Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.6, No.9, 2016

Determination of Bee Space and Cell Dimensions for Jimma Zone Honeybee Eco-Races (Apis malifera), Southwest Ethiopian

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Abstract
The study was conducted from September 2012 to April 2015 at Jimma zone, Oromia regional state, southwest Ethiopia. For this study three trail sites that represent three agro-ecology (highland midland and lowland) areas were selected purposively. Objective of the study was to determine appropriate bee space and cell dimensions for honey bee races found in Jimma zone, southwest Ethiopia**.** The natural bee space and comb cell dimensions of the local honey bee eco-type races were measured in the traditional hives. Bee space is a path or corridor bees need to move between the combs and around the nest in the wild. It is vital to allow bees walk freely on the comb. Bee space was significant along the agro-ecology of the study areas $p<0.05$. The mean bee space of lowland is greater than both midland and highland agro-ecologies. From this result we suggest that higher temperature might have forced the honey bee colonies to leave more space to avoid overcrowding at warm areas.
Keywords: bee space, cell dimension, comb, honey bees, traditional hive

Introduction

In Ethiopia, apiculture is a traditional occupation widely practiced by farmers as a complementary income generating activity. Large and diverse botanical resources combined with suitable climatic conditions make the country favourable for the beekeeping sector (Nuru *et al*., 2001). Accordingly, beekeeping is a well-accepted household activity throughout the country. Ethiopia has the highest bee colony density in Africa. It is estimated that around one million farmer households keep bees. Currently, traditional beekeeping accounts for more than 95 percent of the honey production and almost all the beeswax produced in the country (Central Statistics Authority (CSA), 2012/13). The remaining 5 percent includes transitional and modern beekeeping.

Bee space is a path or corridor bees need to move between the combs and around the nest in the wild. It is vital to allow bees walk freely on the comb (Jones, 1997, 1999). In frame hives, bee space is needed between the outside end of each frame & inner hive wall opposite it, between opposite surface of completed & sealed worker brood combs, and between the top of frames in the lower box & the bottom of the frames in the upper box (Crane, 1990). This varies from 6-10 mm for A.m. races depending on their body sizes.

Wild bees start comb construction from one point & develop other combs on each side at equal distance leaving equal gap (i.e. bee space) between each comb (Jones, 1999). Similarly the comb spacing and cell dimension is thus pre-determined by the size of the worker bees of the particular races. This should be the same as the centre-to-centre distance between adjacent combs and depth and diameter of comb cells built by similar bee races in the wild nest. If too small spacing is used, bees cannot rear brood on both sides of the combs, if the spacing is too large, they are forced to build “burr or bracing” comb in over large gaps between combs (Crane, 1999; Jones, 1999).

Therefore, bee space is what dictates the distance at which the beekeepers space the frames in the modern-box hives and the bars in top-bar hives. It is the respected space that need due attention during any type of hive construction particularly frame hives. Any variation inside measurements of a hive from the standards will result in incorrect bee spaces, which will cause considerable trouble during colony manipulation (Morse and Hooper, 1985).

So in making any type of frame or bar hives and casting mould one has to make sure that the correct bee space and comb cell dimensions is maintained to make the hive operation more efficient. But for local honeybee races in Ethiopia, the appropriate bee space and comb cell dimensions in the wild nest (traditional hives) and the tolerable frame space in modern hives are not yet studied, except for *A.m. bandanssi* honey bee race which are commonly found at the central part of Ethiopia. However, the research, carried out in Holleta bee research centre, on a single race cannot represent all honey bee races in the country, so that determination of natural bee space and comb cell dimensions for each race in the country is important to get the correct tolerable bee space. Moreover, no standardized hive and casting mould design have been made in the country so far. The construction of hives in Ethiopia is simply by adoption of European dimensions that is not comparable with the size of local bees, as a result so many problems have been observed during hive manipulations.

Therefore, the most important aspect of the hives dimensions is the space left for the bees. The "Bee Space" is the gap between and around frames, which the bees will tolerate without trying to enlarge or block off thereby reducing the tendency for bees to stick the frames together or tear down the comb. This bee space, which should be between 6.35 mm and 9.53 mm of an inch, is vitally important to both the bees and the beekeeper. If a

smaller space is left, the bees will stick the comb together, making inspection difficult. If the space is left wider bees will try to build another piece of comb in it (Curtis, 1982). That is why during construction of beehive, it is important to note the species and the races as important determining factor for dimension of hive, frames, queen excluder (size of the opening) foundation sheet (cell dimension) and width of the comb spacing (natural distance of the comb). By considering the design factors, the bee space will be maintained at each end of the frame, above and below and on each side.

