Comparison of Feeding Damage Caused by Four Tetranychid Mite Species on Gas-exchange Rates of Almond Leaves

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ABSTRACT A dual-isotope porometer measured gas-exchange rates on almond leaves exposed to feeding damage by Panonychus citri, P. ulmi, Tetranychus pacificus, or T. urticae. The feeding injury of all four mite species caused significantly lower rates of stomatal conductance, mesophyll conductance, and photosynthesis compared with undamaged controls. No significant differences in gas-exchange rates occurred between species within either genus; however, significant differences between genera were detected. Tetranychus spp. caused lower rates of mesophyll conductance and photosynthesis when compared with Panonychus spp.

AN IMPORTANT COMPONENT in the development of any pest-management program is the quantification of the damage potential of each pest species. This information is necessary in constructing sampling plans and in estimating economic thresholds. The task of categorizing the damage potential of two or more co-occurring pest species is often difficult, especially when considering foliage feeding arthropods bearing styletlike mouthparts. When quantitative data are lacking, the usual procedure is to rate the damage potential of each pest species equally. The inaccuracy of this approach is demonstrated in the study by Flaherty and Huffaker (1970) on the Pacific and Willamette mite complex on grapes which showed that the Willamette mite, unlike the Pacific spider mite, does not often reach significant pest status. The authors stated that, before their work, both mite species were considered serious pests on grapes.

Andrews and Barnes (1981) conducted a 2-year survey of mites on almonds in the southern San Joaquin Valley and found that populations of several species occur simultaneously in the same orchard, and different species may be dominant in different localities.

Several recent studies on almonds have reported reductions in both yield (Barnes and Andrews 1978, Welter et al. 1984) and photosynthesis (Andrews and LaPre 1979, Welter 1981, Youngman 1984) from tetranychid mite feeding damage. These studies, however, focused on either a single mite species or assumed that no differences existed in the damage potential of the mite species present in the study. Because of the lack of information in the literature on differences in damage potential for these mites, a comparative study was conducted to test the null hypothesis that the effects of feeding of equal density and duration by four different mite species on almonds, are equivalent in terms of almond leaf gas-exchange rates.

Materials and Methods

Six 'Mission' variety almond trees were selected on the basis of healthy appearance and uniformity of size from a population of 40 'Mission' trees grown in 45.4-liter plastic containers. The trees were ca. 1 year old and were grown in a greenhouse at the University of California at Riverside (UCR). Before and during the experiment, trees were maintained on a regular water and fertilizer schedule. Each tree served as a complete block within which the five treatments—including five single-leaf subsamples per treatment—were randomly assigned. The five treatments comprised a mite-free control and feeding damage by the citrus red mite, the European red mite, the Pacific spider mite, and the twospotted spider mite.

Citrus red mites were collected in May 1983, from leaves on lemon trees at the Citrus Research Center in Riverside, Calif., and were subsequently maintained in a greenhouse on 'Nonpareil' almond trees. A colony of European red mites was established in May 1983 from almond trees in a Tulare County orchard, and these were cultured in the same manner as the citrus red mites. The Pacific mites were obtained from a large greenhouse colony on 'Henderson' lima beans at UCR which had been in culture since 1951. The twospotted spider mites were collected in November 1982 from a bedding plant nursery in Carson, Calif., and reared on 'Henderson' lima beans at UCR.

The mites were confined to the upper surface of the test leaf in an arena constructed from three
layers of masking tape that enclosed an area of 3.24 cm². A bead of vaseline petroleum jelly was placed on top of the masking tape, which served as a barrier to mite escape.

On 8 June 1983, six adult female mites were placed in each arena between 2:00 and 4:00 p.m. The mites fed for a period of 6.8 days during which time each of the 150 arenas was checked daily for stuck or missing mites. A missing mite was replaced with two females of the same species and one female was removed 24 h later. This manner of replacement was chosen because those mites which became stuck usually did so shortly after being placed in the arena. After the feeding period was completed, all of the mites were removed with a damp sponge.

