Tanzania Journal of Science 50(3): 445-453, 2024
ISSN 0856-1761, e-ISSN 2507-7961

Natural Bee Space and Comb Cell Dimensions of Honey Bee Colonies in Mwinkantsi Village, Babati District, Tanzania

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Received 5 Jul 2024, Revised Sept 13 2024, Accepted Sept 15, Published Sept 30 2024
https://dx.doi.org/10.4314/tjs.v50i3.3

Abstract

The use of improved beehives in beekeeping is emphasized to facilitate easier colony manipulations. The improved beehives used in Tanzania are either imported or manufactured locally by adopting dimensions for European honey bees. However, the dimensions adopted are faulty to the dimensions of local honey bees, leading to problems such as cross-combing which hinder realization of the expected management advantages. This study assessed the characteristic natural bee space and comb cell dimensions of honey bee colonies occupied the traditional split log hives in Mwinkantsi village, Babati district. Results showed that honey bee colonies in Mwinkantsi village exhibited an overall bee space of 11.82 ± 0.36 mm, larger than a range of 7.5 ± 1.5 mm bee space reported for European honey bees. The colonies also exhibited 22.21 ± 0.62 mm overall average comb thickness, 12.01 ± 0.57 mm comb cell depth, and 5.05 ± 0.46 mm comb cell width. Moreover, both bee space and cell dimensions showed significant variations influenced by comb type. These findings add to the body of knowledge and suggest extensive agroecological investigations on natural characteristic dimensions of local honey bee colonies in Tanzania. This will inform the construction of improved hives that suit local honey bee colonies.

Keywords: Honey bees; Bee space; Comb thickness; Cell dimensions; Tanzania.

Introduction

Modern beekeeping in Tanzania is being promoted especially through the use of improved beehives and management practices (Kuboja et al. 2016, 2020). Tanzania's beekeeping sector is, however, at the infant stage despite the ideal environment for beekeeping and the 9.2 million colonies potential of the country (MNRT 1998). Honey bee (*Apis mellifera*) colonies are managed in the forests using traditional hives, which account for the majority of beehives in Tanzania (Mwakatobe and Mlingwa 2006). Beekeepers have significantly adopted improved hives such as Langsthroth and Tanzania Top Bar due to easier management (Kuboja et al. 2016, 2020). Nevertheless, challenges of colony management have been reported in these hives, attributed to the local environment and honey bee behavioural characteristics (Gregory 2009).

Honey bees construct their combs adhering to specific natural dimensions. Naturally, honey bees leave spaces (i.e., bee space) during construction for their movement between combs. The bee space separates combs and is big enough for bees to pass by each other on the opposite comb surfaces without touching (vanVeen 2014). The space enables bees to work, store provisions in the cells, attend to cells with young bees and carry out other operations (Johansson and Johansson 1967). The construction of improved hives imitates dimensions such as bee space as observed in natural nests. The bee space is important in such a way that honey bees build slanting/cross combs in hives that do not have proper bee space (Johansson and Johansson 1967).

Dimensions in natural nests may vary with agroecology and species or subspecies (Hailu and Biratu 2016; Hora 2019; Wakjira et al. 2021). Thus, the construction of improved hives requires consideration of the local environment and honey bee species. In traditional African hives, honey bees construct parallel combs when building their natural nests (Wakjira et al. 2021). The combs are constructed vertically downwards from the roof of the nest cavity almost the same way as they do in wild nests (Wakjira et al. 2021). Improved hives in African countries, such as Tanzania, are constructed simply by adopting European dimensions (Hailu and Biratu 2016; Frazier et al. 2024) which are suitable to the European environment and honey bee races, but different to African environment and honey bees (Winston et al. 1983; Frazier et al. 2024). This has resulted in problems such as cross-combing observed during hive manipulations (Hailu and Biratu 2016), depriving the advantage of easy management expected from improved beehives. Cross combs extend across multiple bars, making it difficult to remove a single bar without disturbing the others (Johansson and Johansson 1967).

