Effects of Treatment Technique on Response of Horn Flies (Diptera: Muscidae) to Permethrin at Different Temperatures

CHARLES D. SCHMIDT AND JACQUELINE L. ROBERTSON

U.S. Livestock Insects Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Kerrville, Texas 78029-0232

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ABSTRACT

The toxicity of permethrin to horn flies, Haematobia irritans (L.), was determined at 21, 27, and 32°C. Two populations were tested by the treated-cloth technique: a positive temperature coefficient was observed for both populations between 21 and 27°C, whereas temperature had no significant effect on toxicity between 27 and 32°C. When one of the populations was tested by topical application, however, negative temperature coefficients were observed between pairs of successively higher temperatures. Since the treated-cloth technique simulates exposure to insecticide in the field and topical application does not, our results suggest that, at higher temperatures, permethrin will be more toxic to horn flies.

Posttreatment temperature effects on insecticide toxicity vary by chemical type. Hoffman & Lindquist (1949) observed, for example, that knockdown was faster and mortality greater when house flies, Musca domestica L., treated with diphenyl aliphatics (DDT and methoxychlor) were held at 21°C rather than at 32°C. However, chlorinated aryl hydrocarbon insecticides (toxaphene, chlordane, and dieldrin) and the organophosphate insecticide (parathion) were more toxic at 32°C than at 21°C. Guthrie (1950) showed that the LD₅₀'s of both DDT or pyrethroids were much lower (i.e., the chemicals were more toxic) when German cockroaches, Blattella germanica (L.), were held at 14.5°C rather than at 32°C. Vinson & Kearns (1952) confirmed the negative temperature coefficient for DDT in experiments with another cockroach, Periplaneta americana (L.). Other investigators have shown that pyrethroids have negative coefficients when applied to insects in several orders (e.g., Diptera, Coleoptera, Lepidoptera, and Orthoptera [Harris & Kinoshita 1977, DeVries & Georgiou 1979, Sparks et al. 1982, Ewen et al. 1984, Scott & Georgiou 1984]).

Field-collected horn flies, Haematobia irritans (L.), are being tested by the treated-cloth technique (described in detail by Schmidt et al. 1985), a method that simulates exposure of flies to insecticides on a treated host. Because most previous research on the effects of temperature on the toxicity of pyrethroids to insects was done by topical application, we also used this method to determine whether toxicity of permethrin was a function of temperature. Only one population was treated topically.

Methods and Materials

Insects. Horn flies from two populations were tested. One population, the laboratory strain (LAB), was in colonization for ca. 17 years at the U.S. Livestock Insects Laboratory, Kerrville, Tex. (Schmidt et al. 1976). The LAB flies, although not exposed to insecticides, are less susceptible to permethrin (Schmidt et al. 1985) than the other strain, from Bexar County, Tex. (BEX). The BEX strain was tested to determine whether a native strain and the LAB strain would react similarly to the treatments.

Bioassays. At each temperature, both populations were exposed to permethrin-treated cloths as described by Schmidt et al. (1985). Twenty-five flies (mixed sexes) were held in each 120-ml plastic specimen cup covered with a treated cloth. LAB flies were between 48 and 72 h old; the age of the BEX flies was unknown. Six concentrations of permethrin were tested in each of five replications. Controls, exposed to an untreated cloth, were included in each replication. In each replication, 2 cups of flies were tested at each concentration, and 2 cups of flies served as controls.

1 This article reports the results of research only. Mention of a pesticide does not constitute an endorsement or a recommendation for its use by USDA, nor does it imply registration under FIFRA as amended.

2 For Serv. USDA, Pac. Southwest For. and Range Exp. Stn., Berkeley, CA 94701.
The toxicity of permethrin to the LAB flies at each temperature was also tested by topical application. Because BEX and LAB flies reacted similarly in the test with treated cloths, they were not used in this test. Five concentrations of permethrin formulated in acetone were tested. A 0.5-μl volume was applied to the thoracic dorsum of each fly. Controls were treated with 0.5 μl of acetone.

### Table 1. Toxicity of permethrin to horn flies (mixed sexes) exposed to treated cloths for 24 h and held at one of three temperatures

<table>
<thead>
<tr>
<th>Temp (°C)</th>
<th>No. flies exposed to permethrin</th>
<th>Slope ± SE</th>
<th>LC50 (95% CL) (μg/cm² of cloth)</th>
<th>LC90 (95% CL) (μg/cm² of cloth)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEX</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21 ± 1</td>
<td>1,500</td>
<td>2.34 ± 0.14</td>
<td>0.19 (0.17–0.20)</td>
<td>0.66 (0.57–0.79)</td>
</tr>
<tr>
<td>27 ± 1</td>
<td>1,500</td>
<td>3.19 ± 0.16</td>
<td>0.09 (0.07–0.11)</td>
<td>0.23 (0.18–0.34)</td>
</tr>
<tr>
<td>32 ± 1</td>
<td>1,500</td>
<td>3.10 ± 0.15</td>
<td>0.09 (0.08–0.11)</td>
<td>0.24 (0.20–0.32)</td>
</tr>
<tr>
<td>LAB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21 ± 1</td>
<td>1,440</td>
<td>2.26 ± 0.16</td>
<td>0.74 (0.55–1.15)</td>
<td>2.73 (1.56–12.4)</td>
</tr>
<tr>
<td>27 ± 1</td>
<td>1,440</td>
<td>3.32 ± 0.14</td>
<td>0.22 (0.16–0.29)</td>
<td>0.56 (0.42–0.91)</td>
</tr>
<tr>
<td>32 ± 1</td>
<td>1,440</td>
<td>2.50 ± 0.14</td>
<td>0.18 (0.09–0.26)</td>
<td>0.50 (0.34–1.12)</td>
</tr>
</tbody>
</table>

**Note:** Estimated natural responses (±SE) of control groups (n = 250 for each group of BEX flies and n = 240 for each group of LAB flies) ranged from 0.024 ± 0.01 to 0.039 ± 0.012 (BEX) and from 0 ± 0 to 0.013 ± 0.008 (LAB).

