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# Further investigations on the interrelations between the apple leaf miner Stigmella malella and its parasite Cirrospilus vittatus in The Netherlands

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**Abstract**

Host feeding by *Cirrospilus vittatus* (Hymenoptera, Eulophidae) is shown to be an important factor in the mortality of the apple leaf miner *Stigmella malella* (Lepidoptera, Stigmellidae). It is also shown that the parasite acts as a density-dependent factor in relation to this host. Both facts emphasize that the parasite may play an important role in the natural control of the apple leaf miner.

## Introduction

In earlier investigations it was shown that *Cirrospilus vittatus* Wlk. is a potentially important factor in the mortality of the apple leaf miner *Stigmella malella* (Stt.) in The Netherlands (Eveleens and Evenhuis, 1968; Evenhuis, 1965). In 1968 the present authors obtained further evidence for the great importance of this parasite.

During investigations in several orchards, varying numbers of dead non-parasitized leaf miner larvae were found. No explanation for this was immediately obvious. However, investigations on the bionomics of the parasite by Talhouk and Soehardjan (1970) suggested that host feeding might be one of the main reasons for this mortality. Accordingly, an attempt was made to test this hypothesis.

## Investigations and discussion on the importance of host feeding

Between 18 October and 13 November 1968, at a time when the leaf miner had stopped its development completely and the parasite almost completely but the leaves had not yet fallen, samples of leaves with mines were collected at random from several orchards near Wageningen and in the Betuwe District. In most cases different parts (front, middle, rear) of the orchards were sampled, as the infestation often varied markedly. From each sample a total of 100 mines were divided into four groups:

a. Mines left by a caterpillar. These are always easily recognized by the semi-circular slit, generally at the end of the mine (Fig. 1, right).

b. Mines left by an adult parasite. These are characterised by the small roundish exit hole near the end of the mine (Fig. 1, left). *Cirrospilus vittatus* is by far the most

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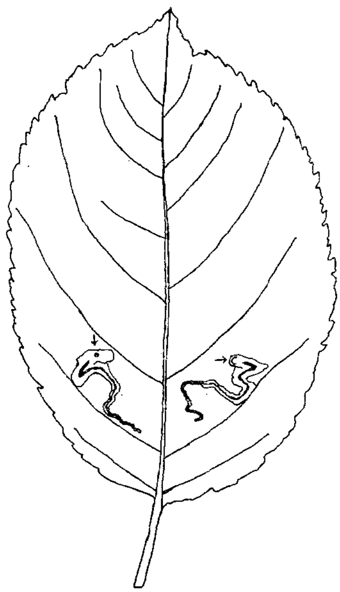

Fig. 1. Apple leaf with two mines of the apple leaf miner. Right, mine with semi-circular slit through which the caterpillar has left. Left, mine with exit hole of the parasite.

*Fig. 1. Appelblad met twee mijnen van de appelbladmineerder, rechts met halfcirkelvormige spleet waardoor de rups de mijn heeft verlaten, links met uitkruipopening van de parasiet.*

numerous parasite of *Stigmella malella*, so the error made by accidentally including mines with exit holes of other parasites may be disregarded.

c. Closed mines containing either a parasite larva or sometimes a parasite pupa and remnants of a dead leaf miner caterpillar. The parasite larva as a rule was in a state of diapause, with the black contents of the gut shining through its body wall.

d. Closed mines containing a dead, usually shrivelled caterpillar without any trace of parasitism.

Living caterpillars were no longer present in the mines; at this time the leaf miner pupae were in the soil.

The percentage of parasitism is represented by b + c and the percentage of dead caterpillars without any trace of parasitism by d. It must be emphasized that these percentages relate to the total number of caterpillars and parasites present during the whole season. So the numbers of individuals refer to the two generations of the leaf miner and to the several generations of the parasite. As the second generation of the leaf miner numerically far exceeds the first one (Eveleens and Evenhuis, 1968), the above percentages relate mainly to this generation.

It is interesting to consider the ratio between b and c. Figures are only available for samples 10 to 18 of Table 1, which contained jointly 196 mines of groups b and c: 61 showed an exit hole of the parasite, while in 135 a full-grown parasite larva or a parasite pupa was found. Thus, according to our observations in 1968, about 70% of the parasite larvae and pupae born in that year hibernated. This indicates that the overwintering population of the parasite in apple orchards may be very large. In samples of fallen leaves, taken during winter 1968–1969 and even at the beginning of March 1969, besides the full-grown parasite larvae a number of pupae were always present. Thus it seems that the parasite hibernates not only as a full-grown larva, but also to a certain extent in the pupal stage. A number of pupae, however, may hatch late in autumn. In 1968 the last adult parasites emerged on 13 November.

