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Sampling Second Generation Spotted Tentiform Leaf miner: a Means to Reduce Overall Control Costs and Facilitate Biological Control of Mites in Apple Orchards

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INTRODUCTION

The spotted tentiform *eafminer (Phyllonorycter blancardella)* (STLM) is a well-known pest of apples in eastern North America. Its biology is described in detail by Pottinger and LeRoux (3). The larval stages form leaf mines by feeding between the upper and lower surfaces of apple leaves, reducing their capacity for photosynthesis. Larvae in the early stages, called sap feeders, are flattened and form mines visible on the leaf underside as small, light-colored patches. Late-stage larvae, called tissue feeders, feed on the inside of the upper surface of the mine, causing translucent spots to appear on the leafs upper surface. Severe STLM infestations can result in early leaf drop, premature ripening and dropping of fruit, reduced fruit size, decreased terminal growth, and reduced fruit set in the year following infestation (1,3,5,6). In New York, STLM completes three generations per year. Research in New York has shown that population densities below one mine per leaf for the first generation and two mines per leaf for the second generation do not result in measurable losses in production (6). The third generation occurs so late in the season that impact on tree growth and fruit production is negligible.

Insecticides commonly used for STLM control (methomyl, oxamyl, and pyrethroids such as esfenvalerate) are highly toxic to predatory mites. Because they greatly reduce mite predator numbers, applications of these insecticides to control STLM often lead to outbreaks of European red mite *(Panonychus ulmi)* (4,7). In a typical year, however, leafminer populations in most New York orchards do not reach densities high enough to justify insecticidal control. A sampling program that would enable growers to determine the need for controlling STLM would reduce pest control costs by eliminating the need for preventive treatments, and minimizing disruption of naturally occurring biological control of European red mite. This report describes such a sampling program for second generation STLM.

LIMITATIONS OF CURRENT SAMPLING PROCEDURES

Sampling for pest control decision-making requires developing a procedure for estimating population densities and comparing these with levels above which control becomes economically desirable. In addition, it is necessary to determine when sampling should take place. Sampling must be done late enough so that sufficient insects are present in the orchard to allow reasonable estimates of population density, yet early enough to allow treatment of high density populations before too much damage is incurred. For many insect pests, sample timing is determined based on heat accumulations above a temperature threshold, called degree-days.

Degree-days can be calculated conveniently from daily minimum and maximum temperatures, which are relatively easy to monitor. Because temperature is most often the primary determinant of developmental rate in insects, degree-day accumulations often work well for predicting when a given developmental stage (e.g., egg, larva, pupa, or adult) of an insect pest is present in the field. However, other factors may also influence insect developmental rates and thereby affect (he accuracy of predictions based on heat accumulations Such factors include wind, rain, relative humidity, leaf nutritional quality, genetic variation among populations, and differences between climate experienced by insects and temperatures measured at weather stations. Unfortunately, it is usually impractical to monitor these factors on a regular basis and incorporate their effects into a procedure for determining sampling times.

For first generation STLM, which lay their eggs on the newly unfolding leaves in the spring, egg sampling is used to determine the need for control (2). Second generation STLM eggs are very difficult to detect, however, due to the texture and hairiness of the more mature leaves. Therefore, for the second

generation, a sampling plan is required that will enable growers to sample STLM during the larval stage and decide whether to treat before significant damage occurs.

In 1990, we closely monitored appearance of STLM mines and adult flight (using pheromone traps) at five locations in western New York. We found enormous variability in degree-day accumulations (base 43 °F) from the start of the second adult flight to appearance of 10,50, and 90 per cent of the total mines at each site (Table 1). This variability makes it extremely difficult to estimate total population density based on a single estimate of mine density. For example, suppose we sampled at 810 degree-days after the start of the second flight. The percentage of total mines present at 810 degree-days at the five sites ranges from 16 per cent to 94 per cent. If sampling results at 810 degree-days gave us a count of one mine per leaf, then an estimate of total density based on the percentage of total mines found at 810 degree-days at the five sites would range from 1/0.94 = 1.06 to 1/0.16 = 6.25 mines per leaf. Clearly, no reliable decision on whether to treat could be made based on such estimates resulting from a single sampling.

