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Morphological variations in Nigerian *Apis mellifera* Linnaeus, 1758 populations in Guinea savannah agro-ecological zone

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Abstract: *Apis mellifera* Linnaeus, 1758 is one of the most economically valuable insects which plays significant role in human medicine, nutrition and crop pollination. The morphometric variations of honeybee from different locations of the southern guinea and northern guinea savannah ecological zone of Nigeria were studied. Fifteen morphological traits were measured for variation on six hundred (600) worker honeybee samples purposively collected from ten different locations within the ecological zone. Data collected were subjected to one-way Analysis of Variance (ANOVA), SNK test ($\alpha=0.05$) and Pearson correlation between morphometric characters were determined. At the same time a dendrogram of morphological proximity based on the fifteen morphological features was constructed. Results showed that morphometry variation ($p<0.05$) existed within the honeybee population in the guinea savannah agro-ecological zone of Nigeria, high morphological similarities were observed in the tibia length of the hind leg and the thorax length. The honeybee samples were classified into two distinct morphoclusters (A and B). Honeybee samples within morphocluster A were closely related in terms of the examined morphometric features and geographic distance (CV=1.65). In contrast, within cluster B, honeybee samples were closely related despite the vast geographical distance (CV=3.30, $p<0.05$). The body length was significantly positively correlated with the leg size, while hind wing length was positively associated with the proboscis, abdominal, thoracic, body length and hooks. Morphometric variations found in *A. mellifera* of guinea agro-ecological zone could significantly impact conservation and future bee breeding programmes of Nigeria.

Keywords: honeybee, body traits, conservation, diversity, ecology, Nigeria

Introduction

The honeybee, *Apis mellifera* Linnaeus, 1758 (Hymenoptera: Apidae), among the highly eusocial bees, is known for its large size colonies, construction of perennial, colonial nests from wax and surplus production and storage of honey (Sauthier *et al.* 2017). Although some other types of related bees produce and store honey such as stingless honeybees, only members of the genus *Apis* are true honeybees. Over the years, the species is known as the most economically valuable insect due to the role it plays in enhancing food security, poverty reduction and food production through pollination of crops, bee products such as honey, pollen, royal jelly, propolis, bee venom, bee wax and larvae which are important products for human nutrition and health (Eleazu *et al.* 2013).

Apis mellifera is otherwise known as the western honeybee probably originated from Tropical Africa and spread to Europe, India and Western Asia (Miguel *et al*. 2011). It is now globally widespread with a wide diversity of subspecies (Abou-Shaara *et al*. 2013). The worker bee is about 0.9 cm to 2.0 cm long in size. The shape of organisms and their biological structures have been of scientific interest for centuries because an organism's phenotype provides a link between the genotype and the environment (Rattanawannee *et al.* 2010). *A. mellifera* has shown great adaptive potential even in highly diverse climates due to modification of their structures to suit environmental demands. They have two large compound eyes which helps understand colour, light and directional information from the sun's ultraviolet rays, three simple eyes which also helps in determining the amount of light present and its intensity (Horridge 2015), a geniculate antennae for smell, taste and odour detection.

Honeybee populations in Africa have been reported to be free from inbreeding with strong adaptability to local conditions due to the wide range of climate, habitats and geographical differences found in the country which encourages the high migratory activity of honeybees and likely lead to existence of ecotypes and biotypes among them (Meixner *et al.* 2010). Bee diversity research and breeding efforts in many parts of Africa, especially Nigeria are still in their infancy, therefore, regional ecotypes and biotypes are free from hybridization and are well adapted to prevailing pests and pathogens in their locality (De la Rúa *et al*. 2009).

In the taxonomy of species, subspecies characterization and identification of *A. mellifera*, morphometric analysis, mitochondrial DNA polymorphism (mtDNA) and biochemical analysis have contributed largely. Morphometric studies have been used to provide lot of information on the structure of *A. mellifera* species (Abou-Shaara *et al*. 2013). Morphometrys has been and continue to be the most widely-used official methodology for identifying honeybees, because of high practicability and low costs. Morphometrys is also a tool used to characterize honeybee races and individuals, to determine the degree of hybridization with foreign races, to discriminate between honeybee subspecies and to check honeybee populations' purity (Szymula *et al.* 2010, Abou-Shaara *et al*. 2012). These morphometric characters can be grouped into three divisions: the body length measurements, the body colour measurements and the wing venation features. More than 35 honeybee characters had been identified, measured and considered very important characters to show geographical variability. These include: proboscis length, legs and wing measurement, hair size, cubital index, colour, body size and some wing venation angles (Miguel *et al.* 2011, Ajao *et al.* 2014). Usman (2016) and Adeoye *et al.* (2020) reported that environmental factors, migratory beekeeping practices have a major impact on variations in morphological characters in a population. The importation of honeybee subspecies into different areas might induce high levels of hybridization and produce subspecies admixtures within populations (Alqarni *et al*. 2011).

