Foraging Activity and Temperature Relationship for the Red Imported Fire Ant[1]

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Abstract The range of temperatures of red imported fire ant, *Solenpsis invicta* Buren, foraging and food bait removal were examined in laboratory assays for six ant colonies collected from central Texas. Ants were observed crawling from laboratory colonies through clear plastic tubes traversing through a temperature controlled water bath in order to access and remove peanut butter bait. The minimum and maximum critical temperature range for these foraging *S. invicta* worker ants was 10 and 50°C, respecitvely. The results suggest that exclusion of ant activity can be attained using temperatures outside of this range. Maximum foraging and bait removal in these assays indicate that optimum temperatures for fire ant bait application are between 25° and 35°C. Using video recordings, crawling speed was found to vary for individual ants between the temperature extremes of 10° and 49°C, ranging from 0.21-cm/sec at 10°C to 3.46-cm/sec at 48°C. There was a significant linear relationship between speed and temperature ($r^2 = 0.71$), where Speed = -0.19 + 0.06 x Temperature.

Introduction

Much of the damage done by imported fire ants, *Solenopsis invicta* Buren (Hymenoptera:Formicidae) occurs when worker ants forage for food and water. The success of suppressing fire ant populations using bait-formulated insecticide products depends on applying these materials during periods when the ants are actively foraging. Defining constraints to ant foraging can be used to prevent ant damage and improve timing of insecticidal baits. Temperatures inside the nest or mound as well as temperatures in subterranean foraging tunnels and on the ground surface each may impact foraging behavior and intensity.

Earlier efforts to document temperature preferences for *S. invicta* were designed to document this preference of this species in comparison to other fire ant species (Cokendolpher and Franke 1985). These authors found that on a linear temperature gradient for 2 hrs, *S. invicta* workers had a temperature preference for 21° to 23.8°C at 0% RH and 25.3° to 27.5°C at 100% RH, depending on acclimation effects resulting from time of field collection. Porter and Tschinkel (1987), through field observation and trapping, noted that *S. invicta* foraged when soil temperatures at 2-cm were between 15° and 43°C and noted that maximal rates were only achieved between 22° and 36°C. They also reported that in their studies, soil temperatures were never so high that foraging ceased altogether. Other researchers, such as Cokendolpher and Philips (1990) and James et al. (2002) focused on minimum critical temperature limits of

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S. invicta for locomotion and survival. Maximum critical temperatures of ants maintained at decreasing temperatures were found by Cokendolpher and Philllips to be 39° to 41.8°C (overall mean of 40.7°C) and the minimum critical temperature to be 1.1° to 6.6°C (mean of 3.6°C) for the entire study. They also reported finding that prior thermal history of ants tested affected the critical values documented. These studies were conducted to help estimate the northern range limits of this species.

This series of trials was conducted to document the impact of the temperature range in laboratory foraging tunnels on ant foraging. In addition, video recording measurements were used to document the effect of temperature on foraging speed.

Methods and Materials

Six polygyne colonies were collected from the field in Brazos County, Texas (Texas A&M Riverside Campus) on 21 November 2003 by shoveling into 5-gal. plastic buckets with the inner surfaces dusted with talcum powder to prevent ant escape. Water was then dripped into the buckets slowly, causing ant colonies to float on the surface, after which they were removed and placed in plastic trays measuring 27 x 37-cm and 9-cm tall. One Petri dish (14-cm diameter and 2.5-cm tall) containing set Castone® moistened with water and with lids in which holes were melted to allow ants to enter and exit was placed in each colony tray to house the queen, brood and worker ants. Each colony was provided with distilled water at room temperature (22-29°C). Colonies used for these assays were examined for estimated worker number, brood (eggs, larvae and pupae) status and presence of queens and winged (alate) adult reproductives on 1 December 2003 prior to conducting trials (Table 1).

Table 1. Assessment of *S. invicta* laboratory colonies used in foraging trials, Brazos Co., TX, 1 December 2003.

Co., TX, 1 December 2003. Colony	No. Workers	Brood (ml)	No. Queens	Alates149
1	20,000	2.0 ml	none[a]	none
2	20,000	trace	2	none
3	30,000	1.0	none[a]	none
4	30,000	2.0	none[a]	none
5	30,000	5.0	none[a]	none
6	50,000	7.0	none[a]	none

[a]Lack of queens denotes none were observed, not necessarily that there were none; presence of brood is an indication that queen ants were present but not observed.

