Life History of *Lyonetia prunifoliella* HÜBNER subsp.
malinella (MATSUMURA) (Lepidoptera : Lyonetiidae)

Norio SEKITA and Masateru YAMADA

Section of Entomology, Aomori Apple Experiment Station, Kuroishi City, Aomori 036-03, Japan

(Received January 10, 1979)

Lyonetia prunifoliella HÜBNER subsp. *malinella* (MATSUMURA) on apple trees produced five complete generations in 1976 and 1977 in Aomori Prefecture, the northern tip of Honshu, where the monthly mean temperature during the apple growing season ranges from 10 to 25 °C. The insect mates before hibernation and passes the winter as a female moth. The hibernating moth is different from that of summer generations not only in coloration but also in physiological and behavioral character.

INTRODUCTION

Two species of leaf miner are commonly found in apple orchards in Aomori Prefecture, the northern tip of Honshu (the main island of Japan); they are *Phyllostonyctus ringoniella* (MATSUMURA) and *Lyonetia prunifoliella* HÜBNER subsp. *malinella* (MATSUMURA). The former suddenly multiplied to reach pest proportions in Nagano Prefecture in the 1950's (HIROSE, 1961), and about ten years later in Aomori Prefecture, where it caused defoliation in the area of outbreak (YAMADA et al., 1970). Although there were differences in time of the first outbreak and the subsequent state of affairs among different districts, this species now maintains high population levels throughout the apple-growing areas in Japan.

On the other hand, the latter has remained almost latent until now. Even if it multiplied, the high population density was restricted to narrow and scattered areas so that it was of little importance as a pest.

It is worthwhile to elucidate factors which are responsible for this difference in population density between the two species. We have continued comparative studies on the ecologies of these species since 1976. Such studies may be more informative than a separate study of each species, particularly in understanding different states of population dynamics of the two species.

The basic information essential for this line of approach has already been accumulated by many workers for *Ph. ringoniella* (e.g., HIROSE, 1961; YAMADA et al., 1970), but not for *L. prunifoliella*. We had, therefore, first to deal with the life history of the latter.

This report thus describes the life history of *L. prunifoliella* based on data obtained during the course of the comparative studies of the two species.

MATERIALS AND METHODS

Larval instars and mine shape. In the earlier season of 1976, leaves with different sizes of mines were arbitrarily picked from apple trees in orchards. The mines were opened carefully under a binocular microscope to collect larvae. The width of their head capsules was measured. If possible, mines were classified into two types, linear and blotch, according to their shapes. The mines were then dissected to determine the position of the larvae.

Seasonal population trend. All the data concerning the seasonal population trends were obtained from the census trees used for the population dynamics studies. The mature larva comes out of the mine and pupates on the undersurface of the leaf in a hammock-shaped web. Small paper tags were attached to all individual webs on the census trees to note the dates of their formation. Subsequently, the webs were examined for adult emergence. This procedure was to count the numbers of pupae and moths without mixing the successive generations. The intervals of dating webs and observations for adult emergence were not regular but sufficiently short to document the sequence of web formation and moth emergence for each generation.

Hibernation flight. In early October, 1976, it was observed by chance that a few moths were resting on the wall of a wooden building near the census field. Subsequently, several sites near or around the apple orchard were subject to observations for the flight activity of the moth before hibernation: the walls of the wooden buildings or barns, hive boxes of the *Osmia* bee, screens for meteorological observation, etc. The moths found were captured and counted. Occasionally, an automatic insect sucker was used to collect moths from the hedges around the census field. The moths thus collected were preserved in 75 per cent alcohol and after identifying their sexes they were dissected to examine ovaries and fat contents.

Again in 1978, similar observations were carried out on the fixed walls of the wooden buildings. Here, the dissected females were also examined to elucidate whether or not their bursae corporatrix were filled with the sperm.

Moths after hibernation. In early spring of 1978, many moths were observed resting on the wall of a wooden building. Presumably, they had hibernated underneath wall boards. Such a situation was not commonly observed previously. It probably represented the unusually high population level of the overwintering generation in the preceeding year.

Such moths were captured, and after identifying their sexes some females were dissected and their ovaries examined. The others were individually kept in small containers each with a young apple leaf for oviposition. The supply of young leaves were obtained by growing apple trees in a green house.