On the day following removal of the mites, the trees were moved out of the greenhouse and placed in direct sunlight and watered. The trees were left from 8:30 to 11:30 a.m. to equilibrate to the surrounding environment. From 11:30 a.m. to 1:30 p.m., gas-exchange measurements were taken directly on the leaf tissue within the arena with a dual-isotope porometer (Johnson et al. 1979). All leaves were sampled in direct, saturated sunlight as determined with a quantum/radiometer/photometer (LI-COR LI-185A). Air-temperature and light-intensity readings were made at 20-min intervals during the sampling period. Air temperature is used in calculating total conductance to isotopic water vapor (THO) and ¹⁴CO₂.

After a leaf had been exposed to the isotopic airstream for a 20-s interval, it was detached from the tree, and a 0.57 cm² disc was removed from within the area of the arena and placed in a glass vial containing 1 ml of cold 80% methanol. The vial was then transferred to an ice chest to reduce evaporation of the methanol. All vials were kept refrigerated until the activity of both isotopes in each sample could be determined. This was accomplished using standard liquid scintillation counting techniques.

The dual-isotope porometer functions on the principle that THO and ¹⁴CO₂ diffuse into the stomata in direct relation to stomatal conductance to H₂O and CO₂. The THO vapor diffuses into the leaf according to its own concentration gradient and equilibrates with the liquid water phase of the cells within the substomatal chamber (Johnson et al. 1979). At the same time, ¹⁴CO₂ diffuses into the leaf along the same pathway as the THO vapor, but continues to pass through cell walls and membranes into the chloroplasts where photosynthesis takes place. Thus, photosynthesis is based on the total conductance of CO₂, which consists of both stomatal and mesophyll conductance to CO₂. Since the leaf is exposed to both isotopic gases simultaneously, stomatal conductance to ¹⁴CO₂ can be calculated from stomatal conductance to THO by multiplying the latter by the diffusion coefficient of CO₂ divided by the diffusion coefficient of H₂O. Mesophyll conductance to ¹⁴CO₂ can then be obtained by subtracting stomatal conductance to ¹⁴CO₂ from the total conductance to ¹⁴CO₂.

Stomatal conductance to THO, rather than transpiration, is reported in this study because it is less influenced by changing ambient conditions, making it a better indicator of stomatal opening.

A two-way analysis of variance was performed on the data that included partitioning the treat-
Table 2. Treatment means for each of the three gas-exchange parameters on ‘Mission’ almond leaves

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Stomatal conductance (cm/s)</th>
<th>Mesophyll conductance (cm/s)</th>
<th>Photosynthesis (µg CO₂/dm²/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>µ ± SE</td>
<td>µ ± SE</td>
<td>µ ± SE</td>
</tr>
<tr>
<td>Control</td>
<td>0.987 ± 0.07 (100)</td>
<td>0.236 ± 0.01 (100)</td>
<td>31.4 ± 0.84 (100)</td>
</tr>
<tr>
<td><em>P. citri</em></td>
<td>0.901 ± 0.07 (91.3)</td>
<td>0.225 ± 0.01 (95.3)</td>
<td>29.6 ± 1.14 (94.3)</td>
</tr>
<tr>
<td><em>P. ulmi</em></td>
<td>0.896 ± 0.06 (90.7)</td>
<td>0.207 ± 0.02 (87.7)</td>
<td>27.9 ± 2.13 (88.8)</td>
</tr>
<tr>
<td><em>T. urticae</em></td>
<td>0.838 ± 0.04 (84.9)</td>
<td>0.202 ± 0.01 (85.5)</td>
<td>27.0 ± 1.23 (86.0)</td>
</tr>
<tr>
<td><em>T. pacificus</em></td>
<td>0.788 ± 0.04 (79.9)</td>
<td>0.190 ± 0.01 (80.4)</td>
<td>25.4 ± 1.30 (80.9)</td>
</tr>
</tbody>
</table>

Means are based on 30 observations from 6 trees, using 5-leaf sub-samples per tree; percent of the control is indicated in parentheses.