Table 1. Degree-days (base 43°F) and average number of days from start of second adult flight to appearance of 10, 50, and 90 per cent of total second generation STLM mines at five sites.

	10%		50%		90%	
Site	Degree-days	Avg. days	Degree-days	Avg. days	Degree-days	Avg. days
1	469	17	771	29	1072	40
2	623	23	825	31	1027	38
3	735	27	1050	39	1365	51
4	497	18	636	24	774	29
5	515	19	751	28	987	37

[a] Degree-day accumulations in late June and early July in western New York average approximately 27 degree-days per calendar day.

A NEW TYPE OF SAMPLING PROCEDURE FOR SECOND GENERATION STLM

To solve the problems described above, we developed a sampling program that incorporates up to three sampling sessions. The sampling plan is designed to call for treatment of any populations likely to exceed a density of two mines per leaf and to ensure that treatment, if necessary, is applied before density of tissue feeder larvae exceeds the two mines-per-leaf threshold.

At each sampling session, trees are sampled along a diagonal path across the orchard block, starting near one corner. Total STLM mines are counted on four leaves per tree. The leaves sampled should be mature leaves from near the middle of terminals randomly selected from around the outside of the tree canopy. After sampling the third tree and after sampling each subsequent tree, cumulative total mine count is compared with values in a table to determine whether to sample an additional tree, to stop sampling and treat the block, to stop sampling and resample the block at a later date, or to stop sampling and not treat the block. The comparison values in the tables were determined so that, at each sampling session, populations with densities above two mines per leaf would be treated, populations with densities low enough to ensure that second generation mine density would never reach two mines per leaf would not be treated, and populations with intermediate densities would be resampled later. Figure 1 diagrams the steps in the sampling procedure which will now be described in detail.

During the first session, approximately 690 degree-days (base 43°F) after the start of the second adult flight, cumulative total counts are compared with the values in Table 2. Trees are sampled sequentially until the cumulative number of mines on a given number of trees either falls below the lower value or exceeds the higher value in the appropriate row. If the cumulative number of mines falls below the lower value, a decision is made to resample the block approximately 840 degree-days after the start of the second flight. If the cumulative number of mines exceeds the higher value, the decision is to treat the block and no additional sampling sessions are required.

If a second sampling session at 840 degree-days is required, sampling is conducted as in the first session and the cumulative mine counts are compared with the values in Table 3. For this sampling session there are three columns of values to compare mine counts with, rather than two as in the first session. Sampling is continued until the cumulative number of mines falls below the value in the leftmost column, exceeds the value in the rightmost column, or falls within the range specified in the center column. If the total mine count is less than the value in the leftmost column, a decision is made to not treat the block and no further sampling sessions are necessary. If the mine count falls within the range given in the center column, then the decision is to resample the block at approximately 1150 degree-days after the start of the flight. For mine counts greater than the value in the rightmost column, the block should be treated and no further sampling sessions are required.

If a third sampling session at 1150 degree-days is required, sampling is conducted sequentially as in the first sampling session and the comparison values in Table 4 are used. The only difference from the first session is that, for cumulative mine counts less than the lower value in the appropriate row, the decision is made to not treat the block and no additional sampling sessions are called for.