Twenty nine subspecies of *A. mellifera* have been identified and clustered into four evolutionary lineages (A, M, C and O) based on morphometric studies (Koca *et al.* 2013). Although Ruttner (1988) described *A. mellifera adansonni* as an indigenous bee race of Nigeria, the presence *A. mellifera unicolour* in Iganmo beekeeping areas of Southern Nigeria was reported by (Lamb, 1978). However, there is no substantial insight reported on possible variations and discrimination existing among honeybee subspecies and different populations within the country. In Nigeria, *A. mellifera* exists throughout the country, especially in the Guinea savanna agro-ecological zone where commercial beekeeping is largely practiced. Within this large agro-ecological zone, most of the honeybee colonies are still kept in Kenyan Top Bar hives (Adeoye *et al.* 2020). In order to protect biological diversity, adequate knowledge of the natural diversity of local *A. mellifera* subspecies and ecotypes is essential for their management and conservation. The European honeybee subspecies have been extensively studied, while the study of the African honeybee subspecies is still in its infancy since Ruttner (1988) classification, in Nigeria. Although a few studies have been carried out on *A. mellifera* recently in Nigeria, there is still a lot to be unraveled on the relationship of geographical position with morphometric characters of Nigerian honeybees (Ajao *et al.* 2014, Usman 2016, Adeoye *et al.* 2020). A thorough analysis of morphometric variation *A. mellifera* populations is needed to preserve existing bee race and them from the danger of hybridization. Thus, the present study attempted to establish and describe the morphological variations of *A. mellifera* populations in guinea savannah vegetation zones of Nigeria

Materials and Methods

The study area

This study was conducted in ten different locations each within southern and northern Guinea savanna agroecological zones of Nigeria having different latitudes (Table 1). The guinea savanna is the most extensive ecological zone in Nigeria. The locations in the southern guinea savanna zone consist mainly of a great expanse of fertile arable land characterized by tall grasses growing intermixed with deciduous trees. The length of growing period in the southern guinea savanna is 211–270 days with mean rainfall above 500 m. The dry season is shorter and less intense than in the northern guinea zone. The density of vegetation, species richness, rainfall and length of the rainy season decrease with the increase in latitude. In this locations, annual plants flower at the end of the rainy season, while trees flower during the dry season (Oladimeji & Abdulsalam 2013). Some of the prevailing economic trees species providing forage for bees in the southern guinea savannah includes: *Citrus sinensi, Parkia biglobosa, Butyrospermum parkii, Azadiracta indica, Mangifera indica, Acacia* spp., *Delonix regia and Anacardium occidentale.*

The length of growing period in locations in northern guinea savanna is 151–180 days with a belt of mixture of shorter grasses and fewer trees (Oladimeji & Abdulsalam 2013). In the Northern Guinea Savannah, species such as *Isoberlinia doka* and *I. tomentosa* form the bulk of the scattered woodland. Also found are locust bean trees (*Parkia filicoidea*), shea trees (*Butyrospermum parkii*) and mangoes (*Mangifera indica*). The agroecological zone also consists of two seasons; the wet season (May–September) having lighter rainfall with a short rainy season ranging from 800 mm to 1 500 mm, the dry season (October–April) and mean annual temperature (31.5°C to 35°C).

Data Collection and Sampling Techniques

Six hundred samples of worker honeybees were randomly collected from 60 colonies located in commercially managed apiaries initiated with captured swarms and unmanaged for queen replacement from 10 different purposively selected localities within the guinea savannah vegetation zone (Table 1) (Fig. 1). The honeybee samples were collected during the dry season (November, 2017 to February, 2018). The honeybee samples were preserved in 70% ethanol inside small sterile plastic which were labeled on the field and then dissected for morphometry studies following standard procedure at the Entomology laboratory, Forestry Research Institute of Nigeria (Meixner *et al.* 2007).

Ten worker bees randomly selected from each colony were dissected under a dissecting microscope fitted with an eyepiece graticle into different body parts (proboscis, right forewing, right hind wing, and right hind leg etc.) and fifteen morphological characters were examined on according to Ruttner *et al.* (1978) (Table 2). The different characters presented below were studied, measured under an electronic stereo-microscope fitted with an ocular scale at a magnification of 40x

Figure 1: Map of Nigeria showing the location of the guinea savannah used in the study.

and statistically compared according to the methods of Ruttner (1988), Sheppard and Meixner (2003) and Meixner *et al.* (2007).

1. Length of proboscis
2. Head length
3. Thorax length
4. Length of hind wing
5. Abdominal length
6. Length of hind leg
7. Hind leg tibia length
8. Hind leg basitarsus length
9. Hind leg basitarsus width
10. Body length
11. Number of hooks
12. Width of hind wing
13. Length of fore wing
14. Width of fore wing
15. Length of femur

The images of the dissected body parts were captured with a digitalized MiScope microscope with a magnification range of 40–140x in millimeter (mm) attached to a laptop (Figs. 2–6). Data collected from the experiment were analyzed by one way analysis of variance (ANOVA) at $p<0.05$,

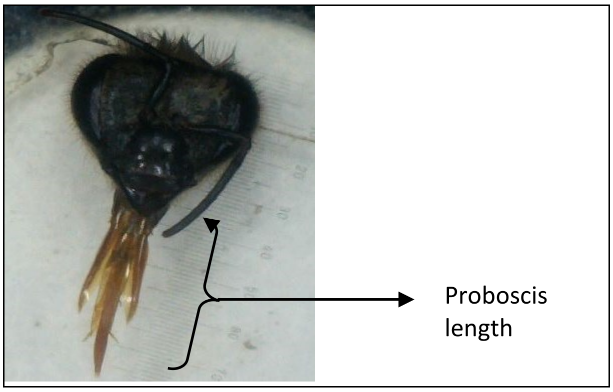

Fig. 2. Dissected head of adult worker honeybee used in morphometric study.

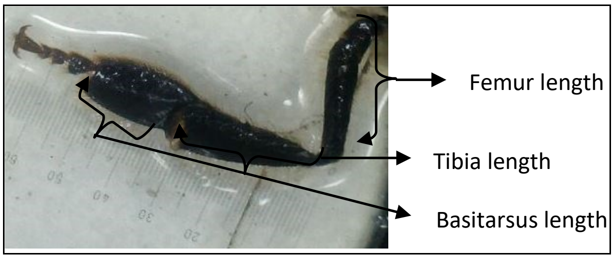

Fig. 3. Dissected hind leg of adult worker honeybee used in morphometric study.

