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Establishing biodiversity in dwarf honey bee, *Apis florea* F. (Hymenoptera: Apidae) workers from north western India based on morphometrics of antenna and mouth parts

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ABSTRACT: The present study was conducted on two head appendages viz. antenna and mouth parts to report morphometric differences in 7 different populations of *Apis florea* F. collected from foot hill regions of Himachal Pradesh (Bangana, Chintpurni, Hamirpur, Parwanoo, Daulatpur and Gagret) and Chandigarh plains (Chandigarh) of north western India. Collection was made during mid June- mid September months of the year, 2010-14. Ten morphometric characters and 4 biometric indices were statistically analyzed by means of factor analysis, discriminant analysis and cluster analysis. Chandigarh and Gagret regions having low altitude tend to show higher values of more number of morphometric characters while Bangana region with high altitude showed the opposite. For both antenna and tongue maximum numbers of characteristics with higher values were in Gagret region while maximum number of characteristics with lower values was exhibited by Bangana population of *A. florea*. The majority of characteristics of the tongue were significantly correlated with altitude suggesting that characteristics associated with foraging were more prone to be affected by altitude.

KEYWORDS: *Apis florea*, biodiversity, intra-specific, morphometrics, antenna, mouth parts

INTRODUCTION

Head of honey bee is triangular shaped bearing two compound eyes and three occelli located on the top of the head. Front side of the head bears the antenna and mouth parts. The two antennae are closely placed near the upper centre of the head. Each antenna consists of a single long joint connected to a prominent knob inserted into a socket. Each antenna has an elongated scape, a pivoted pedicel and a segmented flagellum (geniculate type), which is composed of ten flagellomeres in the worker (Winston, 1987) honey bees.

The mouthparts of dwarf honey bees are of chewing and lapping type. They consist of paired mandibles and the proboscis which is made of labium and maxillae. Proboscis is a more complicated structure and performs the major function of ingestion of liquid food. The role of glossa in pollen carriage was reported by Michener *et al.* (1978) since pollen grains were frequently trapped by glossal hair. Entire proboscis can be folded to Z shape when not in use. Michener and Brooks (1984) reported that flabellum at the tip of tongue helped in absorption and transportation of liquids to the mouth.

Goetze (1964) introduced biometric methods into the micro-systematics of honey bees. Using

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measurements of the body parts he introduced descriptions and classification of honey bees. There are many species specific quantitative characters especially length and width of tongue, antenna, forewing, hind wing, hind leg etc. of the generally recognized *Apis* species.

Morphometric studies on *A. florea* have been made throughout the world by scientists using different characters (Rinderer *et al.,* 1995). Although, there is extensive data related to general biology of *A. florea*, there is still a lack of sufficient morphometric data unlike Iran and Thailand. Morphometric study of dwarf honey bee from India has been reported for some selected characters only (Bhandari, 1983 and Sharma, 1983). In the present investigations, therefore, areas of north-western region of India were chosen to investigate the dwarf honey bee diversity on the basis of morphometric studies.

MATERIALS AND METHODS

Study area: Sample bees were collected from state of Himachal Pradesh and Chandigarh (UT). Detailed description of collection area is given in Table 1 and Fig 1 & 2.

Sample Collection, preparation and examination: Forager bees were collected from each region @150 bees / region. Experimental work was carried out in Entomology laboratory in Department of Zoology, Panjab University. Antenna and tongue were disarticulated and preserved in Pampell's fixative for further processing. Slides were prepared after washing in distilled water and specimens were mounted using a drop of Arabic gum. Slides were oven dried at 50°C for 2-4 hours. All measurements were made using stereo zoom microscope (Radical RSM-9) fitted with camera and provided with sofware (ProgResR CT5 USBC) and scale.

Sample and characteristics chosen

Ten morphometric characters studied included length and width of antennae and mouth parts and 4 biometric indices as considered by Ruttner *et al.* (1978) and Ruttner (1980, 1988). These are: Length of scape (SpL), Length of pedicel (PdL), Length of flagellum (FgL), Length of antenna (AtL), Length of postmentum (PoL), Breadth of prementum (PmB), Length of prementum (PmL), Length of glossa (GL), Length of labial palp (LpL) and Length of tongue (ToL) as shown in Figure 3 and 4.

