Developing Additive Action Thresholds for Spotted Tentiform Leafminer and European Red Mite

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Introduction

Apple trees grown in the eastern United States are subject to attack by several insects and mites that feed on foliage. While injury caused by foliage feeding pests may vary due to the time and type of feeding, the principal mechanism of damage appears to be the reduction of photosynthesis by leaves. If individual pests affect the apple tree via reductions in leaf photosynthesis, it is reasonable to hypothesize that the influence of multiple pests is an additive reduction in leaf photosynthesis. Affirming the additive affect of multiple sources of pest injury would bolster current pest management practices. Spotted Tentiform Leafminer (STLM) (Phyllonorychter blancardella) is an important apple insect pest. Larvae burrow beneath the layers of apple leaves and consume the mesophyll creating mines where most of the green tissue has been removed. Unfortunately, little is known about the influence of damage by this insect on apple tree photosynthesis. Here, we present results from experiments designed to answer three questions:

1. What is the relationship between STLM damage on a leaf and photosynthesis by the leaf?
2. What is the relationship between STLM damage and photosynthesis by the entire tree canopy?
3. Can STLM damage be simulated?

Materials and Methods

STLM damage and leaf photosynthesis We measured photosynthesis by leaves with naturally occurring mines on field-grown 'Red Delicious' trees. Measurements were taken once during the first generation of STLM and twice during the second generation (July 11, Aug. 4 and Aug. 24). On all three occasions, > 95 % of the larvae had completed development to the pupal stage. Measurements were obtained under sunny conditions with a portable infrared gas analyzer with a clamp-on leaf enclosure (PP-Systems, Hitchin, Herts, UK) held perpendicular to the sun. Photosynthesis (μ moles/m2/sec) was expressed on a leaf-area basis for both the entire leaf area measured (with mines) and for the leaf area without mines. The latter allowed us to determine whether there were compensatory or systemic effects of the leafminer damage. The data were analyzed using regression. In the analysis we allowed for nonlinear relationships as well as a differential affect of first and second generation mines.

STLM damage and whole tree photosynthesis To measure whole tree photosynthesis we used small, potted trees that were 2 years old and 1.5m tall as experimental units. To infest the trees with STLM larvae, trees were placed in large screen cages at the time of STLM adult flight (6/26/00) and for a period of 21 days. Nine trees were placed into each of four cages along with 1500, 1000, 500 or no STLM pupae. Adult STLM were allowed to emerge and oviposit on the caged trees. Densities of leafminers were estimated in early August by counting the mines on each of 10 leaves per tree. Photosynthesis by the entire tree canopy was measured by enclosing the tree canopies in flow-through clear Mylar® plastic "balloon" chambers, and measuring the reduction in air CO2 concentration from inlet to outlet. Photosynthesis by leaves with varying levels of STLM injury was also measured at the same time as previously described. Data were analyzed using regression.

Simulation of STLM injury STLM damage was simulated using either oil paint, latex paint, or by punched holes. Paint was applied to both sides of the leaf. Photosynthesis by 2.5 cm^2 healthy leaf tissue and the same area encompassing a simulated STLM mine or a natural STLM mine, was measured using the same apparatus described above, but with a smaller enclosure about the leaf. We also simulated damage by applying nail polish to the top surface of leaves. With this simulation a range of simulated mine densities was used (1-10 mines per leaf) and photosynthesis by entire leaves was measured. Data were analyzed using ANOVA and regression.

Results

STLM damage and leaf photosynthesis The relationship between photosynthesis by the entire leaf surface and the percent of leaf area damaged by STLM mines was approximately linear for both first and second generation STLM; however, the impact of first generation mines on photosynthesis was greater (Fig. 1). For both generations, the loss of photosynthesis was more than proportional to the area mined. This is reflected in the reduced photosynthesis by the non-damaged leaf area as the proportion of leaf area damaged by STLM increased (Fig. 2).

STLM damage and whole tree photosynthesis There was no relationship between STLM injury (mines per leaf) and whole-tree photosynthesis (Fig. 3). Photosynthesis by leaves on the potted trees was lower than that measured for the field-grown trees. As for the field grown trees, STLM mines reduced photosynthesis in a linear manner (Fig. 4). The relative influence of STLM damage was greater on the potted trees compared with the field grown trees.

