An Experiment on Comb Orientation by Honey Bees (Hymenoptera: Apidae) in Traditional Hives

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ABSTRACT The orientation of combs in traditional beehives is extremely important for obtaining a marketable honey product. However, the factors that could determine comb orientation in traditional hives and the possibilities of inducing honey bees, *Apis mellifera* (L.), to construct more desirable combs have not been investigated. The goal of this experiment was to determine whether guide marks in traditional hives can induce bees to build combs of a desired orientation. Thirty-two traditional hives of uniform dimensions were used in the experiment. In 24 hives, ridges were formed on the inner surfaces of the hives with fermented mud to obtain different orientations, circular, horizontal, and spiral, with eight replicates of each treatment. In the remaining eight control hives, the inner surface was left smooth. Thirty-two well-established honey bee colonies from other traditional hives were transferred to the prepared hives. The colonies were randomly assigned to the four treatment groups. The manner of comb construction in the donor and experimental hives was recorded. The results showed that 22 (91.66%) of the 24 colonies in the treated groups built combs along the ridges provided, whereas only 2 (8.33%) did not. Comb orientation was strongly associated with the type of guide marks provided. Moreover, of the 18 colonies that randomly fell to patterns different from those of their previous nests, 17 (94.4%) followed the guide marks provided, irrespective of the comb orientation type in their previous nest. Thus, comb orientation appears to be governed by the inner surface pattern of the nest cavity. The results suggest that even in fixed-comb hives, honey bees can be guided to build combs with orientations suitable to honey harvesting, without affecting the colonies.

KEY WORDS *A. m. mellifera*, comb orientation, honey harvesting, traditional hive, nest pattern

The use of traditional hives is still the dominant beekeeping practice in tropical Africa, the Near East, the Middle East, and many parts of Asia (Crane 1990). Traditional hives are made from a wide range of cheap and locally available materials, including basket (Fig. 1a), log (Fig. 1b), bark, clay, mud, and others. Traditional hives produce a significant proportion of the world's honey and are also the major source of the world's beeswax production (Crane 1990). Raw honey from traditional hives is of good quality before harvesting and processing (Townsend 1976), and it meets export quality standards (Nuru and Eddessa 2006). The majority of beekeepers in developing countries still use traditional hives because of the prohibitively high prices of box hives and beekeeping accessories and a lack of adequate training on how to manage colonies in box hives. Despite their advantages, traditional hives have many limitations, among which irregular comb orientation is the most important.

In traditional hives, some colonies construct highly irregular combs, while others construct circular combs, repeatedly one after the other, some build in spirals; and some build oblong combs in parallel with the length of the hive (Fig. 2). This variability makes honey harvesting without adversely affecting the bees and their brood difficult. In a survey conducted in Ethiopia, >50% of the combs in traditional hives were found to be of irregular orientation (Nuru 2004). If the combs are oblong, a single comb may consist of honey, pollen, and brood in different sections. Such type of comb construction makes it difficult to harvest the honey without affecting the brood and pollen stores. Moreover, it is difficult to check the contents of each comb if the comb orientation is irregular. The harvesting of irregular combs can cause a reduction in honey quality because bees are trapped and crushed during harvesting. Conversely, circular combs are easy to remove in sequence without affecting the brood or crushing many bees. Circular combs are also ideal for the production of comb honey, which commands a higher market price than extracted honey.

The orientation of honey bee combs remained a point of argument for many decades. Brother Adam

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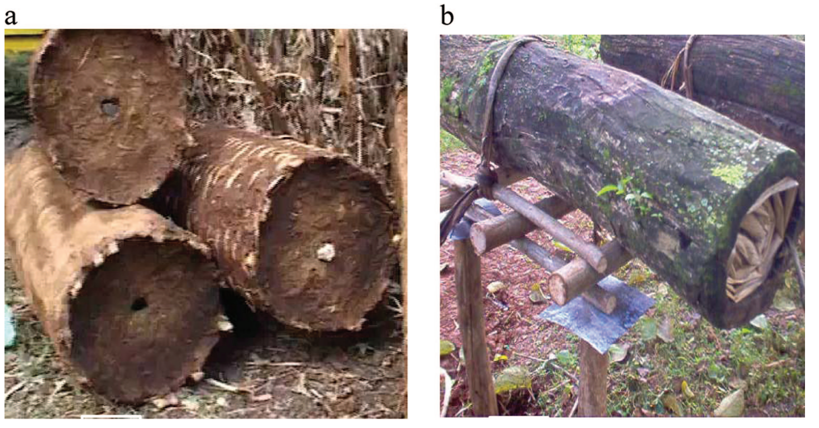

Fig. 1. Different types of traditional hives (a, basket; b, log hive). (Online figure in color.)