Modern beekeeping and hive systems in Tanzania are still in the infant stage as improved hives with adopted European dimensions are still widely used. Knowledge of the basic behaviour of local honey bees is lacking, perpetuating the use of faulty specifications in constructing improved hives (Wakjira et al. 2021). The limited understanding of local bee space limits effective beekeeping management (Schouten et al. 2019). This knowledge gap hampers beekeeping production in Tanzania and prevents beekeepers from taking advantage of improved hive management techniques. This study, therefore, assessed the natural bee space and comb dimensions in honey bee colonies in Northern Tanzania. The findings of this study will not only add to the body of knowledge on the characteristic behaviour of local honey bee colonies but inform the construction of improved hives that observe the natural dimensions of local honey bees dwelling in Tanzania.

Materials and Methods

The study area

The study was conducted in Mwinkantsi village near Ufiome Forest Reserve in Babati district, Tanzania (Figure 1). The district is located between 3^0 and 4^0 South and 35^0 and 36^0 East, characterized by bimodal rainfall with short rainfall from October to December and long rainfall from February to May, amounting between 500 mm to 2000 mm per year. The average temperature is about 25^0C in the hot months of September to November and 10^0C in the cold months of May to July. The dominant vegetation comprises savannah and woodlands with scattered trees and bushes in lowlands, while mainly forests and wood/bushland are prevalent in highlands. Economic activities carried out in the village include agriculture, livestock keeping, tourism, mining, fishing, and beekeeping.

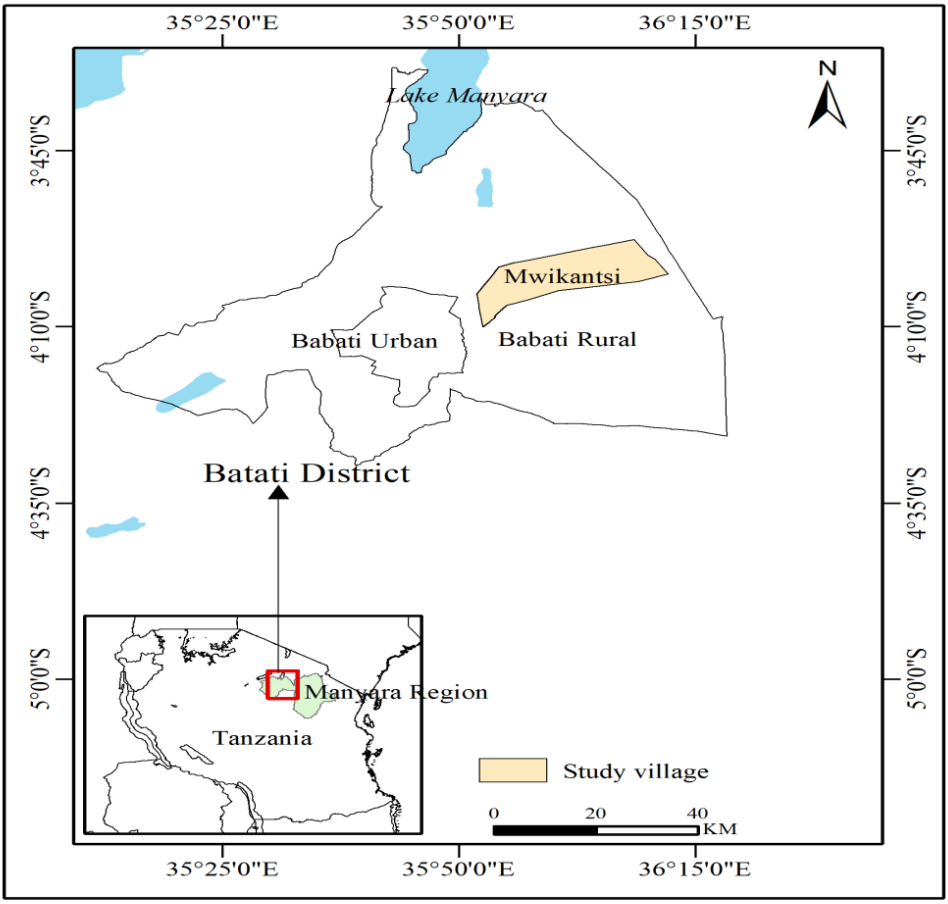

Figure 1: Map showing the study village in Babati district, Manyara Region, Tanzania