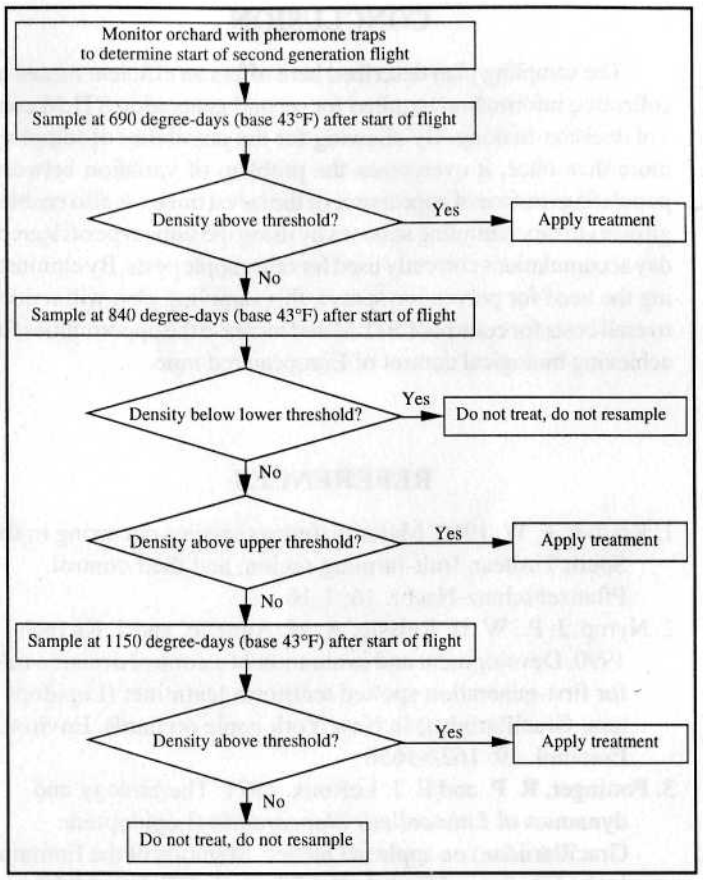

Figure 1. Second generation spotted tentiform leafminer sampling procedure.

Table 2. Comparison chart for first sampling session (690 degree-days, base 43°F, after start of second flight).

No.trees sampled	Resample at 840 degree-days if total mines less than	Continue sampling if total mines is	Treat if total mines exceeds
3	3	3-29	29
4	8	8-35	35
5	13	13-40	40
6	19	19-45	45
7	24	24-51	51
8	29	29-56	56
9	35	35-61	61
10	40	40-67	67
11	45	45-72	72
12	51	51-77	77
13	56	56-83	83
14	61	61-88	88
15	67	67-93	93
16	72	72-99	99
17	77	77-104	104
18	83	83-109	109
19	88	88-115	115
20	108	–	107

Table 3. Comparison chart for second sampling session (840 degree-days, base 43°F, after start of second flight).

No.trees sampled	Do not treat if total mines less than		Resample at 1150 degree-days if total mines is		Treat if total mines exceeds
3	-	C	-	C	29
4	-	O	-	O	35
5	-	N	12	N	40
6	-	T	13-18	T	45
7	-	I	14-23	I	51
8	-	N	14-28	N	56
9	-	U	15-34	U	61
10	-	E	16-39	E	67
11	-		16-44		72
12	-	S	17-50	S	77
13	1	A	18-55	A	83
14	1	M	19-60	M	88
15	2	P	19-66	P	93
16	3	L	20-71	L	99
17	3	I	21-76	I	104
18	4	N	21-82	N	109
19	5	G	22-87	G	115
20	20		20-107		107

able 4, t. omparison chart for third sampling session (1150 egree-days, base 43°F, after start of second flight).

No.trees sampled	Do not treat if total mines less than	Continue sampling if total mines is	Treat if total mines exceeds
3	3	3-29	29
4	8	8-35	35
5	13	13-40	40
6	19	19-45	45
7	24	24-51	51
8	29	29-56	56
9	35	35-61	61
10	40	40-67	67
11	45	45-72	72
12	51	51-77	77
13	56	56-83	83
14	61	61-88	88
15	67	67-93	93
16	72	72-99	99
17	77	77-104	104
18	83	83-109	109
19	88	88-115	115
20	108	–	107

EVALUATION OF THE SAMPLING PLAN

We tested the sampling plan by using a computer to simulate sampling from populations with mean densities ranging from 0 to 15 mines per leaf, and variation in time of appearance of mines equivalent to that seen in the five sites shown in Table 1. The plan worked well on all simulated populations, giving a high probability of a treatment decision for populations with densities above two mines per leaf and a low probability of treatment for populations with densities below the threshold. The expected density of second generation tissue feeder mines remained below two per leaf for all the populations, and the average number of samples required reached a maximum of fewer than 37 trees (total over all sampling sessions). In practice, sampling a block should take approximately 10 to 15 minutes per session.

CONCLUSION

The sampling plan described here offers an efficient means of collecting information required for second generation STLM control decision-making. By allowing for the possibility of sampling more than once, it overcomes the problem of variation between populations in time of appearance of the larval mines. It also enables growers to time sampling sessions by using the same type of degree-day accumulations currently used for other apple pests. By eliminating the need for preventive sprays, this sampling plan will reduce overall costs for control of STLM and increase the opportunities for achieving biological control of European red mite.

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