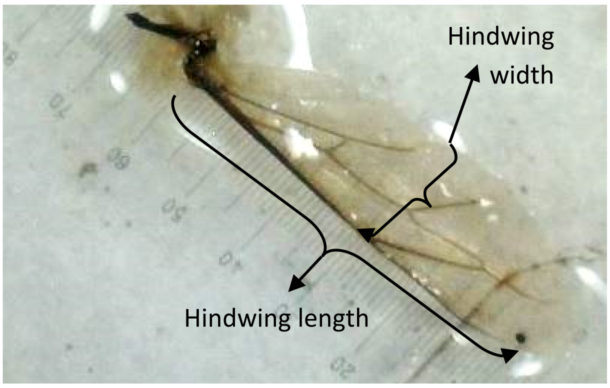

Fig. 4. Dissected hind wing of adult worker honeybee used in morphometric study.

Fig. 5. Dissected abdomen of adult worker honeybee used in morphometric study.

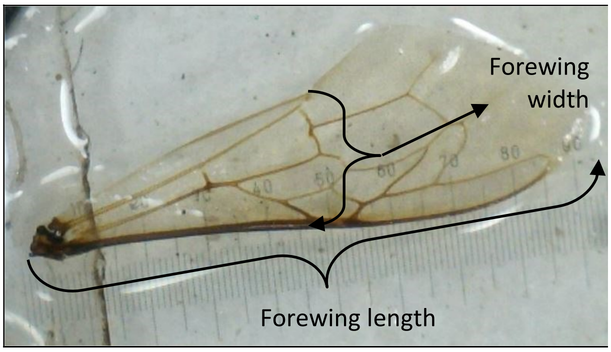

Fig. 6. Dissected forewing of adult worker honeybee used in morphometric study.

Studentized Newman Kuels (SNK) test was used for the means separation at 5% probability level with SAS 9.1 software package. Pearson correlation between morphometric characters was determined using PAST 3.02 software analysis. A hierarchical cluster analysis was carried out with using the means of the 15 morphometric characters for the 10 localities in the study.

Results and discussion

The mean values for the morphometric characters of worker honeybees sampled from ten commercial apiaries within guinea savannah differed significantly ($p<0.05$).

Wing morphometry

The wing dimensions of bee samples collected within the different locations of Guinea vegetation zones were significantly different from each other ($p<0.05$) (Table 3). The length of the hind wing of bee samples collected within commercial apiaries of Igbojaiye and Owotoro of Southern guinea vegetation zones were statistically similar to the dimension of bee samples within locations of Mahuda and Samaru of Northern guinea zone ($p<0.05$) (Table 3).
The hind wings of Otu bee samples (6.55±0.03 mm) were the longest, while bee samples of Temidire were the shortest (6.23±0.00 mm) length of hind wings and no significant difference was observed in the hind wing length of Igbojaiye and Owotoro

Table 1. Geographical locations of the apiaries from which honeybee samples were collected for the study.

Locations	Geographic coordinates	No. of colonies
Vegetation type: northern guinea		
Temidire	7˚24'56.70'' N, 4˚19'53.40'' E	6
Ogede	8˚17'24.20'' N, 4˚11'17.10'' E	6
Igbojaiye	8˚13'50.20'' N, 3˚14'30.70'' E	6
Owotoro	8˚24'29.10'' N, 3˚21'34.20'' E	6
Otu	8˚12'21.50'' N, 3˚24'45.90'' E	6
Vegetation type: southern guinea		
Ladoke Akintola University of Technology, Ogbomosho (LAUTECH)	8˚0'00.00'' N, 4˚16'00.00'' E	6
Samia	11˚36'70.67'' N, 8˚50'28.07'' E	6
Mahuda	11˚17'31.20'' N, 7˚47'36.28'' E	6
Federal College of Mechanization, Afaka	10˚39'00.59'' N, 7˚23'16.00'' E	6
Samaru	11˚90'54.04'' N, 7˚39'5.08'' E	6

Table 2. List of some morphometric characters used in this analysis and their numbers as given by Ruttner's Number.

Ruttner No.	Character
	Forewing
17	Length of forewing
18	Width of forewing
	Size
5	Length of femur
(5+6+7)	Length of hind leg
7	Hind leg basitarsus length
8	Hind leg basitarsus width
6	Hind leg tibia length
4	Length of proboscis
(9+6)	Body length

($p<0.05$). The hind wing widths of Otu, Temidire and Ogede were statistically similar (1.75±0.01bdc) but significantly longer than hind wings of Owotoro and Igbojaiye (1.74±0.02dc) ($p<0.05$) (Table 3). In the Northern guinea savanna, hind wing length of bee samples of Mahuda and Samaru (6.42±0.04 mm) were statistically similar but significantly higher in values compared to Kaduna and Samia (6.26±0.03) ($p<0.05$) (Table 3). The honeybee samples of Northern guinea savanna had significantly expansive hind wing width compared to samples from locations in Southern guinea savanna. Mahuda and Samaru bee samples had the most expansive and statistically similar hind wing sizes (1.80±0.0mm) compared to Kaduna and Samia which had no significant differences (1.77±0.01mm) (Table 3).