Data collection

Sample selection and preparation

Honey bee colonies nesting in traditional split log hives were used for this study. We initially observed flight activities at hive entrances to identify and select the hives occupied with strong honey bee colonies. The strong colonies were identified by the presence of more than 100 incoming forager honey bees per minute (Sagili and Burgett 2011; Grant et al. 2021). Thirty split log hives were assessed of which 10 with characteristic strong colonies were selected for the study. As the hives were hung on trees, ropes were used to take them down to the ground for observations and measurements of dimensions. Equipment used included bee smokers for calming bees, hive tools for opening hives, bee brushes for brushing bees, protective gears for protecting researchers from stings, and a digital calliper for measuring dimensions. In each split log hive selected, eight combs (four honey combs and four brood combs) were randomly picked for dimensional measurements.

Bee space

Natural bee space was measured as the distance between two adjacent (honey and brood) combs. A total of 56 bee space measurements were taken from 10 colonies selected: 28 measurements between honey combs and other 28 between brood combs. Three bee space measurements were taken between four adjacent honey combs and four adjacent brood combs, except in two hives where two measurements were taken for each comb type due to inconsistency in adjacent comb type (Camazine 1991). Measurements were carried out using a digital calliper

(Tactix) with 0.01mm accuracy (Hailu and Biratu 2016; Kidie and Alebel 2019). A digital calliper was placed between adjacent combs and adjusted until it fitted into spaces between the combs.

Comb thickness

Four honey combs and four brood combs were selected in each sampled hive for the measurement of comb thickness. Combs were raised vertically and placed between the jaws of a digital calliper, which was then slid until it contacted the comb. A total of eight comb thickness measurements were recorded per hive, yielding a total of 80 measurements in 10 sample hives.

Comb cell dimensions

Ten comb cells were randomly selected for width and depth measurement from each comb type, making a total of 20 cells measured per hive. This resulted in about 200 measurements of cell width and depth across 10 colonies sampled. Only worker cells were considered from brood combs. A comb was placed horizontally, then comb cell width was measured by placing the inside jaws of the digital calliper at the comb cell, then jaws were slid by adjusting the slide screw until the wall of the comb cell made contact with the jaws. The readings for cell width and cell depth were recorded in a data sheet.

Data analysis

Data analysis and visualization were implemented in *Jamovi* and R computer software (R Core Team 2022; The Jamovi Project 2023). Data on bee space and comb cell dimensions were subjected to Shapiro-Wilk and Levene's tests for normality and equal variance check. Mann-Whitney U test was conducted because the data were not normally distributed and had unequal variances. Discriptive statistics analysis showed nearly similar values of mean and median measures of central tendency. Therefore, we chose to discuss our results based on the mean values for easy comparison with findings in other studies.

Results and Discussion

Bee space

Honey bee colonies exhibited an overall bee space of 11.82 ± 0.36 mm (Table 1). This differs from observations in the southwest (Hailu and Biratu 2016), western (Faji et al. 2018; Kidie and Alebel 2019), and central (Hora 2019) agroecologies of Ethiopia. Larger average bee spaces of 13.12 mm and 16.5 ± 0.5 mm have been observed in the southwest (Hailu and Biratu 2016) and western (Kidie and Alebel 2019) agroecologies of Ethiopia, respectively. Central Ethiopia revealed a 10.04 ± 2.23 mm (Hora 2019) bee space while southern Ethiopia was 11.30 mm (Amano et al. 2020) between combs in traditional hives. Honey bee colonies studied in Mwinkantsi village exhibited larger bee space than 7.5 ± 1.5 mm previously identified for European *A. mellifera* races (Gentry 1982). The bee spaces ranging from 6 mm to 10 mm have also been documented in the literature and adopted in making improved hives depending on the body sizes of *A. mellifera* races (Hailu and Biratu 2016). However, some races such as *A. m. jamenitica* in the Arabian Peninsula (Adgaba et al. 2016) have been found maintaining the bee space identified in by Gentry (1982).