Results

Feeding of all four mite species caused significantly lower rates of stomatal conductance, mesophyll conductance, and photosynthesis of almond leaves compared with undamaged control leaves (*P* < 0.05) (Table 1). There were no differences in the effects produced by different species within the same genus, but mites from different genera had different effects (Table 1). After 6.8 days of feeding (Table 2), *Tetranychus* spp. caused average reductions in mesophyll conductance and photosynthesis of 17 and 16.6%, respectively, compared with reductions by *Panonychus* spp. of 8.5 and 8.4%, respectively.

The percentage reductions for stomatal and mesophyll conductances (Table 2) indicate that feeding by *Tetranychus* spp. mites affected the mesophyll cell layer and stomata equally. *P. citri*, however, appeared to have a slightly greater effect on the stomata than on the mesophyll cells. Overall, the feeding damage of *P. citri* had the least effect on almond leaf photosynthetic rates, causing a reduction of 5.7%. This is in contrast to *T. pacificus* which had the greatest effect on photosynthesis reducing it 19.1% (Table 2).

Discussion

That almond leaves proved to be affected to a lesser extent by the *Panonychus* spp. compared with the *Tetranychus* spp. may, in part, be related to differences in physiological and metabolic requirements. In a review of the literature on the biometrics of tetranychid mites, van de Vrie et al. (1972) stated: “Although considerable variation is evident... the reproductive potential of this mite (*Panonychus ulmi*) is lower than that of many *Tetranychus* species.” This same variation and relatively low (mean = 38 eggs per female) reproductive rate (compared with ca. 100 reported by van de Vrie et al. [1972] for *T. urticae* and *T. pacificus*) was also found by Jones and Morse (1984) in a review of temperature-dependent develop-

ment of *P. citri*. Thus, among the *Panonychus* spp., a generally lower reproductive rate may be linked to a less vigorous feeding rate. This could account for the reduced impact on gas exchange of almond leaves by the *Panonychus* spp. demonstrated in this study.

It may be argued that the results reported for *T. pacificus* are not representative of field-collected mites due to the excessive period of time spent in a laboratory colony on lima beans. However, evidence supporting the lack of differences between *T. pacificus* and *T. urticae* was shown in a similar study (Marcano-Brito 1980) on cotton in which a dual-isotope porometer was also used. Cotton leaves were exposed to various densities of newly established colonies of *T. pacificus*, *T. turkestani*, and *T. urticae* for a period of 7 days. At the highest density level of 160 mites per leaf, both *T. pacificus* and *T. urticae* caused similar (nonsignificant) reductions in photosynthesis of 25%. *T. turkestani*, however, significantly reduced photosynthesis by 64% which was not unexpected given the apparent induction of a toxic reaction in cotton from low population levels of *T. turkestani* reported by Leigh (1963).

The reduced impact on gas exchange of almond leaves exhibited by *P. citri* may be that it is less adapted to almond foliage. Unlike the other three mite species, *P. citri* does not undergo diapause (van de Vrie et al. 1972) and, therefore, can only overwinter on foliage of nondeciduous plants such as citrus. Andrews and Barnes (1981) found that infestations in almonds are initiated by citrus red mite individuals which balloon in from nearby citrus orchards during the spring months.

On almond leaves, Summers and Stocking (1972) estimated that feeding by *Bryobia rubrioculis* on the upper leaf surface affected >200 palisade cells within a 30-min interval. A more recent study on almond leaves by Welter (1981) demonstrated that feeding by *T. pacificus* confined to the lower leaf surface resulted in a collapse of cells in both the spongy and palisade mesophyll cell layers.

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