# Effects of Spotted Tentiform Leafminer and European Red Mite on Apple Leaf Function and Crop Development

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**Several individual leaf feeding pests affect apple trees by reducing leaf photosynthesis which results in reduced carbohydrate supply to developing fruits. While pest level tolerances have been developed or estimated for single pests, several pest stresses often occur concurrently. We found that leaf injury by STLM at relatively high levels does not greatly affect leaf and canopy photosynthesis, fruit growth, or fruit quality but does increase pre-harvest drop of McIntosh. In contrast, mite damage does significantly reduce leaf photosynthesis.**

Apples are subject to attack by several foliage feeders. While pest level tolerances have been developed or estimated for single pests, several pest stresses often occur concurrently. Of the different types of apple pest effects commonly seen, injury from European red mite (ERM) (*Panonychus ulmi* Koch) has been the most extensively studied. Several studies have shown a decline in leaf photosynthesis with ERM injury, which, in turn, can lead to reductions in yield and fruit quality (Lakso et al., 1996). Much less work has been done on the impact of other pests such as spotted tentiform leafminer (STLM) (*Phyllonorycter blancardella* Fabricius), or on the combined effects of two or more pests.

The principal integrating mechanism of foliar pest damage appears to be reductions in the carbohydrate supply for fruit development caused by the reduction of leaf photosynthesis. Many studies of fruit carbohydrate supply and demand have shown that several other internal and external factors, in addition to leaf health, also play a role in tree physiology. Flowering, fruit set fruit growth and sustained cropping depend on an adequate carbohydrate supply in relation to the demand for carbohydrates for growing fruits, shoots, leaves, wood and roots. Consequently, foliar pest thresholds will depend on how the tree integrates the influences of all pest injuries as well as other factors that affect the carbohydrate balance such as cloudiness, drought stress, etc.

If individual pests affect the apple tree by reducing leaf photosynthesis, it is possible that the effect of multiple pests is additive by way of reductions in leaf photosynthesis. This concept was the basis for the research described here.

## Methods

We conducted experiments to assess the effect of STLM feeding damage on leaf and whole-tree photosynthesis and the impacts on fruit yield and quality. In some experiments we measured the influence of STLM and ERM feeding damage on the same leaves. Measurements were taken from mature McIntosh and Red Delicious apple trees at the New York State Agricultural Experiment Station in Geneva. We measured the amount of leaf area injured by STLM mines; photosynthesis of leaves having STLM mines and photosynthesis by leaf tissue within and immediately adjacent to mines; photosynthesis of leaves with both STLM and ERM injury; and whole-tree photosynthesis of trees having simulated STLM infestations. On trees with varying levels of STLM and ERM infestations, we recorded fruit growth, yield, and maturity as indicated by starch staining, sugar concentration and firmness.

## Results

Over three years a somewhat surprising, yet very consistent, result was that up to five STLM mines per leaf caused very little reduction in leaf-level photosynthesis, and even a very high density of 10 mines per leaf resulted in only about a 10-15 percent reduction in photosynthesis (Fig. 1). The mine of a mature STLM larva occupies approximately 0.5 $cm^2$ of leaf area, which corresponds to 2 percent to 3 percent of the area of a normal apple leaf. Therefore, at a density of 10 mines per leaf, leaf area is reduced 20 to 30 percent. Visually, this damage appears to be much more severe than the actual 20-30 percent reduction in leaf surface area. Even at 10 mines per leaf, the reduction in photosynthesis is less than the proportional leaf area consumed by the STLM larvae. Apparently, leaves compensate for some of the leaf area lost by increasing the photosynthesis of the remaining leaf tissue.

The initial mines produced by young STLM larvae are visible only from the

bottom of leaves. Mines produced by these young larvae did not have any measurable effect on leaf photosynthesis. Mines produced by mature STLM larvae show feeding damage on both the upper and lower leaf surfaces. However, there remains some green tissue within mines that continues to photosynthesize. We measured photosynthesis by the tissue occupied by the mine before and after masking the mined area. When we covered the mined area on a leaf with opaque material, it further reduced the photosynthetic capacity of the mined leaf tissue showing that the green tissue remaining in STLM mines contributes some photosynthesis. Combined with some degree of compensation by the remaining healthy leaf tissue, leaf photosynthesis was only slightly affected by STLM mines unless the number of mines was very large.

Considering the modest influence of STLM mines on leaf photosynthesis, we did not expect to observe an effect of STLM mines on whole-tree photosynthesis. Because we were unable to really control STLM numbers on our test trees, we mimicked STLM damage by punching holes in the leaves with the same distribution as the natural pattern of STLM infestation. Although the trees were subjected to as many as nine simulated mines per leaf in the most severely damaged leaves, or up to 8 percent total leaf area "attacked," we found no measurable reduction in whole-tree photosynthesis (Fig. 2). Therefore, the results of our leaf and whole-tree studies suggest that surprisingly the levels of STLM injury commonly found in the field do not cause much effect by reducing photosynthesis.