Moreover, analysis results revealed significant differences in natural bee spaces between comb types (Figure 2). Average bee space was significantly larger for brood combs (12.13 ± 0.16 mm) than for honey combs (11.50 ± 0.18 mm) (Figure 2, Tables S1 and S2). A similar variation in bee space between comb types has been observed within and between lowlands, midlands, and highlands agroecologies (Hailu and Biratu 2016; Faji et al. 2018; Hora 2019; Amano et al. 2020). In contrast to observations in Mwinkantsi village, Hailu and Biratu (2016) observed smaller bee space between brood combs than honey combs in midlands and highlands of Jimma Zone, southwest Ethiopia. However, almost same-sized bee space was observed within lowland agroecology in the same zone (Hailu and Biratu 2016) as well as in midlands and highlands agroecologies in Assosa and Mao-komo western Ethiopia districts, respectively (Faji et al. 2018). Moreover, the type of comb influences the dimension of bee space within and between agroecologies (Faji et al. 2018; Amano et al. 2020). Honey bees change their building behaviour when faced with challenges such as inappropriate bee space in improved hives in order the avoid the challenge (Siefert et al. 2021; Smith et al. 2021). The variations in bee space reveal the great need for detailed studies across different agroecosystems in Tanzanian environment.

Table 1: The overall average bee space, comb thickness, and comb cell dimensions (mm) at Mwinkantsi village, Babati district, Tanzania

Attributes (mm)	N	Mean	Median	SD	Minimum	Maximum
Bee space	56	11.82	11.78	0.36	11.32	12.42
Comb thickness	80	22.21	22.23	0.62	21.30	23.90
Comb cell depth	100	12.01	12.05	0.57	11.19	13.06
Comb cell width	100	5.05	4.90	0.46	4.25	5.84

N = Number of measurements, SD = Standard deviation

Comb thickness

Thicknesses of brood and honey combs differed in the studied natural nests of honey bees in Mwinkantsi village. The overall average thickness of combs in the sampled colonies was 22.21 ± 0.62 mm (Table 1), which was thicker than combs observed in western Ethiopia (19.90 ± 0.14) (Kidie and Alebel 2019) but narrower than those observed in southwest Ethiopia (23.05 mm) (Hailu and Biratu 2016) and central Ethiopia (23.71±0.30) (Hora 2019). Honey combs were found thicker (22.76 ± 0.37 mm) than worker brood combs (21.67 ± 0.19 mm) (Figure 2, Table S1), tallying with Hailu and Biratu (2016) observations across low, mid and high lands in southwest Ethiopia. The thickness of combs can vary significantly between altitudes and types of the comb. For instance, brood combs in the highlands in Ethiopia were found to be about 5.31 mm thicker than brood combs in the lowlands (Hora 2019). Faji et al. (2018) reported that comb type does not affect the bee space and comb thickness compared to differences in agroecology. The findings of this study reveal a need for further study on the relationship between comb type and thickness dimensions. In addition, the study found a weak positive relationship between bee space and comb thickness.