Biometric indices

Antenna and tongue measurements of seven populations from different regions have been described with statistical analysis such as means, standard deviation and coefficient of variation of 4 biometric indices such as SpL / FgL, PmL / PmB, GL / PmL, LpL / PmL respectively termed as

Table 1 Localities, geographical coordinates and altitude from where *A. florea* bees were sampled

S. No.	Collection Area	Latitude	Longitude	Altitude
1	Chandigarh	30°43'59.93"N	76°46'45.90"E	365 m
2	Gagret	31°39'37.88"N	76°03'35.09"E	439 m
3	Daulatpur	31°46'58.52"N	75°59'23.51"E	521 m
4	Parwanoo	30°50'17.02"N	76°57'30.60"E	672 m
5	Hamirpur	31°41'10.23"N	76°31'16.71"E	785 m
6	Chintpurni	31°48'34.53"N	76°07'27.90"E	975 m
7	Bangana	31°39'39.69" N	76°20'51.44"E	1100 m

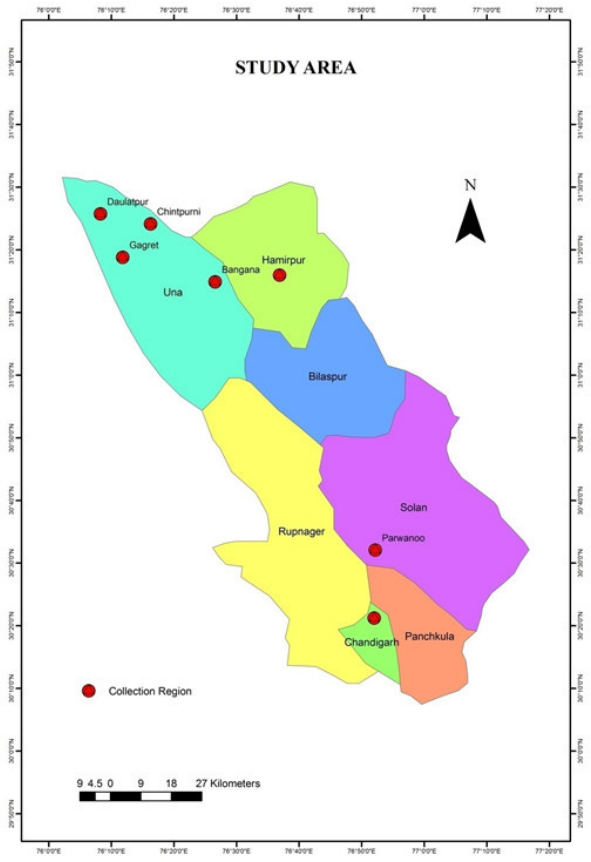

Figure 1 Map showing the locations from where the *Apis florea* sample were surveyed and collected

antenna- scapoflagellal index, Premental index, Glosso premental index and Labiopremental index.

Statistical analysis

A descriptive statistical analysis was carried out and comparisons between locations were determined by mean, standard deviation, analysis of variance (ANOVA), multiple range test, Coefficient of variation and correlation. Statistical analyses were performed using "SPSS" package.

We used 10 morphometric characters (length and width of tongue and antenna) obtained by morphometrics in Principle Component Analysis (PCA) in order to classify the populations of *Apis florea,* worker bees based on the distance from the control individuals. Morphometric analyses of populations were done using means, standard

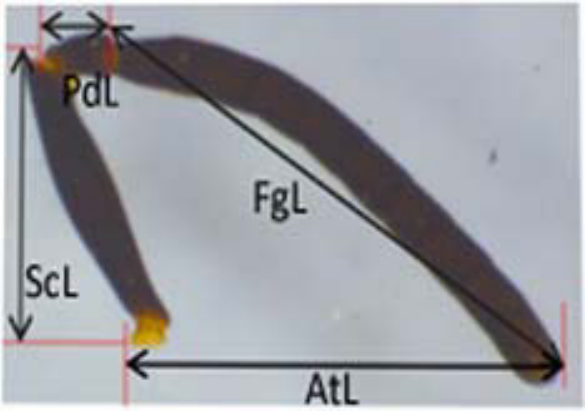

Figure 2 Morphometric characteristics of antenna of *Apis florea*.

deviations and covariances of the morphometric characters. We used one way ANOVA from the individual to the centroid of the group to compare each individual. Data were also analyzed with coefficient of variation and correlation to compare population. Bonferroni test was used to compare multivariate population means between groups. A cluster analysis was carried out of classify populations into morphocluster.