A plastic tray measuring 27 x 37-cm and 9-cm tall was used to make a temperature-controlled foraging tunnel arena that accommodated tubes from six laboratory colonies (Fig. 1). Six, 165-cm long clear plastic hoses (Clean and Fill No Spill® Aquarium Maintenance System, Python® Products, Inc. 7000 W. Marcia Rd. Milwaukee, Wisconsin 53223), 2-mm thick with an 8-mm inside diameter, were threaded through holes drilled on both short sides of the tray and sealed using silicone glue. On one end, the tube emerging on the outside of the tray was sealed using a cap from a Corning 50-ml Centrifuge Tube (Corning Incorporated, Corning, NY 14831, Item #430290, 27-mm inside diameter and 11.3-cm long), with a hole drilled in the center so that the centrifuge tube could be screwed to accommodate a food bait target such as peanut butter (Fig. 2). From the other end, 125-cm of the hose was allowed to dangle into a fire ant laboratory colony onto a stand housing a dowel rod to allow ants to crawl into the hose. The outside of the long end of the hose was painted with Fluon to prevent ants from crawling up the outside (Drees 2002). The foraging tunnel arena or water bath was filled with tap water maintained at 7-to 8-cm deep so that hoses would be submerged. A NESLAB Refrigerated Circulating Bath (NESLAB Instruments, Inc., Portsmouth, NH 03801, Part No. 01115-23) was used to heat and cool water circulating through the tray housing foraging tunnels.

Each day water was heated to 50°C to remove ants from the foraging arena tunnels, and ants were brushed out of the cap of the centrifuge tube. Clean centrifuge tubes housing 5-cm long pieces of clear soda straw (Glad® Flexible Straws, 0.6-cm inside diameter.) in which a 4-mm diameter "bead" of Jif® Creamy Peanut Butter (The J. M. Smucker Co., Orrville, OH 44667), containing roasted peanuts, sugar, 2% or less of molasses, partly hydrogenated vegetable oil (soybean oil), fully hydrogenated vegetable oil (rapeseed and soybean), mono- and diglycerides, and salt, weighing approximately 0.3 g was applied using a plastic squeeze bottle. Temperature was adjusted each day so that the foraging tunnel arena could be maintained at a specified temperature for each 6-hour-long trial period (10:00 -16:00 hrs), beginning 1 December 2003. Over successive trial periods (days) from 1 December through 16 December 2003, temperature settings were randomized to eliminate potential effects of laboratory colony age, food saturation and other possible variables associated with conducting trials in a temperature gradient sequence. Room temperature ranged from 22° to 29°C during these assays.

After 6 hours of exposure to a specified foraging tunnel temperature the amount of peanut butter remaining (estimated as percentage remaining and converted to grams) and estimated number of ants associated with the peanut butter in the centrifuge tube (Fig. 1) was recorded. Means and standard deviations were calculated for data from each temperature trial.

Foraging ants crawling through hoses were videotaped at various temperatures using a using a Sony® Camcorder. The speed at which worker ants crawled through the tubes was determined using the editor function of I-Mac movie software program. This program allows for single ants to be followed for a given increment of time (ranging from 2.14 to 37.3 sec) at different temperatures. By stopping the video at the beginning and end of each sequence, the distance covered by an individual worker ant was measured on a calibrated video screen. Foraging speed (cm/sec) was calculated for up to 1 to 9 ants per temperature increment from 10 to 47°C as follows: 10°C - 1 ant; 12°C - 9; 13°C - 6; 17°C - 3; 18°C - 3; 22°C - 6; 25°C - 5; 31°C - 5; 35°C - 5; 40°C - 5; 46°C - 6; and 47°C - 1. A linear regression, with 95% mean prediction interval and 95% individual prediction interval, was performed on data using SPSS for Windows (Lead Technologies, Inc. Version 11.5).