To elucidate the time of moth appearance after hibernation, selected trees were as a rule examined every morning in the early spring, 1977 and 1978. The number of moths resting on the tree trunks were counted.

RESULTS

Larval instars and shapes of mine

The distribution of the head capsule widths is shown in Fig. 1, in which the observed frequencies of the different shapes of mines are also given. Three distinctive

Fig. 1. The distribution of head capsule width and different shapes of mines.

peaks are recognized in the frequency distribution of the head widths, indicating that the larva passes three instars. The ratios of the head width of the second and third instar larvae to those of the first were 2.0 and 4.7, respectively.

Typical examples of the mines are shown in Fig. 2, in comparison with those of *L. clerkella* in peach leaves. They are similar in shape to those illustrated by KUROKO (1964). The egg is laid singly under the epidermis on the underside of a leaf. The site of oviposition appears as a yellowish-brown spot and is easily detectable from both sides of the leaf by the naked eye. On hatching, the larva burrows through the leaf tissue. In its earlier stage, the mine is linear and of a simple shape in *L. prunifoliella* compared to that of *L. clerkella*. It tends to be straight unless any obstacle is present

Fig. 2. Typical examples of mines of *L. prunifoliella* in comparison with those of *L. clerkella* in peach leaves. E: egg, P: parasitized larva, Ex: exit hole.

in its way, while the latter in its earlier stage makes a coiled mine. As the larva develops, the mine is extended and becomes an irregular blotch. This distinguishes the mines of *L. prunifoliella* from *L. clerkella*, because the latter always forms a club-shaped mine.

The fully grown third instar leaves the mine and pupates on the underside of a leaf in a hammock-shaped web. The leaf chosen for pupation is usually different from the one in which the larva has grown, and is selected rather by chance as the larva dangles down by its thread. It should be noted that the immature larva sometimes leaves its mine, especially when the conditions of the leaf becomes unsuitable due to overcrowding or hardness, and seeks another fresh leaf.

Seasonal population trend

In Fig. 3, the seasonal trends of the numbers of webs and moth emergence are shown by bars and solid curves, respectively. The adult emergence of a parasite, *Apanteles* sp. is also represented in this figure by broken curves.

The seasonal trends of the web formation and the moth appearance were almost identical in 1976 and 1977. Full grown larvae of the first generation left the mine late May to early June to pupate. The first generation moths appeared from early to mid June. The larvae of the second, third, fourth and fifth generations left the mine to pupate from early to mid July, from late July to early August, in late August, and from mid September, respectively. Each of these periods was followed by the appearance of moths.

The overlapping of the successive generations was surprisingly small, despite several generations repeated each year. *L. prunifoliella* chooses young soft leaves to oviposit. This may be a significant factor in reducing the variance in development time thus making the generations clear cut. As the larvae eat leaves with the same quality, their development would be more uniform than otherwise.

Each year eggs laid in the second or later generations were also dated by marking in order to count the number of eggs in each generation. This marking proved that a small portion of the fifth generation moths produced eggs before hibernation in

Fig. 3. Seasonal trends of the numbers of webs (bars), the moth emergence (dots and lines), and the emergence of parasite, *Apanteles* sp. (dots and broken lines), all of which were based on the complete census of fixed trees, and the flight of the moth to an apple orchard after hibernation (broken bars). Numerals in the figure represent generations.

1977. None of the offspring, however, completed their development. An approximate estimate based on the intervals between the dates when 50% of adult of two successive generations emerged and the daily mean temperature showed that a little less than 300 day-degrees above 10°C are required to complete a generation. The annual sum of effective temperature above 10°C was 1470 and 1570 day-degrees in 1976 and 1977, respectively. Thus, due to the excessive heat in 1977, the production of a sixth generation was begun, but it was incomplete because the sum of day-degrees was insufficient.

Fig. 3 shows further that the seasonal occurrence of a parasite, *Apanteles* sp., coincided well with that of the host.

Hibernation flight

L. prunifoliella passes the winter as an adult. The moths which hibernate are different in color from the others. The moths of the hibernating generation are grayish with black stripes, while those in the other generations are silvery with black and golden stripes at the rear part in the resting posture. For convenience, the former will be called 'winter form' and the latter 'summer form'.

