THE SUBLETHAL EFFECTS OF SELECTED INSECTICIDES ON LIFE TABLE PARAMETERS OF PANONYCHUS CITRI (ACARI: TETRANYCHIDAE)

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Abstract


Populations of the citrus red mite, Panonychus citri (McGregor), reared on “rough lemon” seedlings (Citrus limon (L.) Burm.) in a greenhouse and treated with malathion or permethrin were significantly higher than those on untreated seedlings. Significant increases were demonstrated in age-specific fecundity ($m_0$), mortality corrected $m_0$, ($l$, $m_0$), and net reproductive rate ($R_0$) values for mites reared in the laboratory on leaves treated with malathion or permethrin when compared with those reared on untreated leaves. Mites reared on oxamyl-treated leaves exhibited significant reductions in age-specific survivorship ($l_0$), $m_0$, $l_m$, and $R_0$ values compared with those reared on untreated leaves. The importance of reproductive stimulation in relation to other causes of pest resurgence is discussed.

Résumé

Des populations de la mite Panonychus citri maintenues sur des plantules de citronnier “rough lemon” (Citrus limon (L.) Burm.) en serres et traitées au malathion ou à la perméthrine, se sont avérées plus nombreuses que celles maintenues sur des plantules non traitées. Des différences significatives ont pu être mises en évidence quant à la fécondité spécifique de l’âge ($m_0$), la fécondité corrigée pour la mortalité ($l_m$) et le taux net de reproduction ($R_0$), entre des mites maintenues au laboratoire sur du feuillage traité au malathion ou à la perméthrine, et des mites maintenues sur du feuillage non traité. Des mites maintenues sur du feuillage traité à l’oxamyle ont montré des réductions significatives de la survie spécifique de l’âge ($l_0$), et des valeurs de $m_0$, $l_m$, et $R_0$, par rapport à celles maintenues sur du feuillage non traité. L’importance d’une stimulation de la reproduction, en regard des autres causes de résurgence des nuisibles, est commentée dans la discussion.

The rise of tetranychid mites to worldwide pest status following World War II has often been attributed to increased use of synthetic organic insecticides which came into general use at that time (Gunther and Jeppson 1960; Chant 1966; Huffaker et al. 1970). The three main theories used to explain this rise in pest status are: (1) predator inhibition by pesticide application, (2) improved host plant condition, either from improved fertilization and pruning practices or pesticide-induced changes in plant physiology (trophobiology), and (3) direct stimulation of the mite by sublethal doses of a pesticide (hormoligosis) (Huffaker et al. 1970).

Previous field experiments (Fleschner 1952; Jones 1983) have shown that under certain conditions resurgence of citrus red mite populations (Panonychus citri (McGregor)) can occur following pesticide application. The studies reported herein were initiated to determine and characterize which of the above theories could best explain resurgence of P. citri populations. We accomplished this by: (1) studies in the laboratory to determine if changes in life table parameters occur when mites are exposed to sublethal pesticide residues, and (2) greenhouse studies of populations reared on sublethal pesticide residues in the absence of predators to determine if predator inhibition is necessary for pest resurgence to occur.

Materials and Methods

The mites used for both experiments were from a stock culture whose parental line was originally collected from lemon in the Oxnard area of Ventura county in May 1982 from a grove under normal control practices (oil for scale control, chlorobenzilate sprays for citrus rust mite (Phyllocoptruta oleivora (Ashmead)) (Eriophyidae) and citrus bud mite
(Eriophyes sheldoni Ewing) (Eriophyidae) control, and dicofol (or oil) for control of citrus red mite). Mites were reared in the laboratory following the method of Reed (1971).

**Laboratory experiments.** Laboratory studies were performed from the fall of 1982 to early 1983 with the following treatments (rates in Al/100 L water): permethrin 2E (0.83 mL), malathion 25WP (71.8 g), oxamyl 2 L (3.1 mL), and a water control. Materials and methods for the three trials of this study were identical except as noted below. Lemon leaves of a uniform age and size were collected from untreated trees and brought to the laboratory where they were washed with a sponge and distilled water to remove debris. The dry leaves were dipped for 3 sec into their respective treatment solutions, dried and placed ventral side up in a Munger cell (Munger 1942) measuring 3.5 × 8.0 cm with a 19 mm diameter circular arena. A layer of cellucotton was placed between the cell top and the leaf to create a water barrier to prevent the mites from leaving the cell. The cells
were placed on a 7 mm thick water saturated foam rubber pad in a large porcelain coated pan (52 × 32 cm) and held at a temperature of 27°C in an environmentally controlled chamber at ca. 80% R.H. with constant light.