Therefore, the initiation of this study was to investigate bee space and comb cell dimensions of the local honeybee races, and to determine the tolerable frame or bar spacing in modern/box or frame hives and top bar hives respectively by studying the naturally made combs in traditional hives. That is to determine appropriate bee spacing and cell dimensions for honeybee races found in Jimma zone**.** And to recommend an appropriate bee spacing and comb cell dimensions.

Materials and Methods

Description of the study areas

The study was conducted from September 2012 to April 2015 at Jimma zone, of Oromia regional state, southwest Ethiopia. For this study three trail sites that represent the agro-ecology (highland midland and lowland) areas were selected purposively. The sites were for highland (Gera), mid land (Melko/Jimma) and lowland (Gojeb). According to Tolera and Dejene, (2014) report Jimma Zone has considerable potential in beekeeping with rich flora, good ecological conditions, existence large colonies population and modern beehive.

Figure 1: Map showing study sites

Data collection

Cell dimensions of traditional hive, Comb thickness, bee space in sealed brood & honey were measured and collected for each agro-ecology (high, mid and low land).

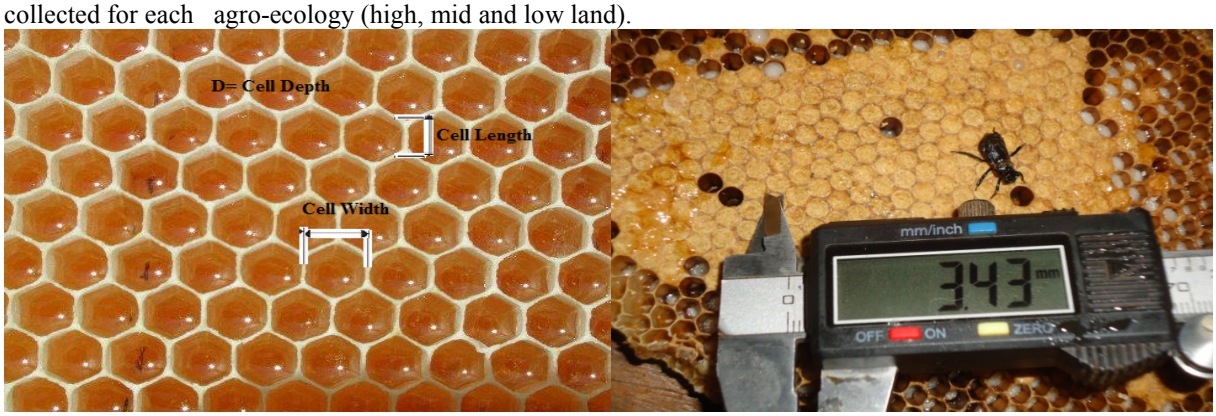
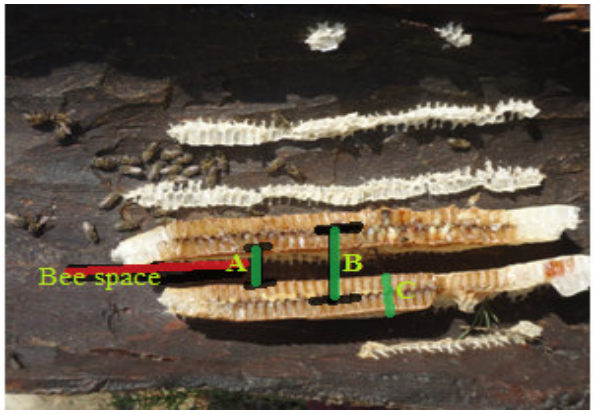


Plate 1: cell length measurement using digital calliper and bee space or comb arrangement



a  b

Plate 2: showing (a) beespace of naturaly made (A= Bee space, B=Center to center, C=comb thickness) and (b) beespace of frame/box hive

The natural bee spaces and comb cell dimensions in naturally constructed combs in the wild nests and/or traditional hives was investigated by measuring the spaces (or gaps) left between each combs and cell dimensions after the combs were completed & sealed with brood or honey, by the bees for their own conveniences to work.