(Adam 1954) suggested that comb orientation in traditional hives is a function of colony size. Lindauer and Martin (1972) and Martin and Lindauer (1973) reported that bees built combs parallel to the same plan and compass direction as the combs of the parent colonies. They also demonstrated the possibility of changing comb orientation by changing the magnetic field surrounding a hive. Moreover, De Jong (1982) showed a positive tendency of colonies to maintain the same comb orientation as that of the natal nest and also concluded that the Earth's magnetic field was an important cue used by bees in the orientation of their combs during building. Conversely, Owens and Taber (1973) inferred that comb orientation was based on the position of the nest entrance. However, Seeley and Morse (1976) concluded that the arrangement of combs was independent of both the position of the nest entrance and the magnetic field of the Earth. Robinson (1981) reported that Jordanian beekeepers believe that different strains of bees build combs with different orientations. For example, "*Kameri*" bees build round combs, whereas "*Harithi*" bees build oblong combs.

In this study, we attempted to identify the factors contributing to different comb orientations in traditional hives, and we tested the possibility of guiding

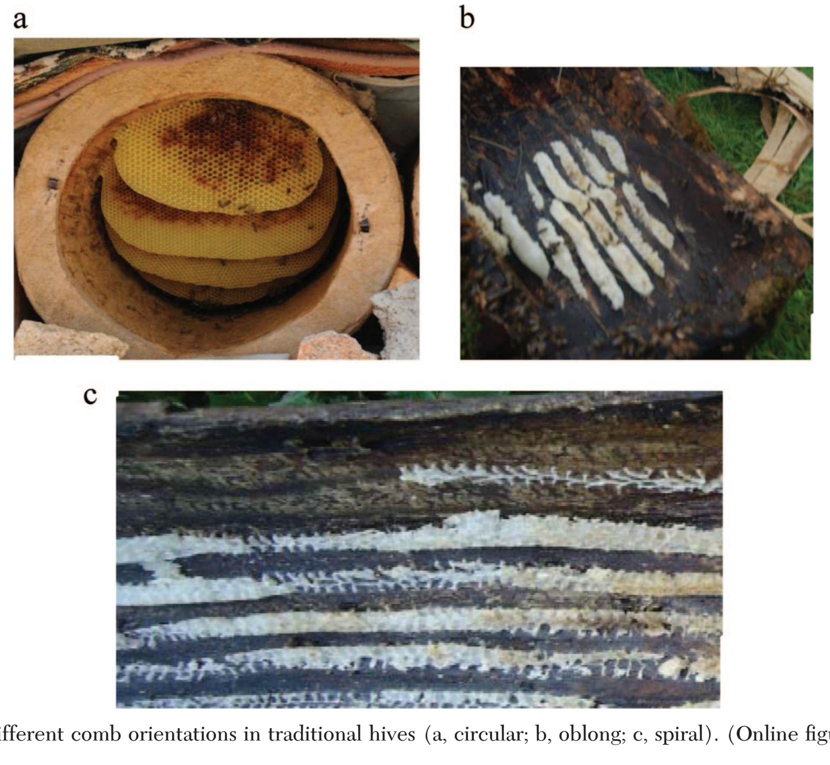

Fig. 2. Different comb orientations in traditional hives (a, circular; b, oblong; c, spiral). (Online figure in color.)