The study revealed that the forewing length of Ogede and Otu bees were statistically similar with Otu bees recording the longest (9.45±0.07mm, Table 3), while no significant differences exists in the forewing length of bee samples of the remaining locations of Southern guinea ($p<0.05$) (Table 3). Similarly, bees of LAUTECH, Mahuda, Temidire and Samaru had the longest and statistically similar fore wing length and width with no statistical differences in the dimensions of honeybee samples from the other locations in the Northern guinea zone in comparison with bee samples from Kaduna and Samia had the shortest dimensions and statistically similar fore wings sizes (8.97±0.09 mm) ($p<0.05$, Table 3). The t test analysis showed that Southern guinea bees had significantly longer hind and fore wings than those collected in Northern guinea savanna agroecological zone ($p<0.05$) (Table 7). Wing morphometry is an important factor in honeybee taxonomy because the sizes of the wings are directly related to the flight ability of bees during foraging and thermal regulation of comb. The sizes of the wings affect the flight, pollen and nectar gathering ability of the honeybees and consequently,

Table 3. Morphometric data (mm±SE) of the wing parameters measured on honeybees collected from ten localities in the Guinea Savannah Zone of Nigeria (N=100).

Location	**Hindwing length**	**Hindwing width**	**Forewing length**	**Forewing width**
Vegetation type: Southern Guinea				
Igbojaiye	6.4±0.04^{bac}	1.74±0.02^{dc}	9.13±0.05^{ba}	2.98±0.02^{b}
Otu	6.55±0.03^{a}	1.75±0.01^{bdc}	9.45±0.07^{a}	3.05±0.01^{ba}
Owotoro	6.4±0.04^{bac}	1.74±0.02^{dc}	9.13±0.05^{ba}	2.98±0.02^{b}
Temidire	6.23±0.0 ^{dc}	1.75±0.01^{bdc}	9.20±0.06^{ba}	3.08±0.02^{a}
Ogede	6.45± 0.07^{ba}	1.75±0.02^{bdc}	9.42±0.04^{a}	3.06±0.02^{ba}
Vegetation type: Northern Guinea				
Kaduna	6.26±0.03^{bdc}	1.77±0.01^{bac}	8.97±0.09^{b}	3.02±0.01^{ba}
LAUTECH	6.23±0.0 ^{dc}	1.75±0.01^{bdc}	9.2±0.06^{ba}	3.08±0.02^{a}
Samia	6.26±0.03^{bdc}	1.77±0.01^{bac}	8.97±0.09^{b}	3.02±0.01^{ba}
Mahuda	6.42±0.04^{bac}	1.80 ±0.0^{a}	9.19±0.10^{ba}	3.07±0.03^{a}
Samaru	6.42±0.04^{bac}	1.80±0.00^{a}	9.19±0.10^{ba}	3.07±0.03^{a}

Means followed by the same letter along the same column are not significantly different using Studentized Newman-Keuls (SNK) test (p>0.05)

Table 4. Pearson correlation (R) between the fifteen morphometric characteristics of *Apis mellifera* workers from Guinea Savannah Zone of Nigeria. Characters: HWL–length of hindwing, WHW–width of hindwing, LFW–length of forewing, WFW–width of forewing, FL–length of femur, HLL–length of hind leg, HLBL–hind leg basitarsus length, HLBW–hind leg basitarsus width, HLTL–hind leg tibia length, PL–length of proboscis, AL–abdominal length, HDL-head length, TOL–thorax length, NH–number of hooks, BL–body length.

	HWL	**WHW**	**LFW**	**WFW**	**FL**	**HLL**	**HLBL**	**HLBW**	**HLTL**	**PL**	**AL**	**HDL**	**TOL**	**NH**	**BL**
HWL	1	0.91**	0.03	0.78**	0.14	0.01	0.02	0.22	0.02	0.84**	0.81**	0.68*	0.87**	0.83**	0.61*
WHW	0.04	1	0.54*	0.23	0.36	0.12	0.05	0.20	0.64*	0.00	0.07	0.00	0.46	0.21	0.45
LFW	0.69*	-0.22	1	0.21	0.11	0.05	0.09	0.02	0.15	0.25	0.79**	0.40	0.41	0.98**	0.43
WFW	-0.10	0.42	0.44	1	0.32	0.26	0.15	0.82**	0.50	0.50	0.28	0.38	0.12	0.20	0.30
FL	0.50	0.32	0.53*	0.35	1	0.22	0.48	0.03	0.47	0.71*	0.22	0.25	0.47	0.91**	0.24
HLL	0.76*	-0.53*	0.62*	-0.39	0.42	1		0.01	0.04	0.08	0.38	0.21	0.70*	0.28	0.93**
HLBL	0.71*	-0.63*	0.56*	-0.49	0.25	0.98**	1	0.03	0.03	0.04	0.23	0.10	0.58	0.22	0.88**
HLBW	0.43	-0.44	0.71**	0.08	0.69*	0.77**	0.69*	1	0.17	0.09	0.88**	0.49	0.81**	0.42	0.64*
HLTL	0.72*	-0.17	0.49	-0.24	0.26	0.65	0.67*	0.47	1	0.57	0.52	0.25	0.95**	0.43	0.88**
PL	0.07	-0.92**	0.40	-0.24	-0.14	0.58	0.65*	0.56	0.20	1	0.03	0.00	0.44	0.60*	0.79**
AL	0.09	-0.59*	0.10	-0.38	-0.42	0.31	0.42	0.06	0.23	0.67*	1	0.00	0.01	0.95**	0.48
HDL	0.15	-0.77**	0.30	-0.31	-0.40	0.44	0.56	0.25	0.40	0.86**	0.85**	1	0.28	0.79**	0.76
TOL	0.06	0.27	0.29	0.52*	0.26	-0.14	-0.20	0.09	-0.02	-0.28	-0.75*	-0.38	1	0.51	0.71*
NH	-0.08	0.43	0.01	0.44	0.04	-0.38	-0.43	-0.29	-0.28	-0.19	-0.02	-0.10	0.24	1	0.03
BL	0.18	0.27	0.28	0.37	0.41	0.03	-0.06	0.17	-0.06	0.10	0.25	0.11	-0.13	0.69*	1

* Correlation is significant at the 0.05 level 2-tailed; R=Correlation coefficient

** Correlation is significant at the 0.01 level 2-tailed

their colony productivity (Aboushaara *et al.* 2013). The wing characters has been reported to be affected by factors such as temperature, season, bee age and vegetation type (Abou-Shaara *et al.* 2012).

