Monitoring of Diamondback Moth (Lepidoptera: Yponomeutidae) in Cabbage With Pheromones[1]

P. B. BAKER, A. M. SHELTON, AND J. T. ANDALORO[2]

Department of Entomology, New York State Agricultural Experiment Station, Geneva, New York 14456

ABSTRACT

J. Econ. Entomol. 75: 1025–1028 (1982)

Studies were conducted in commercial and research cabbage fields during 1979–1980 to determine the potential of pheromone trapping for monitoring *Plutella xylostella* (L.) and determining subsequent larval population trends. Adult catches within fields indicated that seasonal trends were similar between traps on the border and those in the center, despite variation between trap counts. Differences between nearby plantings indicated that each field should be evaluated and treated independently. Peak flights for both seasons, as determined by pheromone catches, corresponded with those predicted by day-degree accumulations. In 40% of the sampled fields for 1979–1980, adult catches correlated with subsequent larval populations which occurred 11 to 21 days later.

The diamondback moth, *Plutella xylostella* (L.), is one of three major lepidopterous pests infesting cole crops in the United States. In New York and Canada, the diamondback moth is an occasional pest that is normally held in check by biotic and abiotic factors (Harcourt 1960). However, in 1978, large populations caused severe injury on cabbage in New York (Seymour et al. 1979) and on Brussels sprouts in Ontario, Canada (Butts 1979).

It is difficult to sample diamondback moth larvae because of their small size and propensity to be concealed in the heart leaves. Therefore, it would be advantageous to obtain other practical monitoring tools that would aid in efficiently determining the first occurrence and magnitude of diamondback moth flights and the subsequent larval populations. Pheromones have been used for initial detection of several lepidopteran species (Mitchell 1981). Pheromone trap catches of moths also have been used to predict subsequent potato tuberworm populations in potatoes (Shelton and Wyman 1979) and tobacco budworm in tobacco (Tingle and Mitchell 1981).

Tamaki et al. (1977) identified two major components (Z-11-hexadecenal: Z-11-hexadecenyl acetate) of the diamondback moth pheromone, and Chisholm et al. (1979) reported that a 7:3 ratio of these components, respectively, gave the highest response in the field. Here we report our investigation of the feasibility of using this diamondback moth pheromone to monitor adults and to predict subsequent larval population trends in cabbage fields.

Materials and Methods

The study was conducted over a 2-year period in a total of 15 commercial cabbage fields in Yates and Ontario Counties and on an experimental plot at the Robbins Vegetable Research Farm near Geneva, N.Y. Six fields, including the experimental plot, were studied in 1979, and nine in 1980. Planting dates of the test fields varied from early to late June, and fields varied in size from ca. 3 to 5 ha. All pest control measures on commercial fields were made by growers based on pest densities reported by pest management scouts. In all tests, Pherocon 1C traps were set 0.3 m above the crop, and rubber septa, baited with 100 μg of pheromone (Chisholm et al. 1979), were changed every 3 to 4 weeks. Trap bottoms and tops were changed every 2 to 3 weeks.

Occurrences of adult population peaks for each year, as determined by the $\bar{x}$ pheromone catches per 24 h of all sampled fields, were compared with those predicted by day-degree accumulation, using a threshold of 7.3°C (Harcourt 1954). Day-degree accumulations for both years, starting 1 March, were obtained from Geneva, N.Y. Day-degrees were derived from air temperatures and were adjusted when minimums were below the threshold (Baskerville and Emin 1968).

The placement of pheromone traps within a field for monitoring the populations was investigated. In 1979, one trap was placed on the upwind border of each field, and catches were enumerated every 3 to 5 days. In 1980, traps were set out in two patterns with either three or six traps per field, with catches enumerated weekly. In the five fields that contained three traps per field, two traps were located at opposite corners ca. 12 m from the border and one in the center. In each of the other four fields, four traps were located at the corners, ca. 12 m from the border, with two near the center at least 20 m apart. Within each field during 1980, the relationship between weekly trap catches and those near the center was determined by correlation coefficient analysis.