Table 1. Observations on parasitism, further mortality and population density of apple leaf miner larvae in various orchards.

| | Locality | Part of the orchard | Kind of orchard | Apple variety | Last day of spraying with insecticides | Percentage of parasitism (b + c, see p. 1 and 2) | Percentage of dead leaf miner larvae (d, see p.2) | Number of mines per 100 leaves (see p. 6) |
|---|---|---|---|---|---|---|---|---|
| 1 | Oosterhout | front | bushes | 'Golden | Beginning | 29 | 25 | 15 |
| 2 | | middle | | Delicious' | July: | 5 | 8 | 5 |
| 3 | | rear | | | azinphos-methyl | 10 | 18 | 9 |
| 4 | Ressen | front | bushes | 'Golden | End June: | 25 | 18 | 703 |
| 5 | | middle | | Delicious' | azinphos- | 29 | 22 | 411 |
| 6 | | rear | | | methyl | 15 | 11 | 379 |
| 7 | Elst | front | bushes | 'Golden | 3 July: | 13 | 14 | 178 |
| 8 | | middle | | Delicious' | azinphos- | 21 | 12 | 161 |
| 9 | | rear | | | methyl | 6 | 7 | 107 |
| 10 | Wageningen | front | trees | 'Belle | 8 August: | 29 | 20 | 74 |
| 11 | | middle | | de | diazinon | 28 | 18 | 69 |
| 12 | | rear | | Boskoop' | | 11 | 19 | 71 |
| 13 | | separate | | | | 13 | 29 | 69 |
| 14 | Wageningen | front | bushes | 'Belle | 8 August: | 8 | 24 | 216 |
| 15 | | middle | | de | diazinon | 15 | 34 | 222 |
| 16 | | rear | | Boskoop' | | 27 | 28 | 300 |
| 17 | Elst | front | trees | 'Belle | 3 August: | 44 | 28 | 338 |
| 18 | | rear | | de<br>Boskoop' | azinphos-<br>methyl | 21 | 31 | 68 |
| 19 | Wageningen | front | trees | 'Belle | Not sprayed | 8 | 12 | 14 |
| 20 | | middle | | de | with | 3 | 15 | 37 |
| 21 | | rear | | Boskoop' | insecticide | 8 | 15 | 20 |
| 22 | Tiel | $I_1$ | bushes | 'Belle | 16 July: | 8 | 5 | 112 |
| 23 | | $I_2$ | and | de | carbaryl | 10 | 8 | 75 |
| 24 | | $G_1$ | trees | Boskoop' | 15 June: | 24 | 22 | 373 |
| 25 | | $G_2$ | mixed | | isolan | 27 | 17 | 256 |
| 26 | | $BD_1$ | | | 12 July: | 4 | 7 | 17 |
| 27 | | $BD_2$ | | | carbaryl | 4 | 8 | 17 |

*Tabel 1. Waarnemingen over de parasitering, de overige mortaliteit en de populatiedichtheid van de larven van de appelbladmineerder in een aantal boomgaarden.*

Samples 22 to 27 need further consideration. These samples were taken from the experimental orchard Thedinghsweert near Tiel. This orchard covers a rather long and narrow rectangular area of about 1.6 hectares. Experiments have been carried out here with different spray programmes since 1960. From 1964 there has been a more or less severe leaf miner infestation every year in the section with spray scheme G.

The orchard was divided into eight successive plots of roughly the same area. Plots

1 and 4 were sprayed according to the intensive spray scheme (I) of a modern Dutch fruit grower; in these plots several kinds of pesticides were used. Plots 2 and 3 were sprayed according to an integrated spray programme (G). Here we sprayed as little as possible and with pesticides as selective as possible, sometimes with the risk of too large an infestation. Plots 5, 6, 7 and 8 were treated in a so-called 'biological-dynamical' way (BD). Here the farmer tried to keep the soil as 'healthy' as possible. The treatments in these plots were beyond our control, but as a matter of interest we took samples from this part of the orchard also. All samples were taken on three dates viz. 21 October, 28 October and 4 November 1968.

Table 2 shows the percentages of mines with some stage of the parasite as well as the percentages of mines with a dead non-parasitized caterpillar, in the leaf samples from the various plots. Parasitism and further mortality in the three treatments I, G and BD are comparable on the three dates. The mean percentages of the two replications on the various dates, however, differ to a certain extent. We cannot explain this. It is evident, however, that real differences exist between the plots with different spray schemes. The figures given in Table 1 (samples 22 to 27) are the averages of the samples taken on the three dates.

