Hibernation and Migration of Diamondback Moth in Northern Japan
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Abstract

It was assumed that one of the most important factors preventing the hibernation of the diamondback moth, Plutella xylostella (L.), in northern Japan is the low temperatures, 0°C or below, and snow cover during the winter. To test this hypothesis, individuals of each developmental stage of diamondback moth were reared at 15°C in the laboratory and kept at 0°C for varying periods of time and returned to 15°C. The mortality of chilled insects increased with the duration of chilling. All larvae and pupae died after chilling for more than 60 days. Although 7.5 – 10% of adults survived after chilling, none of their eggs could hatch normally. These results indicate that hibernation of diamondback moth in fields is impossible in areas where continuous snow cover lasts longer than 60 days. This condition exists in Hokkaido and a large part of Tohoku and Hokuriku districts of Honshu. Since Morioka city is located in the northern part of Honshu Island (39°42'N), diamondback moth hibernation in this area is impossible. A large number of adults, however, were caught by pheromone traps from April to November in Morioka. The first oviposition was observed in the latter part of May and adults which grew from these eggs began to emerge in mid June. Therefore, diamondback moth adults trapped from April to May could not be considered to have hibernated and emerged in Morioka City. This strongly suggests that these moths were migrants from the southern part of Japan.

Introduction

The diamondback moth (DBM), Plutella xylostella (L.) (Lepidoptera: Yponomeutidae), is a worldwide pest of crucifers, and it is found in most parts of Japan, from Okinawa to Hokkaido. The northern limit of its hibernation area in Japan was reported as the plains of Miyagi Prefecture (38-39°N) in Honshu (Maeda and Takano 1984). It was therefore assumed that the hibernation of DBM would be difficult in the northern part of Honshu and Hokkaido where the temperatures during the winter are lower than in Miyagi Prefecture (Honda and Miyahara 1987; Kimura et al. 1987).

Morioka City is located in Iwate Prefecture, in the northern part of Honshu Island where hibernation of DBM is supposed to be impossible. Nevertheless, a large number of DBM are caught by pheromone traps from spring to autumn, and many larvae and pupae are found on
various cruciferous plants. Since it is unlikely these DBM hibernated in the area, they must have been produced by adults which migrated from the southern part of Japan.

My objectives in this paper are the following: First, to examine the effects of continuous coldness (0°C) on the survival of different stages of DBM. Second, to determine the nonhibernating area of DBM in Japan. Third, to investigate DBM survival on overwintering cruciferous plants, the seasonal changes of DBM densities caught by the pheromone traps or observed on cabbage (Brassica oleracea var. capitata) in Morioka City, and the spring migration of DBM in northern Japan.

**Effects of Continuous Coldness on Survival**

DBM larvae and pupae were collected from cabbage fields and reared on cabbage leaves at 15°C, 12 hours light and 12 hours dark, for two or three generations in the laboratory. Eggs, second or third instar larvae, fourth instar larvae, pupae and adults of reared populations were kept at 0°C for different periods of time. The insects were returned to 15°C conditions after the chilling, and the number of survivors determined. The rearing temperature was first lowered to 10°C for 2 days. The temperature was then lowered to 5°C for another 2 days. And finally, the temperature was lowered to 0°C. This process was reversed when the insects were restored to 15°C conditions. The number of individuals used for each experiment was 50 for eggs to pupae and 20 for adults, and all experiments were repeated three times.

Eggs that could hatch after the chilling were regarded as survivors. Larvae and pupae were reared at 15°C after the chilling, and individuals that could successfully grow to adults were regarded as survivors. Some larvae and pupae which were alive just after the chilling failed to survive. Adults that could walk after the chilling were counted as survivors. The adult male and female survivors were put together in petri dishes with small cabbage leaves and a piece of cotton soaked in 0.1% sucrose solution, and the number of oviposited eggs and their hatchability were examined.

The mortality of chilled insects increased with the duration of chilling (Fig. 1). All eggs died when they were chilled over 50 days. All second to fourth instar larvae died when they were chilled over 40 days. Survival rates of pupae were higher than those of eggs and larvae.
but all of them died when they were chilled over 60 days. Survival rates of adults were the highest of all developmental stages, and 7.5% of males and 10.0% of females were alive after they were chilled for 60 days.

