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Determination of bee spacing and comb cell dimensions for Apis mellifera Scutellata honeybee race in western Ethiopia

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A study was conducted at Assosa and Mao-komo districts of Benishangul-gumuz regional state, western Ethiopia, aiming to determine the bee spacing and cell dimensions of honeybee race Apis mellifera scutellata. The measurement of bee spacing and cell dimensions were taken from 20 traditional hives at each agro-ecology. Assosa and Mao-komo districts were purposively selected to represent mid-altitude and highland agro-ecologies respectively. Data collected were analyzed in descriptive statistics, t-test, correlation and General Linear Model (GLM) procedures using statistical package for social sciences (SPSS) computer software. The present results revealed that bee space in naturally built combs of A. mellifera scutellata honeybee race in highland areas was significantly higher (P < 0.001) than that of mid-altitude areas. Cell depths and comb thickness were significantly different (P < 0.001) between the agro-ecologies. Larger cell depth and comb thickness were recorded in combs from mid-altitude than highland areas. On the contrary, cell diameter of naturally built combs in mid-altitude was significantly lower (P < 0.001) than cell diameter in highland areas. Type of comb did not affect the bee space, comb thickness or cell dimensions. Dimensions of traditional hives were not different between the two agro-ecologies except hive length. Traditional hives in highland areas were significantly longer (P < 0.05) than hives in mid-altitude areas. In conclusion, there were variations in bee space and comb cell dimensions within the same honeybees race in different agro-ecologies but this needs designing of new casting molds and box hives pertinent to the agro-ecologies.

Key words: Benishangul-gumuz, cell diameter, comb thickness, hive dimension, natural combs.

INTRODUCTION

Ethiopia has a wide range of topography, climate and vegetation, which favors considerable number of honeybee colonies and a diversity of honeybee races (Gebreyesus, 1976). This makes the country one of the ten major honey producing countries in the world. According to the relatively recent findings on morph-clusters of geographical races of honeybees in Ethiopia, five honeybee races exist in different agro-ecological zones of the country (Amsalu, 2002; Nuru, 2002). These races include *Apis mellifera bandasii, Apis mellifera*

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jementica, *Apis mellifera monticola*, *Apis mellifera scutellata* and *Apis mellifera woyi-gambella*.

Bee space is a path or corridor which bees need to move between combs and around the nest in the wild. It is important 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 and inner hive wall opposite it, between opposite surface of completed and sealed worker brood combs, and between the top of frames in the lower box and the bottom of the frames in the upper box (Crane, 1990). This bee space varies between 6 and 10 mm for the honeybee races, depending on their body sizes. Wild bees start the comb construction from one point and develop other combs on each side at equal distance leaving equal gap (that is, bee space) between each comb (Jones, 1999).

Similarly, the comb spacing and cell dimension have been pre-determined by the body size of the bee workers in 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).

According to Crane (1990), comb spacing is different for various honeybee races depending on the body size of the workers. For examples, the comb spacing for the most European honeybee races is about 35 mm (32 to 38 mm), while about 32 mm (30 to 34 mm) for most African honeybee races. However, honeybees tolerate certain bee space and comb cell dimensions in the honey chamber. Thus, workers' cell dimensions are important factors for determining the bee space and comb spacing of a race.

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. Information on nest volume, bee spaces and dimensions of brood cells are important factors for developing and adapting movable frame hives appropriate to biology of any honeybee race (Nuru et al., 2016). 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). For making any type of frame or bar hives and casting mould, it is important to make sure that correct bee space and comb cell dimensions are maintained to make the hive operation more efficient.

To the best of our knowledge, 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 for the local honeybee races in Ethiopia. So, 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 made 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, objective of the present study was to determine the bee space and comb cell dimensions for Ethiopian honeybee race*, Apis mellifera scutellata*.

MATERIALS AND METHODS

Study area

This study was conducted in two districts of Benishangul-gumuz regional state, namely Assosa and Mao-komo. Mao-komo represents highland and Assosa midland agro-ecologies of the region. Assosa town is located 670 km west of Addis Ababa. Mao-komo is located about 105 km south of Assosa town. Benishangul-gumuz regional state is located between geographical coordinates: 9°30'N-11°39'N latitude and 34°20'E to 36°30' E longitude with altitude ranging from 1272 to 1573 m above sea level. Mean annual rainfall in the region ranges from 700 to 1450 mm and temperature from 21 to 35°C (AMS, 2008). Major crops grown in the areas are sorghum, maize, finger millet, soya bean and ground nut. Livestock species commonly kept are goats, cattle, chicken and donkeys in order of importance (AsARC, 2006).