From Table 1 it may be concluded that there is a relationship between the percentages of parasitized and dead non-parasitized caterpillars. Fig. 2 gives a graphic representation of this relationship and demonstrates that there is a positive correlation between the two (in order to make matters easier to survey, the logarithms instead of the real values have been used). The only logical explanation would seem to be that the mortality of the non-parasitized caterpillars is caused by host feeding of the adult female parasite. It is clear that the percentage of caterpillars killed by host feeding is about the same or only a little less than the percentage of caterpillars killed by parasitism.

In orchards where the parasite is abundant as a result of certain cultural practices, other entomophagous insects may also be numerous. Predatory bugs might be consi-

Table 2. Percentage of parasitism and of further mortality of the caterpillars and population density of the leaf miner in plots with various spray schemes (I, G, BD). Experimental orchard Thedinghsweert near Tiel, 1968.

| Sample No. | Data of sampling | | | | | | Number of mines per 100 leaves |
|---|---|---|---|---|---|---|---|
| | 21 October | | 28 October | | 4 November | | |
| | Parasitism | Further mortality | Parasitism | Further mortality | Parasitism | Further mortality | |
| 22 ($I_2$) | 6 | 9 | 7 | 2 | 11 | 5 | 112 |
| 23 ($I_2$) | 9 | 6 | 7 | 9 | 13 | 9 | 75 |
| 24 ($G_1$) | 36 | 18 | 16 | 26 | 21 | 22 | 373 |
| 25 ($G_2$) | 36 | 17 | 20 | 15 | 25 | 18 | 256 |
| 26 ($BD_1$) | 2 | 6 | 5 | 12 | 5 | 3 | 17 |
| 27 ($BD_2$) | 3 | 4 | 6 | 12 | 4 | 8 | 17 |

*Tabel 2. Parasiteringspercentage, percentage overige mortaliteit van de rupsen en populatiedichtheid van de appelbladmineerder in percelen met verschillende bestrijdingsschema's. Proefboomgaard Thedinghsweert bij Tiel, 1968.*

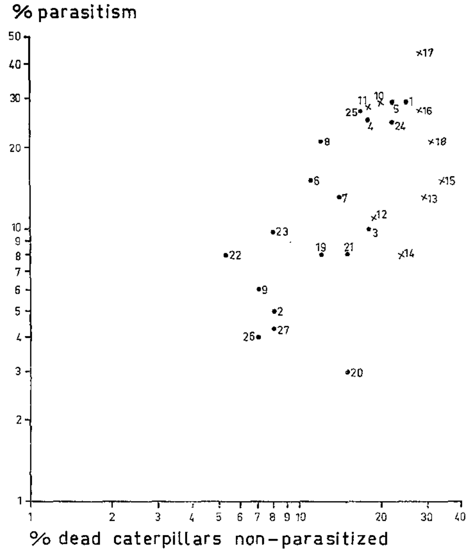


Fig. 2. Diagram showing the correlation between the percentage of parasitized and dead non-parasitized leaf miner caterpillars. For further explanation see text. The numbers correspond with those of Table 1.

*Fig. 2. Grafische voorstelling van de correlatie tussen het parasiteringspercentage en het percentage dode niet beparasiteerde rupsen. Voor verdere verklaringen zie tekst.*

dered as important natural enemies of leaf miner caterpillars. In part G of the experimental orchard Thedinghsweert, indeed, two species of predatory bugs, viz. *Anthocoris nemorum* (L.) and *Phytocoris tiliae* (L.) were found quite commonly during most of the season. Several nymphs and adults of these species were introduced into dishes containing apple leaves with mines in which were living caterpillars. Though the bugs were kept for several days with the caterpillars, no leaf miner larvae were killed.

Fig. 2 shows also that some samples had a higher mortality than was expected. Samples 10 to 18 were collected in plots sprayed with a systemic insecticide early in August (Table 1); these are marked with a cross. In most of these samples mortality of the non-parasitized caterpillars was considerably above the average.

It is well-known that leaf miner larvae within the mines are generally very susceptible to sprays containing systemic insecticides. According to weekly counts the largest number of the second generation caterpillars were found in the field in August. So it is likely that the surplus mortality in a number of the samples 10 to 18 was a result of the spraying with systemic insecticides in August. Sprays before August certainly did not have much influence, because the population density of the parasite was much lower than it was later.

Of course, the situation is far more involved than is suggested here, as the various stages of the parasite, also, are undoubtedly affected by spraying with systemic insecticides. Soehardjan (1969) showed this for the larvae of *Cirrospilus vittatus* on apple. At all events, mortality of the leaf miner caterpillars caused by systemic insecticides seems the most logical explanation for the above surplus mortality.