In 1979, diamondback moth larvae were sampled every 3 to 5 days along a "V" pattern at eight random locations (five plants per location) similar to the method reported by Eckenrode et al. (1981). In 1980, in the fields with three traps, weekly larval counts were obtained as above. During the same week, an additional 20 plants per trap located ca. 10 m from the trap were examined to compare population trends of adults and larvae between border and centers. In fields with six traps, larval counts were obtained by weekly sampling 16 plants within a 10-m radius. For 1980 fields, the relationship between weekly larval counts on the borders and those near the center were determined by correlation coefficient analysis. The relationship between weekly larval counts and nearby pheromone trap catches were

[1]Received for publication 23 November 1981.

[2]Cornell IPM Program.

0022-0493/82/0601-02504$02.00/0

also analyzed in a similar manner. In addition, to identify the lag times between adult and larval populations, correlation coefficients were determined by temporarily offsetting adult male catches, represented as the number of males per trap per 24-h period, with $\bar{x}$ of larvae per plant.

Results and Discussion

Mean larval populations for 1979 and 1980 remained below 3.0 larvae per plant (Fig. 1). Andaloro et al. (1982) reported similar populations for both years in other commercial cabbage fields in New York. In 1979, a $\bar{x}$ of ca. four sprays per field was applied to control lepidopterous pests, but only one commercial field was sprayed specifically to control diamondback moth larvae. In this case, the grower was concerned about larvae feeding on the heart leaves of young plants. In 1980, no growers treated specifically for diamondback larvae, although a $\bar{x}$ of 2.7 sprays per field was applied. In both years, diamondback moth larvae never reached damaging levels, because insecticides were applied to control the more damaging pests, *Pieris rapae* (L.) and *Trichoplusia ni* (Hübner). However, no sprays were applied within 2 days of peak moth flights for either season.

Harcourt (1954) reported that development from egg to adult required 283 day-degrees at a threshold of 7.3°C. Mean peak flights for both seasons, as determined by pheromone catches, correlated with those predicted by day-degree accumulation (Table 1). In all cases, the observed peaks were within 1 to 6 days of the predicted

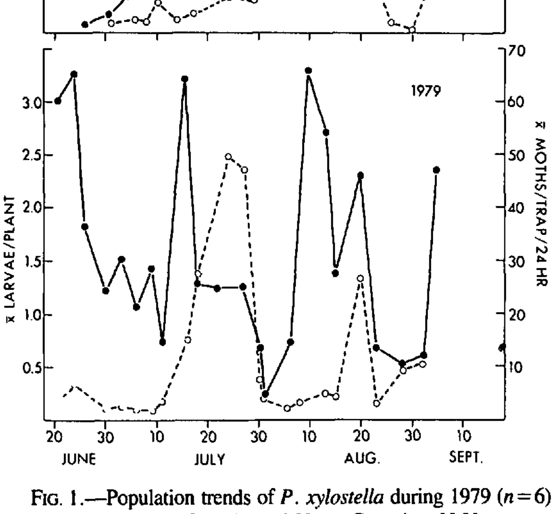

FIG. 1.—Population trends of *P. xylostella* during 1979 ($n=6$) and 1980 ($n=9$) in Ontario and Yates Counties, N.Y.

peaks. Marsh (1917) reported that diamondback adults emerge from their overwintering sites in the spring and fly to flowering cruciferous plants. Since cabbage in our area does not become infested with diamondback moth larvae until mid-to late June (Andaloro et al. 1982), initial trap catches in commercial cabbage are second-generation adults resulting from earlier infestations on cruciferous weeds. From mid-June to September, adult population cycles of 3 to 4 weeks were evident in most fields (Fig. 1). Harcourt (1957) reported the average time for a diamondback moth generation in the field to be 27.1 days during this period. Adult peaks over the two seasons indicated that cabbage in New York is exposed to oviposition by at least three and possibly five generations of diamondback moths.

Mean pheromone trap catches of diamondback moths during both seasons fluctuated markedly (0 to 68 moths per trap per 24-h period) (Fig. 1) Mean adult populations, as determined by pheromone trapping, were dissimilar between fields. Weekly pairing of adult catches between fields over the season resulted in correlation coefficients of -0.26 to 0.47 in 1979 and -0.65 to 0.84 in 1980, with only one significant correlation occurring between fields. Although dissimilar timing of insecticide treatments may have contributed to this lack of significance, the uniqueness of the population pressure on each field must also be considered (Andaloro et al. 1982).

