Pyrethroid Lambdacyhalothrin-Induced Population Increase of *Tetranychus urticae* Koch (Acari: Tetranychidae) in an Apple Orchard

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**ABSTRACT** Based on data from apple trees without the presence of any predatory mites, the effect of the pyrethroid lambdacyhalothrin on population density of the twospotted spider mite, *Tetranychus urticae* Koch, is reported. Results show that significantly \( P < 0.05 \) higher numbers of *T. urticae* were found in pyrethroid-treated trees relative to the untreated controls, indicating that lambdacyhalothrin has a stimulatory effect on the mite population. Pyrethroid application had a significant \( P < 0.05 \) effect on the spatial distribution of motile mites. All Iwao’s \( \beta \) values for the mite in the untreated control trees were significantly greater \( P < 0.05 \) than those in the pyrethroid-treated trees, indicating that *T. urticae* were less aggregated in the field following pyrethroid applications. Pyrethroid-induced population increase of *T. urticae* in the field may result from alteration of its spatial distribution.

**KEY WORDS** *Tetranychus urticae*, pyrethroid-induced, spatial distribution, apple orchard, Acari, Tetranychidae.

Population increases of spider mites related to the use of synthetic compounds have been documented extensively. Van de Vrie et al. (1972) listed approximately 300 cases where the abundance of spider mites on assorted host plants was associated with various chemical applications, including insecticides, acaricides and fungicides. Since then pyrethroids have become available for use in a variety of agroecosystems, including pome fruit orchards (Elliott et al. 1978). Although pyrethroids have shown excellent results in controlling most insect pests of deciduous fruit, they have been associated with numerous accounts of phytophagous mite increases and resurgences (e.g., Hall 1979, Hardman et al. 1988).

Several theories have been proposed to explain increased phytophagous mite populations from the use of insecticides including (1) direct adverse effects on predators which regulate prey mite populations, (2) direct stimulatory effects on prey populations, and (3) indirect effects on prey through host plants. The most commonly accepted explanation of mite outbreaks following applications of
pyrethroids is the eradication of their natural enemies by the chemicals (e.g., Fournier et al. 1985), because pyrethroids are highly toxic to predators but have low acaricidal activity against spider mites (Chapman and Penman 1979). In addition to the eradication of predators by pyrethroids, effects on prey mite behavior and physiological responses may provide an alternative explanation. Jones and Parrella (1984) reported that Panonychus citri (McGregor) increased its reproductive potential when exposed to the pyrethroid permethrin and the organophosphate malathion. Iftner and Hall (1984) found that permethrin and fenvalerate reduced the developmental time of generations of the twospotted spider mite, Tetranychus urticae Koch. Pyrethroids may also delay the onset of winter diapause in spider mites (Gerson and Cohen 1989).

Tetranychus urticae is one of the most serious phytophagous mites on apple in Ontario (Anonymous 1990). Li and Harmsen (1992) reported that the population density of T. urticae increased following pyrethroid applications in apple orchards. However, no detailed reasons for such an increase of the mite population in the pyrethroid-treated apple trees were given. The increase of T. urticae may be due to both the elimination of predators and a stimulatory effect on the mite population by the pyrethroid. In the present report, comparisons are made of mite densities on the predator-free trees among the three treatments of water and two rates of pyrethroid, and the spatial distribution of the mite is analyzed. The objective of the paper was to determine the possible causes of T. urticae population increase other than eradication of predators following pyrethroid applications in apple orchards.

**Materials and Methods**

The study was conducted in an apple orchard at Smithfield Experimental Farm, Agriculture Canada, Trenton, Ontario, from 1988 through 1990. There are 150 semi-dwarf apple trees cv. Paulared on MM106 rootstock in the orchard, with a spacing of 10 m between rows and 3 m between trees. The orchard was treated with three different sprays: a low and high rate of the pyrethroid lambdacyhalothrin (50 EC, ICI Chipman, Ontario) and a water control. The two rates of pyrethroid were 2.5 g (A.I.)/ha (low) and 6.25 g (A.I.)/ha (high) in 1988 and 1990, and 1.25 g (A.I.)/ha (low) and 2.5 g (A.I.)/ha (high) in 1989, respectively. The entire orchard was divided into 24 plots of 5-7 trees each. Each plot served as a replicate, and each of the three treatments was replicated eight times. Three applications were made each year, on 28 June, 28 July and 14 September 1988; on 28 June, 31 July and 30 August 1989; and on 28 June, 24 July and 16 August 1990.