The trend of variation observed in this study was similarly reported by Oyerinde *et al.* (2012), Ajao *et al.* (2014), Usman (2016) and Adeoye *et al.* (2020) in the wing characterization study on honeybee species collected from different locations within the guinea savanna agroecological zone of Nigeria. However, the results of this study showed slightly lower values to those reported by Ajao *et al.* (2014) on Kwara, Nigeria bee samples (hind wing length:

Table 5. Morphometric data (mm±SE) of the leg parameters measured on honeybees collected from ten localities in the Guinea Savannah Zone of Nigeria (N=100)

Locations	Femur length	Hind leg length	Hind leg basitarsus length	Hind leg basitarsus width	Hind leg tibia length
Vegetation type: southern guinea					
Igbojaiye	3.03±0.03^{c}	10.89±0.08^{b}	3.95±0.03^{b}	1.20±0.01^{ba}	3.00±0.00^{a}
Otu	3.05±0.05^{cb}	11.01±0.06 ^{b}	3.98±0.01^{b}	1.19±0.02^{ba}	2.98±0.03^{a}
Owotoro	3.03±0.03^{c}	10.89±0.08^{b}	3.95±0.03^{b}	1.20±0.01^{ba}	3.00±0.00^{a}
Temidire	3.01±0.01^{c}	9.59±0.04^{c}	2.22±0.02^{c}	1.19±0.01^{ba}	2.95±0.03^{a}
Ogede	3.38±0.06^{a}	11.43±0.07^{a}	4.09±0.04^{a}	1.26±0.01^{a}	2.97±0.06^{a}
Vegetation type: northern guinea					
Kaduna	3.02±0.02^{c}	9.64±0.08^{c}	2.20±0.02^{c}	1.16±0.02^{b}	2.92±0.05^{a}
LAUTECH	3.01±0.01^{c}	9.59±0.04^{c}	2.22±0.02^{c}	1.19±0.01^{ba}	2.95±0.03^{a}
Samia	3.02±0.02^{c}	9.64±0.08^{c}	2.20±0.02^{c}	1.16±0.02^{b}	2.92±0.05^{a}
Mahuda	3.19±0.02^{b}	9.82±0.07^{c}	2.27±0.03^{c}	1.18±0.02^{ba}	2.98±0.06^{a}
Samaru	3.19±0.02^{b}	9.82±0.07^{c}	2.27±0.03^{c}	1.18±0.02^{ba}	2.98±0.06^{a}

Means followed by the same letter along the same column are not significantly different using Studentized Newman-Keuls (SNK) test (p>0.05).

Table 6. Morphometric data (mm±SE) of abdomen, proboscis, head and thorax parameters measured on honeybees collected from ten localities of Guinea Savannah Zone of Nigeria (N=100) .

Locations	Proboscis length	Abdominal length	Head length	Thorax length	Number of hooks	Body length
Vegetation type: southern guinea						
Igbojaiye	4.35 ± 0.17^{a}	6.72±0.08^{b}	4.01 ± 0.06^{a}	4.33 ± 0.04^{a}	19.90 ± 0.31^{c}	11.60± 0.22^{a}
Otu	4.22 ± 0.11^{a}	6.73±0.08^{b}	3.94 ± 0.08^{a}	4.40 ± 0.04^{a}	21.60 ± 0.50^{b}	11.80 ± 0.25^{a}
Owotoro	4.06 ± 0.13^{ba}	6.63±0.16^{b}	3.83 ± 0.10^{ba}	4.30 ± 0.06^{a}	20.40 ±0.27^{bc}	11.00 ± 0.00^{b}
Temidire	4.33 ± 0.14^{a}	7.2 ±0.20^{a}	3.94 ± 0.06^{a}	4.27±0.06^{a}	21.80 ±0.35^{bc}	12.20 ± 0.10^{a}
Ogede	4.40 ± 0.08^{a}	5.76±0.17^{d}	3.61 ± 0.04^{bcd}	4.41 ± 0.07^{a}	20.80 ±0.39^{bc}	12.10 ± 0.28^{a}
Vegetation type: northern guinea						
Kaduna	2.61 ± 0.09^{d}	5.64±0.16^{d}	3.35 ± 0.04^{e}	4.34 ± 0.07^{a}	19.90 ± 0.67^{c}	11.00 ± 0.00^{b}
LAUTECH	3.77 ± 0.10^{bc}	5.27±0.07^{d}	3.67 ± 0.03^{bc}	4.56 ± 0.11^{a}	21.10 ±0.31^{bc}	11.00 ± 0.00^{b}
Samia	3.62 ± 0.05^{c}	6.23±0.11^{c}	3.67 ± 0.05^{bc}	4.35±0.06^{a}	23.10 ± 0.41^{a}	12.22 ± 0.15^{a}
Mahuda	2.22 ± 0.06^{e}	5.47±0.09^{d}	3.42 ± 0.06^{de}	4.48 ± 0.05^{a}	22.90 ± 0.10^{a}	12.10 ± 0.10^{a}
Samaru	2.36 ± 0.05^{de}	5.53 ± 0.10^{d}	3.46 ± 0.07^{cde}	4.38 ± 0.04^{a}	20.90 ±0.39^{bc}	11.70 ± 0.22^{a}

Means followed by the same letter along the same column are not significantly different using Studentized Newman-Keuls (SNK) test (p>0.05).