Sampling method

The two districts (Assosa and Mao-komo) were selected purposively based on their agro-ecology. Four peasant associations (PAs) were selected randomly from each district and then five beekeepers from each PA based on merit of having traditional hive. Thus, a total of 40 colonies (one colony per household) were purchased for data collection. Colonies had a similar age of 1 year. The traditional hives were made of bamboo and grass.

Sources and methods of data collection

Bee space

The average natural bee space of *A. mellifera scutallata* was measured as the distance between two adjacent opposite combs in naturally built combs in traditional hives. Both honey and brood combs were considered while sampling for measurement. Accordingly, 20 traditional hives were used per agro-ecology. For each traditional hive, 3 bee spaces at different points in the hive were measured to yield a total of 120 measurements.

Cell dimensions: Brood and honey combs were obtained from 20 colonies in each agro-ecology, and the average depth and width of comb cells was determined. For each colony, the depth and width of 5 cells were measured giving a total of 200 measurements. The measurements were taken in millimetres using calliper to 0.1 mm accuracy.

Comb thickness: Comb thickness was measured for both brood and honey combs collected from 20 traditional hives from each agro-ecology. Combs used for measurements were completed and sealed. Five measurements were done for each colony giving a total of 200 measurements for each comb type.

Table 1. Bee space, cell dimensions and thickness from naturally built honey and brood combs of *A. mellifera scutallata* in two agro ecologies of Benishangul-gumuz region.

Parameters	Agro-ecology	Mid-altitude mean		Highland mean (SE)		SE	P_{AE}	P_{CT}	P_{AExCT}
	Comb type	Honey	Brood	Honey	Brood				
Bee space (mm)		10.4	10.9	20.4	19.6	0.96	***	ns	ns
Cell depth (mm)		11.4	10.8	9.6	9.5	0.27	***	ns	ns
Cell diameter (mm)		2.4	2.5	4.3	4.1	0.20	***	ns	ns
Comb thickness (mm)		22.7	21.5	19.0	19.0	0.53	***	ns	ns

***significant at 1%, ^{PAE} effet of agro-ecology, ^{PCT}effect of comb types ,^{PAExCT}interactioneffect of agro-ecology and comb types.

Hive dimensions: Length, width and height of 20 traditional hives made of locally available materials were measured in each agro-ecology.

Data analysis

Data were entered into statistical package for social sciences (SPSS) computer software and the appropriate data management techniques were applied prior to data analysis. Independent two sample *t*-Test was used to compare hive dimensions in two agro-ecologies. Correlation analysis was done to determine the degree of relationship of variables. Agro-ecology (mid-altitude and highland), comb type (honey and brood) and their interactions were used as fixed factors for the dependent variables using General Linear Model Procedures. The model was $Yijk = \mu + Ai + Cj + ACij + \varepsilon ijk$, where $Yijk$ is dependent variable, μ is the overall mean, A_i is the fixed effect of agro-ecology i, i= mid-altitude, highland; C_j is the fixed effect of comb type j, j= honey comb, brood comb; AC_{ij} is the interaction of agro-ecology and comb type and ε_{ijk} is the random error.

RESULTS

Bee space, cell dimensions and comb thickness

Bee space, cell dimensions and thickness from naturally built honey and brood combs of *A. mellifera scutellata* race in mid-altitude and highland areas of Benishangul-gumuz Regional state of Ethiopia is presented in Table 1. Bee space was significantly different (P<0.001) between the two agro-ecologies, but not significantly different (P>0.05) between comb types. The interaction of agro-ecology and comb type was also not significant (P>0.05). Bee space of naturally built combs in highland was considerably larger than combs in mid-altitude areas. Cell dimensions and comb thickness were also significantly different (P<0.001) between the agro-ecologies, but not between comb types. Honeybee race of *A. mellifera scutellata* in mid-altitude built combs with larger cell depth than highland areas. However, cell diameter of naturally built combs was remarkably higher (P<0.001) in highland than mid-altitude. Comb thickness was significantly higher (P<0.001) in mid-altitude than highland. The average bee space in mid-altitude and highland areas in naturally built combs for *A. mellifera scutallata* were 10.66 and 20.03 mm, respectively, regardless the comb types. The average cell depths in mid-altitude and highland areas were 11.05 and 9.53 mm, respectively. In the same manner, cell diameters in mid-altitude and highland areas were 2.46 and 4.20 mm, respectively; and the average comb thicknesses in mid-altitude and highland areas were 22.10 and 19.01 mm, respectively.