RESULTS

The data obtained by statistical analysis from 10 characteristics of antenna and tongue concerns differences in size *i.e.* length and width. The total variation in all populations of *Apis florea* is worth consideration in identification of races which is altitude specific. Length of antenna (total length) ranged from 2.753 to 2.813 mm and that of tongue (total length) from 3.117 to 3.211 mm. Our results showed that in populations of hilly regions the tongue was longer than plain region i.e. Chandigarh. This is in agreement with Allen's rule (Allen, 1877)

In comparison to other regions, the Chandigarh population exhibited significantly higher value ($p<0.01$) for scape length, pedicel length, flagellum length, and total tongue length; Gagret population for pedicel length, flagellum length, total antennal length and total tongue length; Daulatpur population for scape length, flagellum length and prementum width; Parwanoo population for pedicel length,

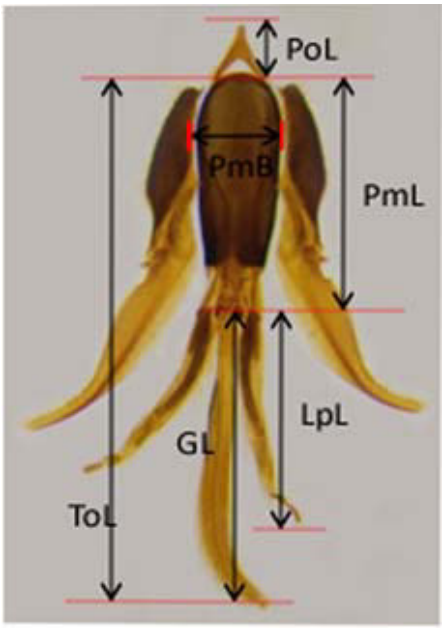

Figure 3 Morphometric characteristics of mouth parts of *Apis florea*.

flagellum length; Hamirpur population for pedicel length, flagellum length, total antennal length; Chintpurni population for pedicel length; Bangana population for flagellum length, prementum width (Table 2).

Antenna: The values were statistically significant ($p<0.05$) for scape length in Gagret, Parwanoo populations; pedicel length in Daulatpur and Bangana populations; flagellum length in Chintpurni and Bangana populations; total antennal length in Chandigarh, Daulatpur, Parwanoo, Chintpurni and Bangana populations; postmentum length in all populations, prementum width in Chandigarh, Gagret, Parwanoo, Hamirpur, and Chintpurni populations; prementum, glossa and labial palp length in all the populations of *A. florea*. The two morphometric characteristics with insignificant value were scape length in Hamirpur, Chintpurni and Bangana population, and tongue length in

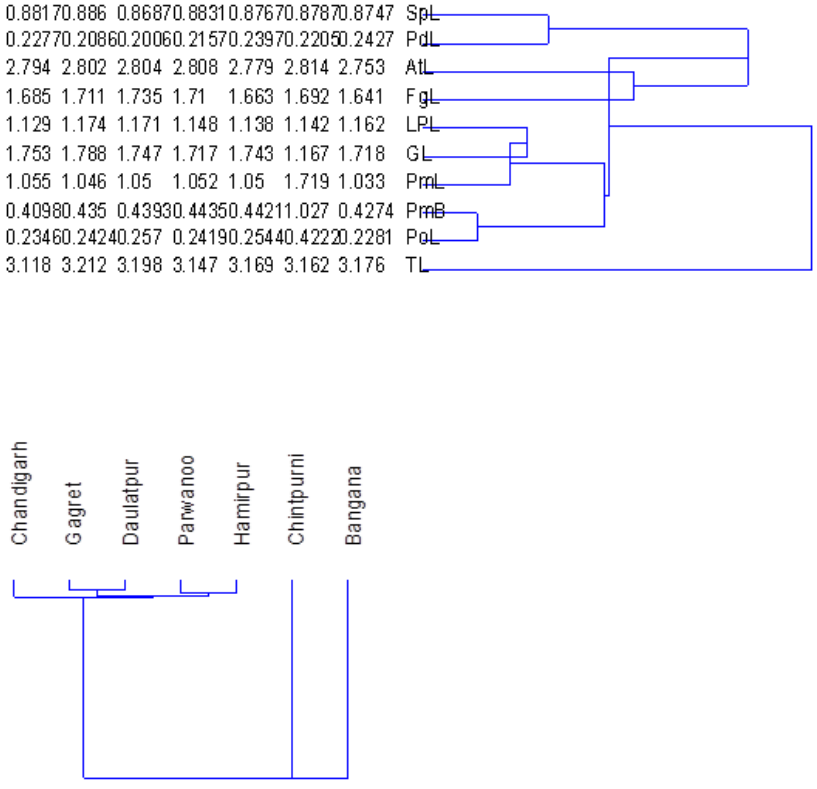

Figure 4 Cluster analysis (Paired group, Euclidean, two way)

Daulatpur, Parwanoo, Hamirpur, Chintpurni and Bangana populations of *A. florea*. Further, comparison of characteristics by ANOVA revealed that length of scape, pedicel, flagellum and total antennal length (F= 4.549, 39.345, 41.183 and 19.949 respectively and d.f. =6 (between groups), 133 (within groups), 139 (total), were significantly different P<0.001) in bee samples collected (Table 3).

