Critical Thermal Limits and Locomotor Activity of the Red Imported Fire Ant (Hymenoptera: Formicidae)

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ABSTRACT Critical thermal (CT) maxima (CTMAX) and critical thermal minima (CTMIN) were determined for minor caste workers of the red imported fire ant, Solenopsis invicta Buren. Ants were tested from polygynous colonies collected from northwestern Texas. Mean CTMAX is lower than that reported for the upper lethal temperature for short exposures and higher than that reported for the upper foraging limit. Mean CTMIN was, likewise, lower than the reported lower foraging limit. The CT values obtained at weekly intervals as colony maintenance temperatures were reduced from 29 to 9°C showed significant reductions in both CTMAX and CTMIN. The CT values averaged 40.7 (MAX) and 3.6°C (MIN). Differences between critical thermal values and those reported in previous studies of lethal and foraging temperatures are discussed.

KEY WORDS Insecta, Solenopsis invicta, fire ant, temperature

The red imported fire ant, Solenopsis invicta Buren, has become a major pest since its introduction into the United States approximately 50 yr ago. Although thought to be native to the floodplain of the Paraguay River and its tributaries in South America, it has rapidly spread throughout the southern and southeastern United States (Lofgren 1986). To better understand the physiological limits of this pest, a study of critical thermal limits was conducted.

The term “critical temperature” may lead to some confusion. It has been cited in numerous articles and textbooks as the transitional temperature at which the wax monolayer of the cuticle is re-orientated, resulting in rapid water loss. Herein, critical temperature or critical thermal (CT) limits are defined as the temperatures at which the locomotor ability of the ant is so reduced that it can no longer escape lethal temperatures. This definition is well established in the literature for both vertebrate and invertebrate animals. In particular, CTs of ants have been reported by numerous authors (Schumacher & Whitford 1974, Whitford & Ettershank 1975, Whitford et al. 1975, Kay & Whitford 1978, Curtis 1985).

This research was undertaken to answer four questions. What are the critical thermal maxima (CTMAX) and critical thermal minima (CTMIN) for the red imported fire ant? Does thermal history influence CT responses? If thermal history does influence CT responses, then in what manner? How do the CTMAX and CTMIN values obtained in this study compare with foraging and thermal tolerance values reported in previous studies?

Materials and Methods

Ants. Ten multiple-queened colonies were collected from Lubbock, Lubbock County, Tex., on 19 August 1987, separated from soil, and housed following methods of Banks et al. (1981). Colonies were maintained at a photoperiod of 12:12 (L:D) with daily additions of food (diet used by Banks et al. [1981], excluding 2,000 ml of insects), water, and a 50% aqueous honey solution provided once a week. Colonies were maintained at about 22°C for approximately 1 mo before the experimental period to verify the reproductive status of queens. Subsequently, the maintenance temperature was changed to approximately 30°C. Thereafter, temperatures were reduced each week (see Table 1 for temperatures), and the CT responses were measured at the end of each week. Because ants became inactive unless disturbed when maintained at 5.4–5.8°C for one day, no CT measurements were taken at or below this maintenance temperature.

Experimental Apparatus. Test chambers consisted of 100-ml beakers, the inside walls of which were coated with Fluon Ad-1 (polytetrafluoroethylene; ICI Americas, Wilmington, Del.) to prevent escape by the ants and were filled with 20 ml of 0.08–0.50 mm diameter sand. Each 100-ml beaker was placed inside a 400-ml Pyrex beaker, but to prevent direct contact between beakers, four pieces of neoprene (approximately 0.5 mm3) were glued to the inside bottom of the 400-ml beaker. Plastic Petri dish tops were used to cover the larger beakers. Ten of these chambers were constructed; five were used for heating and five for cooling experiments.

For CTMAX experiments, chambers were placed on a metal tray with sand packed under and around the beakers to distribute the heat evenly. Heat was applied by placing an electric hot plate beneath the tray to raise the beaker temperature 0.34 to 0.52°C per minute. For CTMIN tests, a preformed ice block was placed in a plastic tray. The ice block was made by placing five 400-ml Pyrex beakers,
Table 1. Mean critical thermal maxima (CTMAX) and mean critical thermal minima (CTMIN) for red imported fire ants maintained at decreasing temperatures

<table>
<thead>
<tr>
<th>Week</th>
<th>Test date</th>
<th>Weekly temp. maintained (°C)</th>
<th>CTMAX °C ± SD</th>
<th>CTMIN °C ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17 Sept.</td>
<td>29.1 ± 2.9</td>
<td>40.5 ± 2.5</td>
<td>6.6 ± 1.9</td>
</tr>
<tr>
<td>2</td>
<td>29 Sept.</td>
<td>36.4 ± 2.7</td>
<td>41.6 ± 1.0</td>
<td>6.3 ± 2.0</td>
</tr>
<tr>
<td>3</td>
<td>2 Oct.</td>
<td>23.2 ± 2.4</td>
<td>41.8 ± 1.0</td>
<td>2.4 ± 1.4</td>
</tr>
<tr>
<td>4</td>
<td>9 Oct.</td>
<td>20.9 ± 2.4</td>
<td>41.2 ± 1.4</td>
<td>1.1 ± 1.4</td>
</tr>
<tr>
<td>5</td>
<td>16 Oct.</td>
<td>17.4 ± 2.0</td>
<td>40.6 ± 2.3</td>
<td>2.7 ± 2.1</td>
</tr>
<tr>
<td>6</td>
<td>23 Oct.</td>
<td>15.0 ± 1.6</td>
<td>40.0 ± 1.6</td>
<td>3.9 ± 1.3</td>
</tr>
<tr>
<td>7</td>
<td>30 Oct.</td>
<td>12.6 ± 1.3</td>
<td>40.6 ± 1.4</td>
<td>2.9 ± 1.7</td>
</tr>
<tr>
<td>8</td>
<td>6 Nov.</td>
<td>9.1 ± 0.6</td>
<td>39.0 ± 2.0</td>
<td>2.7 ± 1.7</td>
</tr>
</tbody>
</table>

