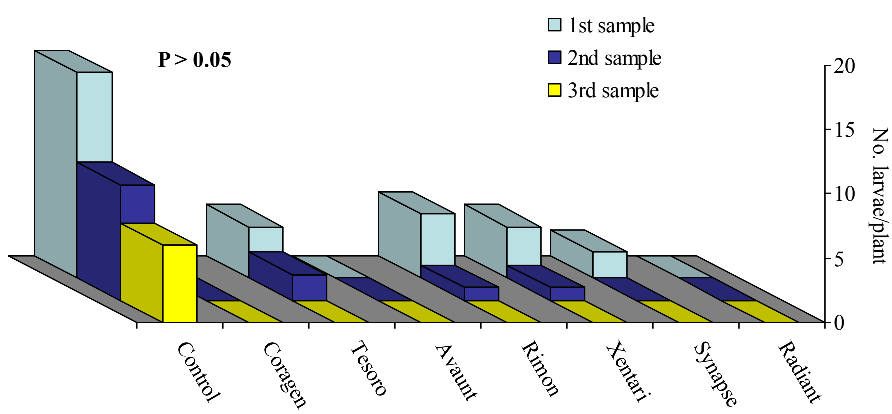

Fig. 4. Mean numbers of DBM larvae per plant of cabbage treated with various new insecticides.

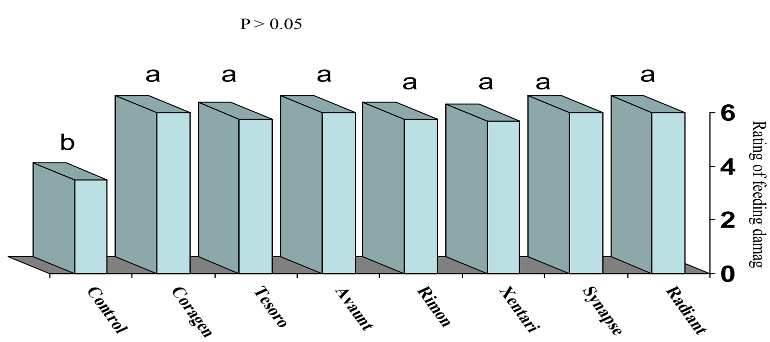

Fig. 5. Mean rating of DBM feeding damage on cabbage foliage treated with various new insecticides.

Literature Cited

Calderon, J.I. and C.J. Hare. 1986. Control of diamondback moth in Southeast Asia by profenofos, p. 289–295. In: N.S. Talekar and T.D. Griggs (eds.). Diamondback moth management: Proc. 1st Intl. Wkshp., Asian Vegetable Research and Development Center, Shanhua, Taiwan.

Chen, J.S. and C.N. Sun. 1986. Resistance of diamondback moth (Lepidoptera: Plutellidae) to a combination of fenvalerate and piperonyl butoxide. J. Econ. Entomol. 79:22–30.

Cheng, E. 1986. The resistance, cross resistance and chemical control of diamondback moth, p. 329–345. In: N.S. Talekar and T.D. Griggs (eds.). Diamondback moth management: Proc. 1st Intl. Wkshp., Asian Vegetable Research and Development Center, Shanhua, Taiwan.

Elwakil, W.M. and M. Mossler. 2013. Florida Crop/Pest Management Profile: Cabbage. <http://edis.ifas.ufl.edu/pi042>.

Hama, H. 1986. Resistance spectrum to various insecticides in the diamondback moth, *Plutella xylostella* L. (Lepidoptera: Yponomeutidae). Jpn. J. Appl. Entomol. Zool. 30:277–284.

Horikiri, M. and S. Makino. 1987. Susceptibility of the diamondback moth, *Plutella xylostella* L., to insecticides in Kagoshima prefecture. Proc. Assoc. Plant Prot. Kyuswhu 33:131–135.

Jansson, R.K. and S.H. Lecrone. 1988. Potential of teflubenzuron for diamondback moth (Lepideoptera: Plutellidae) management in southern Florida. Florida Entomol. 71:605–614.

Kao, C.H., C.F. Hung, and C.N. Sun. 1989. Parathion and methyl parathion resistance in diamondback moth (Lepideoptera: Plutellidae) larvae. J. Econ. Entomol. 82:1299–1304.

Kobayashi, S., S. Aida, M. Kobayashi, and K. Nonoshita. 1990. Resistance of diamondback moth to insect growth regulators, p. 383–390. In N.S. Talekar (ed.). Diamondback moth and other crucifer pests: Proc. 2nd Intl. Wkshp., Asian Vegetable Res. Development Center, Tainan, Taiwan.

Liu, M.Y., Y.J. Tzeng, and C.N. Sun. 1981. Diamondback resistance to several synthetic pyrethroids. J. Econ. Entomol. 74:393–396.

Liu, M.Y., Y.J. Tzeng, and C.N. Sun. 1982. Insecticide resistance in the diamondback moth. J. Econ. Entomol. 75:153–155.