Fig. 4A shows results of 1976. The flight was observed from early October when the moth emergence of the fifth generation was at its peak. It continued until the first snow fall in late November. The moths captured at these sites were of the winter form without exception. The reproductive system of the female was in earlier stage of development, with ovarioles remaining undeveloped and the body cavity being full of fat body. In contrast, the fat body was almost absent in the male. The sex ratio just after emergence together with the sample size is given on the left side of the figure. It was not significantly different from 1:1. Until early November, its deviation from unity was not large enough to reject the null hypothesis of 1:1. In mid November and thereafter, however, the female outnumbered the male. During this period a

Fig. 4. The number of moths flying to hibernation sites (bars; captured on the walls, dots and broken bars; captured in the hedges), the sex ratio (open circles), the proportion of females with their bursae corporulatrix being full of the sperm (closed circles) and pairs mating (crossed and broken bars). The circle and bar on the left side in A represent the sex ratio just after emergence in the field and the sample size, respectively.

Table 1. ON THE MORPHISMS OF THE FIFTH GENERATION MOTHS IN RELATION TO THE TIME OF WEB FORMATION, 1977

Forms	Date of web formation					
	Sep.					Oct.
	16	17	20	23	28	3
Summer	2	0	0	0	0	0
Winter	19	22	13	25	7	8

single case of copulation was observed, as indicated by an arrow in the figure.

Fig. 4B shows the results of 1978. In this year observation was started later than in 1976. The results were almost identical to the previous ones and assured further that the mating takes place before hibernation. Mating pairs were repeatedly observed until mid November and the proportion of the females with their bursae copulatrix being full of the sperm increased gradually until late November.

In 1977, observations were made to confirm whether all the moths of the hibernating generation were of the winter form or not. The results are summarized in Table 1. The majority of the moths were of the winter form but a few derived from the larvae which had left the mine earlier were of the summer form. As was indicated in the preceeding section, a small part of the fifth generation produced eggs in 1977. This was probably due to a few moths of the summer form occuring on earlier dates. The circumstantial evidence described here indicates that the two forms represent variations not only in body color but also in physiological and behavioral characters.

Moths after hibernation

In Table 2, parameters representing the reproductive state after hibernation were given. All the moths were female. The majority had reached sexual maturity by the time of resumption of activities in the spring and were ready for oviposition if the environmental requirments were met.

From these observations together with the facts mentioned in the previous section, it seems 1) that both sexes of the winter form gather together at or near a site suitable for hibernation, and 2) that after mating there, the male dies out and only the female survives the winter.

The numbers of females reappearing on apple trees in spring are shown in Fig.

Table 2. ON THE MOTHS AFTER HIBERNATION, 1978^a

Items	No. of moths or ratio
A. Total moths captured (C+D)	83
B. Female/A	1.0
C. Females dissected (a+b)	59
a. with matured eggs	54
b. with unmaturred eggs	5
D. Females tested on oviposition (c+d)	24
c. oviposited	21
d. not oviposited	3

^a The data on moths captured from April 18 to 24 was pooled.

3 (broken bars). The return flight began in mid April and continued until early May, when apple trees resumed growth.

DISCUSSION

In Europe the species closely related to the present one commonly occurs. It is *Lyonetia clerkella* L. which tends to multiply suddenly on a massive scale at intervals of 5 to 10 years (KREMER, 1963). As a great percentage of the moths pass the winter outside of orchards, those trees which are located near forests, hedges or buildings are more heavily attacked by moth in the first generation than other trees (WILDBOLZ, 1963). Low temperatures during the winter season are considered to be important for the termination of outbreak as they lead to a high mortality of hibernating moths (KREMER, 1963).

Recently, *L. clerkella* has become an important pest in Japan also. Its infestation, however, is mainly restricted to peaches. Intensive studies on this pest have been carried out in prefectures where the production of peaches is of economical importance (e.g., NARUSE, 1978). This species does not occur in apple orchards to any noticeable extent. This is strikingly different from the situation in European countries, where a migration of the population between different host plants is repeatedly observed, especially when the infested plants have stopped growth and become unsuitable (WILDBOLZ, personal communication). In Japan this species is replaced by *L. prunifoliella* HÜBNER subsp. *malinella* (MATSUMURA) in apple orchards.

