Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

J E Z S Journal of Entomology and Zoology Studies

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2017; 5(4): 364-371

Received: 15-05-2017
Accepted: 16-06-2017

Shahnawaz Ahmad Dar
Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir – 190025 (J&K) India

Sheikh Bilal Ahmad
Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir – 190025 (J&K) India

Correspondence
Shahnawaz Ahmad Dar
Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir – 190025 (J&K) India

Morphometric variations and expression of body colour pattern of honeybee, *Apis cerana* F. in Kashmir

Shahnawaz Ahmad Dar and Sheikh Bilal Ahmad

Abstract
The present investigation was conducted on morphometric variations and expression of body colour pattern of honeybee, *Apis cerana* from five different locations of Kashmir region viz; Pahalgam, Tral, Srinagar, Sonamarg and Bandipora at insect systematic laboratory, Division of Entomology, SKUAST Kashmir during 2011-2012. *A. cerana* F. collected from areas of mountainous zone (Pahalgam and Sonamarg) showed significant higher value of several morphological characters as compared to those found in sub mountainous zone (Srinagar and Bandipora).Similarly, the colour pattern of honeybees in Kashmir region showed a wide range of variation and this high variation reflects the ecological diversity from different locations. *A. cerana* F. collected from mountainous zones were darker in colour as compared to those found in sub-mountainous zones, which indicated that the colour pattern of *A. cerana* F. varies with the altitude. The results confirmed that the bees get darker at higher elevation. Thus morphometric and colour pattern variations found in *A. cerana* F. viz-a-viz altitudes could have a significant impact in future bee breeding programmes with respect to *A. cerana* F. in Kashmir.

Keywords: *Apis cerana*, morphometric variation, colour pattern, Kashmir

1. Introduction
Honeybee, *Apis cerana* Fabricus, (Hymenoptera: Apidae) is widespread in temperate and tropical Asia [1]. *A. cerana* F. is found at varying altitudes with appropriate flora and climate. Morphometry is a powerful tool for discriminating populations [2-4] but is not suitable for inferring phylogenetic relationship between them. So far only four sub-species of *A. cerana* F. are recognized, although there may be several more because of its wide range of geographic distribution [5]. The maximum taxonomic diversity is met within Indo- Malayan region, suggesting it to be the probable centre of their origin [6]. Three subspecies of *A. cerana* have been recognised in the Himalayan region and they have been named as *A. cerana cerana, A. cerana himalaya* and *A. cerana indica* [7]. There are morphological variations between these subspecies. Geographical and seasonal variations have been attributed to influence morphological traits of these honeybees [8, 9].
Body colour is the most distinct character of any honeybee species or subspecies. The pattern of light (yellow, orange) and dark (black, brown) colour varies between species, within species as well as between the three casts (workers, queens and drones) of the same honey bee colony. Ruttner [5, 10] also recorded bimodal distribution of body colour among his collection of honey bees. Earlier, Woyke [11] explained the bi-modal distribution of body colour. There are two major body colour gene: Y responsible for the yellow colour and y^b responsible for black colour. As a result two groups of body colour bees appear a series of yellow variations, and of black variations. There is a peak of frequency within the yellow range, and other within the black range. General description of body colour of one or three castes of honey bee, *Apis cerana* were given by several authors [12-14]. However, variation of body colour of *A. cerana* workers were described by [15] and seasonal colour variations were found by [14, 16]. The body colour pattern of Asian honey bee is different in the three castes. The purpose of this investigation was to study the principles of heredity and the differences in expression of body colour of Himalayan honey bee, *A. cerana.* The aim of the present investigation was to study the morphometric variations and expression of body colour pattern of, *A. cerana* in Kashmir.

2. Materials and Methods
The present investigation was conducted at insect systematic laboratory, Division of Entomology, SKUAST Kashmir during 2011-2012.