Our previous research has shown that ERM feeding and resulting damage can greatly reduce photosynthesis (Lakso et al., 1996). Compared to the ERM results, our results with STLM are surprising because damage by STLM is visually more dramatic. To evaluate the combined effects of ERM and STLM on photosynthesis, we measured photosynthesis on leaves injured by both these pests. ERM damage was visually scored on a scale that related to a range of approximately 0 to 1250 mite days[1] (current IPM thresholds for ERM are about 500-700 mite days). We found that the reductions in photosynthesis from STLM and ERM seem to be simply additive and

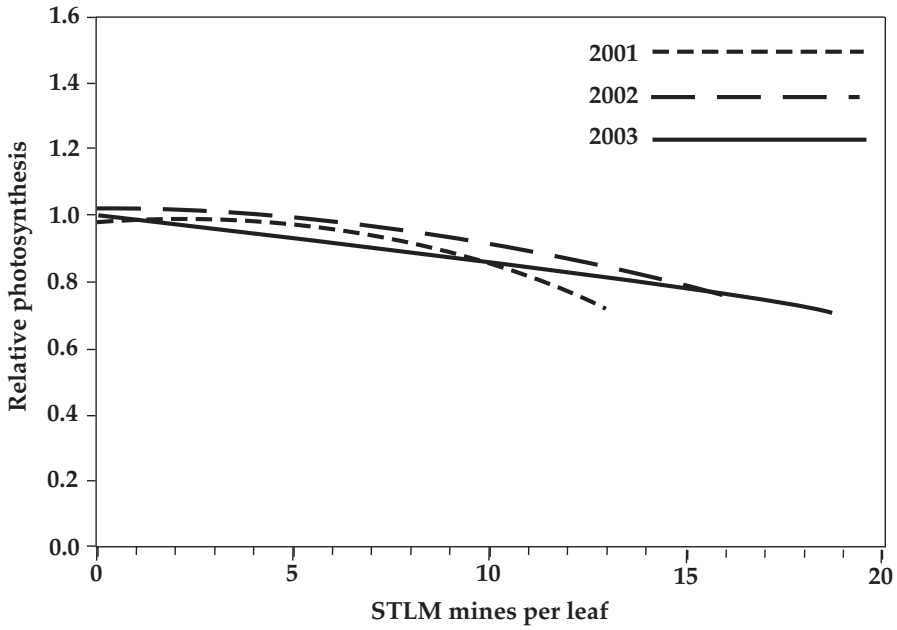


Figure 1. Influence of mature second generation spotted tentiform leafminer mines on photosynthesis by apple leaves. Readings are relative to the photosynthesis of leaves with no mines on the days of measurement. The three lines describe the relationships found in many measurements in 2001, 2002 and 2003.

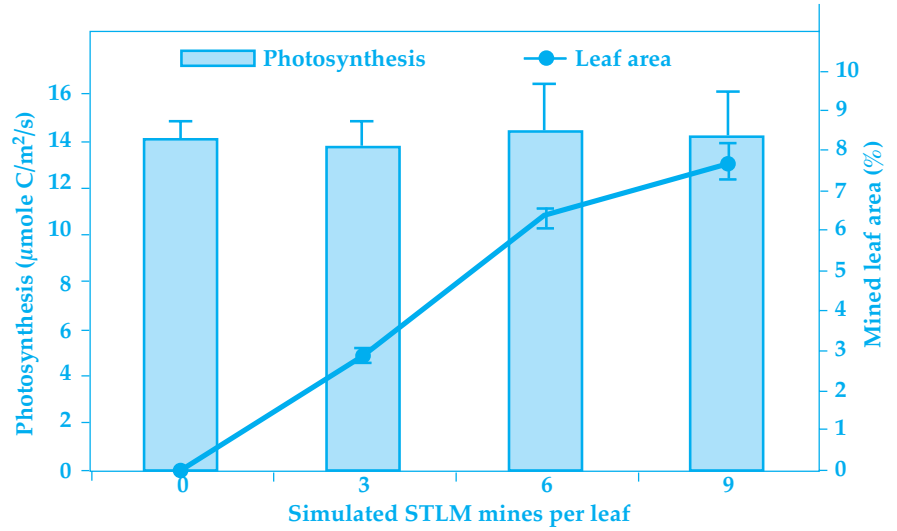


Figure 2. Influence of simulated spotted tentiform leafminer mines on average percent leaf area mined and on whole-tree photosynthesis of Red Delicious apple trees. Error bars indicate the variation in results of each treatment.

independent of each other (Fig. 3). Furthermore, the influence of ERM feeding damage on photosynthesis was greater than that for STLM even though the apparent visual effect of STLM on the leaf was greater. For example, 750 mite days reduces leaf photosynthesis about 15 percent. Mite damage corresponding to 750 mite days is not uncommon, while heavy bronzing that can occur relates to mite days in excess of 2000. In comparison, 10 STLM mines per leaf reduced photosynthesis about only 10-12 percent. Ten STLM mines per leaf appears visually to be a much more severe injury than 750 mite days. So with these two pests, what you see, is not what you get!

