American Cockroach Response to Cold Temperatures

Author(s): David L. Bradt III, W. Wyatt Hoback and B. M. Kard
Source: Southwestern Entomologist, 43(2):335-342.
Published By: Society of Southwestern Entomologists
URL: http://www.bioone.org/doi/full/10.3958/059.043.0205

American Cockroach[1] Response to Cold Temperatures

David L. Bradt III[2], W. Wyatt Hoback[3]*, and B. M. Kard[3]

Abstract. Survival and mobility of American cockroaches, *Periplaneta americana* L, that originated from a wild population were compared in semi-natural and laboratory cool-temperature conditions. In a non-heated building all American cockroaches died when air temperatures were ≤0°C despite having access to wood mulch substrate that remained above freezing. Under constant temperatures of 8, 9, and 10°C, approximately 40% of cockroaches died within 72 hours. Mobility was defined as the ability of a cockroach to right itself when flipped over. At all tested temperatures the percentage of individuals that became immobile increased with time. Survival and mobility increased with temperature. Data showed that adult American cockroaches were not able to survive several days at ≤10°C, suggesting a potential cultural control method for tropical cockroaches.

Introduction

The American cockroach, *Periplaneta americana* L, is a common pest of structures and an exotic species associated with humans throughout the world (Sinclair et al. 2015). Native to Africa it was introduced into North America in the 1600s and was given its common name when described by Linnaeus (1758) using his binomial system. It can cause asthma in children in urban areas (Oudin et al. 2016) and is a vector of food-borne bacterial diseases (Pai et al. 2005). It is commonly found outdoors in the southern United States and is rarely observed away from heated dwellings in more temperate zones, including Oklahoma. This may be because climate-controlled human dwellings provide micro-climates similar to outdoor temperatures in the tropics (Cornwell 1968).

In temperate zones, insects overwinter by two strategies: freeze avoidance by producing compounds allowing supercooling, and freeze tolerance by controlling ice formation in their bodies (Sinclair et al. 2003). Using a third strategy, other insects survive by seeking favorable environments including human dwellings where they may remain active, or diapause to overwinter. Many pest cockroaches, including the American cockroach, seem to use the third strategy, especially in temperate areas although data generally are lacking on temperature thresholds for survival (Hamman and Turney 1987).

The American cockroach has been studied as a model organism for insect physiology (Bell 1981) and to document its life history and methods for chemical control (Cochran 1999). Several authors anecdotally report that the American

[1]Blattodea: Blattidae

[2]255th Medical Detachment (Preventive Medicine), Joint Base Lewis-McChord, WA 98433
[3]Department of Entomology and Plant Pathology, 127 Noble Research Center, Oklahoma State University, Stillwater, OK 74078-3033
*Corresponding author: whoback@okstate.edu

cockroach dies when exposed to cold temperature. Cold receptors on its antennae have been identified (Loftus 1966).

When unable to avoid cold, insects become immobile at a species-specific temperature threshold referred to as the 'chill-coma temperature' (Mellanby 1939). American cockroaches quickly become immobile when exposed to freezing temperatures. However, Staszak and Mutchmor (1973) reported recovery from cold-induced coma after 1 hour at sub-zero temperatures. Recently, a closely related species, *Periplaneta japonica* Karny, was found in New York. This species survives temperatures below freezing for several days (Tanaka and Tanaka 1997). In addition, studies have shown that some insects need to be acclimated to survive freezing temperatures, and many species with access to areas sheltered from cold survive previously reported lethal temperatures (Danks 2012). These reports suggest the need for more research to determine lethal temperatures and recovery from exposure to sub-lethal cold by the American cockroach.

In contrast with the American cockroach, some native USA cockroaches are not pests of human dwellings. There are 12 endemic species in the genus *Parcoblatta* (Eliyahu et al. 2011). These cockroaches can be abundant, accounting for the greatest amount of arthropod biomass in some pine forests in the southeastern United States (Horn and Hanula 2008). Little is known of the effects of temperature on their biology, although Blatchley (1920) reported that *Parcoblatta* seemed not affected by cold and had the same level of activity on a cold January day as on a hot June day. Beyond this anecdotal evidence all life stages are found in early spring, suggesting the ability to survive freezing environmental temperatures (Horn and Hanula 2002).