Tongue: There were no significant differences between tongue segment such as postmentum (p>0.05), labial palp (p>0.05) and glossa (p>0.05) but there were significant differences in the total tongue length of *A. florea* (p<0.05) populations. Comparison of characteristics by ANOVA revealed that length of postmentum (F=910.897), breadth of prementum (F=7047.105), length of prementum (F=22617.056), glossa length (F=2138.839), labial palp length (F=1327.478) and total tongue length (F=56.948), d.f. = 6 (between groups), 133 (within groups), 139 (total), were significantly different (P<0.001) in bee samples collected (Table 3).

On the basis of the data observed from foothills of Himachal Pradesh and Chandigarh plains regions we conclude that single species of *Apis florea* with two morphoclusters persists throughout the study area (Figure 4). Common ecotypes are found in most of the regions due to the migratory tendency of the bee. For more precision and possibility of existence of ecotypes a wider range of geographic areas is needed.

DISCUSSION

The present study on *Apis florea* indicated that altitude variations affect the characteristic size of honey bee (Table 2 and 3). This study corresponded well with earlier work on *A. florea*. The characteristics of head appendages (antenna and tongue) with respect to length and width were affected by geographic location of the colony and showed significant differences (pd"0.01). The differences in scape, pedicel and flagellum length could be correlated to antenna length as total antenna length was significantly positively correlated to these segments. The differences in postmentum, prementum, labial palp, glossa length, could be correlated to total length of tongue.

The SpL in antenna of *A. florea* from different study regions was in following order: Gagret (0.886 mm)> Parwanoo (0.883 mm) > Chandigarh (0.881 mm) > Chintpurni (0.878 mm) > Hamirpur (0.876 mm) > Bangana (0.874 mm) respectively. Sharma (1983) reported length of scape in the following order, as Hamirpur (0.889 mm) > Una (0.886 mm) > Hoshiarpur (0.884 mm) > Kalka (0.883 mm) which is in corroboration of the present findings. However, the scape length of Hamirpur bees in the present case was distinctly less than that observed by Sharma (1983). The PdL in antenna of *A. florea* was in the order of : Bangana (0.242 mm) > Chandigarh (0.227 mm) > Chintpurni (0.221 mm) > Parwanoo (0.215 mm) > Gagret (0.208 mm) > Daulatpur (0.201 mm) respectively. This was the only antennal parameter that had highest value in the Bangana bees which otherwise showed the shortest antenna. Highest FgL of antenna was recorded for Daulatpur (1.734 mm) and lowest for Bangana (1.641 mm) populations. Bangana bees also had the shortest total length. Sharma (1983) reported flagellum length for *A. florea* from Una (1.743 mm), Kalka (1.736 mm), Hoshiarpur (1.703 mm) and Hamirpur (1.702 mm). Al-Kahtani and Taha (2014) observed significant differences in flagellum length of antenna for *A. florea* from Al-Ahsa (1.73 mm) and Jubail (1.69 mm) provinces respectively of Saudi Arabia. AtL in the present studies on *A. florea* was observed to range between 2.753 mm to 2.813 mm across seven regions of study and this difference was significant (pd"0.01). Sharma (1983) had observed similar variations in the populations of *A. florea* studied by him and reported that the total length of antenna was highest in *A. florea* from Una (2.846 mm) followed by Kalka (2.834 mm), Hamirpur (2.798 mm) and Hoshiarpur(2.784 mm). Al-Kahtani and Taha (2014) reported higher antennal length for dwarf honey bees from Al-Ahsa (2.75 mm) than those from Jubail (2.70 mm) provinces from Saudi Arabia. They (Al-Kahtani and Taha, 2014) reported significant correlation of body size with characteristics from head region i.e. antenna and mouth parts. These observations are in agreement

Table 2. Comparative morphometric data of Apis florea F. workers collected from 7 regions (Chandigarh and Himachal Pradesh). Means ± Standard deviation (in mm) of 10 morphological characters (mm) of worker bees.

