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EVIDENCE OF PRE-IMAGINAL OVERWINTERING OF DIAMONDBACK MOTH, *PLUTELLA XYLOSTELLA* (LEPIDOPTERA: PLUTELLIDAE) IN MICHIGAN

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ABSTRACT

We investigated the possibility of overwintering of the diamondback moth, *Plutella xylostella* L., in central Michigan. In the spring of 1993, counts of immature stages on brassicaceous weeds in a field previously planted to broccoli revealed a small but significant number of late instars that could not be attributed to oviposition of immigrant moths from the southern United States. We suggest that crop debris and snow cover played an important role in sheltering the larvae, which are known to tolerate sub-freezing temperatures. There was no indication of adult survival.

The diamondback moth, *Plutella xylostella* L., is a major cabbage pest worldwide. In Michigan, it commonly occurs at relatively low population densities, rarely reaching outbreak levels. This is probably due to the abundance of *Diadegma insulare* (Cresson)(Hymenoptera: Ichneumonidae), a larval parasitoid, that regulates diamondback moth populations. Parasitism rates of 70–100 percent have been reported in the US (Biever et al. 1992, Idris & Grafius 1993) and Canada (Harcourt 1986).

The diamondback moth is believed not to overwinter in the Great Lakes region. For example, in southwestern Ontario, Smith & Sears (1982) found that no life stages survived winter conditions in the field, or simulated winter conditions in the laboratory. In southeastern Ontario, populations are thought to die out completely each year to be replaced in spring by migrants from the south (Harcourt 1986). Recent observations have indicated that pre-imaginal stages of the diamondback moth may successfully overwinter in western Canada, and that volunteer canola plants provided an early larval food source (Dosdall 1994).

In temperate areas of the United States, the diamondback moth overwinters as adults. In the upper midwestern states (Michigan, Wisconsin and Minnesota), diamondback moth populations are not thought to overwinter but early infestations often occur near cabbage debris, indicating that overwintering of adults in protected areas is possible (Mahr et al. 1993).

The objectives of our study were to determine whether the diamondback moth overwinters in Michigan, and to identify possible overwintering life stages.

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MATERIALS AND METHODS

In early spring 1993, volunteer plants of three weed species, *Barbarea vulgaris* R. Br., *Thalspi arvense* L. and *Capsella bursa-pastoris* (L.) Medic were abundant in a field previously planted in broccoli at the Michigan State University Collins Road Entomology Research farm and in other areas at the Michigan State University Farm. On 10, 15, 20 and 25 May, we selected 50 to 70 plants of each species at random. The plants were pulled out of the ground and inspected for the presence of diamondback moth larvae or pupae by placing individual weeds on white paper placed on the ground. We recorded the number of larvae and pupae found on each weed species separately. We reared larvae in 25 × 15 × 10 cm covered rearing pans in the laboratory at 25 ± 2°C and photoperiod of 16:8 (L:D) h until pupation, to evaluate parasitism.

To determine the presence of diamondback moth eggs, we randomly selected and detached leaves from each plant collected above. These were kept in the laboratory as described above and checked daily for 5 d for egg hatch.

Overwintering of adults was evaluated in early April of 1993 by setting up five cages (180 × 165 × 165 cm) in and near a field previously planted with broccoli. We pulled up the residue of 50 to 70 broccoli plants by hand and placed them in each cage. To trap emerging moths we hung white sticky traps (Pherocon™ 1C - bottom; Trece Inc., Salinas, CA) on wooden stakes within each cage. These were inspected every other day. We also put five potted broccoli plants in each cage as a substrate for oviposition. The presence of eggs or larvae on broccoli leaves was checked using a 10x magnifying glass once every 3 d until the end of May 1993.

The Michigan State University Climatological Resources Center (Dr. Jeff Andresen) provided air and soil temperature data. Degree-Days (DD) accumulation above 7.3°C, developmental threshold for the diamondback moth (Butts & McEwen 1981), was calculated following Zalom et al. (1983).

RESULTS

Most of the life stages were found on *B. vulgaris*. We found a total of 24 fourth instars on the four sampling dates (Table 1). They were found beginning on the first sample date, 10 May. In addition, one late third instar was found on 10 May. No eggs were collected before 20 May (based on the larvae from detached leaves collected on this date, Table 1). We did not find any first or second instars before 25 May, when three first instars were recorded from *B. vulgaris*. On the same day we found a total of four pupae (three from *B. vulgaris* and one from *C. bursa-pastoris*). There were 11 and 23 first instars from the detached leaves collected on 20 and 25 May, respectively. No diapausing *Diadegma insulare* or other parasitoids were recorded from weeds inspected in the field or reared from diamondback moth larvae. No diamondback moth adults were caught by the sticky traps in the field cages. We did not find eggs or larvae on the broccoli plants placed inside the cages.