Cold tolerance, survival, and response to decreasing temperature were evaluated for the American cockroach in a laboratory. Two native cockroaches, *Parcoblatta fulvescens* Saussure and Zehntner and *P. virginica* von Wattenwyl were also tested for response to cold conditions.

Materials and Methods

American cockroaches were obtained from Kansas State University, Manhattan. Using a vacant greenhouse with open windows and doors, survival of the American cockroach was tested in a semi-sheltered environment. Adult cockroaches were placed individually into plastic 1,000-ml containers filled with damp wood mulch for shelter, given a moist cotton ball for water, and dry dog food. In total, 85 adult cockroaches were placed in the greenhouse. Temperatures were recorded with Hobo® data loggers (Bourne, MA) and cockroaches evaluated after 10 days. Check cockroaches were kept at approximately 20°C and 50% relative humidity in a controlled-environment, indoor insect-rearing facility.

Preliminary tests were done from -4 to 27°C to determine American cockroach survival across a range of temperatures. Groups of cockroaches were exposed to constant temperature for 12 hours and mobility and mortality were recorded. Almost all cockroaches died at ≤5°C, whereas 8 and 10°C allowed survival but induced loss of mobility. Therefore, behavior was assayed at these temperatures.

Three growth chambers set at 8, 9, or 10°C were used. Cockroaches (N = 12) were placed individually with a piece of moist paper towel and dry dog food into glass containers. Cockroach groups (N = 12) were evaluated at 24, 48, and 72 hours, and behaviors quantified. After 72 hours in growth chambers, all individuals

were moved to room temperature to determine survival. Check cockroaches were kept at 20°C.

For comparison, native wood cockroaches, *P. virginica* and *P. fulvescens*, were tested for survival at 4°C and for mobility at 8, 9, and 10°C. Check American cockroaches were kept at 20°C.

Results

In greenhouse conditions with open windows and doors, American cockroaches were evaluated after 10 days. During this period 100% of the greenhouse cockroaches died, while all protected check cockroaches kept indoors at ~23°C survived. Air temperatures in the open greenhouse between 20 November and 6 December 2014 are shown in Fig. 1. Temperatures ranged from -4 to 41°C.

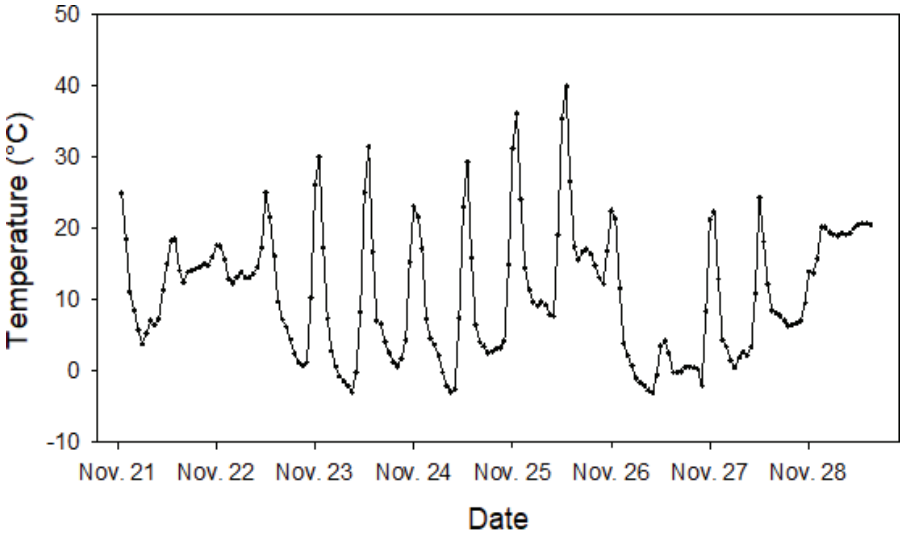

Fig. 1. Air temperatures in a non-heated open greenhouse during 2014.

Under growth chamber conditions, 10 to 40% of American cockroaches died within 72 hours. No significant differences in cockroach survival were observed among the three temperatures tested although 40% died after 3 days at 8°C (Fig. 2). All check and comparative wood cockroaches survived.

Cockroaches were characterized as being either normal and upright, on their backs (inverted) but responsive, or inverted and dead. Exposure to cold for 24 and 48 hours caused most American cockroaches to lose their ability to maintain upright posture (Fig. 3a). An increasing percentage became inverted over time (Fig. 3b). Cockroaches that lost the ability to maintain upright posture or were inverted did not recover when monitored for 24 hours after exposure.