Simulation of STLM injury There were no significant differences among the photosynthesis measurements for natural damage and damage simulated using latex paint, oil paint or a hole punch (Table 1). Reductions in photosynthesis due to natural damage and simulated damage using oil paint or a hole punch were similar (Table 1). However, simulated damage using latex paint did not result in a significant decline in photosynthesis compared to a healthy leaf (Table 1). Damage simulated using nail polish resulted in a similar pattern of response, but a steeper reduction in photosynthesis compared to natural mines (Fig. 5).

Table 1. Photosynthesis ($\mu moles/m^2/sec$) (Pn) by apple leaves with natural or simulated STLM mine damage of similar area (numbers in parentheses are standard errors).

Damage type	Pn control[1]	Pn damaged[2]	Pn control - Pn damaged
Natural	13.81[a] (2.03)	11.01[a] (2.03)	2.81[b]
Oil paint	14.61[a] (2.10)	12.27[a] (2.06)	2.34[b]
Latex paint	12.71[a] (2.37)	12.45[a] (1.93)	0.26
Hole punch	14.05[a] (3.25)	11.81[a] (1.97)	2.24[b]

[1]Photosynthesis measured from 2.5 cm^2 of undamaged leaf area,
[2]Photosynthesis measured from 2.5 cm^2 of leaf area that included a natural or simulated mine
[a]Numbers in a column followed by the same letter are not significantly different
[b]Significantly different from 0 at a 0.01 level.

Discussion

Photosynthesis by apple leaves declined as a linear function of the leaf area removed by STLM larvae. There was also an effect by the mines on the photosynthetic capacity of the surrounding, healthy leaf tissue, and this effect was nonlinear. Therefore, as the foliage area removed by STLM larvae exceeds the maximum in our study (ca. 25%), reductions in photosynthesis may become nonlinear. It should be noted that on average, STLM mines of 0.5 cm^2 represent only about 1.5 to 2% leaf area reduction in typical apple leaves of 20-25 cm^2.

For the level of leaf miner injury we obtained in the caged-tree experiment (up to 3 mines per leaf), we observed no effect of this damage on whole-canopy photosynthesis. STLM damage on photosynthesis of individual leaves on the same trees showed similar responses to other leaf studies. There are several possible explanations for the lack of effect on the whole tree. First, variations due to variability in tree size and structure, a low number of replicates, and spatial variation in pest injury may have obscured any effect. The trees used were not as vigorous or uniform as desired. Second, 3 mines/leaf was a relatively low level of injury (representing about 8-10% leaf area damage with those leaves) that had no significant effect on the whole tree. Alternatively, dilution of damage by the undamaged leaves or compensation by the undamaged leaves may have lessened the overall impact to an undetectable level or eliminated it entirely.

It might be possible to simulate leaf miner damage. The nail polish data was promising in that it showed a general response similar to STLM mines. However, our results suggest that artificial damage of the same area had a greater impact on photosynthesis than natural mines, possibly due to lateral movement of toxic solvents. Logically, using nail polish on smaller treatment areas with may compensate for the stronger effect per unit area, but this will need to be confirmed.

Comparison of results from the single leaf photosynthesis measurements with comparable measurements taken for leaves damaged by European red mite (Lakso et al. 1996) indicates that each STLM mine causes about a 2.5% reduction in photosynthesis that is equivalent to approximately 125 mite days. Current recommendations are that no than about 500 mite days (or about a 10% reduction in leaf photosynthesis) be allowed on apples trees with a moderate crop load in order to prevent yield or quality reductions in the fruit (Francesconi et al. 1996). This suggests that apple trees can tolerate at least 4 STLM mines per leaf before adverse affects accrue to the fruit. This threshold may be even greater given the results from our whole tree photosynthesis measurements. A threshold of 4 mines per leaf is considerably higher than the current recommended threshold of 2 mines per leaf. Further work is required to verify and extend the results we obtained in this study. Fortunately, this project will continue for three additional years at the conclusion of which we should have a good understanding of the individual and combined effects of STLM and European red mite on apple tree performance.

