Citrus Rust Mite (Acari: Eriophyidae) Damage Effects on 'Hamlin' Orange Fruit Growth and Drop

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ABSTRACT Effects of early-season damage by the citrus rust mite, *Phyllocoptruta oleivora* (Ashmead), on 'Hamlin' orange fruit growth and drop were studied from 8 June through 17 December 1991, in Hendry County, FL. 'Hamlin' fruit drop increased with increasing fruit surface damage by the citrus rust mite. The data also indicated a slightly accelerated fruit drop with increasing mite damage and time. The overall data suggested a slight negative relationship between fruit size and mite damage. Cumulative percentage drop and percentage diameter increase were fitted to two-variable logistic functions of damage and time. These functions could be used in management models for calculating volume losses from rust mite damage.

KEY WORDS *Phyllocoptruta oleivora*, economic loss models, pest management

THE CITRUS RUST MITE, *Phyllocoptruta oleivora* (Ashmead), is an important eriophyid pest of citrus in most humid regions of the world (Commonwealth Institute of Entomology 1970, McCoy & Albrigo 1975) and is one of the most common and serious pests of citrus in Florida, Texas, Louisiana, and some citrus districts of California (Davidson & Lyon 1987). It infests branches, leaves, and fruit of all commercial species and varieties of citrus (Yothers & Mason 1930). Reports on the economic importance of citrus rust mite refer not only to fruit surface discoloration, but also to fruit drop and size reduction, with an associated loss of fruit quality and yield. Hubbard (1885) noted that ". . . if severely attacked by rust mite before it has completed its growth, the orange does not attain its full size. Very rusty fruit is always small." Yothers (1918) observed that "russet" grade (damaged) oranges and grapefruit were 12.5% (volume) smaller than undamaged fruit before shipment. Those studies did not indicate whether damaged and undamaged fruit of the same initial size actually grow at different rates. Small size could presumably be correlated with rust mite damage because of location effects on the tree or because of higher mite densities on fruit that were initially small compared with other fruit. Allen (1979a) made the first attempt to establish a cause-effect relationship between rust mite damage and small fruit size at harvest, and showed that damaged 'Duncan' grapefruit grew slower and their final diameter was smaller than for undamaged fruit. Another effect of rust mite damage is increased fruit drop. Ismail (1971) showed that, after picking, fresh fruit were found to lose water faster and develop an abscission zone more readily if they had rust mite damage. Studies by Allen (1978, 1979b) indicated that fruit drop rates were increased by rust mite damage on 'Valencia' and 'Pineapple' oranges and also on 'Duncan' grapefruit. The objective of our study was to measure the effects of rust mite damage on 'Hamlin' orange fruit growth and drop, and to construct loss models for this variety for use in rust mite management programs.

Materials and Methods

This study was conducted at a commercial citrus grove in Hendry County, FL, from 8 June to 17 December 1991 with 5-yr-old 'Hamlin' orange trees on Swingle rootstock. Fruit were damaged by rust mites a week before the experiment was started, and no subsequent damage occurred. Fruit were chosen to include a range of rust mite damage from 0 to 100% of the fruit surface. Fruit with different amounts of rust mite damage were tagged evenly around each tree to eliminate potential location effects. Every 2–3 wk, transverse fruit diameters were measured with a caliper, fruit surface damage was estimated visually, and fruit drop was recorded. A total of 593 fruit were tagged on 55 trees (10–20 fruit per tree) for both growth and drop studies. An additional 228 fruit (on another 10 trees) were tagged for the drop study only. A follow-up study of correlation of

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fruit size with mite damage was conducted in a 'Hamlin' orange grove of the University of Florida Horticultural Sciences Department in Alachua County in January 1992. Nine trees were chosen, and diameters and damage of all the fruit on each tree were recorded. Mean diameter and mean damage of all the fruit on each tree were obtained.