2.1 Sampling

Samples of worker honeybee, *A. cerana* F. were collected from feral/wild colonies of four different locations of Kashmir region viz., Pahalgam, Srinagar, Sonamarg and Bandipora having different altitudes, latitudes and climatic conditions (Table-1). 100 worker bees were collected and anaesthetized with ethyl acetate and preserved in 70% ethyl alcohol, until morphometric analysis. Honeybees were put into small plastic/ killing bottles, which were labelled and brought to the laboratory. Honeybees were dissected and different morphological parts were mounted on glass slides for morphometric analysis.

Table 1: Physiographical details of various places of collection of honeybee, *A. cerana* F. samples from Kashmir region.

S. No.	Name of locations	Altitude (meters)	Number of samples (n)
1.	Pahalgam	2750	20
2.	Tral	2007	20
2.	Srinagar	1780	20
3.	Sonamarg	2790	20
4.	Bandipora	1870	20

2.2 Measurements of different morphological parts of honeybee, *A.cerana* F.

Different morphological parts of honeybee, *A. cerana* F. were dissected out. These parts were then mounted on glass slides covered with cover slips except tergites and sternites. The later were mounted on glass rods so as to retain their natural shape and also for simplifying the procedure of measurement. The slides were dried in the oven at 40 to 45°C. All measurements were taken with the help of a stereo binocular microscope equipped with an ocular scale calibrated against a fixed and known ruler, the stage micrometer. Measurements of different parameters of wings and various wing venation angles were taken with the help of a slide projector. The following morphometric characters studied in the present investigation are:

Tongue
1. Total tongue length

Antenna
2. Length of scape
3. Length of pedicel
4. Length of flagellum
5. Total length of antenna

Fore wing
6. Length of fore wing
7. Breadth of fore wing
8. Length of radial cell
9. Breadth of radial cell
10. Length of 1st abscissa of vein M 3+4 in cell 2m (a)
11. Length of 2st abscissa of vein M 3+4 in cell 2m (b)
12 to 17. Different wing venation angles (31 to 36)

Hind wing
18. Length of hind wing
19. Breadth of hind wing
20. Length of vein RL
21. Length of vein ML
22 Length of vein VL
23. Length of vein IL (indica vein)
24. Number of hooks (hamuli)
25. Extent of hamuli
26. Length of jugal lobe
27. Length of venal lobe

Hind leg
28. Length of femur
29. Length of tibia
30. Length of metatarsus
31. Breadth of metatarsus

Tergites
32. Total length of third tergite
33. Total length of Fourth tergite

Sternites
34. Total length of third sternite
35. Total length of sixth sternite

However, great part of the investigations was conducted on fresh specimens. Since the principles of body colour expression honeybee, *A. cerana* were studied, different shades of the light colour is designed as yellow, although it may be orange. The variation of dark body colour patterns in particular castes is also not considered. The following morphological parts were studied for colour pattern variations are:

- General body colour
- Colour of antenna
- Colour of thorax
- Colour of wings
- Colour of hind leg
- Colour of third tergite
- Colour of fourth tergite
- Colour of third sternite
- Colour of sixth sternite

*Colour patterns were studied in fresh specimen

2.3 Statistical analysis

Statistical analysis of the data was done by calculating colony mean, standard deviation and covariance of the morphometric characters. Further one way analysis of variance and t test were applied for testing the significance of results.

3. Results and Discussion

3.1 Morphometric study of honeybee, *Apis cerana*

From the perusal of data in Table-2, the various morphological characters were studied and are summarized as follows:

3.2 Tongue length

Tongue length is an important character upon which depends the quality of the nectar gathered from flowers [17]. Present study also revealed that tongue length was significantly longer in bees of mountainous zones than sub mountainous zone. Zone wise comparison of *A. cerana* F. revealed that in the mountainous zone i.e. Pahalgam and Sonamarg, the total tongue length was greater (P.D = 2.25, $P<0.05$) in bees than those present in Srinagar and Bandipora area of sub mountainous zone. Hepburn [18] reported that the total tongue length of *A. cerana* was greater in Himachal Pradesh than Utter Pradesh and North East Himalayan region as 5.31, 4.46 and 4.65mm respectively. Fernando [19] studied the tongue length of *A. cerana* in Sri Lanka and reported that the tongue length was significantly longer in bees of mountainous districts than lowlands.