Hive dimensions

Dimensions of the traditional hives made of locally available materials, like bamboo and grass in the study areas is presented in Table 2. Traditional hives were significantly different in length (P<0.05) between mid-altitude and highland agro-ecologies of the study area; otherwise they were similar in terms of width and height. Hives used in highland areas were markedly longer than that of hives used in mid-altitude areas.

Correlations among bee space and cell dimensions

The correlation analysis among bee space and cell dimensions is indicated in Table 3. All variables were significantly (P<0.001) correlated each other. The bee space was negatively correlated with cell depth and comb thickness but positively correlated with cell diameter. Cell depth was negatively correlated with cell diameter, but positively correlated with cell thickness. Comb thickness was negatively correlated with cell diameter.

DISCUSSION

Bee spaces and the dimensions of brood cells vary among honey bee races (crane, 1990; Nuru et al., 2016). In this study, however, bee space, cell dimension and comb thickness of naturally built combs varied across agro-ecologies within the same honeybee race of *A. mellifera scutallata* in western Ethiopia. As reported by Endale et al. (2015), the agro-ecology had a significant effect on bee space and cell dimensions within the same

Table 2. Dimensions of traditional hives in two agro-ecologies of the study area (N=70).

Parameter (cm)	Mid-altitude		Highland		T	P-value
	Mean	SE	Mean	SE		
Hive length	64.07	0.65	66.31	0.55	-2.422	0.016
Hive width	28.71	0.36	28.83	0.50	-0.150	0.881
Hive height	29.28	0.42	30.46	0.53	-1.421	0.157

Table 3. Correlations among bee space and cell dimensions.

Variable	Bee space	Cell depth	Cell diameter
Bee space	-	-	-
Cell depth	-0.441***	-	-
Cell diameter	0.724***	-0.424***	-
Comb thickness	-0.447***	0.997***	-0.431***

honeybee race in South Western part of Ethiopia.

In the current study, bee space in mid-altitude was nearly within a recommended bee space range (between 6.5 to 10 mm) (Curtis, 1982), but in highland areas it was found to be over this range. The higher bee space in highland areas could be associated with the higher size of honeybees as they need more space to move freely compared to honeybees with smaller body size. However, it was unclear in this study why honeybees in highland areas use double bee space than honeybees in mid-altitude areas. This implies the importance of considering honeybee race as well as agro-ecology in terms of bee space while constructing modern box hives. This finding is important since Teffera and Selassie (2011) reported that the inappropriate bee space reduces honey production in box hives.

The average cell depths in mid-altitude and highland of study areas (11.05 and 9.53 mm, respectively) were comparable to *A. mellifera* races, 11 mm (Seeley and Morse, 1976). The average cell diameter in highland areas of the study area (4.20 mm) was comparable to other *A. mellifera* races of Africanized bees (4.84 mm) (Piccirillo and De Jong, 2003) and European *Apis meliffera* races (5.2 mm) (Steeley and Morse, 1976). However, the average cell diameter recorded from mid-altitude in the present investigation (2.46 mm) was shorter than the previously reported findings (Steeley and Morse, 1976; Piccirillo and De Jong, 2003; Nuru et al., 2016).

The longer cell diameters of combs in highland areas could be associated with larger body size of honey bees. This implies that importance of designing new wax mold as currently used wax sheet maker has a diameter of 5.4-5.5 mm which is opt for temperate bees (David, 2007). The mismatch between natural cell diameter and wax molds could be a reason for higher absconding rate of *A. mellifera scutallata* race in Benishangul-gumuz region of Ethiopia (Alemayehu et al., 2015). Also, Nuru et al. (2016) indicated that the low success rate of box beekeeping in Africa and Asia is associated with direct use of technology designed for temperate bees without considering the biology of the target races.

In present study, comb thickness in mid-altitude areas was larger than that of highland areas. Abera and Kassa (2016) and Endale et al. (2015) also reported that agro-ecology had effect on thickness of naturally built combs. The difference in comb thickness between the agro-ecologies could be associated with availability of honey in the combs as David (2007) reported that in a strong nectar flow season, honey cells are lengthened resulting in thicker combs.

Conclusions

This study highlighted the presence of variations in natural bee space and cell size within the same honeybee race at different agro-ecology in Benishangul-Gumuz region of Ethiopia. Thus, considering the natural bee space is important while constructing box hive and it would be worthy to use casting molds with a suitable cell size that matches with honeybees' natural cell size. However, further studies should be done to quantify the performance of honeybees in box hive designed based on their natural bee space and comb cell size.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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