Data Analysis. *Fruit Drop and Mite Damage.* Fruit were grouped into five equal 20% intervals of percentage surface damage: 0–19, 20–39, 40–59, 60–79, and 80–100%. Mean damage and cumulative rate of fruit drop were calculated for each category based on all the fruit tagged initially. Cumulative percentage fruit drop (y) was fitted to a two-variable logistic function of damage (x) and time (t) with the SAS-NLIN procedure (SAS Institute 1985). The form of the logistic function is

$$y = \frac{100}{1 + \exp(a - (b + cx)t)} \quad (1)$$

A positive value of parameter c would indicate increasing fruit drop with increasing mite damage (x). This function assumes that cumulative percentage fruit drop (y) is logistic and that the rate ($b + cx$) within the logistic is a linear function of damage (x).

Fruit Growth and Mite Damage. To reduce the possible effects of initial diameter differences on fruit growth, we used percentage diameter increase instead of diameter as the growth indicator. Percentage diameter increase for each fruit was obtained using the following formula:

$$\text{percentage diameter increase} = \frac{\text{diameter at sampling date} - \text{initial diameter (8 June)}}{\text{initial diameter (8 June)}} * 100$$

Fruit were grouped into five equal 20% intervals of percentage surface damage: 0–19, 20–39, 40–59, 60–79 and 80–100%. Mean damage and mean percentage diameter increase were calculated for each category. Percentage diameter increase (y) from individual fruit was fitted to a two-variable logistic function of damage (x) and time (t) with SAS-NLIN procedure (SAS Institute 1985). The form of the logistic function is

$$y = \frac{k + \beta x}{1 + \exp(a - (b + cx)t)} \quad (2)$$

A negative value of parameter β would indicate smaller final percentage fruit growth ($k + \beta x$) with increasing mite damage (x). A negative value of parameter c would indicate decreasing percent fruit growth (y) with increasing mite damage (x). This function assumes that percentage fruit growth (y) is logistic and that both the final percentage fruit growth ($k + \beta x$) and the rate ($b + cx$) within the logistic are linear functions of damage (x). The predetermined significance level for testing R^2 (Cornell & Berger 1987) was $P = 0.05$.

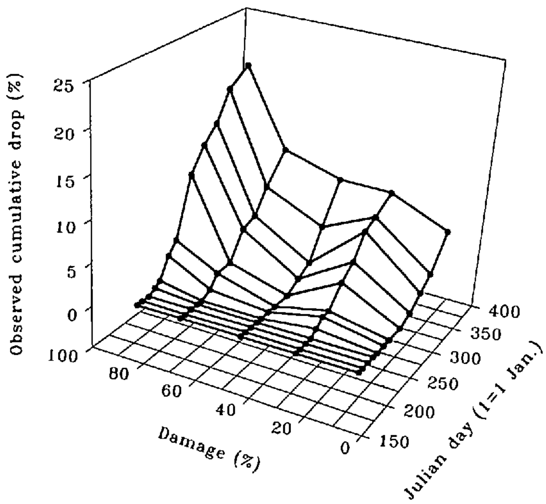

Fig. 1. Observed cumulative fruit drop (percentage) for 'Hamlin' orange fruit with different amounts of rust mite damage (Hendry County, FL, 1991).

Results

Fruit Drop and Mite Damage. Fruit drop rate increased with increasing mite damage, and most drop occurred late in the fruit growing season (Fig. 1). The cumulative drop by 17 December for damage categories 0–19, 20–39, 40–59, 60–79, and 80–100% was 6.4, 9.3, 9.4, 12.6, and 21.0%, respectively. These results were similar to those obtained by Allen (1979b) on 'Valencia' and 'Pineapple' oranges and 'Duncan' grapefruit. Our results also indicated an accelerating fruit drop with increasing mite damage and time (Fig. 1). This effect is illustrated more clearly by fitting equation 1 to the data (Fig. 2). The data-fitted model is

$$y = \frac{100}{1 + \exp(7.230067 - (0.010659 + 0.00007473x)t)} \quad (3)$$

where y = cumulative percentage fruit drop, t = Julian day (1 = 1 January), x = percentage fruit surface damage, $R^2 = 0.8197$ ($P < 0.05$). Notice here that parameter c of equation 1 is positive, indicating increasing fruit drop with increasing mite damage as expected.

