Effect of Selected Acaricides on Photosynthetic Rates of Lemon and Orange Leaves in California

V. P. JONES, R. R. YOUNGMAN, AND M. P. PARRELLA
Department of Entomology, University of California, Riverside, California 92521

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ABSTRACT The “Riverside” dual-isotope porometer was used to measure the change in photosynthetic rates of mature ‘Lisbon’ lemon, Citrus limon (L.) Burmann, and ‘Valencia’ orange, Citrus sinensis (L.) Osbeck, leaves after acaricide application. Initial changes in photosynthetic rate were attributed to an alteration of stomatal conductance, whereas on the later sampling date they were caused by changes in mesophyll conductance. The implications of pesticide effects on photosynthetic rate of citrus and the selection of pesticides for use in citrus pest management programs are discussed.

Lemons and oranges in California had a total estimated worth in 1980 of ca. $380 million (McGregor et al. 1982). Although good biological control of the major mite pests of these crops has generally been achieved, ca. 1.9 million kg (AI) of synthetic acaricides was applied for control of the major mite pests, and ca. 2.1 million kg of oil was applied for mite and insect pests in 1980 (Anonymous 1981). The majority of these acaricide applications were for control of three pest species: citrus red mite, Panonychus citri (McGregor) (Tetranychidae) (one to three applications per year) citrus rust mite, Phyllocoptera oleivora (Ashmead) (Eriophyidae) (one to two applications per year), and citrus bud mite, Eriophyes sheldoni Ewing (Eriophyidae) (one application per year).

The effects of pesticidal oils on citrus have been intensely investigated and have been associated with yield loss, reduction in photosynthesis and transpiration, and fruit coloration problems (Knight et al. 1929, Wedding et al. 1952, Riehl et al. 1954, Riehl and Wedding 1959, McMillan and Riedhart 1964, Dean et al. 1978). The negative aspects of pesticidal oils have prompted the use of synthetic acaricides for control of mite pests. Acaricides successfully protect the crop from mite damage, but at present there is little knowledge of the effect of these compounds on citrus physiology. In this study, we evaluated several specific acaricides and Narrow range 440 (NR-440) (Carman et al. 1980) oil for their effect on photosynthetic rates of ‘Lisbon’ lemon, Citrus limon (L.) Burmann, and ‘Valencia’ orange, Citrus sinensis (L.) Osbeck, leaves.

Materials and Methods

Two experiments were conducted in mite-free plots selected at the University of California’s Citrus Research Center in Riverside. The first study, undertaken in spring 1982, consisted of 32 15-year-old lemon trees arranged in a randomized block design (RBD) with four treatments, eight single tree replicates, and six samples per tree. The treatments were (per 100 liters of water): proparpargite 30W (0.136 kg of AI), dicrof 1.6E (0.048 kg of AI), NR-440 oil (1.2 liters), and a water check. One application of each material was made to the trees (ca. 37.8 liters per tree) by handgun at 450 lb/in² until runoff. Tree tops were not sprayed in order to minimize drift. A second study was undertaken in the fall of 1982 on 30 17-year-old orange trees in a RBD with five treatments, six replicates, and 10 samples per tree. The treatments were (per 100 liters water): dicrof 1.6E (0.048 kg of AI), fenbutatin-oxide 50W (0.022 kg of AI), NR-440 oil (1.2 liters), and oxythioquinox 25W (0.037 kg of AI) and a water check. The trees were sprayed as before, except that the north-facing sides of the trees were not sprayed to further reduce drift. Pesticides were applied at rates recommended by the University of California’s treatment guide for control of the citrus red mite (Carman et al. 1980).

The Riverside porometer described by Johnson et al. (1979) was used to take simultaneous measurements of ¹⁴CO₂ and tritiated water (THO) uptake. The uptake of carbon-14 quantifies photosynthetic rate; THO uptake is related to stomatal conductance, which is an indicator of stomatal opening. Since the rate of uptake of both isotopes is measured simultaneously, the pathway of carbon uptake can be partitioned further into mesophyll conductance. Mesophyll conductance can be defined as total conductance to CO₂ minus stomatal conductance to CO₂, as calculated from THO uptake. Therefore, mesophyll conductance reflects the resistance CO₂ encounters as it moves from the substomatal chamber into the mesophyll where the biochemical reactions of photosynthesis occur. Decreases in mesophyll conductance are viewed as internal leaf damage. Changes in mesophyll or stomatal conductances can cause changes in the photosynthetic rate (Sances et al. 1982).