Larvae were removed from the stock culture and reared (3–4/cell) on treated leaves until the teliochrysalis stage at which time the teliochrysalids were confined in separate cells on treated leaves with two mature colony males to ensure mating. The treatments were considered sublethal because survivorship to the teliochrysalis stage was ca. 90%. Each cell was considered a replicate and was checked daily for egg production and mortality.

The first trial consisted of 6 replicates per treatment; percentage female offspring was determined by rearing the F₁ progeny to the adult stage. The second trial had 10 replicates and percentage female offspring was determined only for progeny laid on days 3 and 4 of each adult females life. The third trial consisted of 15 replicates and the percentage female progeny was not determined. Leaves within the cells were exchanged every other
day for freshly collected and treated leaves (except in trial 1 when they were changed daily) to minimize the possibility that the pesticides would affect leaf chemistry.

Data from all three trials were analyzed collectively to obtain large enough sample sizes for calculation of \( l_e \) (surviorship curve), \( m_e \) (no. of female eggs produced per female), \( l_m \) (mortality corrected \( m_e \)), and cumulative \( l_m \) (Birch 1948). Differences between each treatment and the water control were tested by use of paired \( t \) tests (Steel and Torrie 1980) with day of adult life being used as the pairing factor. An arcsin \( X^{1/2} \) transform was used prior to analysis of percent female data because of the wide range of values encountered (Steel and Torrie 1980). All other laboratory analyses were based on untransformed data.

**Greenhouse experiments.** Two greenhouse experiments were conducted during the fall of 1982. The first experiment was performed on 30 "rough lemon" (Citrus limon (L.) Burmann) seedlings ca. 0.3 m high growing in 4-L containers and pruned so that only 9

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**Fig. 3.** Comparison of the water check and sublethal insecticide treatments on age-specific production of female offspring (\( l_m \)).
leaves per tree remained. Each tree was fertilized weekly with 45 mL of a modified Hoagland's fertilizer (Jones 1983) which was diluted with ca. 450 mL water. The experiment consisted of 5 treatments with 6 replicates in a completely random design. The treatments included (rates in Al/100 L water): chlorobenzilate 4E (3.7 mL), permethrin 2E (0.83 mL), malathion 25WP (71.8 g), oxamyl 2 L (3.1 mL), and a water control. Plants were sprayed to run-off at 60 psi with a 4-L hand sprayer. Three days following treatment application, two adult female citrus red mites ca. 3 days old were introduced per leaf. Populations were sampled by examining each leaf with a 5-power binocular magnifier for all motile stages 8, 15, and 23 days after introduction. The second experiment used 24 rough lemon seedlings ca. 1-m high which were grown in 8-L containers and pruned as before. There were 4 treatments with 6 replicates in a completely random design. The same materials and methods as above were used except that chlorobenzilate was omitted from the test and populations were sampled at 8, 14, and 19 days post-introduction. Temperatures were continuously monitored in both experiments with a Bendix model 594 hygrothermograph. Analysis of variance and Duncan's new multiple range test were used to compare treatment means.

Results

Laboratory experiments. Life table analysis showed significant reductions in % l, m, l,m, and cumulative l,m, values for mites reared on the oxamyl-treated leaves compared with the water control (Figs. 1–4). The % l, curve showed a decreased survivorship in mid-adult life and the m, l,m, and cumulative l,m, curves were significantly lower throughout the total life span. The R, value (net reproductive rate) for mites reared on oxamyl residues was 11.74 compared with 23.4 for mites on the water control (significant at P < 0.05) and the percentage female (43.6), mean longevity (7.0 days), and mean oviposition period (3.8 days) were all significantly lower (P < 0.05) than the same values for mites on the untreated leaves (63.9%, 8.6 days, and 7.1 days, respectively).

The % l, curve for mites reared on permethrin residues was nearly identical with that of mites reared on untreated leaves (Fig. 1). However, the m, l,m, and cumulative l,m, curves for the treated mites were significantly higher than those for the untreated mites beginning the third day of female life and continuing through the entire life span (Figs. 2–4). The R, value of 30.31 was significantly higher than that of the water check (P < 0.05) while the percentage females (67.1), life span (8.6 days), and mean oviposition period (6.6 days) were not significantly different from those of the water control.

Mites reared on malathion residues exhibited reduced survivorship in mid-adult life, and an increased survivorship in late adult life compared with mites on the untreated leaves. The divergence in the m, l,m, and cumulative l,m, curves from those observed on the untreated leaves became statistically significant beginning on day 4 and continued for the rest of the adult life (Figs. 2–4). The R, value of 29.26 was significantly higher (P < 0.05) than the value obtained for mites from the untreated control. The percentage females (70.6), mean adult life span (8.5 days), and mean oviposition period (7.0 days) were not significantly different from values obtained in the water control.