Fruit Growth and Mite Damage. Fruit with almost the same initial transverse diameter and different amounts of rust mite damage grew at slightly different rates and diverged slightly with time (Fig. 3). Diameter growth (percentage increase) was always highest for the lowest damage category, and fruit diameters (by 17 December) for damage categories 20–39, 40–59, 60–79, and

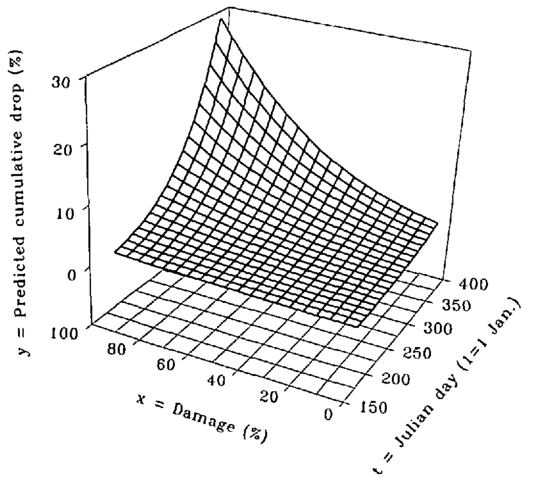

Fig. 2. Predicted cumulative fruit drop (percentage) for 'Hamlin' orange fruit with different amounts of rust mite damage (see equation 3 in text).

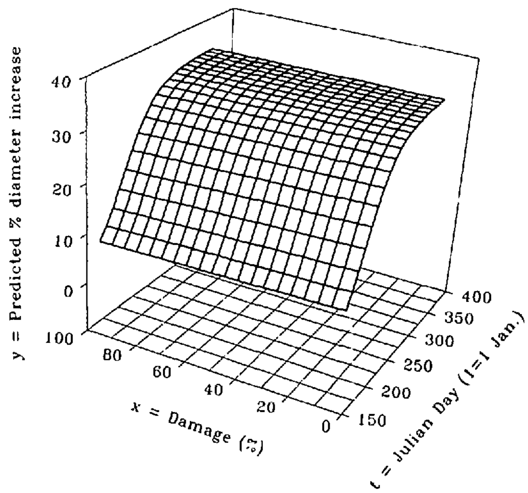

Fig. 4. Predicted transverse diameter increase (percentage) of 'Hamlin' orange fruit with different amounts of rust mite damage (see equation 4 in text).

80–100% grew 2.6, 2.5, 2.4, and 1.7% less, respectively, than that of the lowest category (Fig. 3). The overall data suggested a slight negative relationship between final fruit size and mite damage (Fig. 3). This effect is demonstrated in the data-fitted percentage diameter increase model (Fig. 4). Fitting to the data, we obtained the following parameterized form of equation 2:

$$y = \frac{33.73 - 0.0108x}{1 + \exp(7.994361 - (0.039723 - 0.00000916x)t)} \quad (4)$$

where y = percentage increase in fruit diameter, t = Julian day (1 = 1 January), x = percentage fruit surface damage, $R^2 = 0.8405$ ($P < 0.05$). Notice here that parameter β and c of equation 2