Margaro, J.J. and J.V. Edelson. 1990. Diamondback moth (Lepidoptera: Plutellidae) in south Texas: A technique for resistance monitoring in the field. J. Econ. Entomol. 82:1299–1304. 83:1201–1206.

Miyata, T., T. Saito, and V. Noppun. 1986. Studies on the mechanism of diamondback moth resistance to insecticides, p. 347–357. In: N.S. Talekar and T.D. Griggs (eds.). Diamondback moth management: Proc. 1st Intl. Wkshp., Asian Vegetable Research and Development Center, Shanhua, Taiwan.

Miyata, T., T. Saito, and V. Noppun. 1982. Insecticide resistance in the diamondback moth, *Plutella xylostella* L. (Lepidoptera: Yponomeutidae). Appl. Entomol. Zool. 17:539–542.

Noppun, V., T. Miyata, and T. Saito. 1986a. Laboratory selection of resistance with phenthoate and fenvalerate in the diamondback moth, *Plutella xylostella* L. In: Joint Annu. Mtg. Jpn. Soc. Appl. Entomol. and Zoology and the Entomol. Soc. Japan, 19–22 June 1986, Sapporo. Abstr. Vol. 205.

Noppun, V., T. Miyata, and T. Saito. 1986b. Mechanisms of resistance to phenthoate and fenvalerate in the diamondback moth, *Plutella xylostella* L. In: Joint Annu. Mtg. Jpn. Soc. Appl. Entomol. and Zoology and the Entomol. Soc. Japan, 19–22 June 1986, Sapporo. Abstr. Vol. 205.

Perng, F.S., M.C. Yao, and C.N. Sun .1988. Teflubenzuron resistance in diamondback moth (Lepidoptera: Plutellidae). J. Econ. Entomol. 81:1277–1282.

Sagemueller, A. and E. Rose. 1986. Hoe 522 (CME 134), a new insect growth regulator for control of the diamondback moth, p. 271–278. In: N.S. Talekar and T.D. Griggs (eds.). Diamondback moth management. Proc. 1st Intl. Wkshp., Asian Vegetable Research and Development Center, Shanhua, Taiwan.

Salinas, P.J. 1986. Studies on diamondback moth in Venezuela with reference to other Latin American countries, p. 17–24. In: N.S. Talekar and T.D. Griggs (eds.). Diamondback moth management. Proc. 1st Intl. Wkshp., Asian Vegetable Research and Development Center, Shanhua, Taiwan.

SAS Institute. 1989. SAS/STAT User's guide. SAS Inst., Cary, NC.

Seal, D.R. 1995a. Management of diamondback moth, *Plutella xylostella*, using biological insecticides. Proc. Fla. State Hort. Soc. 108:197–201.

Seal D.R. 1995b. Control of diamondback moth (diamondback moth) on cabbage, Spring 1994. Arthropod management tests, Vol. 20. Entomological Society of America, Lanham, MD.

Shelton, A.M. and J.A. Wyman. 1990. Insecticide resistance of diamondback moth in North America. In: 2nd Intl. Wkshp. on Management of Diamondback Moth and Other Crucifer Pests. Abstract volume, Asian Vegetable Research and Development Center, Shanhua, Taiwan.

Sun, C.N. T.K. Wu, M.Y. Liu, J.S. Chen, and C.J. Lee. 1986. Insecticide resistance in diamondback moth, p. 359–371. In: N.S. Talekar and T.D. Griggs (eds.). Diamondback moth management. Proc. 1st Intl. Wkshp., Asian Vegetable Research and Development Center, Shanhua, Taiwan.

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.

Tabashnik, B.E., N.L. Cushing, and M.W. Johnson. 1987. Diamondback moth (Lepidoptera: Plutellidae) resistance to insecticides in Hawaii: Intra-island variation and cross-resistance. J. Econ. Entomol. 80:1091–1099.

Tabashnik, B.E. and N.L. Cushing. 1989. Quantitative genetic analysis of insecticide resistance: Variation in fenvalerate tolerance in a diamondback moth (Lepidoptera: Plutellidae). J. Econ. Entomol. 82:5–7.

Talekar, N.S. and T.D. Griggs (eds.). 1986 Diamondback moth management: Proc. 1st Intl. Wkshp., Asian Vegetable Research and Development Center, Shanhua, Taiwan.

Talekar, N.S., H.C. Yang, S.T. Lee, B.S. Chen, and L.Y. Sun (compilers) 1985. Annotated bibliography of diamondback moth: Proc. 1st Intl. Wkshp., Asian Vegetable Research and Development Center, Shanhua, Taiwan.

Sun, C.N., H. Chi, and N.T. Feng. 1978. Diamondback resistance to diazinon and methomyl in Taiwan. J. Econ. Entomol. 71:551–554.

Tabashnik, B.E. 1986. A model for managing resistance to fenvalerate in the diamondback moth (Lepidoptera: Plutellidae). J. Econ. Entomol. 79:1447–1451.