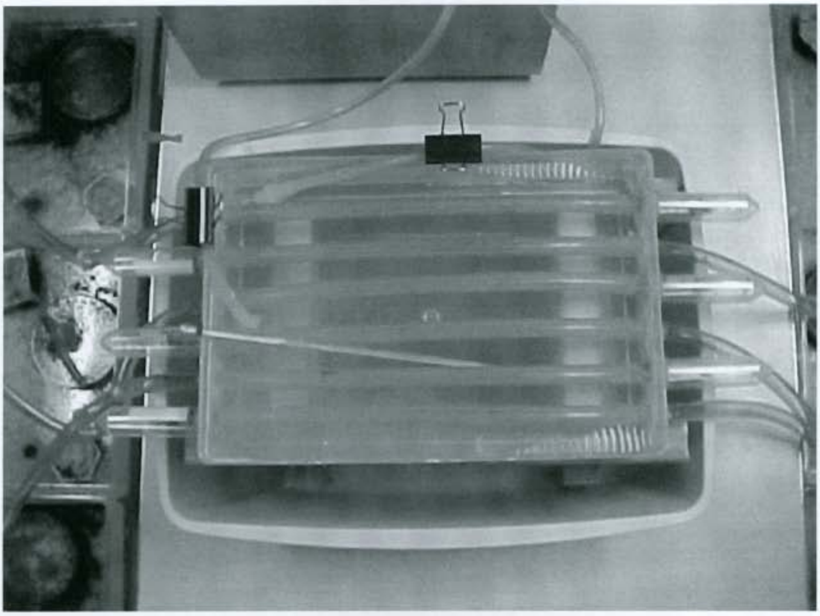


Fig. 1. Foraging structure used to assess effect of temperature on *S. invicta* foraging activities.

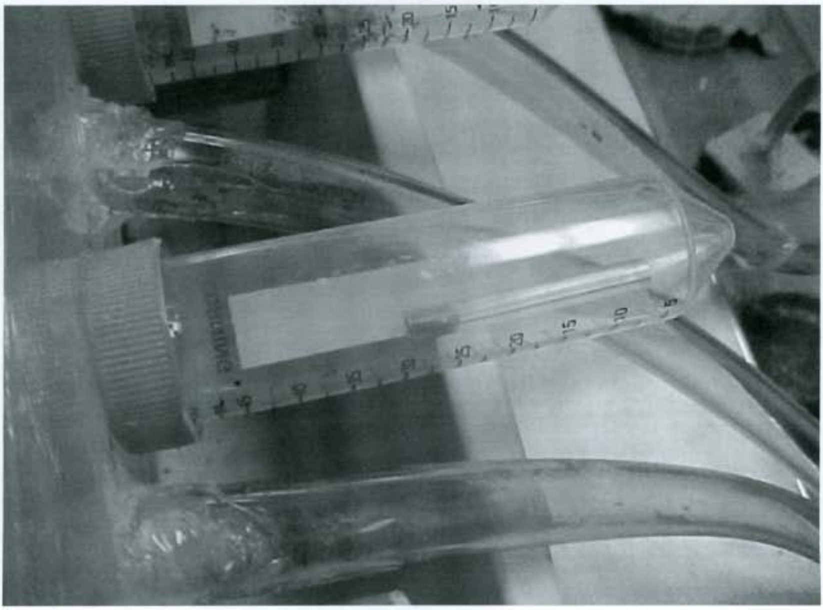
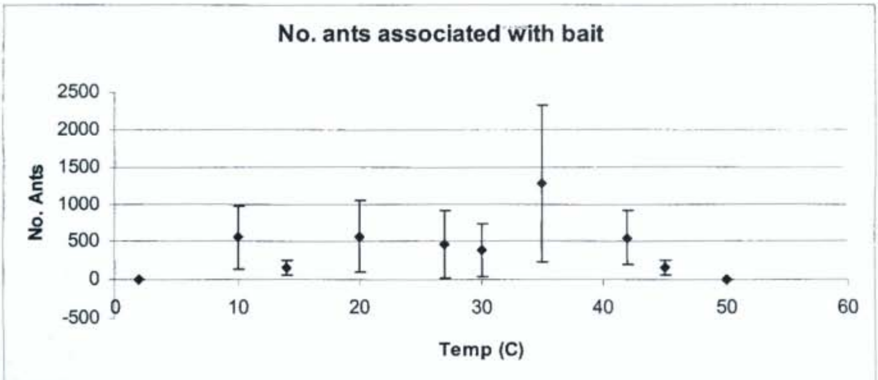


Fig. 2. Food bait (peanut butter) target in centrifuge tube.

Results and Discussion

Results reported herein are relevant particularly for polygyne *S. invicta*, from Brazos Co. in Central Texas and may vary for worker ants from other collection sites or other preconditioning regimes. In these trials, maximum foraging occurred at 35°C, and maximum peanut butter removal was highest at 27°C (Fig. 3).