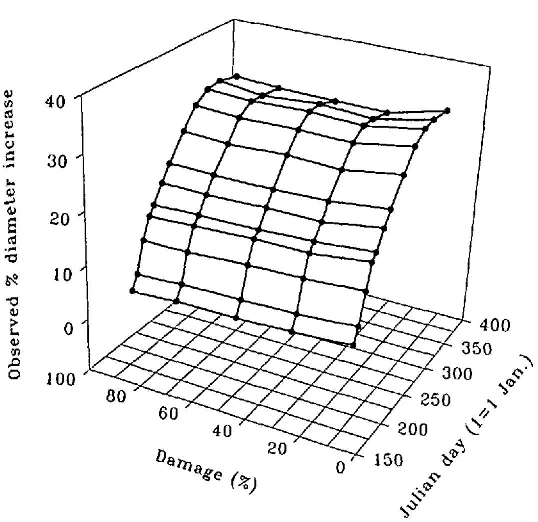

Fig. 3. Observed transverse diameter increase (percentage) of 'Hamlin' orange fruit with different amounts of rust mite damage (Hendry County, FL, 1991).

are both negative, indicating a negative effect of mite damage on fruit growth.

Discussion

A study by Allen (1979a) on the effect of mite damage on 'Duncan' grapefruit growth showed a greater size reduction than in our 'Hamlin' orange study. In the grapefruit study, size reduction resulted from growth divergence of the damage categories during June, July, and August (the primary period of fruit expansion). Timing of damage in relation to the fruit growth cycle is important. In our study, most of the fruit growth terminated ≈3 mo after damage had occurred ('Hamlin' is an early maturing variety), and differences in mean diameter among damage categories were not as pronounced as in the case of 'Duncan' grapefruit (Allen 1979a). One reason for this is that the remaining diameter growth following the damage for the 'Hamlin' oranges in this study was ≈30% as compared with 50–80% remaining growth for the 'Duncan' grapefruit (Allen 1979a). Late-season (January 1992) observations on 'Hamlin' oranges at the University of Florida Horticultural Science Department grove showed a strong negative correlation of fruit size with mite damage (Fig. 5). This is probably due to fruit shrinkage from water loss. It is known that water loss from fruit is exacerbated (approximately a three-fold increase) by rust mite damage both on and off the tree (Ismail 1971; McCoy et al. 1976; Allen 1978, 1979a) and is apparently worse on small rootstock systems than on large ones (Allen 1979a). Thus, water stress may be the mechanism responsible for increased fruit drop with mite damage.

Because rust mite damage is associated with increased water loss, future research might ex-

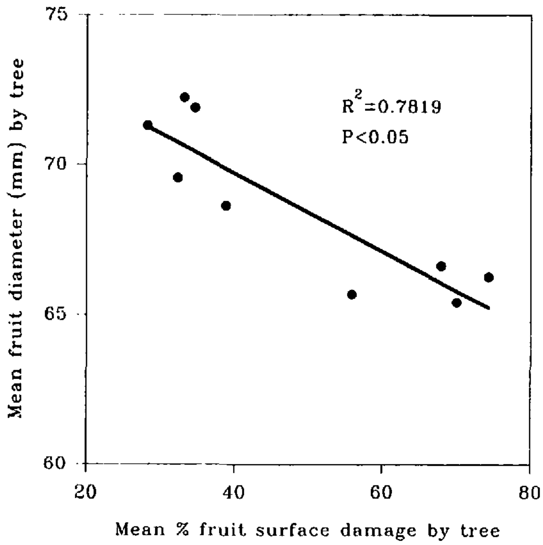

Fig. 5. Mean fruit surface damage plotted against mean fruit diameter by tree for nine 'Hamlin' orange trees (Gainesville, FL, January 1992).

amine the possibility of reducing yield loss by minimizing water stress on damaged fruit. That is, can we reduce pesticide usage and maintain yield by substituting water management for rust mite management? Further studies should also look for differences between early and late-season mite damage on fruit growth and drop and on the effects of leaf damage on yield. The fruit growth and drop models developed in this study will be used to estimate yield loss (percentage volume) from rust mite damage. The difference between the yield loss and cost of mite control will determine whether control action at a certain time is economically justified in a given grove.

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