Greenhouse experiments. In the first experiment, the mean number of motile mites per leaf on the permethrin- and malathion-treated trees were significantly higher than those in the water control at 15 days post-introduction (Table 1). At 23 days, only the permethrin treatment was significantly different from the water control; oxamyl, chlorobenzilate, and malathion treatments were only slightly (not statistically) higher than the water control.

In the second experiment, the numbers of motile mites per leaf on the later sampling dates were much higher than those in the first experiment. This was not due to temperature (daily temperatures being very similar during both experiments) but can probably be explained by differences in age and suitability of the foliage (Fleschner 1952). The malathion
Fig 4. Comparison of the water check and sublethal insecticide treatments on the cumulative production of female offspring ($\Sigma l.m_i$).

Table I. Effect of selected pesticides on the population levels of Panonychus citri in the absence of predators in the first greenhouse experiment

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean no. mites per leaf$^1$ (days after introduction)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Permethrin</td>
<td>2.0 a</td>
</tr>
<tr>
<td>Malathion</td>
<td>2.0 a</td>
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<tr>
<td>Oxamyl</td>
<td>2.0 a</td>
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<tr>
<td>Chlorobenzilate</td>
<td>2.0 a</td>
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<tr>
<td>Water</td>
<td>2.0 a</td>
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</tbody>
</table>

$^1$Mean of 6 single replicate trees, each tree with 9 leaves. Means within a column followed by the same letter are not significantly different at $P = 0.05$ according to Duncan's new multiple range test.
Table II. Effect of selected pesticide treatments on the population density of *Panonychus citri* in the absence of predators in the second greenhouse experiment

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean no. mites per leaf(^1) (days after introduction)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Malathion</td>
<td>2.0 a</td>
</tr>
<tr>
<td>Permethrin</td>
<td>2.0 a</td>
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<tr>
<td>Oxamyl</td>
<td>2.0 a</td>
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<tr>
<td>Water</td>
<td>2.0 a</td>
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</tbody>
</table>

\(^1\)See footnote Table I.

treatment resulted in significantly higher mite populations than did the water check at 14 and 19 days post-introduction (Table II). Although populations in the permethrin and oxamyl treatments were slightly higher than the water control, neither was statistically significant. Population densities decreased between the 14 and 19 day samples probably because of extensive leaf damage which had occurred by that time.

**Discussion**

These data showed the complexity of the pest resurgence phenomenon. The greenhouse studies demonstrated that resurgence can occur in the absence of predators, which confirms the conclusions of Huffaker and Spitzer (1950) working with *Tetranychus bimaculatus* Harvey (= *Tetranychus urticae* (Koch) (Tetranychidae)) on DDT-sprayed pear. The result of the laboratory studies confirmed those obtained in the greenhouse study (for malathion and permethrin) and indicated that the mechanism for resurgence in the absence of effective predators is reproductive in nature. The lack of agreement of the oxamyl greenhouse treatment with the two laboratory tests may have been because of the differences in ages of residues; in the greenhouse the oxamyl concentration may have degraded to a level below that needed to cause the sublethal effects shown in the laboratory. The work of Dittrich *et al.* (1974) using carbaryl and DDT, and Maggi and Leigh (1983) using methyl parathion, demonstrate that *T. urticae* can also respond with increased reproduction when certain insecticides are used.

While our study demonstrated the importance of hormoligos, it did not deny the importance of either predator inhibition or host plant effects. Fleschner (1952) pointed out that *P. citri* populations may sometimes not develop even if all other factors seem to favor an increase, and attributed this to host plant nutrition. Our study, however, demonstrated the role hormoligos can play if plant nutrition is adequate and effective predators are absent.

The importance of predator inhibition was demonstrated by van de Vrie and Boersma (1970) working on apple. They found that the predatory mite *Amblyseius potentillae* (Garman) (Phytoseiidae) could control populations of *Panonychus ulmi* (Koch) (Tetranychidae) stimulated with increased nitrogen levels by inflicting compensatory mortality. Their studies therefore demonstrate that an effective predator which is not inhibited by pesticide residues is able to counter prey hormoligos.

Further studies are necessary to determine the sublethal effects of pesticides on the predators. A change in reproductive rate of the predator (either positive or negative) may be as important to the predator-prey interaction as direct toxicity. An understanding of the physiological basis of the hormoligos phenomenon and knowledge of predator-prey responses to sublethal doses of pesticides is essential to the proper integration of a pesticide into a pest management scheme.
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References


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