Literature Cited

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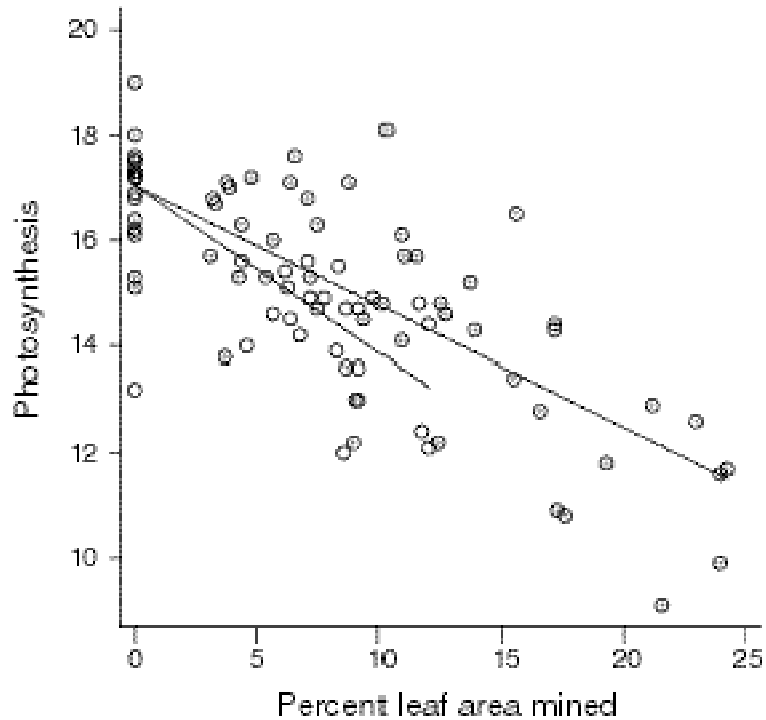

Figure 1. Photosynthesis (μmoles/m^2/sec) (Pn) by leaves with varying levels of first and second generation STLM mine injury. First generation data are indicated by open circles and corresponding predicted values from a linear model by the lower line. Average mine sizes were 0.64 cm^2 and 0.48 cm^2 for the first and second generation mines respectively. Leaf areas for which photosynthesis measurements were taken averaged 24.2 cm^2 and 26.4 cm^2 for the first and second generations. The fitted model was Pn = 17.03 - b*(% leaf area mined) where b = 0.316 for the first generation and 0.227 for the second generation. R^2 for the model was 0.57 and all parameters were significant at a 0.05 level.

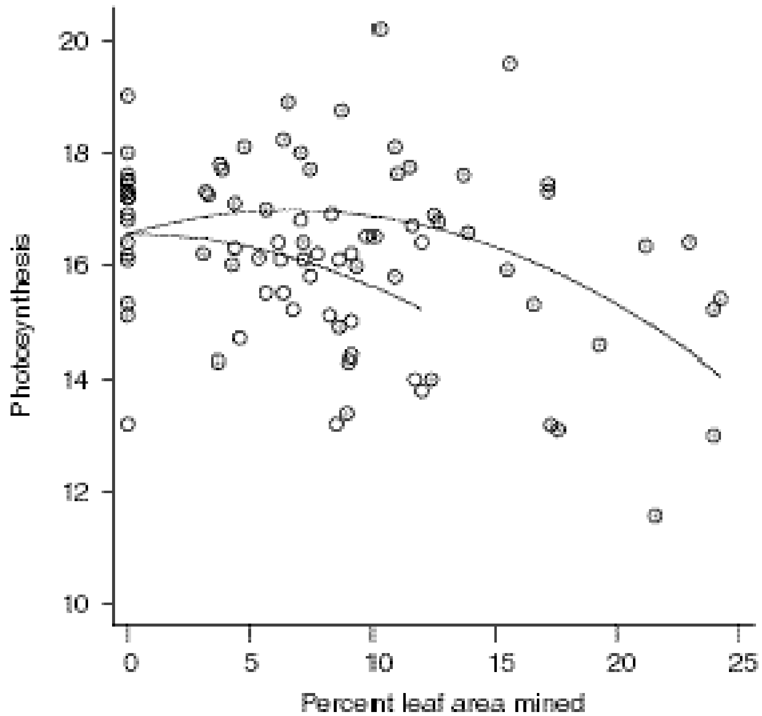

Figure 2. Photosynthesis (µmoles/m^2/sec) (Pn) by the non-damaged area of leaves with varying levels of first and second generation STLM mine injury. First generation data are indicated by open circles and corresponding predicted values by the lower line. The fitted model was Pn = 16.55 -.0094(% leaf area mined)^2 + 0.126*(% leaf area mined)*gen2 where gen2 = 1 for the second generation data and 0 otherwise. R^2 for the model was 0.16 and all parameters were significant at a 0.01 level.