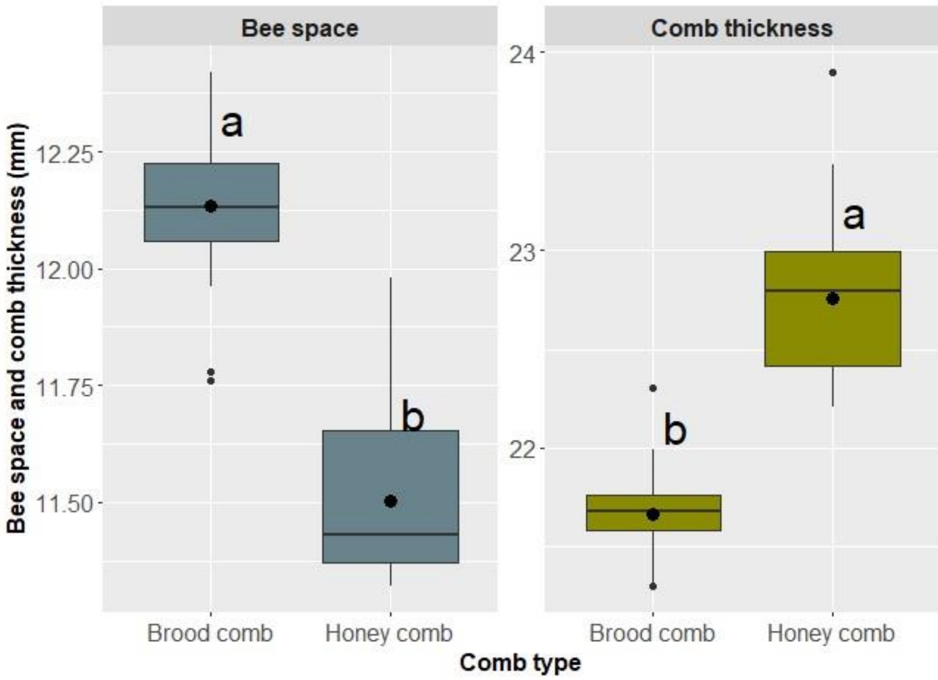

Figure 2: Variation of bee space and comb thickness dimensions between comb types at Mwinkantsi village, Babati district, Tanzania

Comb cell depth

Comb cells showed an average depth of 12.01 ± 0.57 mm (Table 1), deeper by 1.12 mm than the average cell depth found across agroecological zones in Ethiopia (Hailu and Biratu 2016). The depth of comb cells can be significantly influenced by agroecology/ altitude (Faji et al. 2018; Hora 2019), comb types (Hailu and Biratu 2016), bee caste, and species/subspecies (Yang et al. 2021). Non-significant variation in comb cell depth between different agroecologies/altitudes has been reported in some studies (Hailu and Biratu 2016; Kidie and Alebel 2019). This study in Mwinkantsi village found honey and brood comb cells 12.51 ± 0.30 mm and 11.51 ± 0.23 mm deeper, respectively (Figure 3, Table S1). Tallying results have been reported in Ethiopian lowland and midland agroecologies with honey comb cells being 4 mm and 5 mm deeper than brood comb cells, respectively (Hailu and Biratu 2016). Other honey bee species also exhibit differences in the depths of brood and honey comb cells. For instance, a recent study by Yang and colleagues has reported cell depths of 9.6 mm and 15.5 mm for worker brood and honey cells in Chinese honey bees (*Apis cerana cerana*), respectively. Similarly, cell depth for worker and honey cells in Italian honey bees (*A. m. ligustica*) was found to be 12.1 mm and 16.9 mm, respectively (Yang et al. 2021).

Comb cell width

Honey comb cells were wider than brood comb cells as brood comb cells had 4.74 ± 0.26 mm than honey comb cells with 5.35 ± 0.41 average width (Figure2, Table S1). Similar observations have also been reported across agroecologies. For instance, cell widths of 5.48 mm and 5.09 mm were reported for honey and brood combs, respectively, in Southwest Ethiopia (Yadessa et al. 2015). Cell width varies not only between comb types (Figure 3) but can also vary between ecological zones. Honey and brood comb cells in the highlands of southwest Ethiopia were found to be relatively narrow than those in the lowlands (Yadessa et al. 2015). Northern European dark bee *A. m. mellifera* exhibited cell widths ranging from 4.9 to 5.1 mm (David 2007). Moreover, McMullan and Brown (2006) noted the standard cell size range from 5.44 to 5.48 mm and from 5.04 to 5.07 mm in small comb sizes. These major changes in cell size have been observed especially with the introduction of commercially produced foundation sheets (McMullan and Brown 2006), as the range has risen from 5.4 to 5.5 mm diameter which no longer corresponds to the natural size of honey bee comb cells (David 2007). The size of brood comb cells influences the size of bees produced (McMullan and Brown 2006; Zhang et al. 2024). The overall average width of cells (5.05 ± 0.46 mm) observed in this study (Table 1) is lower than the average width observed in other studies (McMullan and Brown 2006; David 2007; Yadessa et al. 2015). This indicates the need for further studies on natural honey bee dimensions in different agroecological zones of Tanzania. Also, the analysis result of this study did not reveal a clear relationship between cell width and depth in different honey bee comb types.