Percentages of females which could oviposit after chilling were low, and the number of oviposited females became zero when they were chilled over 50 days. The number of females whose eggs could hatch was lower than the number of oviposited ones, and it also became zero when they were chilled over 50 days. Therefore, it is considered that all immature stages and adults of DBM cannot survive or oviposit when they are chilled at 0°C for more than 60 days.

Nonhibernating Area of DBM in Japan

The results suggest that DBM cannot survive or reproduce in places where the temperatures are 0°C, or below, continuously for 60 days. The temperature of cabbage leaves under the snow was nearly 0°C and it was constant in spite of the fluctuations of the temperature measured at 1 m above the ground (Fig. 2). In northern Japan, snowfall is common in winter and the ground is usually covered with snow for long periods. The duration of continuous snow cover is therefore considered a useful index to estimate the nonhibernating areas of DBM in Japan.

The area where the duration of continuous snow cover is longer than 60 days is shown in Fig. 3, including Hokkaido and a large part of Tohoku and Hokuriku districts of Honshu. The hibernation of DBM is supposed to be impossible in these areas, making the northern limit of DBM hibernation the plain area of Miyagi Prefecture.

There are some places where the duration of continuous snow cover is shorter than 60 days, for example in the seaside areas of the northern part of Honshu. Small populations of DBM may hibernate in these areas. For example, DBM hibernation was reported in the seaside area of Yamagata Prefecture (38°54′ N) (Ishigaki et al. 1990).

Fig. 2. Daily maximum and minimum temperatures of a cabbage plant under the snow, compared with temperatures measured at 1 m above the ground. Temperatures were measured with copper-constantan thermocouples which were covered with white filter paper and located both in the center of the cabbage and above the ground (Honda, unpublished data).
Field Surveys of DBM Hibernation in Morioka City

The average duration of continuous snow cover is 79.8 days in Morioka City, making DBM hibernation impossible. To test this theory, surveys were carried out in 1985-86 on two fields (each 0.1 ha) of rape (*Brassica napus* subsp. *oleifera*) and on one 0.01 ha field of Chinese cabbage (*Brassica campestris pekinensis*) where 200 plants were cultivated. The fields are located in the Tohoku National Agricultural Experiment Station, Morioka City. These fields were sown or planted in September 1985 and cultivated until April 1986. Fifteen to twenty plants were sampled from the Chinese cabbage field in November, March and April and they were dissected to find DBM. Densities of DBM in 0.25 m² quadrats (50 × 50 cm) were checked on two rape fields in October, November, March and April, where 10 quadrats were randomly placed per field.

Live third or fourth instar larvae and pupae were found at densities of 5.3 and 3.3 individuals/10 plants, respectively, from the Chinese cabbage sampled on 22 November. Living individuals, however, could not be found from the plants sampled on 15-20 March, when these plants were under the snow, and on 10 April 1986. Live third or fourth instar larvae and pupae were found also in the rape in October and November at densities of 12.0 and 5.0 individuals/m² on 21 October, and 7.2 and 4.6 individuals/m² on 20 November, in two fields, respectively. In the spring, however, live DBM individuals could not be found in the same fields on 28 March, 18 and 28 April. These results support the contention that hibernation of DBM is impossible in Morioka City because of the duration of snow cover.

Seasonal Changes of DBM Density Around Morioka City

Seasonal changes in the number of DBM adults caught by the pheromone traps in Morioka are shown in Fig. 4. These traps were located in a white clover (*Trifolium repens*) field (A)
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Fig. 4. Seasonal changes in the number of DBM adults caught by the pheromone traps in Morioka City and Takizawa Village. Values of the number of DBM adults are the average of 5 years (1983-87) in A, 4 years (1984-87) in B and 2 years (1986-87) in C. (The data were collected by the Laboratory of Entomology in Tohoku National Agricultural Experiment Station.)

and a cabbage field (B) in the Tohoku National Agricultural Experiment Station. The values in vertical axis are the totals of DBM adults caught in 5 days and these are the means of 4 or 5 years. The pheromone trap was a water pan-type (36 cm diam and 12 cm deep). A lure of DBM pheromone was a rubber septum on which Z-11-hexadecenal, Z-11-hexadecenyl acetate and Z-11-hexadecanol were coated in the ratio of 5:5:0.1 (0.1 mg/septum) (Koshihara et al. 1978), which was made by Takeda Chemical Industries, Ltd. The rubber septum was renewed every month. In the cabbage field (about 0.01 ha), 200 cabbage plants were continuously cultivated from May to October.