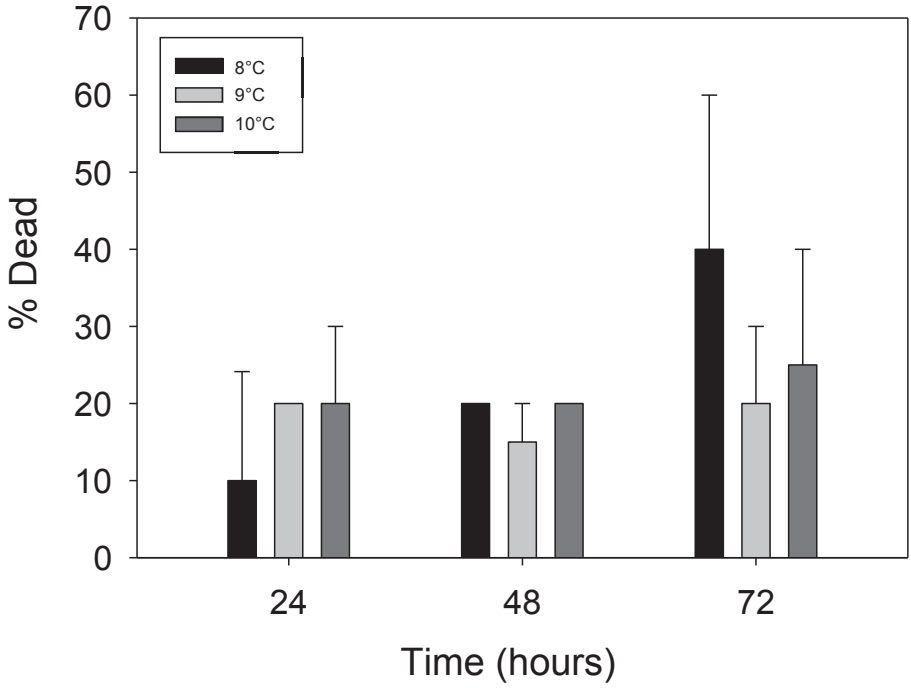

Fig. 2. Mean percent mortality (±1 SE) of American cockroaches during three exposure periods at each of three temperatures.

P. virginica and *P. fulvescens* were tested in the same growth chamber conditions as American cockroaches. After 2 weeks they did not appear to be affected by cold temperatures as they maintained normal activities including walking, response to stimuli, feeding, and antennal cleaning similar to those observed at room temperature.

Discussion

Data show that American cockroaches struggled to survive at moderately cool temperatures (≤10°C) and suggest this cockroach depends on heated buildings in much of its introduced range across the United States. These findings suggest using cold temperature as a management strategy. Uninhabited buildings could be allowed to reach cold temperatures during winter months as a potential method to reduce populations. Future studies should determine the appropriate temperatures and length of time needed to facilitate cockroach mortality.

Immobility in response to cold also has been observed for insects such as *Drosophila*. Before chill-coma occurs, *Drosophila* spp. lose their ability to right themselves (Block 1990; David et al. 1998). Similarly, American cockroaches lost

mobility and rolled onto their backs when exposed to chill-coma temperatures as warm as 9.3°C (Anderson and Mutchmor 1968). The criterion for chill-coma is measured by whether or not an insect responds to being prodded. Chill-coma is an established method to immobilize, easily manipulate, and transport cockroaches (Cornwell 1976) and is reversible if the insects do not suffer chilling-injury (Gibert and Huey 2001). Previous studies show that American cockroaches can recover after being maintained in a cold-induced coma for 1 hour (Staszak and Mutchmor 1973).

This study assessed only survival of adult American cockroaches. Refrigerated American cockroach oöthecae take longer to hatch than those at room temperature (Tee and Lee 2013). This suggests that egg cases of American cockroaches could survive mild winter temperatures. However, additional study is required to determine the length of time and effects of cold temperatures.

Periplaneta japonica survived freezing temperatures for several days including walking unharmed on top of snow (Tanaka and Tanaka 1997). Future studies should compare its temperature tolerance with *P. americana*. It could also be determined if Japanese cockroaches seek shelter in buildings or if they survive in more natural, exposed environments.