The average daily maximum air temperatures and soil surface temperatures were similar during the winter of 1992–1993 (Fig. 1 A & B). However, the surface minimum temperature above debris was higher than the air temperature. From December 1992 through March 1993, air and soil surface temperature were below 7.3°C, and there were more days below freezing than in the fall of 1992 and the spring of 1993 (Fig. 1, A to C). In February 1993, it snowed for 17 d causing an accumulation of snow and soil surface temperatures were warmer than air temperatures (Fig. 1C). The total degree-days accumulated (DD) above 7.3°C was 45.8 from December through March, as op-

Table 1. Diamondback moth stages recorded from weeds and detached weed leaves, Michigan State University Farm, 1993.

		Larvae					
Weed species	Dates	1st	2nd	3rd	4th	Pupae	First instars from detached leaves*
Barbarea vulgaris	10 May	0	0	1	2	0	0
	15 May	0	0	0	3	0	0
	20 May	0	0	0	6	1	11
	25 May	3	0	0	4	2	23
Thalspi arvense	10 May	0	0	0	1	0	0
	15 May	0	0	0	0	0	0
	20 May	0	0	0	1	0	3
	25 May	0	0	0	2	0	6
Capsella bursa-pastoris	10 May	0	0	0	0	0	0
	15 May	0	0	0	1	0	0
	20 May	0	0	0	0	0	2
	25 May	0	0	0	1	1	8
	TOTAL	**3**	**0**	**0**	**24**	**4**	**53**

*Diamondback moth first instars from eggs laid on weed leaves that were detached and brought to the laboratory on the stated date.

posed to 217 DD from October through December plus January through April (Fig. 1D).

DISCUSSION

The above results indicate that larvae may have overwintered in the study plots. There were no eggs or early instars found until long after the third or fourth (late) instars (Table 1), which supports this. The late instars are reported to have very low super cooling points (–14.3°C), indicating that some of them can tolerate sub-freezing temperatures (Hayakawa et al. 1988). Higher temperatures in or below the crop debris and higher accumulations of snow in February than in the other months (Fig. 1C) may have protected the larvae. The surviving individuals may have begun to enter diapause or became inactive in November when weeds were dead (no food available), and the minimum and maximum air temperatures were less than 7.3°C (Fig. 1A). The larvae then continued their development in late April 1993, when early season weeds flourished (food became abundant) and temperatures were moderate (Fig. 1A).

The developmental period of diamondback moth larvae from hatch to the third or fourth instar requires 110 or 170 DD above 7.3°C (Butts & McEwen 1981). The degree-days base 7.3°C accumulated in late April was 80.2 DD and in May was 422.8 DD (°C)(Fig. 1 D). According to these heat unit accumulations, the third and fourth instars we found in May could have come from overwintered first or second instars. In the laboratory, however, we observed these two larval stages survived for only a week when placed in empty 15.0 cm diam Petri dishes and kept at 4°C, while the third and fourth instars sur-