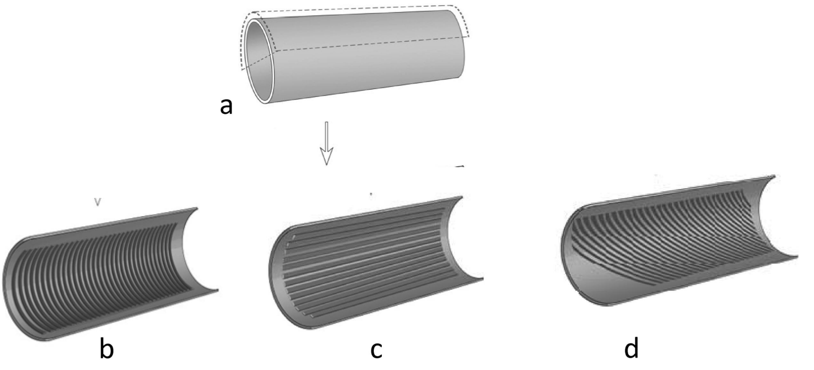

Fig. 3. Cross section of the hive showing patterns of ridges formed on ceiling part of the experimental hives (a, external view of the hive, area marked with dots indicate where ridges were formed; b, circular ridges; c, oblong ridges; and d, spiral ridges).

honey bees to construct circular combs, which are the most suitable for honey harvesting.

Materials and Methods

The experiment was conducted with colonies of *Apis mellifera* over 12 mo, between September 2008 and September 2009, in the highlands of Ethiopia. For this study, 32 traditional basket hives were constructed using splits of a local perennial plant, the giant reed (*Arundinaria donax* (L.)). The hives were uniformly cylindrical, with fixed dimensions of 1.2 m length × 30 cm diameter (Fig. 1a). The insides of the hives were plastered with well-fermented mud and were allowed to dry. The hives were randomly grouped into four treatment groups of eight replicates each. For each treatment, the desired pattern of ridges was constructed using mud on the inner surface destined to become the ceiling of the hives. The hives in treatment one had circular ridges, treatment two had horizontal ridges and treatment three had spiral ridges. Circular ridges ran crossways to the length of the hive, horizontal ridges parallel to the hive length, and spiral ridges at acute angles to the long axis of the hive (Fig. 3). During ridge formation, only the ceiling parts of the hives were marked with mud, leaving the curved walls and bottom parts smooth. In the control group, the mud was plastered to a smooth finish without any ridges or marks.

Thirty-two well-established honey bee colonies of approximately equal size in traditional hives were obtained from local beekeepers and moved to the study site. The colonies were kept in the same hive in the new site for 30 d and then transferred to the four newly prepared experimental groups of hives. The colonies were randomly assigned to the four treatment groups (circular, horizontal, spiral, and smooth) with eight replicates each. During transfer the marked surfaces of the hives were positioned upward so that the bees would initially cling to these points to start comb construction. When the colonies were transferred to the experimental groups, the comb orientation types of their previous hives were also recorded for subsequent comparison with the combs built in the experimental hives. During the random assignment of colonies into the three treatment hives with different guide marks (circular, spiral, and horizontal), 18 of 24 colonies randomly fell to hives with guide marks that differed from the comb orientations of their previous hives, whereas the remaining six colonies were fell to hives with guide marks similar to the comb orientation positions of their previous hives. Eight of the colonies were assigned to control hives without guiding marks.

Table 1. Comb orientation in relation to guide marks and previous comb orientation

	Comb orientation built after treatment			*G*-value	df	*P*
	Circular	Horizontal	Spiral			
Guide marks						
Circular	7	0	1	10.75	2	0.0046
Horizontal	0	7	1	10.75	2	0.0046
Spiral	0	0	8	16.00	2	0.0003
Total G				37.50	6	<0.0001
Heterogeneity G				36.75	4	<0.0001
Previous nest comb orientation type						
Circular	1	2	2	0.40	2	0.8187
Horizontal	3	2	6	2.36	2	0.3067
Spiral	3	3	2	0.25	2	0.8825
Total G				2.61	6	0.8559
Heterogeneity G				0.36	4	0.9856