DBM adults were caught by the traps from April to November in Morioka each year. The number of adults increased during May-July and there were two peaks in the number of adults in May (I) and July (II) as shown in Fig. 4. The number of DBM adults at these two peaks was about equal to those in the white clover field. In the cabbage field, however, the number of adults at the peak in July (II) was much larger than that for May (I). This increase of DBM in the cabbage field in July can be explained by the reproduction of this insect on cabbage plants. Similar seasonal changes in the number of DBM adults were also observed in Takizawa village, 10 km west of Morioka, where the trap was placed in orchard grass (Dactylis glomerata). The number of DBM adults increased in May (I) and July (II) (Fig. 4-C).

The seasonal changes in the densities of immature stages of DBM and newly emerged adults at the cabbage field are compared with the number of adults caught by the pheromone trap in Fig. 5. This cabbage field was planted at the beginning of May 1986. Oviposition of DBM started in the latter part of May and the density of eggs increased at the beginning of June. The density of larvae increased in mid June and that of pupae increased in the latter part of June. Emergence
of new adults, which was estimated by the occurrence of empty pupal cases, started in mid June and the number increased at the end of June and early July.

The beginning of oviposition and the increase in eggs in the cabbage field occurred at the same time as the first increase of adults (I) caught by the trap. The increase of newly emerged adults in the cabbage field also occurred at the same time as the second increase of adults (II) caught by the trap. These results suggest that DBM adults that appeared in May oviposited in the cabbage field, and the emergence of the next generation of adults that grew on the cabbage plants caused the second increase in adults caught by the trap.

Discussion

Investigations of the seasonal changes of DBM densities showed that adults that emerged from the end of June in Morioka were derived from offspring of the adults that appeared in May. Therefore, DBM adults caught in July can be regarded as the newly emerged adults that grew on various cruciferous crops or wild plants around Morioka. On the other hand, according to the results of our 1985-86 field surveys, DBM adults that appear in the spring cannot be regarded as ones that hibernated or emerged there. It is likely, therefore, that those adults found in April-May in Morioka are migrants from the southern part of Japan.

The notable increase of DBM adults in May, which was considered to be caused by migrating individuals, was observed in both Morioka and Takizawa village. This suggests that there is a large-scale DBM migration in the spring covering a wide area.
In Europe, it has been established that DBM migrate for long distances, often 1000 km or more, with a storm caused by low atmospheric pressure (French and White 1960; Shaw 1962; Lokki et al. 1978). Harcourt (1957) and Smith and Sears (1982) showed that DBM cannot hibernate in Ontario, Canada, and a spring migration from southern United States likely occurs.

In Japan, the following examples show the extent of DBM migration: adults were caught at the top of a 1200 m mountain (Yamashita 1964); adults were caught on meteorological observation ships at sea (Asahina and Turuoka 1970); there was a sudden increase in adults following a typhoon (Miyahara 1986).

However, there have been few studies on the seasonal migration of DBM in Japan. The spring migration of DBM probably occurs not only around Morioka but also in the whole area of northern Japan. More intensive investigation of DBM seasonal migrations in this area are necessary, however.

The mechanisms of DBM migration and the source areas of migrants are not yet clear. One possible mechanism which can carry DBM migrants is a strong south wind caused by low atmospheric pressure systems. In the spring and early summer, there are many low pressure systems from northeastern China and the Korean peninsula to northern Japan. DBM adults could migrate with the strong south winds caused by these low pressure systems from the southern part of Japan, where DBM density increases in the spring.

In addition to the strong south wind, other factors probably contribute to DBM migration: the density of source population in the area of hibernation; the meteorological conditions when adults take off; the physiological condition of migrants; and the temperature of the upper air in which they migrate. The relationships between these factors and DBM migration need further study.

References