### Results

For both the LAB and BEX strains exposed to treated cloth, permethrin was significantly less toxic at 21°C than at either 27 or 32°C (Table 1). The response at 21°C was neither parallel nor equal to responses at the higher temperatures. Responses at 27 and 32°C were, however, equal. At LC50, toxicity increased 2.1-fold (BEX) and 3.4-fold (LAB) when flies were held at 27°C rather than 21°C. A positive temperature coefficient was also observed at LC90; the toxicity of permethrin increased 2.9-fold (BEX) and 4.9-fold (LAB) from 21 to 27°C.

When permethrin was topically applied to the LAB strain, however, a negative temperature coefficient was observed (Table 2). At the LD50, the toxicity of permethrin decreased by 1.5-fold at 27°C compared with 21°C, and by 1.7-fold at 32°C compared with 27°C. At the LD90, toxicity decreased

### Table 2. Toxicity of topically applied permethrin to LAB strain female horn flies held for 24 h at one of three temperatures

<table>
<thead>
<tr>
<th>Temp (°C)</th>
<th>No. flies exposed to permethrin</th>
<th>Slope ± SE</th>
<th>LD50 (95% CL) (μg/fly)</th>
<th>LD90 (95% CL) (μg/fly)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 ± 1</td>
<td>725</td>
<td>5.06 ± 0.49</td>
<td>0.0025 (0.0018–0.0029)</td>
<td>0.0045 (0.0018–0.0029)</td>
</tr>
<tr>
<td>27 ± 1</td>
<td>725</td>
<td>3.84 ± 0.25</td>
<td>0.0038 (0.0018–0.0053)</td>
<td>0.0081 (0.0056–0.027)</td>
</tr>
<tr>
<td>32 ± 1</td>
<td>725</td>
<td>4.60 ± 0.61</td>
<td>0.0065 (0.0046–0.0075)</td>
<td>0.0123 (0.0010–0.028)</td>
</tr>
</tbody>
</table>

**Note:** Weight (mean ± SD) of flies was 6.09 ± 0.77 mg.

**a** Estimated natural response (±SE) of control groups tested with each group ranged from 0 ± 0 to 0.106 ± 0.022.

**b** 95% CL could not be computed because the value of g was >0.50 at P = 0.95 (Russell et al. 1977). Numbers in parentheses are 90% CL.
by 1.8-fold between 21 and 27°C, and by 1.5-fold between 27 and 32°C. No response was equal to that at another temperature: the hypothesis of equality was uniformly rejected in all comparisons of responses.

**Discussion**

Most posttreatment holding conditions available to the investigators who use the treated-cloth method range between 27 and 32°C. The results of our investigation indicated that response to permethrin did not vary significantly within this temperature range. Therefore, test results from different facilities are expected to be similar when the temperatures used are within this range.

This is the first report of a positive temperature coefficient for a Dipteran species exposed to a pyrethroid. Since comparable results were obtained with both the LAB and BEX strains, this response is clearly not peculiar to horn flies reared continuously in the laboratory. Sparks et al. (1982) first reported a positive temperature coefficient when either fenvalerate or deltamethrin was topically applied to the fall army worm, Spodoptera frugiperda (J. E. Smith), or to the tobacco budworm, Heliothis virescens (F.). The positive temperature coefficient observed with the treated cloth method may result from changes in horn fly behavior at higher temperatures. As temperatures increased, meal size increased (Kuramochi & Hori 1984). If this were true in our tests, the increased feeding of the flies through the treated cloth may have increased the exposure to permethrin. Although they could not distinguish whether the behavior was caused by irritancy or repellency, Quisenberry et al. (1984) observed that resistant horn flies were irritated more than susceptible horn flies in the presence of permethrin. In our study with susceptible horn flies at three different temperatures, this behavior may have been elicited more at the lower temperature to account for the positive temperature coefficient observed between 21 and 27°C. Further research will be required to identify whether one of these behavioral effects or other behavior is responsible for the increased toxicity of permethrin at 27°C and above.

Another possible factor might be a fumigant effect at the higher temperatures. For example, Hoffman & Lindquist (1949) found that the vaporization of lindane caused a positive temperature coefficient in house flies. However, permethrin has a very low vapor pressure and volatilizes very slowly (Elliott et al. 1978). Therefore, we consider the possibility of fumigant action of permethrin at temperatures ≥27°C to be unlikely.

The negative temperature coefficient that we observed when permethrin was topically applied to horn flies is consistent with results reported for other insects. Based on such results, Harris & Kinosita (1977) and Scott & Georgiou (1984) suggested that pyrethroids may provide better control of a target species if applied at lower temperatures. Since the horn fly is controlled principally by residues rather than direct, immediate contact with an insecticide, it appears that residues of permethrin would be more toxic at the higher temperatures.

The results observed with the treated-cloth method compared with topical application emphasize the need for basing recommendations for field efficacies of laboratory test methods that simulate field exposure. Robertson & Haverty (1981) and Haverty & Robertson (1982) described similar differences in apparent insecticide efficacy attributable to test methods for the western spruce budworm, Choristoneura occidentalis Freeman. Results of our experiments with horn flies reinforce their conclusion that only methods that simulate the test insect's natural situation should be used as the basis for recommended use patterns in the field.

**Acknowledgment**

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**References Cited**


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