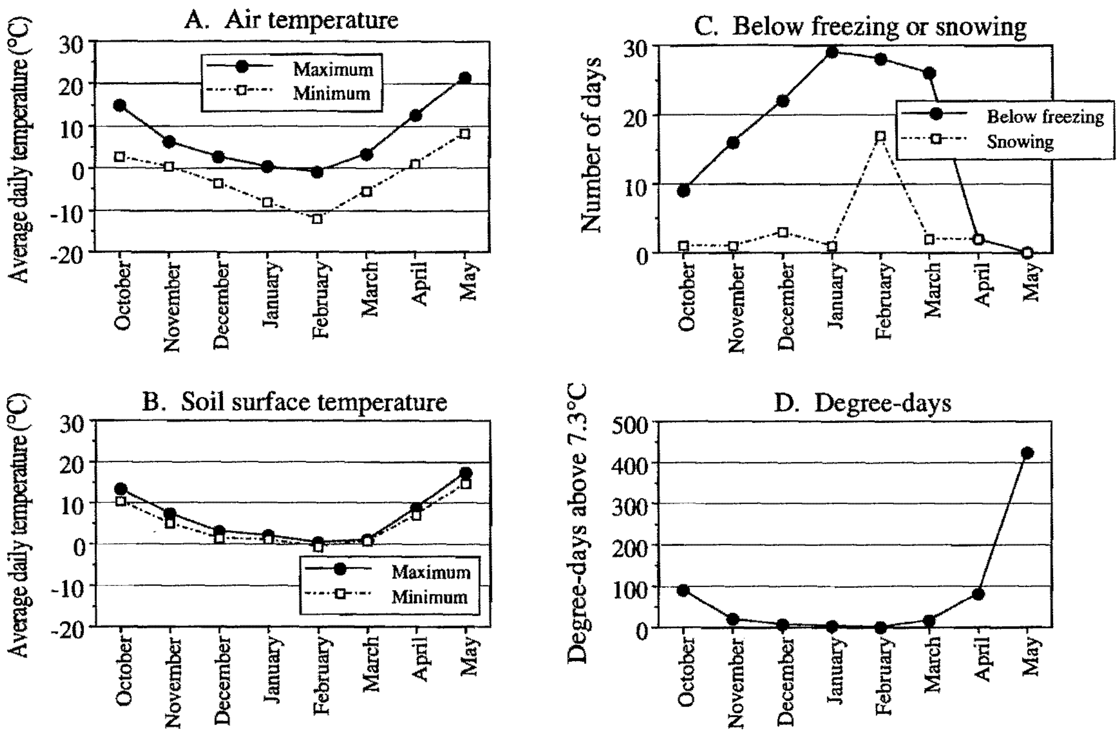

Figure 1. Average daily air (A) and soil surface (B) temperatures, numbers of days snowing or below freezing (C) and the Degree-Days accumulation (D) from October 1992 to May, 1993 (Michigan State University Horticulture Farm, 1.5 km southeast of Collins Road Entomology Farm).

vived over two months (unpublished data). This suggests that the third and fourth instars were the ones that successfully overwintered. However, fourth instars require only 40 DD to become pupae (Butts & McEwen 1981); they should have been pupae by May 1 but we didn't find pupae until 20 May. The development of diamondback moth during April and early May may have been prolonged because of poor quality food.

Diamondback moth pupae could possibly overwinter within or under the crop debris. They can also tolerate super-cooling down to –19.2°C (Hayakawa et al. 1988). However, at above 7.3°C, the development from pupae to adult would require 100 DD (Butts & McEwen 1981). Mortality of an egg is 100% at below 10°C (Hardy 1938)(the maximum air temperature between mid-October 1992 to week three of April 1993 was lower than 10°C, Fig. 1A) or if exposed to cold temperature for 60 d (Honda 1992). This suggests that our field collected larvae did not originate from adults emerged from pupae.

In our field cage study, there were no diamondback moth eggs observed or adults caught even though they were monitored until the end of May. This suggests that adult moths did not overwinter in Michigan in 1992-1993. Similarly, in Alberta, Canada, diamondback moth adults were first caught by the emergence traps on 26 May, indicating adults may originate from the successful overwintering larvae (Dosdall 1994).

In southern Ontario, where temperatures are similar to mid-Michigan, diamondback moth adults arrive from the southern United States around mid-May (Harcourt 1986). In our study, considerable numbers of first instars were recorded from the detached leaves collected on 20 and 25 May (Table 1), suggesting that oviposition began in mid-May. If oviposition occurred at this time, the developmental time from egg hatch to third or fourth instars would have been 23 d at 20°C (Salinas 1986). This indicates that larvae collected in this study were the offspring of these migrants.

The average daily maximum air temperatures were below 7°C in March 1993 (Fig. 1A), and no oviposition has been observed at this temperature (Hardy 1938). Oviposition by the successful overwintered diamondback moth adults could occur in late April when the average daily maximum air temperature was at 12°C, but it would require 13 d for egg to hatch (Hardy 1938). If this happened then the diamondback moth first instars should have been in the field and collected on 10 May (our first sampling date). On this date, however, only third and fourth instars were found (Table 1). Therefore, if any adults successfully survived the winter they could not be the source for the larvae that we collected.

This is the first evidence of diamondback moth overwintering in the Great Lakes region. However, numbers of successful individuals may be significantly reduced in colder winters.

Our results indicate the importance of proper treatment on the previous cabbage field for managing the diamondback moth. Tilling of field before planting is a common practice that could destroy overwintering diamondback moth larvae, *D. insulare* pupae or parasitized larvae although no *D. insulare* pupae or parasitized larvae were found in this study. Further research on overwintering sites for the diamondback moth and *D. insulare* should be conducted.

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