Porometer determinations were made at 4 and 12 days postspray on lemon and 3 and 11 days postspray on orange. Leaf samples in both studies were taken between 10 a.m. and 3 p.m. on the west, south, and east portions of the outer canopy ca. 1 to 2 m from the ground; all leaves were in direct, saturated sunlight as determined by a Li-Cor quantum-radiometer-photometer.² Variation in the physiological parameters caused by time of day were controlled by using time (ca. 40-min intervals) as a blocking factor in a balanced complete-block design.

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²Li-Cor, Inc. Lincoln, NE 68504.
Table 1. Effect of selected acaricides on physiological parameters of ‘Lisbon’ lemon, Riverside, Calif., Spring 1982

<table>
<thead>
<tr>
<th>Treatment</th>
<th>4 Days postspray</th>
<th>12 Days postspray</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stomatal conductance (cm/sec)</td>
<td>Mesophyll conductance (cm/sec)</td>
</tr>
<tr>
<td>Propargite</td>
<td>0.255 (94.4)a</td>
<td>0.037 (86.1)a</td>
</tr>
<tr>
<td>Water</td>
<td>0.270 (100)a</td>
<td>0.043 (100)a</td>
</tr>
<tr>
<td>NR-440</td>
<td>0.262 (97.0)a</td>
<td>0.042 (97.6)a</td>
</tr>
<tr>
<td>Dicofol</td>
<td>0.278 (103.5)a</td>
<td>0.043 (100)a</td>
</tr>
</tbody>
</table>

*Mean of eight single-tree replicates (six samples per tree), followed by the percent water control in parentheses. Means within a column followed by the same letter are not significantly different, by ANOVA and Duncan’s multiple range test at P = 0.10.

Table 2. Effect of selected acaricides on physiological parameters of ‘Valencia’ orange, Riverside, Calif., Fall 1982

<table>
<thead>
<tr>
<th>Treatment</th>
<th>3 Days postspray</th>
<th>11 Days postspray</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stomatal conductance (cm/sec)</td>
<td>Mesophyll conductance (cm/sec)</td>
</tr>
<tr>
<td>Fenbutatin-oxide</td>
<td>0.107 (112.2)a</td>
<td>0.154 (91.9)a</td>
</tr>
<tr>
<td>Dicofol</td>
<td>0.074 (77.5bc</td>
<td>0.045 (26.9)a</td>
</tr>
<tr>
<td>Water</td>
<td>0.095 (100ab)</td>
<td>0.168 (100a)</td>
</tr>
<tr>
<td>Oxythioquinox</td>
<td>0.080 (83.3bc)</td>
<td>0.128 (76.1a)</td>
</tr>
<tr>
<td>NR-440</td>
<td>0.062 (64.8c)</td>
<td>0.114 (67.8a)</td>
</tr>
</tbody>
</table>

*Means are average of six single-tree replicates (10 samples per tree; percent water control indicated in parentheses. Means followed by the same letter are not significantly different, by ANOVA and Duncan’s multiple range test at P = 0.10.

Analysis of variance (ANOVA). Duncan’s multiple range test was used to separate treatment means.

Results

There were no significant differences at 4 days postspray in stomatal conductance, mesophyll conductance, or rate of photosynthesis of lemon leaves (Table 1). Dicofol increased stomatal conductance and photosynthesis slightly (3.5 and 0.4%, respectively) compared with the water check, whereas propargite and the NR-440 oil treatments decreased both measurements slightly. These data are in contrast with the work of Wedding et al. (1952) which showed that, on ‘Eureka’ lemon, medium-grade oil caused the greatest reductions in photosynthesis and transpiration 2 days after application. However, their work was done with plants grown in a greenhouse, and photosynthesis and transpiration rates were determined with a Warburg respirometer.