Traditional hives made of bamboo and log hives were used to evaluate the natural honey bee space and cell dimensions. And frame removed box hives was used and top of the hives covered by uniformly smeared flat timber with beeswax. Bee colonies were introduced in to the hives. The number of replication for each agro-ecology was 12 at farm level. The measurements were taken in both the sealed brood & honey-combs. From each hive 10-15 bee space and comb cell dimensions measurements were taken at different position of the comb. The bee space and comb cell dimensions were measured for worker bees. The measurements were in millimetres (mm) using digital calliper to 0.01mm accuracy. Source of errors has been considered on instrumental, Personal and Weather condition (agro-ecology).

Data Analysis

The data was analyzed using SPSS 95% (alpha=0.05) level of significance. GLM multivariate ANOVA procedures were done to compare means. For the significance $P< 0.05$ post hoc, LSD, mean separation was done.

Result and Discussion

The discussion was based on the results of bee space and comb cell dimensions collected from Gera, Melko and Gojeb trail sites. These three sits were representing for highland, mid-land and lowland agro-ecologies of Jimma zone, southwest Ethiopia respectively. It was aimed to investigate natural size of hive bee-spaces at the respective agro-ecological locations. Bee space is the fundamental unit in modern hive intervention. Curtis (1982), the bee space is simply the crawl space needed by a bee to pass easily between two structures (7.5 mm +/- 1.5 mm for the western hive bee, less for the eastern hive bee). If the space between any two surfaces in the hive is too small for a bee to pass through easily, the bees will seal it with propolis. If the space is larger than a bee needs to pass through easily, the bees will construct comb in the area. The outcome of the result has been given in (table 1) below sealed honey and brood combs along agro-ecological and means of the treatments. Analysis of variance result also shown in table 2. Bee space is the gap between the frames in the hive, and around the walls and above and below the frames. This gap gives the bees enough space to work on opposite sides of the comb and pass each other back to back. The Rev. Lorenzo Langstroth of Philadelphia was the first person' to make use of the bee space in hive construction. He constructed the first modern hive in 1851, using moveable frames to contain the comb within the hive (Curtis, 1982).

Table 1: Mean average of honey bee space and cell dimensions of sealed honey and brood comb in (mm) along agro-ecology

Agro-ecology/ comb type	Average of bee space (mm)	Average of thickens (mm)	Average of cell length (mm)	Average of cell depth (mm)
High land	**11.59**	**22.94**	**3.68**	**10.45**
Brood	10.88	22.79	3.77	9.33
Honey	13.50	23.33	3.44	13.42
Mid land	**12.61**	**23.33**	**3.59**	**10.48**
Brood	11.97	22.93	3.62	9.41
Honey	14.94	24.79	3.50	14.41
Low land	**14.47**	**23.01**	**3.56**	**11.60**
Brood	14.38	22.65	3.48	10.49
Honey	14.53	23.24	3.61	12.33
Grand average	**13.12**	**23.05**	**3.61**	**10.98**

Along agro-ecology only bee space is significance (P=0.000) the rest parameters comb thickness, cell length and cell depth are not significance (P > 0.05).

Table 2: Summary of GLM multivariate analysis of variance

Variables	Dependent Variable	Df	Mean Square	F	P-value
Agro-ecology	Bee space	2	15.772	11.626	0.000*
	thickness	2	3.054	1.460	0.240
	Cell length	2	0.021	0.300	0.742
	Cell depth	2	1.025	0.570	0.569
Type of comb (Brood/honey)	Bee space	1	20.514	15.122	0.000*
	thickness	1	11.374	5.437	0.023*
	Cell length	1	0.129	1.880	0.175
	Cell depth	1	150.940	83.896	0.000*
Agro-ecology* type of comb	Bee space	2	5.392	3.975	0.024*
	thickness	2	1.627	0.778	0.464
	Cell length	2	0.298	4.330	0.018*
	Cell depth	2	12.119	6.736	0.002*

*. The mean difference is significant at P< 0.05.

Based on observed means the bee-spaces produced significant difference among the agro-ecology. However as F is an overall index, does not indicate which of the difference among the agro-ecologies of mean are significant. To find this, post hoc comparisons between treatments means is done for P < 0.05. The result was shown in table 3 below.