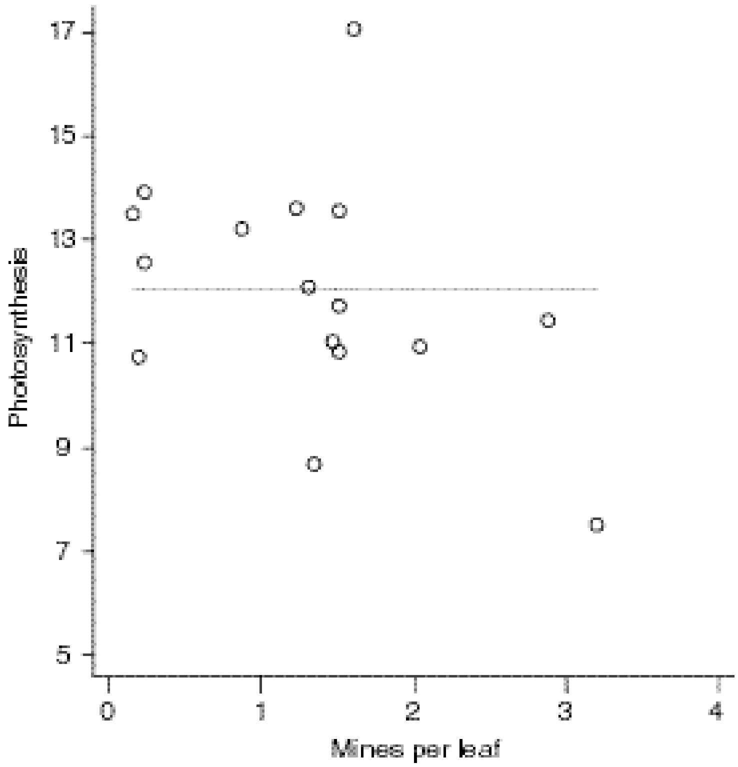

Figure 3. Whole-canopy average photosynthesis (μmoles/m^2/sec) by trees with varying levels of second generation STLM damage. The line is the overall mean response.

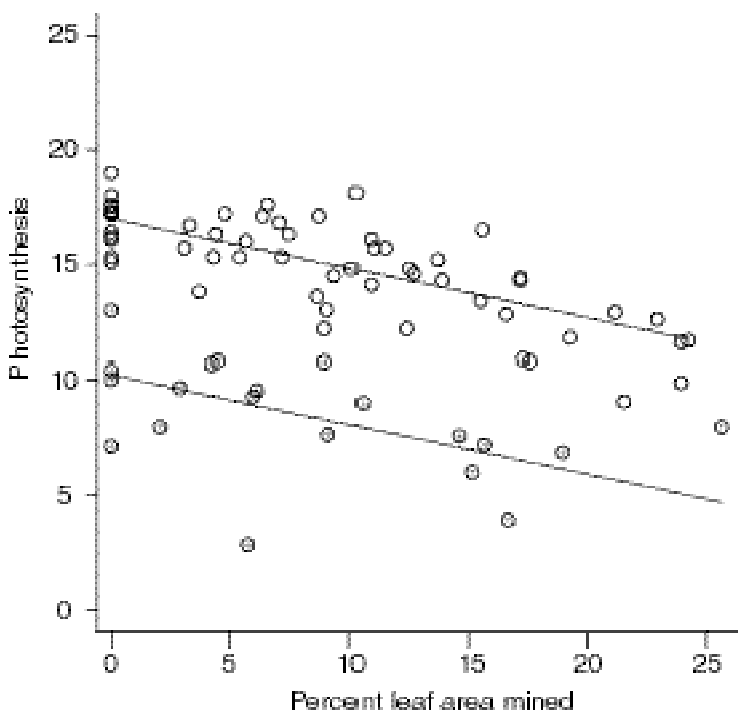

Figure 4. Photosynthesis (μmoles/m^2/sec) (Pn) by leaves from two sets of trees with varying levels of second generation STLM mine injury. The first set of trees were field grown

(open circles) and the second set were the potted trees used in the whole-canopy photosynthesis measurements (highlighted circles). The slopes of the two fitted lines were the same (-0.215); however, the intercepts were significantly different (16.96 vs 10.23).