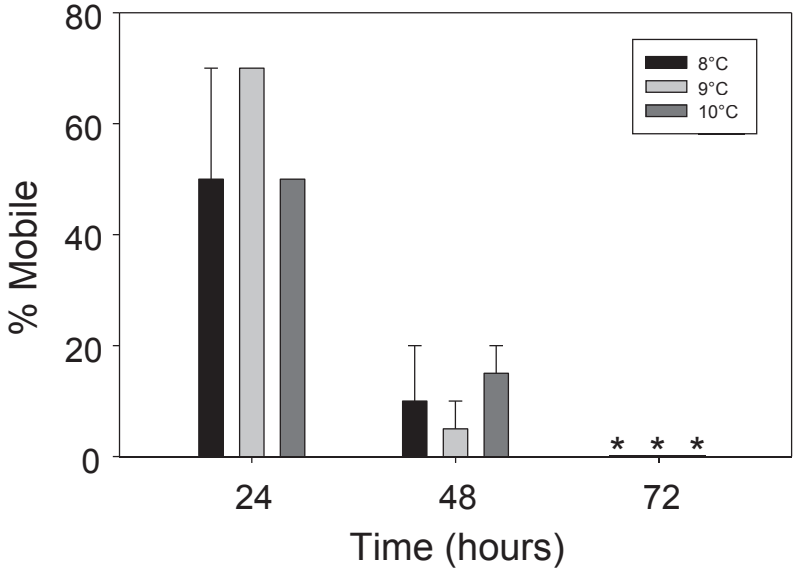

Fig. 3a. Mean (±1 SE) number of American cockroaches mobile and responsive when exposed to different temperatures for different times. *All immobile but not all dead (Immobile cockroaches did not recover within 24 hours).

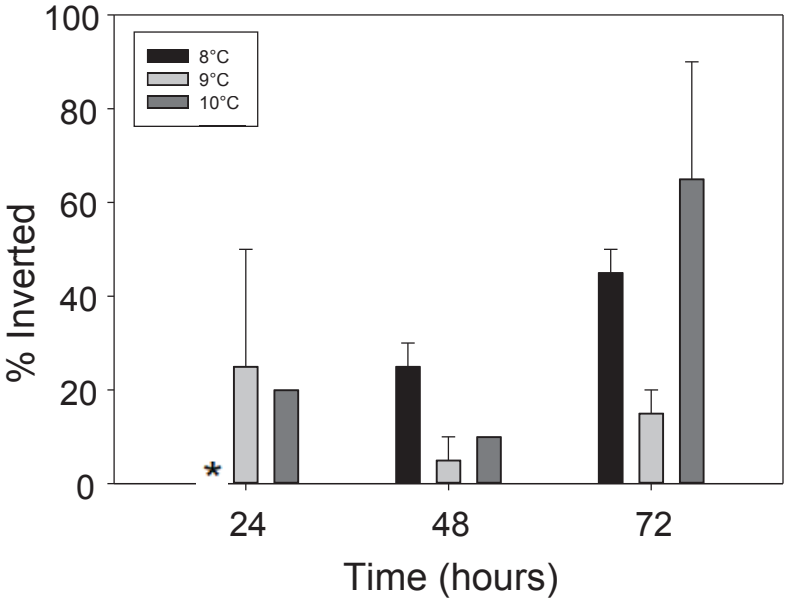

Fig. 3b. Mean (±1 SE) number of American cockroaches inverted but not dead when exposed to different temperatures for different times. *All inverted but not all dead. Inverted cockroaches did not recover within 24 hours.

To apply the strategy of cold temperatures to control American cockroaches, additional studies in non-inhabited buildings that evaluate thermal refuges would be helpful. A similar study on *Gromphadorhina portensa* (Schaum), another tropical cockroach, found that in response to cold stress it increased the amount of protein in its fat body, an example of "cold hardening" that improved survival (Chowanski et al. 2015). Considering results of the open building experiment and growth chamber studies, it may be possible to induce cold-hardening in American cockroaches, perhaps by using shorter exposure periods than those tested here. However, permanent chill-coma injury was 100% after 72 hours at 8 to 10°C. Future studies could evaluate inducement of cold hardiness in American cockroaches.

Acknowledgment

Thanks to John and Heidi Niblack and the Niblack Scholars Program for funding, and to Andrine Shufran and Kiffnie Holt for providing cockroaches.

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