Characters	Chandigarh (a)	Gagret (b)	Daulatpur (c)	Parwanoo (d)	Hamirpur (e)	Chintpurni (f)	Bangana (g)
1 SpL	0.881±0.005 c# 0.68%	0.886±0.004 c* 0.41%	0.868±0.005 a# b*d* 0.61%	0.883±0.004 c* 0.54%	0.876±0.003 Ns 2.64%	0.878±0.009 Ns 1.05%	0.874±0.007 Ns 2.04%
2 PdL	0.227±0.002 b*c*d# e# g* 1.18%	0.208±0.004 a*e*f# g* 1.84%	0.200±0.009 a*d*e*f*g* 5.57%	0.215±0.013 a# c*e*g* 6.28%	0.239±0.010 a# b*c*d*f* 4.58%	0.220±0.005 b# c*e*g* 2.39%	0.242±0.019 a*b*c*d*f* 8.05%
3 FgL	1.684±0.002 b*c*d# e*g* 0.16%	1.711±0.004 a*c# e*g* 0.23%	1.734±0.013 a*b# d*e*f*g* 0.76%	1.709±0.018 a# c*e*g* 1.11%	1.662±0.029 a# b*c*d*f*g# 2.37%	1.691±0.028 c*e*g* 1.70%	1.641±0.021 a*b*c*d*e# f* 1.33%
4 AtL	2.794±0.018 g* 0.29%	2.802±0.019 e# g* 0.33%	2.804±0.029 e*g* 0.69%	2.808±0.014 e*g* 0.52%	2.779±0.073 c# d*f*g* 1.36%	2.813±0.020 e*g* 0.73%	2.753±0.022 a*b*c*d*e*f* 0.81%
5 PoL	0.234±0.013 c*e*f* 1.43%	0.242±0.010 c*e*f*g* 4.40%	0.257±0.009 a*b*d*f*g* 3.74%	0.241±0.011 c*e*f*g* 4.58%	0.254±0.010 a*b*d*f*g* 4.08%	0.237±0.009 a*b*c*d*e*g* 2.68%	0.228±0.012 b*c*d*e*f* 5.28%
6 PmB	0.409±0.023 b*c*d*e*f*g* 5.75%	0.434±0.012 a*f* 0.63%	0.439±0.010 a*f*g# 2.46%	0.443±0.009 a*f*g* 2.08%	0.442±0.009 a*f*g* 0.95%	0.422±0.011 a*b*c*de*g* 0.93%	0.427±0.011 a*c#d*e*f* 2.69%
7 PmL	1.054±0.007 b*f*g* 0.75%	1.046±0.003 a*f*g* 0.35%	1.049±0.007 f*g* 0.72%	1.051±0.009 f*g* 0.90%	1.049±0.007 f*g* 0.75%	1.027±0.009 a*b*c*d*e*g* 0.46%	1.033±0.007 a*b*c*d*e*f* 0.68%
8 GL	1.753±0.004 b*d*f*g* 0.26%	1.788±0.013 a*c*d*e*f*g* 0.20%	1.746±0.021 b*d*f*g* 1.24%	1.717±0.014 a*b*c*e*f* 0.86%	1.742±0.018 b*d*f*g* 1.67%	1.718±0.009 a*b*c*d*e*g* 3.36%	1.717±0.007 a*b*c*e*f* 0.45%
9 LpL	1.129±0.022 f* 1.95%	1.174±0.036 f* 3.14%	1.171±0.028 f* 6.74%	1.147±0.034 f* 3.92%	1.138±0.027 f* 4.32%	1.166±0.029 a*b*c*d*e*g* 6.73%	1.162±0.024 f* 4.71%
10 ToL	3.117±0.005 b# 0.17%	3.211±0.005 a# 0.17%	3.197±0.027 ns 0.87%	3.147±0.027 ns 0.88%	3.168±0.017 Ns 0.58%	3.161±0.212 Ns 0.87%	3.176±0.022 Ns 0.71%

Values are expressed as Mean ± S.D. Lower case alphabet 'a' represents Chandigarh, 'b'=Gagret, 'c'= Daulatpur,'d'= Parwanoo, 'e' =Hamirpur, 'f'= Chintpurni and 'g'= Bangana.
Mean ± S.D. is followed by Post hoc test of Bonferroni to compare the values of different regions with each other in which Means are statistically highly significant at pd"0.01*, significant at pd"0.05# and non significant above 0.05 =ns.
It is followed by C.V. %
All the mean values are in mm.

with the present data. A significant positive correlation was found between length of antenna and flagellum (r=0.619) (Table 4). Postmentum length was having weak positive correlation with width (r=0.307) of prementum. Negative correlation was found for pedicel length with that of flagellum length (r=-0.665) and antennal length (r=-0.365, p<0.01).