Within any of the nine fields in 1980, differences between individual trap catches over the same time period ranged from 9.6 to 69.8 males per trap per 24-h period. This variation could be accounted for by moth distribution or by the limited active space of the diamondback sex pheromone. Ishii et al. (1981) reported the maximum distance of the active space of their diamondback pheromone lure as less than 1 m, and this could explain the variation within our test fields and indicate the necessity of utilizing more than one trap per field to assess the population.

In 89% of the fields, significant correlations were found between weekly counts of larvae on the borders and those in the center (Table 2). Similarly, significant correlations between pheromone catches of adults on the border and center were found in 67% of the fields. Although this does not necessarily indicate uniform distribution within the field, both phenomena do indicate similar patterns of activity in the borders and center. Therefore, information derived from either location could be useful in assessing population trends.

Temporal relationships between $\bar{x}$ adult catches and $\bar{x}$ larval populations were determined by comparing adult male catches (number of males per trap per 24 h) with a lag of 7 to 24 days to the subsequent larval population ($\bar{x}$ larvae per plant) (Table 3). When larval populations were offset 11 to 21 days, significant correlations were obtained in 50% of the fields in 1979; 40% of the fields with three traps, and 25% of the fields with six traps in 1980. In most of the remaining fields, significant correlations did not occur, due to suppression of larval populations by insecticides. Pairing trap and adjacent larval counts did not improve the correlations over those derived from field means.

Table 1.—Peak occurrence of diamondback moth adults as determined by pheromone traps and predicted by 283 day-degree accumulations at Geneva, N.Y., 1979 and 1980

	1979[a]		1980[b]	
Generation	Observed	Predicted[c]	Observed	Predicted[c]
1		27 May		30 May
2	21 June	22 June		28 June
3	16 July	17 July	16 July	20 July
4	10 Aug.	4 Aug.	10 Aug.	9 Aug.
5	3 Sept.	31 Aug.	4 Sept.	30 Aug.
6		28 Sept.		21 Sept.

[a]Mean of six fields.
[b]Mean of nine fields.
[c]Day-degree accumulaated above 7.3°C (Harcourt 1954).

Table 2.—Correlation coefficients between larval counts (border vs. center) and pheromone catches (border vs. center) of the diamondback moth in commercial cabbage fields in New York, 1980

	3 Traps/field		6 Traps/field	
Field	Larvae[a]	Adult	Larvae[a]	Adult
1	0.853*[b]	0.740*	0.987**	0.872*
2	0.249	0.910**	0.880*	0.568
3	0.799*	0.590*	0.949**	0.956**
4	0.965**	0.488	0.857**	0.982**
5	0.780*	0.132		

[a]Larval means determined from plants ca. 10 m from trap.
[b]*,Significant difference, .05%; **, significant difference, .01%.

Table 3.—Correlation coefficients between the $\bar{x}$ numbers of diamondback moth larvae per plant and males per trap per 24-h period with larval populations offset by 7 to 21 days, New York, 1979–1980

	Correlation coefficients offset by sample days of:				
Field	7	11	15	18	21
1979					
1	−0.245	0.006	−0.067	0.036	0.060
2	−0.453	−0.290	−0.032	0.451	0.685*[a]
3	−0.549	−0.285	−0.403	−0.424	−0.344
4	−0.230	0.311	0.767*	0.384	
5	−0.143	0.263	0.796*	0.590	0.400
6	−0.145	−0.147	−0.191	−0.103	0.082
1980[b]					
1	0.216	−0.252	−0.101	0.421	−0.285
2	−0.299	0.281	0.417	0.651*	0.648
3	−0.401	−0.206	−0.528	0.208	0.021
4	−0.452	−0.251	0.222	0.195	0.905*
5	−0.392	−0.302	−0.053	0.141	0.361
1980[c]					
1	0.284		0.918**		0.100
2	0.690		0.734		0.575
3	0.091		−0.179		−0.115
4	−0.263		−0.344		−0.186

[a]*,Significant difference, .05%; **, significant difference, .01%.
[b]Fields with three traps.
[c]Field with six traps.