7.91≥7.92 mm and forewing length: 9.54≥9.56 mm), while the sizes of the forewings in the study were slightly higher compared to bee samples of Lake Chad basin (forewing length: 8.04≥8.20 mm and forewing 2width: 2.76≥2.79 mm).

The correlation analysis shows a significant positive association between hind wing length and length of forewings, femur length, hind leg length, hind leg barsitarsus length and hind leg tibia length (R≥0.50, Table 4). The width of hind wings of the honeybee was significantly positively correlated with hind wing length while negatively correlated with hind leg, hind leg barsitarsus, proboscis, abdominal and head length (R≥0.53, Table 4).

Table 7. The t-test analysis of means of different morphometric characters (mm±SE) of Nigerian Honeybee, *Apis mellifera adansonni* from commercial apiaries in southern guinea and northern guinea savanna agro-ecological zones of Nigeria (*N*=100).

S/N	Character	Southern guinea	Northern guinea	P (T<0.05)	P (F<0.05)
	Wings				
1	Length of hindwing	6.43 ±0.03	6.29 ± 0.04	0.02	0.66
2	Width of hindwing	1.75 ± 0.01	1.78 ± 0.01	0.08	0.73
3	Length of forewing	9.36 ± 0.06	9.07 ± 0.06	0.01	0.91
4	Width of forewing	3.03 ± 0.02	3.03 ± 0.02	0.87	0.96
	Legs				
5	Length of femur	3.13 ± 0.06	3.08 ± 0.04	0.50	0.47
6	Length of hind leg	11.07 ± 0.09	9.69 ± 0.05	1.11	0.19
7	Hind leg barsitarsus length	3.99 ± 0.03	2.23 ± 0.02	8.64	0.49
8	Hind leg barsitarsus width	1.19 ± 0.02	1.19 ± 0.01	0.79	0.21
9	Hind leg tibia length	2.96 ± 0.02	2.89 ± 0.05	0.24	0.05
	Other body parts				
10	Length of probosics	4.27 ± 0.06	2.92 ± 0.32	0.00	0.01
11	Abdominal length	6.61 ± 0.23	5.63 ± 1.62	0.01	0.49
12	Head length	3.87 ± 0.07	3.51 ± 0.07	0.01	0.91
13	Thorax length	4.34 ± 0.03	4.42 ± 0.04	0.15	0.42
14	Number of hooks	21.66 ±0.61	21.04 ± 0.51	0.46	0.73
15	Body length	11.98 ±0.12	11.36 ± 0.23	0.04	0.26

Means followed by the same letter along the same column are not significantly different using Studentized Newman-Keuls (SNK) test (p>0.05)

Forewing length was also found to be positively correlated with hind wing width, femur length, hind leg length, hind leg barsitarsus length and width, while the forewing width was found to be significantly positively correlated with the hind wing length and thoracic length (R≥0.52, Table 4). This was in agreement with the earlier reports that a significant and positive correlation was observed between the wing sizes and the hind leg dimension in honeybee samples from Saudi Arabia (Saad *et al.* 2014) and Kashmir (Shahnawaz *et al.* 2017). The variations that occurred in the wing morphometric features of honeybees from the different locations of the study could be attributed to increase human activities such as urbanization as well as climate change which could have affected the vegetation structure and possibly lead to loss of honeybee natural habitat in both Southern and Northern guinea ecological zone. The stress in most bee plant due to climate change impact has led to changes in their floral scent causing disorientation in the olfactory cues of bees in search for food. Climate change has also resulted in the mismatch between the period when flowers produce pollen and when the bees are ready to feed on the pollen. This loss of synchronization causes changes in bee physiology as well as food shortages for bees and human population.

Hind leg morphometry

There were no significant differences in the length of the tibia of hind legs of bee samples in all the locations studied in both Southern and Northern guinea savanna. The results showed that the leg morphometry characters studied on bee samples from Igbojaiye, Otu and Owotoro in Southern guinea were not significantly different. The bees of Ogede showed significantly higher values in length of femur, total hind leg length, length and width of basitarsus as compared to bees of other locations in Southern guinea. Similarly, in Northern guinea, Mahuda and Samaru bee samples had longer legs with statistically similar features, while the other locations in the study had shorter legs with no significant differences in the parameters measured ($p<0.05$) (Table 5).

The t-test analysis further revealed that there were significant differences in the leg features of honeybee species from Southern guinea and Northern guinea savanna. The present results showed that the size of hind leg length of the worker bees in the study area was lesser (9.59 to 11.47 mm) as compared to 12.07 to 12.08 mm reported by Ajao *et al*. (2014) on the length of hind legs of worker bees in Kwara State (Guinea vegetation) Nigeria. The mean values of femur length of the bee samples in the study are however larger (3.01 to 3.38 mm) than those reported by Usman (2016) in worker bee samples from Lake Chad Basin (2.36 to 2.50 mm), while the tibia length (2.92 to 3.00 mm) in this study is similar to the trend reported in Lake Chad Basin worker bees (2.82 to 3.05 mm). The non-significant variation observed in the sizes of the hind leg characters may be attributed to similarity in their vegetation and ecology type due to their closeness in geographic coordinates (Temidire, Ogede, Igbojaiye, Owotoro, Otu, LAUTECH) and (Samia, Mahuda, Federal College of Mechanization, Samaru). Sizes of hind leg characters affect the power flight ability and the pollen carrying capacity of honeybees (Adeoye *et al*. 2020, Szymula *et al.* 2010).