The present study shows that the latter resemble *L. clerkella* in many respects. That is, both pass the winter in the adult stage (KREMER, 1963 WILDBOLZ, 1963; BÖHM, 1968), show seasonal dimorphism (KUMATA, personal communication), prefer young leaves (BÖHM, 1968), deposit eggs into the leaf tissue, feed in the mine, form hammock-shaped webs to pupate, etc. A detailed comparison shows, however, that there are slight differences between them; they form mines of different configuration, and the male passes the winter in *L. clerkella* but not in *L. prunifoliella*. In the former, mating has frequently been observed after hibernation in Yamagata Prefecture (SHOJI, personal communication). It would be interesting to examine which way of mating is more advantageous for the species (i.e., in respect to the mating success and the number of offspring in the next generation).

It appears that seasonal dimorphism of this insect is determined by a combination of daylength and temperature and that the winter form is typically associated with diapausing generation and the summer form with nondiapausing generation. It is uncertain, however, whether diapause induction and form determination are expressions of the same physiological mechanism or, although both effects are responses to the same factors, they are mediated by different genetic loci and different physiological mechanisms.

Under climatic conditions of Aomori Prefecture it would seem difficult for *L. prunifoliella* to produce six complete generations in a normal year. A rough estimate based on the seasonal trends of 1976 and 1977 showed that about 300 day-degrees above 10°C are required to complete a generation, while the annual sum of effective temperatures in Aomori is about 1500 day-degrees.

SUMMARY

The eggs of *L. prunifoliella* are laid under the epidermis of the underside of apple leaves. The larva feeds in the mine. After passing three instars, it leaves the mine and forms a web like a hammock on the underside of the leaf to pupate. Five complete generations were produced in 1976 and 1978 in Aomori Prefecture. This species passes the winter as a female moth. The hibernating moths are different from those of summer generations not only in coloration but also in physiological and behavioral characters. The re-appearance of the female after hibernation coincides with the time of bud development of apple trees.

ACKNOWLEDGMENTS

The authors wish to express their sincere thanks to Dr. T. KUMATA of Hokkaido University for identifying the specimen of the present study. Thanks are also due to Dr. S. MASAKI of Hirosaki University for his critical reading of the manuscript.

REFERENCES

- BÖHM, H. (1968) Miniermotten treten stärker auf. *Der Erwerbsobstbau*, **10** : 227-229.
- HIROSE, K. (1961) Studies on the apple pest and its control in Nagano Pref. III. Ecological studies and its control of the apple leaf miner, *Lithocolletis blancardella*. *Bull. Nagano Hort. Expt. Stn.* **3** : 51-66 (in Japanese with an English summary).
- KREMER, Fr. W. (1963) Major leaf miner species occurring in the South Tirolean fruit-farming region, and their control. *Pflanzenschutz-Nachrichten, Bayer* **16** (1) : 1-16.
- KUROKO, H. (1964) Revisional studies on the family Lyonetiidae of Japan (Lepidoptera). *ESAKIA* **4** : 1-61.
- NARUSE, H. (1978) Defoliation of peach tree caused by the injury of the peach leaf-miner, *Lyonetia clerkella* L. I. Influence of larval density. *Jap. J. appl. Ent. Zool.* **22** : 1-6 (in Japanese with an English summary).
- WILDBOLZ, Th. (1963) Beobachtungen über Befallskonzentrationen der ersten Generation der Obstbauminiermotte (*Lyonetia clerkella* L.) und über das Verhalten der Falter. *Mitt. der Schweiz. Ent. Ges.* **35** : 273-283.
- YAMADA, M., N. OYAMA, N. SEKITA, Sh. SHIRASAKI and Ch. TSUGAWA (1970) Forecasting the outbreak of destructive insects in apple orchards. VIII On the biology of the leaf miner, *Lithocolletis ringoniella* MATSUMURA, on apples in Tsugaru-district and 1964's explosion at Hiraka-Town. *Bull. Aomori Apple Expt. Stn.* **14** : 1-27 (in Japanese with an English summary).