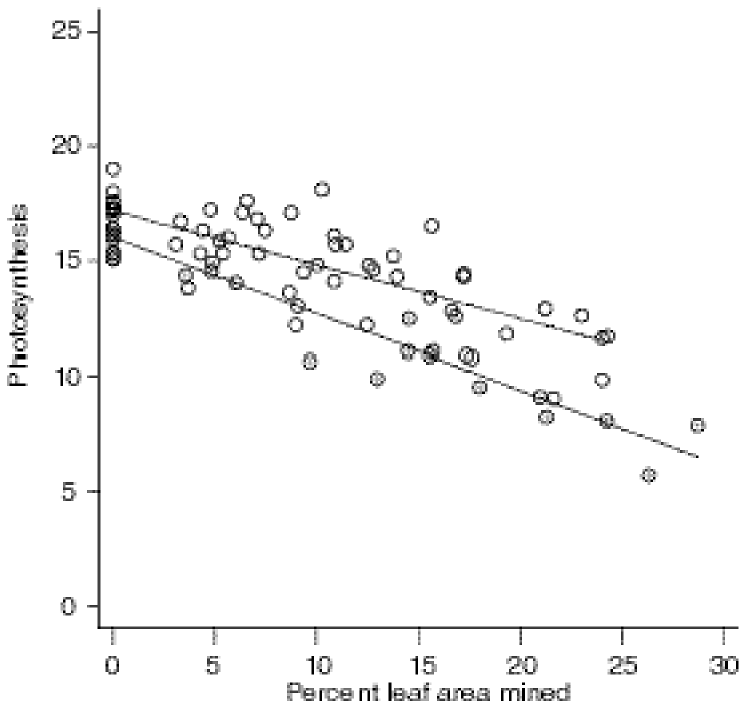

Figure 5. Photosynthesis (μmoles/m^2/sec) (Pn) by leaves with varying levels of second generation STLM mine injury (open circles) and injury simulated using nail polish (highlighted circles). The intercepts (17.15 and 15.98) and slopes (-0.235 and -0.329) differed significantly for the natural and simulated damage, respectively.

Abstract

Apple trees grown in the eastern United States are subject to attack by several insects and mites that feed on foliage. While injury caused by foliage feeding pests may vary due to the time and type of feeding, the principal mechanism of damage appears to be the reduction of photosynthesis by leaves. If individual pests affect the apple tree via reductions in leaf photosynthesis, it is reasonable to hypothesize that the influence of multiple pests is an additive reduction in leaf photosynthesis. Affirming the additive affect of multiple sources of pest injury would bolster current pest management practices. Spotted Tentiform Leafminer (STLM) (*Phyllonorychter blancardella*) is an important apple insect pest. Larvae burrow beneath the layers of apple leaves creating mines where most of the green tissue has been removed. We conducted experiments to better understand the influence of damage by this insect on apple tree photosynthesis. We found that photosynthesis by apple leaves declined linearly as the leaf area removed by STLM larvae increased. On shoot leaves of 20-25 cm^2 leaf area, each mine damaged about 2% of the leaf area. There was no clear effect by the mines on the photosynthetic capacity of the surrounding, healthy leaf tissue, except an apparent reduction in photosynthesis above 15% leaf area damaged.

We observed no effect of up to 3 mines per leaf on whole-canopy photosynthesis. STLM damage on photosynthesis of individual leaves on the same trees showed similar responses to other leaf studies. The lack of effect on the whole tree was likely due to inherent variations (variability in tree size and vigor, a low number of replicates, and spatial variation in pest injury), and the relatively low level of injury (3 mines/leaf represented about 8-10% leaf area damage with those leaves) that had no significant effect on the whole tree. The undamaged leaf area in that study showed no photosynthetic compensation in response to the miners.

Comparison of results from the single leaf photosynthesis measurements with comparable measurements taken for leaves damaged by European red mite indicates that each STLM mine causes about a 2.5% reduction in photosynthesis that is equivalent to approximately 125 mite days. Current recommendations are that no than about 500 mite days (or about a 10% reduction in leaf photosynthesis) be allowed on apples trees with a moderate crop load in order to prevent yield or quality reductions in the fruit. This suggests that apple trees can tolerate at least 4 STLM mines per leaf before adverse affects accrue to the fruit. This threshold may be even greater given the results from our whole tree photosynthesis measurements. A threshold of 4 mines per leaf is considerably higher than the current recommended threshold of 2 mines per leaf. Further work is required to verify and extend the results we obtained in this study.

STLM mine injury was simulated with similar areas treated with oil paint, latex paint, punched holes, or finger nail polish. The nail polish treatment was promising with similar effects to STLM's on photosynthetic reduction, although the reduction was somewhat stronger for the same leaf area affected.