Leaf samples were taken at 2-wk intervals from mid-June to late September 1988 and 1989. In 1990, the orchard was sampled monthly from mid-May to late August. Ten apple leaves were randomly taken from all quadrants of each tree canopy up to 2 m above the ground (Li and Harmsen 1992). Population densities of T. urticae and predatory mites, the phytoseiid Amblyseius fallacis (Garman) and the stigmaeid Zetzeilia mali (Ewing), were estimated from counts of mites on both sides of the leaves with the aid of a binocular microscope in the laboratory.

To partition the effect of predators from the possible effects of pyrethroid stimulation on the T. urticae population, analyses of mite density among the three treatments were made only on the trees in the absence of predators. The data were
transformed as $\sqrt{x + 0.5}$, where $x$ is the number of mites per 10 leaves from each tree, and subjected to analysis of variance (Zar 1984). Mean numbers of mites per 10 leaves were compared among the three treatments, and were separated by Scheffé’s $F$-test of repeated measures at the $P = 0.05$ level (Zar 1984).

Iwao’s regression (Iwao 1968) was used to describe the relationship between mean density and variance for within-tree spatial distribution of motile $T. urticae$:

$$m^* = a + \beta m$$  (1)

where $m$ is mean density per leaf and $m^*$ is mean crowding, estimated by Lloyd’s equation (1967),

$$m^* = m + \left(\frac{s^2}{m - 1}\right)$$  (2)

where $s^2$ is variance of mean density. Mean density ($m$) per leaf and variance ($s^2$) were estimated based on the total number of leaves sampled from each plot (5-7 trees) on each sampling date. Homogeneity of slopes of the resulting equations were compared among the three treatments using the Student’s $t$-tests.

### Results and Discussion

$T. urticae$ was not found on apple trees before the first lambdacyhalothrin application in 1988. Although very few $T. urticae$ infested apple trees early in the season in 1989 and 1990, no significant differences ($P > 0.05$) in both eggs and motile mites (larvae, nymphs, and adults) were found among the three treatments (data not shown). These results clearly indicate no differences in the population base of $T. urticae$ on different apple trees during the early season each year.

The effect of lambdacyhalothrin applications on $T. urticae$ eggs varied from year to year (Fig. 1A,C,E). In 1988, the low rate (2.5 g [A.I.]ha$^{-1}$) treated trees had the highest egg counts, while the lowest egg counts were found in untreated trees. The differences, however, were not significant ($P > 0.05$). More eggs in the pyrethroid-treated trees were also evident in the samples of 1989. The highest egg density was found in the high rate (2.5 g [A.I.]ha$^{-1}$) treated trees, and the differences were significant ($P < 0.05$) between this treatment and the control, but not significant ($P > 0.05$) as compared with the low rate of 1.25 g [A.I.]ha$^{-1}$. In 1990, egg numbers were almost equal in the three treatments.

The pyrethroid applications increased populations of motile $T. urticae$ in the field (Fig. 1B, D, F). In 1988, the low rate (2.5 g [A.I.]ha$^{-1}$) of lambdacyhalothrin induced more mites than the high rate (6.25 g [A.I.]ha$^{-1}$). A significant difference ($P < 0.05$) was noted between the 2.5 g [A.I.]ha$^{-1}$ treatment and the control in the samples from 26 August to 23 September, while differences between the 6.25 g [A.I.]ha$^{-1}$ treated trees and the controls were not significant ($P > 0.05$). After 30 June 1989, significantly more motile $T. urticae$ were found in the 2.5 g [A.I.]ha$^{-1}$ treatment than untreated control trees ($P < 0.05$). Significantly more mites were found in the 1.25 g [A.I.]ha$^{-1}$ treatment than control trees in two of three samples ($P < 0.05$). However, the two treatments with lambdacyhalothrin had no difference ($P > 0.05$) in mite abundance. In two post-treatment samples in 1990, significantly more mites were also found in pyrethroid-treated trees ($P < 0.05$). Results reported here demonstrate...
that in the absence of predatory mites, *T. urticae* was more abundant in the pyrethroid-treated trees as compared with the untreated controls on apple, suggesting that lambda-cyhalothrin might have functioned as a stimulant leading to an increase in mite numbers.

