

Hoarding Behavior of the Honey Bee: Effects of Empty Comb, Comb Color, and Genotype^{1,2}

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ABSTRACT

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Honey bees, *Apis mellifera* L., from 5 colonies, were placed in laboratory cages supplied with either 46.75 or 140.25 cm² of comb surface area (CSA) that was either dark-brown brood comb or light-yellow comb.

A 3-way analysis of variance showed that bees hoarded more in the presence of greater CSA ($P < 0.005$). Overall, bees did not hoard more in the presence of either color of comb. Bees from different colonies hoarded at different rates ($P < 0.005$). Hoarding responses for bees from different colonies interacted with responses to different colors of comb ($P < 0.025$). This interaction opens the possibility for the genetic selection of stock that would produce maximum amounts of honey when supplied with light storage combs.

Hoarding behavior of the honey bee (*Apis mellifera* L.) has been measured in laboratory cages (Free and Williams 1972, Kulinčević and Rothenbuhler 1973) and shown to be variable between colonies (Kulinčević and Rothenbuhler 1973; Rinderer and Sylvester 1978). This variability is correlated to honey production of field colonies (Kulinčević et al. 1974, Kulinčević and Rothenbuhler 1973). Consequently, measurement of hoarding behavior has been suggested for identification of genotypes prior to selective breeding.

Assessment of hoarding behavior has also helped identify environmental factors which influence the phenotypes of hoarding and honey production. Bees hoarded more in dark-colored comb in which brood had previously been raised than they hoarded in new light-colored comb (Free and Williams 1972). Also, bees hoarded more if more comb was available in experiments using dark comb (Rinderer and Baxter 1978a).

These independent and parallel observations did not show whether greater amounts of light comb increase hoarding or if any interactions occur between the factors of comb color, amount of comb, and sources of bees. This experiment was designed to answer these questions.

Materials and Methods

Laboratory hoarding cages (Kulinčević et al. 1973) were fitted with either 3 pieces of light-yellow comb, 3 pieces of dark-brown comb, one piece of light comb, or one piece of dark comb. The light comb never had brood reared in it, while the dark comb had been used for brood rearing repeatedly. The total surface area of one piece and 3 pieces of comb was 46.75 and 140.25 cm², respectively. Each hoarding cage was supplied with one feeder that contained 50% (wt/wt) sucrose in water solution; a 2nd feeder contained water; a 3rd contained a pollen substitute (Rinderer and Elliott 1977).

Combs of emerging adult worker bees were obtained from 5 colonies and held in an incubator (35°C and 50% RH) until the bees were 0-24 h old. Bees from each colony were then placed in 4 of each of the 4 types of

cages. All cages received 30 bees (Rinderer and Baxter 1978b).

After the hoarding cages were stocked with bees, they were placed in an incubator (35°C and 50% RH). Each cage was inspected daily for 7 days; the amount of sucrose solution removed from the feeders was measured, and all feeders were replenished. Data on the volume of sucrose solution removal during 7 days were submitted to a 3-way analysis of variance.

Results

Analysis revealed that bees hoarded more ($P < 0.005$) in cages with 3 combs ($\bar{x} = 23.9$ ml) than they did in cages with 1 comb ($\bar{x} = 19.6$ ml) (Tables 1 and 2). Bees from all 5 source colonies followed this trend and consequently the term in the analysis of variance testing interaction of comb surface area and source colonies is insignificant (Table 2). Also, the interaction between the factors of comb area and comb color was insignificant (Table 2).

Analysis also revealed that while overall bees hoarded more in dark comb (22.7 ml) than they did in light comb (20.8 ml) (Table 1), the difference was not significant (Table 2). Further inspection of the data showed that bees from 3 colonies (2, 4, and 5) hoarded greater volumes of sucrose solution in light comb, and bees from 2 colonies (1 and 3) hoarded greater volumes of sucrose solution in dark comb (Table 1). These differences resulted in a significant ($P < 0.02$) comb color by source colony interaction.

Significantly different amounts ($P < 0.005$) were hoarded by bees from different colonies (Table 2). In the classification by colonies, the range of hoarding responses was from a mean of 32.9 to 15.8 ml (Table 1).

Discussion

These results support the conclusion of Rinderer and Baxter (1978a) that bees hoard more rapidly with greater amounts of available dark comb than they hoard with lesser amounts of available dark comb. Furthermore, these results support the extension of that conclusion to include greater and lesser amounts of light comb.

The results of our experiment also extend the results of Free and Williams (1972). Using only "bees . . . collected from the same hive" they concluded that "bees

¹ Hymenoptera: Apidae.

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Table 1.—Milliliters of sucrose solution hoarded by bees from 5 colonies with 2 colors of comb and 2 levels of comb surface area.^{a,b}

Colony	Treatments				Colony mean
	Dark comb		Light comb		
	3 combs	1 comb	3 combs	1 comb	
1	31.0±5.2	24.5±2.3	21.8±3.4	14.5±1.2	22.9±2.1
2	16.5±1.4	19.3±1.7	23.3±5.7	16.8±1.4	18.9±1.6
3	23.0±0.4	17.8±2.4	14.5±1.3	17.5±2.6	18.2±1.2
4	19.8±4.0	11.0±0.7	16.8±1.4	15.5±0.7	15.8±1.3
5	33.0±3.5	31.5±1.8	39.5±2.3	27.8±1.3	32.9±1.5
$\bar{x} \pm SE$ of treatment	24.7±2.0	20.8±1.7	23.2±2.4	18.5±1.3	
$\bar{x} \pm SE$ of main effects from comb	Dark comb 22.7±1.3	Light comb 20.8±1.4	3 combs 23.9±2.0	1 comb 19.6±1.1	

^a N = 4 for each colony by comb color by comb surface area combination.
^b Analysis appears in Table 2.

Table 2.—Results of a 3-way analysis of variance of data on honey bee hoarding response to comb color, surface areas of comb, and source colonies of bees presented in Table 2.

Source of variation	df	F Value	Probability
Surface area of comb (S)	1	13.01	<0.005
Comb color (C)	1	2.64	NS
Source colonies (SC)	4	26.02	<0.005
S×C	1	0.13	NS
S×SC	4	1.04	NS
C×SC	4	3.53	<0.02
S×C×SC	4	2.81	<0.05

in the cages with the old comb collected more and stored more in combs." In our experiment, which used 5 colonies as sources of bees, this was true for bees from 2 colonies but not true for bees from 3 colonies. Also, there was a significant interaction between comb color and colony source. This indicates that the tendency to store more in dark comb is not universal but rather a point of variability among colonies of bees.

This variation in the response of bees from different source colonies to comb color is of special interest. Honey extracted from light comb is itself lighter (Townsend 1969), and preferred by honey producers. The results of this experiment indicate that a breeding program aimed at maximizing honey production when bees are supplied with light-colored storage combs would likely be successful.

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