The Femur length has no association with all determined characteristics, except for the barsitarsus width ($R\geq0.69$, Table 5), while the hind leg length was significantly associated with the barsitarsus length and width of the bees. The sizes of the barsitarsus were also found to be positively associated with the proboscis length, while the width of the barsitarsus was also found to be significantly positively correlated to the width of the forewings of the bees. The hind leg tibia length was positively associated with the width of the hind wings and fore wings ($p<0.05$) (Table 5). Similar observations were also made by Shahnawaz *et al*. (2017) and Hepburn *et al.* (2001) who reported a positive correlation between length of femur and metatarsus of worker honeybees. Mostajeran *et al.* (2002) also found that honey production was related to tongue length, fore wing length and width, hind wing length, leg length, femur length, tibia length and metatarsus width.

Other body parts morphometry

The proboscis length of Ogede bee samples were longer (4.40±0.08 mm) compared to bee samples of Otu, Igbojaiye and Temidire in Southern guinea which were all statistically similar. There were significant variation in the proboscis length of honeybees within Northern guinea with LAUTECH honeybees having the longest (3.77±0.10 mm) while Mahuda bees had the shortest proboscis ($p<0.05$). The t-test analysis revealed that honeybees from Southern guinea agro-ecological zone had significantly longer proboscis than bees from Northern guinea ($p<0.05$) (Table 6). Proboscis length is an important character which influences the quantity and quality of nectars gathered from flowers during foraging. Hepburn *et al.* (2001) also reported significant variation in the proboscis length of *A. ceran*a of Himachal Pradesh, Utter Pradesh and North East Himalayan region. In Southern guinea, the abdomen of Temidire bees were significantly longer than other locations of study, while Ogede bees had the shortest abdominal length ($p<0.05$) (Table 6). The same trend of similarity was observed in honeybees within the locations studied in Northern guinea. There was no significant difference in the thoracic length of all bee samples collected from the different locations of study ($p<0.05$) (Table 6), while the study revealed significant variations in the hook numbers, head, body and abdominal length of the bee samples in all the locations with Samia bees recording the longest body length (12.22±0.15 mm), highest hook number (23±0.41 mm) ($p<0.05$).

The t-test analysis revealed that southern guinea honeybees had significantly longer abdomen, head and body compared to bees from northern guinea agro-ecological zone. A significant and positive correlation was found between the length of hind wing, femur, abdomen, hind leg tibia, head, width of the fore wings and proboscis ($R \geq 0.50$, Table 4). The body length was also positively associated with the length of hind wing, hind leg, barsitarsus sizes, tibia, proboscis and thoracic length ($R \geq 0.61$, Table 4). The numbers of hooks were also closely associated with the length of hind wings, fore wings, femur, proboscis, abdomen, body and head length ($p<0.05$) (Table 6).

Based on the dendrogram constructed using means of 15 morphometric characters for *A. melllifera* populations drawn from 10 localities in Guinea savannah zone of Nigeria, the dendrogram topology indicated two major morphoclusters (Class A and B) of entry (Fig. 7). Class A was made up of honeybees from region of Ogede, Otu, Owotoro and Igbojaiye which are on a simplicifolious clade at 1.65. Class A further branched into two sub-classes (sub-class 1: Ogede and Otu and sub-class 2: Owotoro and Igbojaiye). Honeybee samples from Ogede and Otu are closely related on a biofolious clade of 1.50, while Owotoro and Igbojaiye also shares closeness based on the morphometric traits studied on the same biofolious clade at 0.80.

Similarly, class B branched out into two distinct sub-classes on a simplicifolious clade at 3.30. Honeybee samples from Mahuda and Samia showed relatedness on biofolious clade at 1.65, while Temidire was distantly related to them on a simplicifolious clade at 2.40. Kaduna and Samaru bees had a distinct cluster on same biofolious clad at 1.30, while honeybee samples from LAUTECH was distantly related to them on a simplicifolious clade at a 1.65 distance (Fig. 7).

The mingling and relatedness of honeybees of the northern region with samples from the western 1region of the studied vegetation zone (Mahuda and Samia, Temidire; LAUTECH and Kaduna, Samaru) is in agreement with Amorin and Ribeiro (2001) findings which stated that honeybee species could migrate over wider vegetation belt in search of food (nectar and pollen), water and appropriate nesting site during swarming season or in a period of adverse environmental condition. This study confirmed previous reports by Oyerinde *et al*. (2012), Ajao *et al.* (2014), Usman (2016) and Adeoye *et al.* (2020) of the existence of intra-locality variations in honeybee morphological characters within a colony, meaning that a colony should not be considered as a simple individual, and assuming otherwise can lead to a regrettable loss of information (Paraïso *et al.* 2011).

Conclusions

This study confirmed that a wide range of variation exist in some morphometric features such as the wings, proboscis, abdomen, head and body length of *A. mellifera adansonni* in southern and northern guinea vegetation zone of Nigeria which may be due to environmental impact on the natural habitat of honeybees as a result of climate change and thereby reflecting ecological diversity in the studied location. The Interrelated morphometric features within each of the guinea vegetation type which shows similarity of biology of the honeybee species and bee plants in the same geographical zone can serve as an effective tool for grouping *A. mellifera* in guinea savannah vegetation zone. Since these morphological characters affect the flight ability, nectar and pollen collection activity and sense perception, they could have a significant impact in future bee breeding programmes with respect to *A. mellifera adansonni* in guinea vegetation zone of Nigeria.

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References

Abou-shaara HF, Al-ghamdi AA, Mohamed AA. 2013. Body morphological characteristics of honey bees. *Agricultura* 10(1–2): 45–49.