Table 3. Multiple comparisons with ANOVA

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
SpL	Between Groups	0.004	6	0.001	4.549	<.001**
	Within Groups	0.02	133	0		
	Total	0.024	139			
PdL	Between Groups	0.029	6	0.005	39.345	<.001**
	Within Groups	0.016	133	0		
	Total	0.045	139			
FgL	Between Groups	0.12	6	0.02	41.183	<.001**
	Within Groups	0.065	133	0		
	Total	0.185	139			
AtL	Between Groups	0.053	6	0.009	19.949	<.001**
	Within Groups	0.058	133	0		
	Total	0.111	139			
PoL	Between Groups	0.563	6	0.094	910.897	0
	Within Groups	0.014	133	0		
	Total	0.576	139			
PmB	Between Groups	6.073	6	1.012	7047.105	0
	Within Groups	0.019	133	0		
	Total	6.092	139			
PmL	Between Groups	7.727	6	1.288	22617.056	0
	Within Groups	0.008	133	0		
	Total	7.735	139			
GL	Between Groups	5.792	6	0.965	2138.839	0
	Within Groups	0.06	133	0		
	Total	5.852	139			
LPL	Between Groups	69.151	6	11.525	1327.478	0
	Within Groups	1.155	133	0.009		
	Total	70.305	139			
TL	Between Groups	0.116	5	0.023	56.948	0
	Within Groups	0.046	114	0		
	Total	0.163	119			

The ToL was found to be highest in *A. florea* from Gagret (3.211 mm) followed by Bangana (3.176 mm), Hamirpur (3.168 mm), Chintpurni (3.161 mm), Parwanoo (3.147 mm) and Chandigarh (3.117 mm). Sharma (1983) reported highest tongue length for Hoshiarpur (3.270 mm) followed by Hamirpur (3.224 mm), Kalka (3.203 mm) and Una (3.200 mm). These values were higher than those recorded in the present study. Al-Kahtani and Taha (2014) reported higher tongue length for *A. florea* from Al-Ahsa (3.22 mm) than from Jubail (3.14 mm) province of Saudi Arabia. Rinderer (1995) reported the total tongue length for *A. florea* from Thailand as 3.273 mm. Wongsiri *et al*. (1996)

Table 4. Comparative biometric indices of antenna and tongue of *Apis florea* workers collected from seven regions

Characteristic	Chandigarh (a)	Gagret (b)	Daulatpur (c)	Parwanoo (d)	Hamirpur (e)	Chintpurni (f)	Bangana (g)
1 SpL/FgL	0.523±0.007 c* 0.66%	0.517±0.005 c*g* 0.46%	0.500±0.001 a*b*d*e*f*g* 1.07%	0.516±0.001 c*g* 1.47%	0.527±0.004 c* 4.06%	0.519±0.002 c*g* 1.99%	0.533±0.003 b*c*d*f* 2.75%
2 PmL/PmB	2.588±0.043 b*c*d*e*f*g* 7.44%	2.405±0.004 a*f* 0.75%	2.390±0.013 a*f* 2.51%	2.373±0.012 a*f* 2.42%	2.374±0.005 a*f* 0.96%	1.673±0.003 a*b*c*d*e*g* 1.07%	2.419±0.014 a*f* 2.77%
3 GL/PmL	1.662±0.003 b*d*f* 0.81%	1.709±0.001 a*c*d*e*f*g* 0.35%	1.664±0.006 b*d*f* 1.64%	1.632±0.004 a*b*c*f*g* 1.26%	1.659±0.006 b*d*f* 1.72%	1.678±0.004 a*b*c*d*e*g* 3.15%	1.662±0.002 b*d*f* 0.78%
4 LPL/PmL	1.070±0.004 f* 1.98%	1.122±0.007 f* 3.12%	1.115±0.017 f* 6.90%	1.091±0.010 f* 4.13%	1.084±0.010 f* 4.22%	1.239±0.027 a*b*c*d*e*g* 6.80%	1.124±0.011 f* 4.55%

Values are expressed as Mean ± S.D. Lower case alphabet 'a' represents Chandigarh, 'b'=Gagret, 'c'= Daulatpur,'d'= Parwanoo, 'e' =Hamirpur, 'f'= Chintpurni and 'g'= Bangana. Mean ± S.D. is followed by Post hoc test of Bonferroni to compare the values of different regions with each other in which Means are statistically highly significant at $p<0.01$*, significant at $p<0.05$# and non significant above 0.05 =ns. It is followed by C.V. % (Coefficient of variation in percentage).