The dates of the last insecticide applications in Table 1 are not always stated precisely. This is because the orchards in question were mostly chosen in the course of the autumn of 1968 and the various owners and managers did not always remember the exact dates of spraying.

## Investigations and discussion about the parasite as a density-dependent factor in relation to the leaf miner

Besides the sampling of the leaves with 100 mines in the several orchards mentioned on p. 1, also 100 leaves were sampled in the same plots at the same time in autumn. By counting the numbers of mines in these samples, an impression of the population densities of the leaf miner in the several plots was obtained. Table 1 shows the data. In the experimental orchard Thedinghsweert the counting of the mines took place on 19 September. As the last moths in the field were observed on 5 August, it may be assumed that after 19 September 1968 no or very few new mines were formed.

From Table 1 it may be concluded that a positive correlation exists between the percentage of parasitism and the population density as indicated by the number of mines per 100 leaves in the various samples. Fig. 3 attempts to illustrate this relationship. For this purpose it seemed best to express the number of mines per 100 leaves on a logarithmic scale.

The parasite thus acts as a density-dependent factor. This is especially striking in the experimental orchard Thedinghsweert (Table 2). The differences in the population density of the leaf miner and the percentage of parasitism between the various plots in this orchard may be explained by the different sprays with insecticides, viz:

Spray scheme I – 24 April: malathion; 11 June: diazinon; 18 June: propoxur; 6 July: carbaryl.

Spray scheme G – 15 June: isolan.

Spray scheme BD – 2 April: malathion; 11 June: diazinon; 17 June: propoxur; 12 July: carbaryl.

The differences may also be partially explained by the different methods of soil culture and insecticidal treatment employed since 1960, but we cannot go into details here. However, in the summer of 1968 the leaves in BD seemed to be rather hard and they were therefore perhaps unattractive to the leaf miner; this may be the reason why the leaf miner infestation was so low in these plots.

Fig. 3. Diagram showing the correlation between percentage of parasitism and population density of the apple leaf miner. For further explanation see text.

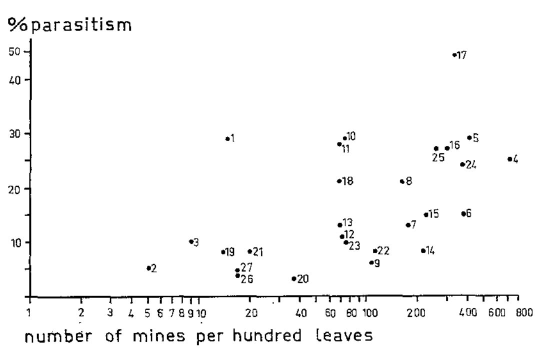


*Fig. 3. Grafische voorstelling van de correlatie tussen parasiteringspercentage en populatiedichtheid van de appelbladmineerder. Voor verdere verklaringen zie tekst.*

## Conclusions

The phenomenon of host feeding and the action of the parasite as a density-dependent factor provide additional evidence to that mentioned by Eveleens and Evenhuis (1968) that *Cirrospilus vittatus* is a valuable factor in the control of *Stigmella malella* in apple orchards. The same authors, however, drew attention to the fact that host and parasite show considerable phenological differences. This seems one of the main reasons why the parasite is in many cases not sufficiently effective to control the leaf miner population.

## Acknowledgments

The authors are indebted to Miss A. C. Oud for valuable assistance and to Mr C. A. van den Anker for advice on statistical treatments.

## Samenvatting

*Verder onderzoek over de betrekkingen tussen de appelbladmineerder en zijn parasiet Cirrospilus vittatus in Nederland*

Door tellingen in een aantal appelboomgaarden in het najaar van 1968 aan monsters bladmijnen waarin de gastheer al dan niet beparasiteerd was (Fig. 1), werden gegevens verzameld over het parasiteringspercentage en het percentage overige dode mineerrupsen. Het wijfje van de sluipwesp voedt zich met de lichaamsvloeistof van de mineerrupsen; op deze wijze blijkt ongeveer hetzelfde percentage van de rupsen gedood te worden als door de parasitering zelf (Tabel 1, Fig. 2). Deze sterfte en het feit dat de parasitering min of meer met de populatiedichtheid van de mineerrupsen toeneemt (Table 1, Fig. 3), worden als nieuwe argumenten beschouwd voor het grote belang van de parasiet voor het in toom houden van de mineerderpopulaties in appelboomgaarden.

Aan de feiten die zich in dit verband in de proefboomgaard Thedinghsweert bij Tiel voordeden, wordt bijzondere aandacht besteed (Tabel 2).

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