Abou-shaara HF, Draz KA, Al-aw M, Eid K. 2012. Stability of honey bee morphological characteristics within open populations. *Uludag Bee Journal*, 12: 31–37.

Adeoye OT, Pitan OR, Ademolu KO, Ayandokun AE. 2020. Morphometric studies on Nigerian honeybee *Apis mellifera adansonni* L. workers of rainforest and Sudan agroecological zones of Nigeria. *International Journal of Tropical Insect*, 1255–1263. DOI: 10.1007/s42690-020-00316-3

Horridge A. 2015. How Bees Discriminate a Pattern of Two Colours from Its Mirror Image. *PLoS ONE,* 10(1): 1–11.

Ajao AM, Oladimeji YU, Idowu AB, Babatunde SK, Obembe A. 2014. Morphological Characteristics of *Apis mellifera* L. (Hymenoptera: Apidae) in Kwara State, Nigeria. *International Journal of Agricultural Sciences*, 4: 171–175.

Amorim JA, Ribeiro OB. 2001. Distinction among the puparia of three blowfly species (Diptera: Calliphoridae) frequently found on unburied corpse. *Memórias do Instituto Oswaldo Cruz*, 96: 781–784.

Delarúa P, Jaffé R, Dall'olio R, Muñoz I, Serrano J. 2009. Biodiversity, conservation and current threats to European honeybees. *Apidologie*, 40: 263–284. DOI: 10.1051/apido/2009027

Eleazu CO, Iroaganachi M, Okoronkwo J. 2013. Determination of the physico-chemical composition, microbial quality and free radical scavenging activities of some commercially sold honey samples in Aba, Nigeria: The effect of varying colours. *Journal of Nutrition and Food Science*, 3(2): 189.

Koca AO, Kandemir I. 2013. Comparison of two morphometric methods for discriminating honey bee (*Apis mellifera* L.) populations in Turkey. *Turkey Journal of Zoology*, 37: 205–210.

Meixner MD, Costa C, Kryger P, Hatjina F, Bouga M, Ivanova E, Buchler R. 2010. Conserving diversity and vitality for honey bee breeding. Journal of Apicultural Research 49(1): 85–92. DOI: 10.3896/IBRA.1.49.1.12

Meixner DM, Worobik M, Wilde J, Fuchs S, Nikolaus K. 2007. *Apis mellifera mellifera* range in eastern Europe morphometric variation and determination of its limits. *Apidologie* 38: 1–7.

Miguel I, Baylac M, Iriondo M, Manzano C, Garnery EA. 2011. Both geometric morphometric and microsatellite data consistently support the differentiation of the *Apis mellifera* M evolutionary branch. *Apidologie*, 42: 150–161.

Mostajeran MA, Edriss MA, Basiri MR. 2002. *Heritabilities and correlations for colony traits and morphological characteristics in honey bee (Apis mellifera meda)*. Isfahan University of Technology, 17th World Congress on Genetic Applied to Livestocks Production, Montpellier, France, session 7 August 19-23, 2002.

Oladimeji YU, Abdulsalam Z. 2013. Analysis of technical efficency and its determinants among small scale rice farmers in patigi area of kwara state, Nigeria. IOSR Journal of Agriculture and Veterinary Science 3(3): 34–39.

Oyerinde AA, Dike MC, Banwo OO, Bamaiyi LJ, Adamu RS. 2012. Morphometric and

Landmark Based Variations of *Apis mellifera* L. Wings in the Savannah Agro-Ecological Zone of Nigeria. *Global Journal of Science Frontier Research*, (22): 33–41.

Paraïso A, Viniwanou N, Akossou AYJ, Mensah GA, Abiola W. 2011. Caractérisation morphométrique de l’abeille *Apis mellifera adansonii* au Nord-Est du Bénin. *International Journal of Biological and Chemical Sciences*, 5(1): 331–344.

Rattanawannee A, Chanchao C, Wongsiri S. 2010. Gender and Species Identification of Four Native Honey Bees (Apidae: Apis) in Thailand Based on Wing Morphometic Analysis. *Annals of the Entomological Society of America*, 103(6): 965–970.

Ruttner F. 1988. *Biogeography and taxonomy of honeybees*. Springer Verlag, Berlin, 298 pp.

Ruttner F, Tassencourt L, Louveaux J. 1978. Biometrical statistical analysis of the geographical variability of *Apis mellifera* L. I. Material and Methods. *Apidologie*, 9: 363–381.

Saad NA, El-kazafy AT. 2014. Morphometric studies on dwarf honey bee *Apis florea* f. workers in Saudi Arabia. *Journal of Apicultural Science*, 58(1): 127–134.

Sauthier R, I’Anson Price R, Gruter C. 2017. Worker size in honeybees and its relationship with season and foraging distance. *Apidologie,* 48(2): 234–246.

Shahnawaz AD, Sheikhbilal A. 2017. Morphometric variations and expression of body colour pattern of honeybee, *Apis cerana* F in Kashmir. *Journal of Entomology and Zoology Studies*, 5(4): 364–371.

Sheppard WS, Meixner MD. 2003. *Apis mellifera pomonella*, a new honey bee subspecies from Central Asia. *Apidologie* 34: 367–369.

Szymula J, Skowronek W, Bienkowska M. 2010. Use of various morphological traits measured by microscope or by computer methods in the honeybee taxonomy. *Journal of Apicultural Science*, 54: 91–97.

Usman H. Dukku. 2016. Evaluation of Morphometric Characters of Honeybee (*Apis mellifera* L.) Populations in the Lake Chad Basin in Central Africa. *Advances in Entomology*, 4: 75–89.

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