Table 3: Post hoc test result for multiple comparison of mean of treatments (LCD)

Dependent Variable	(I) agro-ecol	(J) agro-ecol	Mean Difference (I-J)	Std. Error	P-value	95% CI Lower Bound	95% CI Upper Bound
Bee space	highland	lowland	-3.501875	0.7534941	0.000*	-5.030032	-1.973718
		midland	-1.088346	0.7728176	0.168	-2.655692	0.479001
	lowland	midland	2.413529	0.8236229	0.006*	0.743145	4.083914
Cell depth	highland	lowland	-1.157917	0.4429741	0.013*	-2.056310	-0.259523
		midland	-.072373	0.4543343	0.874	-0.993806	0.849060
	lowland	midland	1.085544	0.4842024	0.031*	0.103536	2.067552
Cell length	highland	lowland	0.293333	0.1137650	0.014*	0.062607	0.524059
		midland	0.157500	0.1166825	0.186	-0.079143	0.394143
	lowland	midland	-0.135833	0.1243533	0.282	-0.388033	0.116367

*. The mean difference is significant at P<0.05.

Based on the mean honey bee space of sealed honey and brood comb in (mm) along agro-ecology it was increasing from highland (11.59mm), mid-land (12.62mm) and low land (14.47mm) while, the grand

average was 13.12mm. From this result we conclude that there is direct relationship between temperature and the need of bee space and bee space was significant along the agro-ecology. The significant was between low land and high land and low land and mid land while there was non-significant between mid and high land agro-ecology. Mean of comb thickness was not significant (P > 0.05) along the agro-ecology highland (22.94mm), mid-land (23.33mm) and low land (23.01mm) while, the grand average was 23.05mm. To made langstroth frame hive it depends on frame size from center to center. Therefore, based on the study result frame size depends on bee space not on comb thickness. It also supported by Curtis G. (1982) an understanding of the "bee space" permits the building of hives which allow for the removal and replacement of combs. According to Crane (1990) comb spacing is different for various honeybee races depending on the body size of the worker honeybees. E.g., for most European bees (A.m. races) it is about 35mm (ranging from 32 to 38mm), while for most African A.m. races it is about 32mm (30 to 34). However, honeybees tolerate certain bee space and comb cell dimensions in honey chamber. So the study shows that frame size from center to center along agro-ecology ranges at highland (34.53mm), mid-land (35.95mm) and low land (37.48mm) while, the grand average was 36.17mm.

Mean of honey comb thickness along the agro-ecology was highland (23.33mm), mid-land (24.79mm) and low land (23.24mm) while, the brood comb thickness along the agro-ecology was highland (22.79mm), mid-land (22.93mm) and low land (22.65mm). The range of honey comb thickness was 23.24-24.79mm which is greater than brood comb thickness 22.65-22.93mm. In agreement to this study, Endale *et al*. (2015) reported that honey comb thickness was in the range of 24.59- 24.99 mm and brood comb thickness (19.97-22.52 mm). According to David (2007) in a strong nectar flow season, honey cells are lengthened and which results in the greater thickness and in most cases the thickness of finished comb is in the range of 22 to 24 mm.

The honey comb cell length was 3.60 mm which range from 3.21-3.87 mm where as the brood comb cell length was 3.58 mm and range from 3.03-4.25 mm. The honey comb cell length was 3.60 mm which range from 3.21-3.87 mm where as the brood comb cell length was 3.58 mm and range from 3.03-4.25 mm. In opposite to this study, Francis (2014) reported relatively smaller length of workers cells in which every side of the same cell has a length of 3.0 mm. This variation might be due to the body size differences of the bee races that are found in different regions and agro ecologies.

Conclusion and Recommendations

In conclusion the study revealed that there was significant of bee space among the agro-ecologies. The mean bee space of lowland is greater than both midland and highland agro-ecologies. From this result that we suggest higher temperature might have forced the honey bee colonies to leave more space to avoid overcrowding at warm areas.The grand average bee space of the study area honeybee eco-races was 13.12mm. An understanding of the "bee space" permits the building of hives which allow for the removal and replacement of combs. This also allows for the construction of hives which separate the brood nest from the honey stores, permitting separate access to each area. Hence, it is essential to identify the size of bee space to use according to the bee races or environmental condition. So that the accessible Langstroth/box or frame beehive should be further studied on farmer's management's at different agro ecology conditions for their suitable bee space for existing bee races to produce convenient working environment for the bee activities to harvest better honey and able to make appropriate recommendation of bee space for different agro ecology.

Acknowledgement

The authors would like to acknowledge Ethiopian Institute Agricultural Research//EIAR/ for its financial support and Gera and Gojeb area beekeepers for their cooperation to give their hives with honey bee colonies to conduct the experiment.

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