Table 5. Pearson correlation coefficients for 10 characteristics of dwarf honey bee (*Apis florea*) workers

	SpL	PdL	FgL	AtL	PoL	PmB	PmL	GL	LPL	TL
SpL	1	-0.003	-0.131	0.257	-0.061	0.026	0.101	0.18	0.07	-0.086
PdL	-0.003	1	-0.665	-0.365	-0.236	-0.181	-0.164	-0.234	-0.071	-0.112
FgL	-0.131	-0.665	1	0.619*	0.365	0.163	0.177	0.242	0.026	0.233
AtL	0.257	-0.365	0.619	1	0.159	0.044	0.111	0.14	-0.005	-0.2
PoL	-0.061	-0.236	0.365	0.159	1	0.307	0.211	0.226	0.042	0.189
PmB	0.026	-0.181	0.163	0.044	0.307	1	0.107	0.012	0.139	0.215
PmL	0.101	-0.164	0.177	0.111	0.211	0.107	1	0.283	-0.098	-0.212
GL	0.18	-0.234	0.242	0.14	0.226	0.012	0.283	1	0.093	0.106
LPL	0.07	-0.071	0.026	-0.005	0.042	0.139	-0.098	0.093	1	0.023
TL	-0.086	-0.112	0.233	-0.2	0.189	0.215	-0.212	0.106	0.023	1

*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

observed differences between tongue length of *A. andreniformis* (2.797 mm) and *A. florea* (3.272 mm) from Thailand which helped to differentiate the two species. Niem and Trung (1999) reported proboscis length for *A. florea* from Vietnam (3.45 mm) and Thailand (3.57 mm) respectively. The PoL in tongue of *A. florea* from different populations was observed as Daulatpur (0.257 mm)>Gagret (0.242 mm) > Parwanoo (0.241 mm) > Chintpurni (0.237 mm) > Chandigarh (0.234 mm)

> Bangana (0.228 mm) respectively. The PmL in tongue of *A. florea* was lowest in bees from Chintpurni (1.027 mm) and showed significant difference (pd"0.01) with the bees of other populations. The PmB was lowest in bees from Chandigarh (0.409 mm) followed by Chintpurni (0.422 mm) < Bangana (0.427 mm) < Gagret (0.434 mm) < Daulatpur (0.439 mm) < Parwanoo (0.443) respectively. Niem and Trung (1999) reported 0.56 mm in width of prementum of *A. florea* from Vietnam and Thailand which was higher than that observed in the present case. Postmentum length was having weak positive correlation with width (r=0.307) of prementum.

Data for six characteristics namely length of pedicel, glossa, labial palp, postmentum and length and width of prementum of *Apis florea* is not reported till date.

In present study, 4 biometric indices have been studied to find out variations in the populations of *A. florea* from different regions (Table 5). The index was studied by Sharma (1983) who reported highest value for Kalka population which was different from the present findings. GL/PmL was highest in Gagret population and was significantly different from all other populations of *A. florea*. LpL/PmL exhibited highest value in Chintpurni (1.239) population and was significantly different from all other populations of *A. florea*. In similar studies Sharma (1983) reported highest value for Hamirpur population (1.440 mm) which was different from present studies.

These inter locality differences were significant ($p<0.01$) and could be related to altitudinal variations which significantly differed among seven regions and previously reported findings from the world. Our results also confirmed the findings of Tahmasebi et al. (2002) who reported that areas with higher altitudes have larger honey bees.

CONCLUSION

Data on tongue measurements revealed significant differences among samples of *Apis florea*. All the characteristics employed in the analysis proved to be of value in discriminating all the populations into two morphoclusters within the species of *A. florea* (Figure 4). Morphocluster A which was formed by the populations of Chintpurni and Bangana and morphocluster B formed by populations of Chandigarh, Gagret, Daulatpur, Parwanoo and Hamirpur *A. florea* population of morphocluster A belonged to regions located at highest altitude of the study area and were exposed to colder environmental condition with faster wind velocity and wild flora as forage source. Morphocluster B populations of *A. florea* belonged to lower altitude areas and had to face less cold climate, lower wind velocity and agricultural flora as forage source. Antennal characters exhibited significantly higher values in Daulatpur population of morphocluster B.

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REFERENCES

Akahira F., Sakagami S.F. (1959) Notes on the difference in some external characteristics between Japanese and European honey bees. Studies on the Japanese honey bee *A. cerana cerana* F. Annotationes Zoologicae Japonenses 32: 35-42.