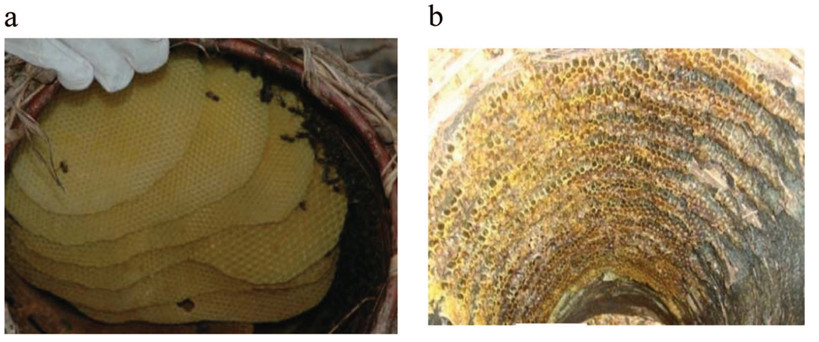

Fig. 4. Comb orientation built following circular ridge marks (a, hive filled with circular combs; b, combs removed revealing their attachments to the hive). (Online figure in color.)

The transfer of the colonies was performed during the early flowering period in the area (September).

Observations were made to determine whether building bees followed their assigned guide marks and to ascertain any changes in comb orientation from the onset to the end of comb building. Observations were made every 10 d during two active seasons: the major flowering season (September, October, and November) and the minor flowering season (April, May, and June), when comb building mainly occurs. The observations were continued until all colonies had completed building combs to the length of the experimental hives. The statistical analysis for differences in the numbers of colonies observed with combs that followed the pattern of guide marks were tested using G test of heterogeneity (Sokal and Rohlf 1995). All tests were performed using Statistica 10.0 software (StatSoft Inc. 2010).

Results

Twenty-two of the 24 honey bee colonies (91.66%) that were randomly assigned to one of the three treatments, built combs following the patterns of the guide marks given, whereas only 2 (8.33%) did not (Table 1; Figs. 4-6). The comb orientation was strongly associated with the type of guide marks given to the bees (heterogeneity G-test: $\chi_4^2 = 36.75$, $P < 0.0001$; Table 1). In the control hives without any guide marks, two colonies constructed circular combs, three constructed spiral combs, and the remaining three constructed oblong combs. These results clearly show that bees may construct combs of quite variable orientation in the absence of definite guide marks.

Seventeen of the 18 colonies (94.4%) that fell to hives with guide marks different from their previous nests comb orientations pattern, constructed combs irrespective of the comb orientations in their previous hives. There was no association between the previous nest's comb orientation and the orientation of combs built in the treatment hives (heterogeneity G-test: $\chi_4^2 = 0.36$, $P = 0.9856$; Table 2). Of the remaining six colonies that fell to the guide marks matching their previous comb orientations, five built combs following the surface ridge patterns to which they had been assigned, which were also the same as in their previous nests. One colony built combs following neither the given guide marks nor the type of comb in its previous hive. It was also observed that once colonies

Fig. 5. Comb orientations built following spiral marks. (Online figure in color.)

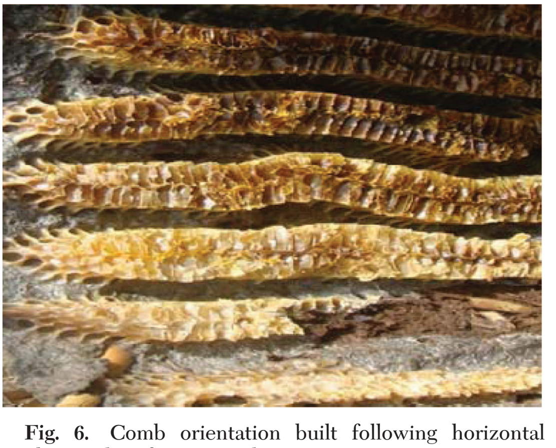

Fig. 6. Comb orientation built following horizontal marks. (Online figure in color.)

Table 2. Comb orientations built by colonies in relation to assigned guide marks and their previous nests comb orientation types

	Comb orientation built by honeybee colonies		
	Circular	Horizontal	Spiral
Previous nest comb orientation types of colonies that assigned to guide marks differed from the parent nest			
Circular (n = 4)	0	2	2
Horizontal (n = 8)	3	0	4
Spiral (n = 6)	3	3	0
Previous nest comb orientation types of colonies that assigned to guide marks similar to the parent nest			
Circular (n = 1)	1	0	0
Horizontal (n = 3)	0	2	0
Spiral (n = 2)	0	0	2

started to build combs in a particular orientation, they continued to build the same type of combs throughout the hive.