As the previous studies have shown, leaf damage from ERM feeding can impair leaf and canopy photosynthetic function. In moderately to heavily cropped trees a shortage of carbohydrate supply can result in smaller fruit size and inferior fruit quality. In contrast, STLM does not greatly affect leaf and canopy photosynthesis. The carbohydrate

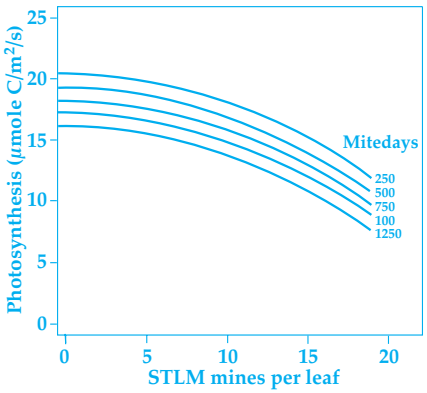


Figure 3. Influence of spotted tentiform leafminer mines on leaf photosynthesis of McIntosh apple leaves when the leaves also had 250, 500, 750, 1000 and 1250 mite days of European red mite injury.

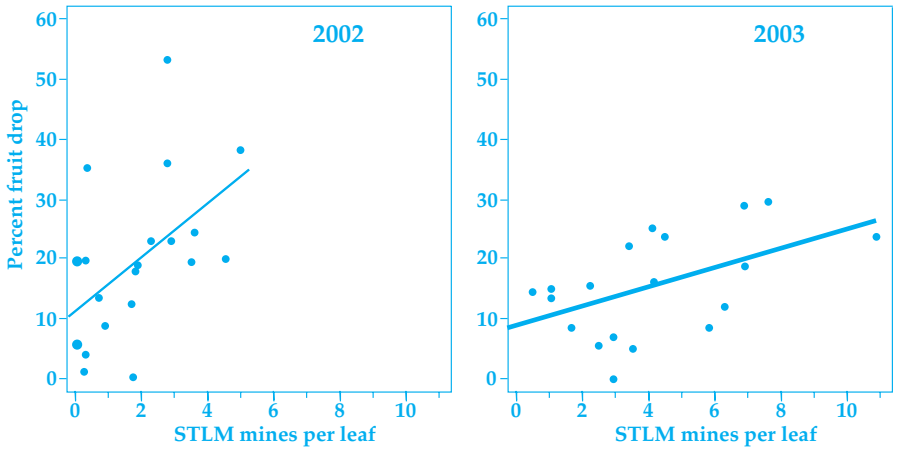


Figure 4. Influence of spotted tentiform leafminer mines on pre-harvest drop of McIntosh fruit. Fruit drop was adjusted to account for natural variation across the orchard. STLM mine density was the average number of mines counted on mid-aged leaves of vegetative terminals.

supply vs. demand would suggest fruit growth, fruit size, and fruit quality would not be affected much by STLM. We tested these predictions by measuring fruit yield and quality from McIntosh and Red Delicious trees with varying levels of STLM infestation.

We found that STLM infestations of nearly 10 mines per leaf did not influence fruit quality as measured by sugar content and firmness. However, pre-harvest fruit drop from McIntosh trees was significantly increased by damage from STLM (Fig. 4), but this did not occur on Red Delicious trees. In 2003, the test trees were damaged by both STLM and ERM, with mite levels reaching approximately 1500 mite days. Mite injury did not alter pre-harvest drop on the McIntosh trees. These results indicate that the effect of STLM damage on pre-harvest fruit drop in McIntosh is caused by factors other than by reducing carbohydrate supply. In general, McIntosh trees are very prone to pre-harvest drop, although the mechanism is unknown.

## Summary

Our studies have shown that leaf injury by STLM at relatively high levels does not greatly affect leaf and canopy photosynthesis, fruit growth, or fruit quality. Reductions in photosynthesis caused by STLM and ERM feeding injury are additive, indicating that the carbohydrate supply vs. demand is an integrator of their effects on photosynthesis. However, STLM damage elicits significant pre-harvest drop of McIntosh but not Red Delicious. From the perspective of carbohydrate supply and demand balance, current thresholds for STLM of 1-2 mines/leaf are conservative except for McIntosh trees or perhaps other varieties known to be susceptible to pre-harvest fruit drop.

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[1] **Mite days is a measure of cumulative mite density. Ten mites for 10 days results in 100 mitedays as does 20 mites for 5 days.**