Al-Kahtani S.N., Taha E.K.A. (2014) Morphometric studies on dwarf honey bee *Apis florea* F. workers in Saudi Arabia. Journal of Apicultural Science 58 (1):127-134. DOI: 10.2478/jas-2014-0013.

Allen, Joel Asaph (1877). "The influence of Physical conditions in the genesis of species". Radical Review. 1: 108–140.

Bhandari V.C. (1983) Biometrical studies on *Apis florea* F. and *Apis dorsata* F. of northwestern India, PhD Thesis, Himachal Pradesh University, Shimla, India, 92 pp.

Chaiyawong T., Deowanish S., Wongsiri S., Slyvester H. (2004) Multivariate morphometric study of Apis florea in Thailand. Journal of Apicultural Research 43(3): 123-127.

Goetze G.K.L. (1964) Honey bees under natural and artificial selective breeding. Paul Parey, Hamburg. (In German).

Mattu V.K. (1982) Morphometric and behavioural studies

on Indian honey bee (*Apis cerana indica* F.) Ph. D. Thesis: Himachal Pradesh University, Shimla, India.

Mattu V.K., Verma L.R. (1983) Comparative morphometric studies on introduced European bee *Apis mellifera* L. and Indian honeybee *Apis cerana indica* F. in Himachal Pradesh. In: Proceedings of Second International Conference, Apiculture in Tropical Climate, New Delhi, pp 262–277.

Michener C.D., Brooks R.W. (1984) Comparative study of the glossae of bees. Contributions of the American Entomology Institute 22: 1-73.

Michener C.D., Winston M.L., Jander R. (1978) Pollen manipulation and related activities and structures in bees of the family, Apidae. University of Kansas Science Bulletin 51: 575- 601.

Narayanan E.S., Sharma P.L., Phadke K.G. (1960) Studies on biometry of the Indian bees. II. Tongue length, wing hooks, worker-brood-cell size and thickness of comb of *Apis florea* F. at Pusa (Bihar). Indian Bee Journal 22: 81-88.

Narayanan E.S., Sharma P.L., Phadke K.G. (1961) Studies on the biometry of the Indian bees III. Tongue length and number of hooks on the hind wings of *Apis indica F* collected from Madras State. Indian Bee Journal 23: 3-9.

Niem N.V., Trung L.Q. (1999) Morphological comparison of three Asian native honey bees (*Apis cerana*, *A. dorsata*, *A. florea*), Biotropia 14: 10-16. DOI: http://dx.doi.org/10.11598/btb.1999.0.14.153

Rahman K.A., Singh S (1948) Variation in the tongue length of the honey bee. Indian Journal of Entomology 10: 63-73.

Raina S.K., Kimbu D.M. (2005) Variations in races of the honeybee *Apis mellifera* (Hymenoptera: Apidae) in Kenya. International Journal of Tropical Insect Science 25(4): 281–291. DOI: http://dx.doi.org/10.1079/IJT200588 .

Rinderer T.E., Oldroyd B.P., Wongsiri S., Sylvester H.A., de Guzman L.I., Stelzer J.A., Riggio R.M. (1995) A morphological comparison of the dwarf honey bees of southeastern Thailand and Palawan, Philippines. Apidologie 26: 387-394. DOI: http://dx.Doi.org/10.1051/apido:19950504.

Ruttner, F. (1980), *Apis mellifera Adami* (nssp), Die Kretische Biene, Apidologie 11,385-400.

Ruttner F. (1988) Biogeography and Taxonomy of Honey Bees, Springer-Verlag Berlin, ISBN 0- 387-17781-7, Heidelberg, Germany.

Ruttner F., Tassencouyt L., Louveaux J. (1978) Biometrical statistical analysis of the geographic variability of *Apis mellifera* L. Apidologie 9: 363-381. DOI: http://dx.doi.org/10.1051/apido:19780408.

Sharma P.C. (1983) Morphometric studies on *Apis florea* F. and *Apis dorsata* F. of Himachal Pradesh and Punjab, PhD Thesis, Himachal Pradesh University.

Winston M.L. (1987) The Biology of the honey bee. Harvard University Press, Cambridge, Massachusetts, 281 pp.

Wongsiri S., Lekprayoon C., Thapa R., Thirakupt K., Rinderer T.E., Sylvester H.A., Oldroyd B.P., Booncham U. (1996) Comparative biology of *Apis andreniformis* and *Apis florea* in Thailand. Bee World 77: 23-35.

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