Discussion

Twenty-two of the 24 colonies (91.66%) transferred to hives with guide marks built combs following the ridge patterns given to them, demonstrating that comb orientation is largely governed by the inner surface patterns present in traditional hives. This result shows that honey bees start comb building by anchoring bits of beeswax to the ridges in the hive. Indeed, even in commercial box hives, strips of beeswax foundation are inserted in the frames to guide the workers in starting their combs. Moreover, our results are similar to those obtained from hives constructed with vines, splits of bamboo, or *Arundinaria donax* (L.), all of which have circular weave marks on the inner sides. In most cases, the bees were observed to construct circular combs following these ridges (A.N., unpublished observation). Similarly, if construction sticks are oriented parallel to the length of a traditional hive and are not completely covered during plastering, the bees build oblong combs along the ridges of the horizontally arranged sticks (A.N., unpublished observation) and (Fig. 7).

Bees may prefer to orient their combs following a ridged rather than flat surface because 1) the former provides the bees with a firmer base on which to properly anchor their combs than the latter and 2) the former provides a greater surface area within the same linear distance on which to build combs than the latter. As the radius of a ridge increases, the surface area of the ridge also increases proportionately, providing more space than flat surfaces. In contrast to box hives, bees are highly likely to reinforce the base of the comb in the absence of comb-supporting structures in traditional hives or natural nests. In this regard, Kigatiira (1974) noted that bees attach combs to the vertical side walls of top bar hives and inferred that as the weight and area of the comb increases, the bees must reinforce the combs with more attachment points; the greater the area of attachment, the more stable the combs. Thus, one of the possible reasons that bees follow ridges is to obtain a greater surface area for anchoring the combs to make more stable combs.

The bees transferred from their previous nest cavities to the experimental hives with guide-mark orientations different from their natal nests did not retain the same type of comb orientation in the new hives. These results demonstrate that the honey bees can easily shift from one comb orientation to another depending on the surface pattern of the nest cavity (Tables 1 and 2). The association between the comb orientation before and after treatment was not significant (heterogeneity G-test: $\chi_4^2 = 0.36$, $P = 0.9856$; Table 1). This result suggests that the comb orientation is primarily governed by the inner surface pattern of the nest cavity. Generally, the vast majority of colonies (17 of 18) that were placed in hives with guide marks differing from their previous nest comb orientation built combs following the ridges and not in their previous orientation. Likewise, five of the six colonies placed in hives with guide marks similar to those of their previous nests also built combs following the assigned guide marks. This result clearly demonstrates the importance of the nest's environmental factors (i.e., the nest surface patterns) in influencing the comb orientation of honey bees.

Fig. 7. Oblong combs built following horizontal sticks. (Online figure in color.)

The possible factors determining comb orientation have been previously assessed. For example, Lindauer and Martin (1972), Martin and Lindauer (1973), Gould et al. (1978), and De Jong (1982) reported that the Earth's magnetic field was an important cue used by bees in the orientation of their combs during building. Moreover, Lindauer and Martin (1972), Martin and Lindauer (1973), and De Jong (1982) reported that bees built combs in parallel and in the same compass directions as the combs of their parent colonies. However, the current study results (Tables 1 and 2) do not support the idea that bees maintain the same comb orientation as in the natal nest during building of their combs in new nest. Owens and Taber (1973) inferred that comb orientation was based on the position of the nest entrance, a conclusion that is inconsistent with the results of the current study. Seeley and Morse (1976) concluded that the arrangement of combs was independent of both the position of the nest entrance and the Earth's magnetic field.

Generally, this study may indicate that comb orientation is primarily influenced by the inner surface patterns of the nest. This may further indicate that honey bees can be guided to construct desirable types of combs if traditional hives are provided with guide marks on which the bees can build. Further studies using different honey bee races and different induction methods would be important to further illuminate comb-building behavior in honey bees.

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