In New York during June and early July, young cabbage plants are susceptible to diamondback injury on the heart leaves. Day-degree accumulation and pheromone trapping accurately predict peak flights of the early generations of diamondback moths. Either of these techniques could be used to indicate the need to intensify field sampling for larvae. The utilization of pheromone trap catches for threshold decision-making regarding this pest needs further clarification. Additionally, variations in adult catches and larval densities between fields of commercial cabbage make it necessary to monitor fields individually.

Acknowledgment

We thank the Vegetable IPM Program for technical support, A. Hill (posthumously) and B. Stanley for advice, and the National Research Council of Canada for supplying pheromone caps.

REFERENCES CITED

Andaloro, J. T., A. M. Shelton, and C. J. Eckenrode. 1982. Seasonal abundance of lepidopterous larvae in commercial cabbage fields. Environ. Entomol. 11: 144–146.

Baskerville, G. L., and P. Emin. 1968. Rapid estimation of heat accumulation from maximum and minimum temperatures. Ecology 50: 514–517.

Butts, R. A. 1979. Some aspects of the biology and control of *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) in southern Ontario. M. S. thesis, University of Guelph, Guelph, Ontario. 94 pp.

Chisholm, M. D., E. W. Underhill, and W. F. Steck. 1979. Field trapping of the diamondback moth *Plutella xylostella* using synthetic sex attractants. Environ. Entomol. 8: 516–518.

Eckenrode, C. J., J. T. Andaloro, and A. M. Shelton. 1981. Suppression of lepidopterous larvae in commercial sauerkraut cabbage fields and research plots. J. Econ. Entomol. 74: 276–279.

Harcourt, D. G. 1954. The biology and ecology of the diamondback moth *Plutella maculipennis* Curtis, in eastern Ontario. Ph.D. Thesis, Cornell University, Ithaca, N.Y. 107 pp.

1957. Biology of the diamondback moth, *Plutella maculipennis* (Curt.) (Lepidoptera: Plutellidae) in eastern Ontario. II. Life-history, behaviour, and host relationships. Can. Entomol. 89: 554–564.

1960. Biology of the diamondback moth, *Plutella maculipennis* (Curt.) (Lepidoptera: Plutellidae) in eastern Ontario. III. Natural enemies. Ibid. 92: 419–428.

Ishii, T., K. Nakamura, K. Kawasaki, H. Nemoto, K. Takahashi, and A. Kubota. 1981. Active space of sex pheromone of the diamondback moth, *Plutella xylostella* (L.). Jpn. J. Appl. Entomol. Zool. 25: 71–76.

Marsh, O. H. 1917. The life history of *Plutella maculipennis*, the diamondback moth. J. Agric. Res. 10: 1–10.

Mitchell, E. R. 1981. Management of insect pests with semiochemicals: concepts and practices. Plenum Press, New York. 514 pp.

Seymour, P. K., W. T. Wilsey, and A. C. Davis. 1979. Diamondback moth and cabbage looper control on cabbage and Brussel sprouts, 1978. Insecticide Acaricide Tests 4: 61–62.

Shelton, A. M., and J. A. Wyman. 1979. Time of tuber infestation and relationships between pheromone catches of adult moths, foliar larval populations, and tuber damage by the potato tuberworm. J. Econ. Entomol. 72: 599–601.

Tamaki, Y., K. Kawasaki, H. Yamada, T. Kashihaka, N. Osaki, T. Ando, S. Yashida, and H. Kakinohama. 1977. Z-11-hexadecenal and Z-11-hexadecenyl acetate; sex pheromone components of the diamondback moth (Lepidoptera: Plutellidae). Appl. Entomol. Zool. 12: 208–210.

Tingle, F. C., and E. R. Mitchell. 1981. Relationships between pheromone trap catches of male tobacco budworm, larval infestations, and damage levels in tobacco. J. Econ. Entomol. 74: 437–440.