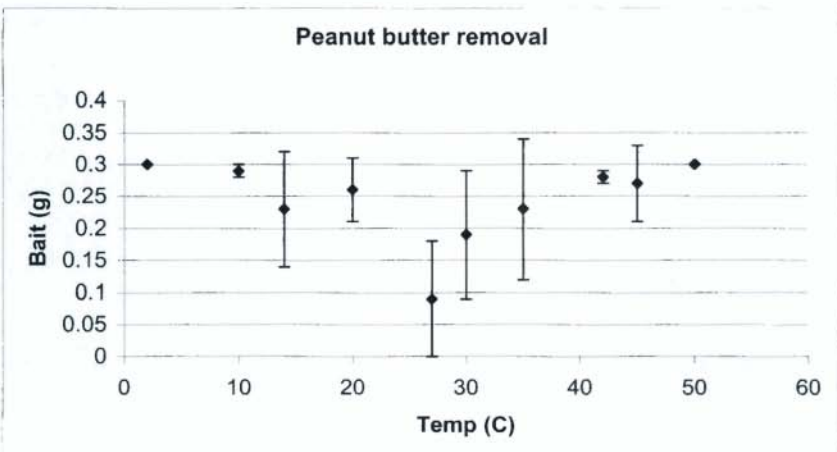


Fig. 3. Average *S. invicta* foraging activity (estimated number of worker ants associated with bait) and peanut butter removal (of 0.3 g) over a 6 hr period at various temperatures in laboratory assays, Brazos Co., TX, Dec. 2003.

No peanut butter was removed at low and high temperatures of 2 and 50°C, respectively. One foraging ant, which may have entered when the temperature dropped to 47°C degrees for a short period of time, was observed in a foraging tube at 50°C. However, no ants were observed crossing hoses to the peanut butter bait in the centrifuge tube beyond these temperature extremes. On 2 December, during cooling water from 50°C, worker ants were observed beginning to enter hoses at 47-48°C. On 4 December, when heating water from 2°C, ants were observed entering the hoses at 7-8°C. Bait exposure for 6 hrs resulted in recruitment for additional foraging ants to the food source.

Foraging speed varied for individual ants between the temperature extremes of 10 and 49°C. Ant crawling speed ranged from 0.21-cm/sec (12.6-cm/min) at 10°C to 3.46-cm/sec (207.60-cm/min) at 48°C. Ants would not enter the tubes submerged in water at lower or higher temperatures. There was a significant linear relationship between speed and temperature ($r^2 = 0.71$), where Speed = -0.19 + 0.06 x Temperature (Fig. 4).

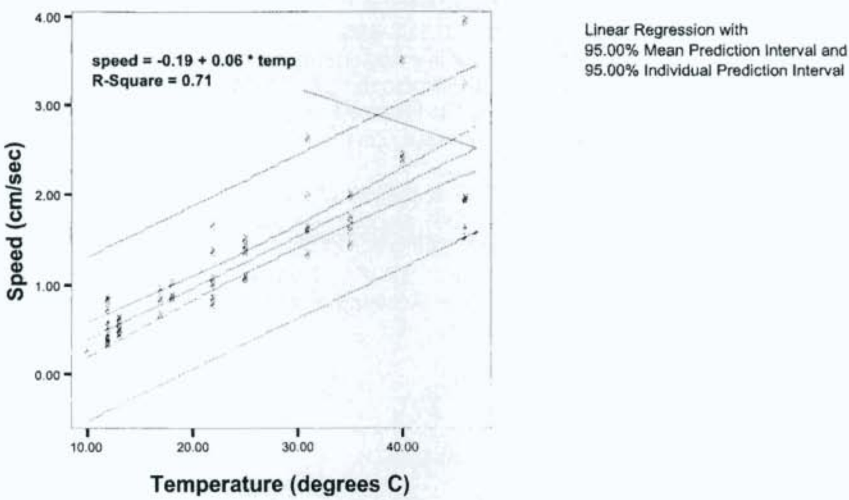


Fig. 4. Foraging *S. invicta* worker crawling speed (cm/sec) at various temperatures in laboratory assays, Brazos Co., TX, Dec. 2003.

The minimum and maximum critical temperature range for foraging *S. invicta* worker ants, attained in this study from surface and air inside experimental plastic tubes, was from 10 to 50°C. The results suggest that optimum temperatures for ant bait application are between 25° and 35°C. These findings are similar to the optimum range (22-36°C soil temperature at 2-cm) reported by Porter and Tschinkel (1987), as well as the 30.4°C peak and 18.1-42.5°C maximum range of surface temperature for *S. invicta* foraging reported by Helms and Vinson (2005).

For development of imported fire ant control products, such as treatments for protecting utility box housings, experiments should be conducted within the range of temperatures in which the ants will forage. Conversely, extreme temperatures (i.e., below 10°C and above 50°C) could be used as a surface barrier or air temperature control method to prevent imported fire ant foraging activities. Finally, speed of foraging is important to understand when considering how fast ants can explore areas for resources or recruit rapidly, as in the case of hatching birds, newborn animals or multiple stinging incidents involving people indoors (Drees 1994, 1995).

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