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HEATING ADULT HONEY BEES TO REMOVE VARROA JACOBSONI

JOHN R HARBO

USDA-ARS, Honey Bee Breeding, Genetics and Physiology Laboratory, 1157 Ben Hur Road, Baton Rouge, Louisiana 70820, USA

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For more than 20 years, heat has been used in many parts of eastern Europe (Karpov & Zabelin, 1978; Komissar, 1979; Komissar, 1985; Akimov *et al.*, 1988) to remove many and perhaps most of the varroa (*Varroa jacobsoni*) from adult honey bees (*Apis mellifera*). Bees are removed from their colony in autumn when there is very little brood. They are caged, placed in a chamber, and rapidly heated to 46°–48°C (RH ≤ 20%) until mites stop falling from the bees (c. 2–15 min). This technique is 85–95% effective (Komissar, 1985; Akimov *et al.*, 1988). However, Hoppe & Ritter (1986) reported only a 23% mite mortality with this procedure. The procedure causes mites to fall from live bees, but apparently does not kill the mites.

Heat has also been effective for treating mites on adult bees in field colonies and in treating mites in capped brood. Hoppe & Ritter (1989) found heat to be much more effective when combined with oil of wintergreen. Mites in brood cells failed to reproduce or were killed when they were exposed to 40°C for 24 h or to 42° for 6 h (LeConte *et al.*, 1990). Engles (1994) recommended controlling mites by heating combs of capped brood without adult bees.

The purpose of this study was to evaluate the removal of mites from caged, adult bees during a longer (48 h) treatment period and at temperatures below what had been practiced heretofore. Unlike other heat treatments, the duration of this test required that the bees be given food and water during the treatment. I wanted to find the lowest temperature that would remove all varroa from a cage of bees. Of four temperatures tested (25°, 35°, 38°, and 40°C), 40°C showed potential for practical application.

Each replicate of the test used about 3 kg of bees that were naturally infested with varroa. The bees were collected into a single, large cage and then subdivided into test populations by scooping bees into smaller cages (14 × 22 × 16 cm) that were put into incubators. Each cage contained about 150 g of bees and 20–60 mites.

Cages were made of plywood and screen (8 wires per 2.5 cm). The top, bottom and ends were wood, and the two large (22 × 16 cm) sides were screen. Screen was also placed over the 9 cm (diam) circular opening at the top. The cages were placed sideways in the incubator so that the screened sides were at the top and bottom. Candy and water were on the top screen; mites dropped through the bottom screen. Four staples kept the cage about 1 cm above the oiled surface that trapped the fallen mites. This surface was provided for each cage and consisted of a 22 × 29 cm board that was painted white and covered with a sheet of freezer paper (plastic side down). Mites die quickly after contacting oil, so the paper and the board were coated with canola oil. The oil was applied to the paper with a large paintbrush and to a groove near the edge of the board that served as an additional barrier (moat) to trap mites.

Except for the first replicate which consisted of 14 cages, 16 cages of bees were tested during each of three test periods by placing four cages of bees into each of four incubators. In subsequent test periods, each treatment (temperature) was randomly assigned to a different incubator. During the 48-h treatment period, bees were fed water and candy (a 2 : 1 mixture of confectionery sugar and honey). Temperature and humidity (RH always 55 ± 10%) were monitored in each incubator with a hygrothermograph.

Heat treatments were continued for 48 h. Mites falling from the cages were killed and trapped as they fell onto the oiled papers below the cages. Oiled papers were replaced 16 h, 24 h and 42 h after the start of the experiment. Mites were counted when papers were changed and at the end of the test.

I calculated the mite population that remained on the bees at the end of the 48-h treatments. Mites were counted in a sample of 30–60 g of bees that was washed in 70% ethanol (Harbo & Zuhlke, 1988). Estimates of final mite populations were based on total weight of the bees in each cage, the weight of each sample, and the number of mites in the sample.

Data were evaluated with analysis of variance using a General Linear Model procedure and SAS software. The interaction of temperature by replicate served as the error term in the analysis. Mean differences were evaluated with least significant difference analysis. Because there was no variance in the data from cages given a 40°C treatment for 48 h (no mites were found on adult bees), this treatment was not included in the initial ANOVA and was treated as a constant in the mean separation.

These data suggest that 40°C is the lowest temperature at which all mites can be removed from caged bees. ANOVA detected differences among treatments at the 24-h and 48-h test intervals ($F = 37.3$; d.f. = 3, 6; $P = 0.0003$ and $F = 23.1$; d.f. = 3, 6; $P = 0.006$; respectively). Means are presented in table 1.

Heat treatment involves many variables: the number of bees treated, cage size and shape, air flow, temperature, humidity and time. These all need to be considered when

TABLE 1. The mean percentage of mites that dropped from caged bees when held in incubators for 24 and 48 hours (RH = 55 ± 10%). Each temperature (row) consisted of 11 or 12 observations. Treatments were compared within each time period (column comparisons) and means followed by different letters were significantly different at the 0.05 level (LSD mean separation)

Temperature (°C)	24 hours (% mite drop)	48 hours (% mite drop)
25°	4.7 a	8.3 a
35°	31.2 b	41.7 b
38°	38.7 b	46.8 b
40°	97.4 c	100.0 c1
lsd	21.9	17.2

¹Since this observation had no variance, it was treated as a constant and comparisons between this and other means had an lsd of 12.2

TABLE 2. Water and sugar consumption by the caged bees described in table 1.

Temperature (°C)	g sugar per 100 g of bees per day	g water per 100 g of bees per day
25°	10.5 ¹	10.7
35°	7.5	42.1
38°	4.7	72.0
40°	2.9	94.4

¹These means are intended as a guide for maintaining bees in incubators (c. 55% RH). This is not necessarily a measure of food or water that were metabolized by bees because food reserves in the bees were not measured at the beginning and end of the treatment period.

trying to remove mites without killing bees, and there are probably many combinations that will succeed. I was unable to remove all mites when I provided the bees with comb (which they filled with water), when treating 1 kg of bees in a cage measuring 13 × 34 × 24 cm, or when using 30% RH. However, treatment of ≤ 500 g of bees at 40°C and c. 60% RH was consistently effective.

Overall, heat treatment is a risky procedure. Even 40°C, the lowest temperature that can remove all the mites, is perilously close to temperatures that kill bees. Bees do not survive for two days at 42°C (Harbo, 1993), but they can survive even higher temperatures for shorter periods. The Russian technique (Komissar, 1985) recommended a low humidity ≤ 20% RH, and I suspect that this was to reduce the mortality of bees (Free & Spencer-

Booth, 1962). In general, as temperatures increase, less time is needed for both killing bees and removing mites.

Food and water are not important during a 15-min treatment, but are needed if bees are held for longer periods. Table 2 shows the water and sugar consumption of the bees in the cages. Bees at 40°C required about their weight in water per day, whereas bees at cooler temperatures consumed more sugar. To prevent water from dripping onto the bees, water needs to be as warm or warmer than the incubator at the start of the treatment.

Since temperatures of 25° and 35°C are common in a colony of bees, the falling of live varroa from adult bees may be part of a natural routine. Live mites may be able to return to the brood nest on an incoming forager. Therefore, it may not be valid to estimate the natural mortality of mites in a colony by using oil or sticky boards on a floorboard. These boards are traps that may tend to overestimate the natural mortality of mites.

Results of this study suggest a few practical applications for heating bees. Heat can be used to measure mite populations on adult bees without killing the bees and to establish mite-free populations of bees. Conversely, avoid heat to keep mites on caged bees; mites adhered well to bees at room temperature.

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