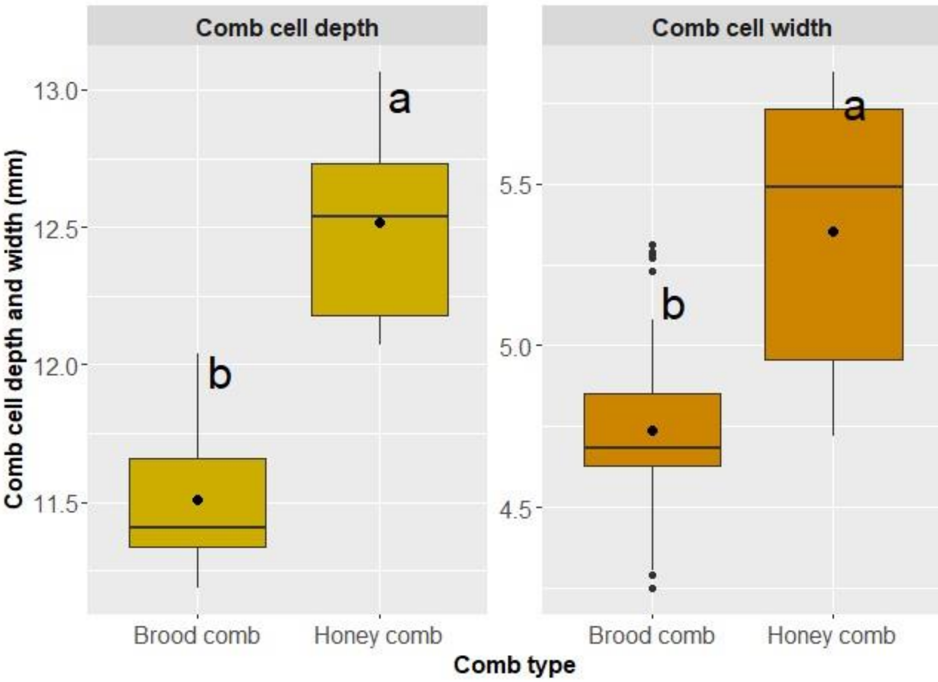

Figure 3: Variation of comb cell depth and width dimensions between comb types at Mwinkantsi village, Babati district, Tanzania

Conclusion

Our results showed that the natural bee space and comb cell dimensions of honey bee colonies in Mwinkantsi village vary from the dimensional specifications used for European honey bees. These findings call for further investigation in different local agroecologies and emphasise the importance of beehives that suit local honey bee colonies and the environment in Tanzania, for reaping the expected management advantages of improved hives.

Acknowledgements

The authors would like to thank Mr. Stephano Abel, a beekeeper in Mwinkantsi village, for allowing this study to be conducted in his apiary.

Declaration of Competing Interests

The authors declare that they have no competing interests.

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Supplementary materials

Table S1: Bee space, comb thickness, and comb cell dimensions (mm) per comb type at Mwinkantsi village, Babati district, Tanzania

Attribute (mm)	Comb type	N	Mean	Median	SD	Minimum	Maximum
Bee space	Brood comb	28	12.13	12.13	0.16	11.76	12.42
	Honey comb	28	11.50	11.43	0.18	11.32	11.98
Comb thickness	Brood comb	40	21.67	21.68	0.19	21.30	22.30
	Honey comb	40	22.76	22.80	0.37	22.21	23.90
Cell depth	Brood comb	50	11.51	11.41	0.23	11.19	12.04
	Honey comb	50	12.51	12.54	0.30	12.07	13.06
Cell width	Brood comb	50	4.74	4.69	0.26	4.25	5.31
	Honey comb	50	5.35	5.49	0.41	4.72	5.84

N = Number of measurements, SD = Standard deviation.

Table S2: Comparison of comb type on bee space, comb thickness, and comb cell dimensions between comb types (Mann-Whitney U test) at Mwinkantsi village, Babati district, Tanzania.

Attributes	Test	Statistic	p
Bee space	Mann-Whitney U	7.00	< .001
Comb thickness	Mann-Whitney U	4.50	< .001
Cell depth	Mann-Whitney U	0.00	< .001
Cell width	Mann-Whitney U	226.50	< .001

H_a $\mu_{\text{Brood comb}} \neq \mu_{\text{Honey comb}}$