Pyrethroid applications had a significant ($P < 0.05$) effect on the spatial distribution of motile *T. urticae* (Table 1). In 3 yr of field observations, $\beta$ values for the trees treated with the pyrethroid were significantly smaller ($P < 0.05$) than those for the untreated controls. No significant differences ($P > 0.05$) in $\beta$ values were found between the two rates of the pyrethroid. These observed results suggest that pyrethroid applications caused motile mites to be less aggregated under orchard conditions. Trumble (1985) found a similar phenomenon with *T. urticae* on strawberry following applications of acaricides. In Trumble's study, the decrease of aggregation of *T. urticae* was due to a high mortality (about 99%) of the mite by chemicals. In our study, however, the pyrethroid did not have an acaricidal effect on this species (Li and Harmsen 1992). Sublethal rates of lambda-cyhalothrin may function as a repellent to affect the spatial distribution of *T. urticae*, which, in turn, increases population density.
It is well documented that pyrethroids have irritant or repellent properties on spider mites (e.g., Iftner and Hall 1983, Penman and Chapman 1983, Penman et al. 1986). After lambdacyhalothrin applications, motile *T. urticae* may expedite dispersal activity and redistribute themselves among apple leaves. This dispersal activity would lead to more leaves infested with mites. Consequently, the degree of aggregation of motile mites would decrease. The fact that less aggregation is related to mite abundance may reveal that lambdacyhalothrin induced population increase of *T. urticae* by changing its spatial distribution. Less aggregation of motile mites following pyrethroid applications may reduce density-dependent competition, and *T. urticae* may attain a higher reproductive ability which is not realized under crowded, more competitive conditions (Iftner et al. 1986).

Previous studies have indicated that adult females of spider mites disperse more than adult males in the field (Smitley and Kennedy 1985); thus female dispersal may be expedited after lambdacyhalothrin applications. The female dispersal activity would decrease the mean density of colonizing females per infested leaf. According to local mate competition theory (Hamilton 1967), in

Table 1. Spatial distribution of motile *T. urticae* following pyrethroid applications in an apple orchard, Ontario, 1988-1990.

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>α</th>
<th>$\beta \pm SE^b$</th>
<th>$r^2$</th>
<th>n$^c$</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>C</td>
<td>4.059</td>
<td>4.678 ± 0.510 a</td>
<td>0.743</td>
<td>53</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>6.907</td>
<td>3.074 ± 0.578 b</td>
<td>0.598</td>
<td>53</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>5.131</td>
<td>2.963 ± 0.508 b</td>
<td>0.762</td>
<td>46</td>
<td>0.0001</td>
</tr>
<tr>
<td>1989</td>
<td>C</td>
<td>3.379</td>
<td>4.518 ± 0.641 a</td>
<td>0.721</td>
<td>48</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>8.987</td>
<td>1.626 ± 0.255 b</td>
<td>0.633</td>
<td>63</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>7.672</td>
<td>1.571 ± 0.145 b</td>
<td>0.813</td>
<td>62</td>
<td>0.0001</td>
</tr>
<tr>
<td>1990</td>
<td>C</td>
<td>6.346</td>
<td>4.433 ± 0.499 a</td>
<td>0.770</td>
<td>8</td>
<td>0.0254</td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>3.037</td>
<td>2.951 ± 0.483 b</td>
<td>0.949</td>
<td>10</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>8.342</td>
<td>2.533 ± 0.277 b</td>
<td>0.678</td>
<td>11</td>
<td>0.0218</td>
</tr>
<tr>
<td>88-90</td>
<td>C</td>
<td>3.954</td>
<td>4.559 ± 0.412 a</td>
<td>0.731</td>
<td>109</td>
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<tr>
<td></td>
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<td>8.138</td>
<td>1.916 ± 0.220 b</td>
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<td></td>
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<td>8.372</td>
<td>1.652 ± 0.143 b</td>
<td>0.730</td>
<td>119</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

$^a$ C = Control; L = Low rate (2.5, 1.25 and 2.5 g [A.I.]/ha of lambdacyhalothrin for 1988, 1989 and 1990, respectively); H = High rate (6.25, 2.5 and 6.25 g [A.I.]/ha for 1988, 1989 and 1990, respectively).

$^b$ Values of $\beta$ followed by the same letters within a year are not significantly different ($P > 0.05$), using the Student's $t$-tests: $t = (\beta_1 - \beta_2)(SE_1^2 + SE_2^2)^{1/2}$ with $df = (n_1 - 1) + (n_2 - 1)$, where $\beta_1$ and $\beta_2$ can represent any two slopes of the three regression lines within each year.

$^c$ n represents sample size, and each n contained 50-70 leaves from each plot of 5-7 trees.
sparse and patchy populations, an ovipositing female would produce the minimum number of sons required to fertilize all her daughters so as to reduce competition between sons. Therefore, a mother would produce more daughters in this situation. More female offspring in the patch would increase the population density of the next generation.

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