Results and Discussion

Critical thermal values are presented in Table 1. Weekly mean CTMAX ranged from 39.0 to 41.8°C, with an overall mean of 40.7°C. The CTMIN values exhibited a greater range, from 1.1 to 6.6°C and a mean of 3.6°C for the entire study. Analysis of variance indicates that the temperature regime (F = 49.43; df = 7, 720; P < 0.01) to which the colonies were exposed and the colonies (F = 34.47; df = 9, 720; P < 0.01) from which the minor workers were tested had a significant effect on the CTMAX recordings obtained. Likewise, the interaction of these two sources of variation (F = 5.22; df = 63, 720; P < 0.01) was also significant. The same is true regarding the CTMIN data in that the temperature regime (F = 30.42; df = 7, 720; P < 0.01) and colony (F = 19.67; df = 9, 720; P < 0.01) had a significant effect on the ability of workers to withstand decreasing temperatures. In addition, the interaction of temperature regime and colony (F = 15.22; df = 63, 720; P < 0.01) was also significant. The direction of the effect for temperature is consistent across the 10 colonies.

Linear regression of the CTMAX and the CTMIN values plotted against the maintenance temperatures is presented in Fig. 1. Although not large, the coefficients of determination were significant for both the CTMAX (r² = 0.22; F = 21.86; df = 1, 78; P < 0.01) and the CTMIN (r² = 0.21; F = 20.79; df = 1, 78; P < 0.01). Higher r² values and a better-fit line were obtained and could be presented through curvilinear regression; however, the biological significance of such a polynomial regression would be obscure at best, or even meaningless. The fact that the regression is significant, regardless of the low predictive and descriptive value of the r² values obtained, indicates that the changes in both the CTMAX and the CTMIN are partially accounted for by decreasing maintenance temperatures.

Although our CTMIN values were within the range reported for other ants, the CTMAX for the red imported fire ant is lower than that recorded for other species (Schumacher & Whitford 1974, Whitford & Ettershank 1975, Whitford et al. 1975, Kay & Whitford 1978, Curtis 1985). This lower CTMAX may be explained in part by the fact that all previously examined ants inhabit either the Namib or Chihuahuan deserts. The CTMAX values for all (except for one nocturnal species reported by Kay & Whitford 1978) of the tested desert ants are higher than the lethal temperature of the red imported fire ant.

Our data clearly show that prior thermal history affects CT values. The influence of thermal history on CT values is similar for CTMAX and CTMIN and suggests that the red imported fire ant has an ability to deal (at least in part) with lower tem-
temperatures as winter approaches. Because fire ants remain active year-round, this adaption would prove beneficial. Kay & Whitford (1978) similarly recorded an increase in CTMAX values with increasing acclimation temperatures (5, 15, 25, 35°C) for the ant Myrmecocystus depilis Forel. However, those authors did not investigate the effects of acclimation temperatures on CTMIN.

Values from studies on lethal temperature (Francke et al. 1985) and foraging (Porter & Tschinkel 1987) are higher than those reported herein for CTMAX (44.6, 43, 40.7°C, respectively). These differences may be partially accounted for by thermal history. Differences among studies in the size (Francke & Cokendolpher 1986), age, and class of workers could possibly account for some of these differences in thermal values, if such information were available (which it is not). Information on the reproductive status (monogyny versus polygyny) of the tested colonies is likewise not available. Researchers should be careful to record information on the thermal history and other parameters of the colony and individual ants.

Our data on CTMIN are the first on fire ants and therefore they are difficult to compare to other studies. Because fire ants are not freeze tolerant, their supercooling points indicate the lower lethal limits (Francke et al. 1986, Taber et al. 1987) and obviously are lower than the CTMIN. One might expect the CTMIN and lower foraging temperatures to be similar; however, Porter & Tschinkel (1987) reported that the lower foraging limit was 15°C (11.4°C higher than the CTMIN we recorded). With a CTMIN lower than the lower activity temperature, foragers would not be in danger of being trapped in low lethal temperatures. Apparently, the cessation of foraging activity is triggered by temperatures higher than temperatures required for other activities.

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References Cited


Fig. 1. Regression of CTMIN and CTMAX means as a function of mean weekly maintenance temperature for the red imported fire ant.
COKENDOLPHER & PHILLIPS: CRITICAL THERMAL LIMITS FOR FIRE ANT


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