The propargite treatment, even though it showed visible phytotoxicity to younger lemon leaves, caused mesophyll conductance and photosynthetic rates that were significantly higher than results of all other treatments at the 12-day sample (26.8 and 26.6% increase over the water controls, respectively) (Table 1). Therefore, visible phytotoxicity cannot always be used as an indicator of biochemical phytotoxicity. In a crop such as citrus where the fruit is the marketed commodity, visible damage to the leaf is not important, provided long-term physiology (and productivity) of the plant is not adversely affected. NR-440 and dicofol decreased both photosynthesis and mesophyll conductance slightly, but not statistically so, compared with the water check.

Acaricides had a greater effect on the photosynthetic rate of orange leaves than on lemon leaves (Table 2). Both stomatal conductance and photosynthetic rate were slightly higher in the fenbutatin-oxide treatment compared to the water treatment at 3 days postspray (12 and 9%, respectively). Values of both parameters were significantly higher than those of other treatments. Leaves treated with oxythioquinox and dicofol were slightly lower than those sprayed with water in stomatal conductance (16.7 and 22.5%, respectively) and photosynthetic rate (12.3 and 21.8%, respectively). After 3 days, stomatal conductance and photosynthetic rates of leaves treated with NR-440 were significantly lower than the water check.

Leaves treated with fenbutatin-oxide and dicofol were significantly higher in mesophyll conductance and photosynthetic rate compared with those treated with oxythioquinox or NR-440 at 11 days postspray (Table 2). Oxythioquinox and NR-440 oil decreased photosynthetic rate and mesophyll conductance ca. 21%. However, the effect of the NR-440 oil decreased as shown by difference in percent reduction of photosynthesis on day 3 compared with day 11 (31.8 to 20.7%). In contrast, the reduction in photosynthesis due to the oxythioquinox treatment actually increased slightly from 12.3 to 20.6% between sampling dates. Therefore, the NR-440 oil treatment may be the better choice of the two materials if they are equally efficacious against the same mite species.
Discussion

Ferree (1979) reviewed the effect of pesticides on photosynthesis of crop plants and concluded that inhibition of photosynthesis by spray oils results from a mechanical interference with gaseous exchange. Baker (1970) stated that mechanical interference was important, but thought that additional explanations such as internal leaf damage or inhibition by accumulation of end products could also contribute to reduced photosynthesis. Our study shows that the initial change in photosynthetic rate results from an alteration in stomatal conductance, followed several days later by a change in mesophyll conductance. This is seen most clearly with orange leaves (Table 2), where, at 3 days postspray, stomatal conductance was significantly different among treatments and mirrored the change in photosynthetic rate, whereas mesophyll conductance was not affected significantly. The reverse occurred at 11 days postspray; there were no significant differences in stomatal conductance, but mesophyll conductance showing significant differences which paralleled the changes in photosynthetic rate. Lemon leaves showed no significant change in photosynthetic rate, mesophyll, or stomatal conductance at 4 days postspray. However, at 12 days postspray, when a significant difference in photosynthetic rate was detected, mesophyll conductance again was significantly lower. The work of LaPre et al. (1982) demonstrated a similar trend on strawberry; acaricide-induced changes in stomatal conductance were temporary, and with one compound, long-term reductions in mesophyll conductance were observed.

Our study shows that the same pesticide may have a different effect on closely related plants (even within the same genus), so that generalizations about a pesticide effect between different species could lead to errors (e.g., the comparative effect of dicofol on lemon and orange). Further testing is required to determine whether the active ingredient or the formulation causes the change in photosynthetic rates, and how long these effects last. Since these formulated materials did show an effect on photosynthetic rates, the choice of a pesticide (or perhaps the formulation) should be based not only on the efficacy against the pest and effect on natural enemies, but also on changes in photosynthetic rate. Also, changes in photosynthetic rate should be considered when economic injury levels are calculated, since the total damage that the plant can withstand is a function of the pesticide effect as well as the damage caused by the pest. Toscano et al. (1982) concluded that the phytotoxic effects of certain compounds on lettuce were severe enough to warrant consideration of a pesticide threshold for that crop. Further studies designed to correlate change in photosynthetic rate and change in yield on citrus are necessary to integrate pesticide effects into economic injury levels.

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REFERENCES CITED