3.3 Antenna

Antenna is the centre of many sense perceptions [20]. Zone wise comparison of different antennal characteristics viz; length of flagellum and the total length of antenna (P.D = 1.06 and 1.18 respectively at $P<0.05$) was significantly greater in bees of mountainous zone as compared to those collected from the areas of sub mountainous zone. Present findings draw the support from Kshirsagar [12] who reported the bigger size of antenna at higher elevations. This is because of the fact that bees found at the higher elevations require longer antenna in order to have better sense perception, so as to cope with the larger environmental disturbances at these altitudes. Akahira and Sakagami, [21]reported bigger antennal size of *A. mellifera ligustica* F. than *A. cerana cerana* F. Antontseva [22] also reported bigger size of antenna in bees collected in summer than spring season for *A. mellifera* F. A significant increase in length of flagellum and total length of antenna with age but no such increase was observed for length of scape and pedicel. These results suggested that older bees are superior in their sense perception than the young nurse bees.

3.4 Fore wing

Size of fore wing is directly related to the flight ability of bees [23]. The breadth of fore wing (P.D = 2.05, $P<0.05$), length of radial cell (P.D = 1.36, $P<0.05$), breadth of radial cell (P.D = 2.55, $P<0.01$), length of 1st and 2nd abscissa (P.D = 3.67 and 3.77 respectively at $P<0.01$) and different wing venation angle numbers 34, 35 and 36 (P.D = 2.31, 1.20 and 1.03 respectively at $P<0.05$) showed significant higher values in bees of mountainous zone as compared to the bees of sub mountainous zone. However, length of fore wing and angle numbers 31, 32 and 33 did not show any significant differences in bees of both the zones. Significant higher values were observed for length and breadth of hind wing (P.D = 1.11 and 2.19 respectively at $P<0.05$), length of wing veins namely RL, VL and IL (P.D = 2.35, 1.48 and 2.28 respectively at $P<0.05$), number of hamuli (P.D = 7.53, $P<0.01$) and length of venal lobe (P.D = 1.43, $P<0.05$) in bees collected from mountainous and sub mountainous zones. However, length of vein ML, extent of hamuli and length of jugal lobe were not significantly different in bees collected from both the zones. The parameters of hind leg i.e. length of femur (P.D = 1.50, $P<0.05$) and breadth of metatarsus (P.D = 1.25, $P<0.05$) were significantly greater in mountainous zone, compared to bees of sub mountainous zone. However, length of tibia and length of metatarsus did not show any difference between the bees of two zones. Length of third and fourth tergite (P.D = 1.22 and 2.10 respectively at $P<0.05$) was significantly larger in bees collected from locations of mountainous zone than in bees collected from the locations of sub mountainous zone. Length of third and sixth sternite (P.D = 1.88 and 1.73 respectively at $P<0.05$) was significantly larger in bees collected from locations of mountainous zone than in bees collected from sub mountainous zone. Kshirsagar [12] collected the similar data for length and breadth of fore wing from Mandi and Kangra areas of Himachal region. Similar trends were also observed by [8, 12, 18, 24] for this species. In bees of Kashmir region, only breadth of fore wing was positively correlated with altitude of mountainous zones. However, Akahira and Sakagami [21] did not find any relationship between and altitude and the size of fore wing for *A. cerana cerana* F. Results of these authors showed slightly higher values than those observed in the present investigation. These variations may be observational due to different reasons of collection or less number of specimens examined by these investigators. However, present data on length and breadth of fore wing of this species was close to the results of [8] for *A. cerana indica* F. from Northern India. Other reports on the length and breadth of fore wing of *A. cerana* F. from different parts of India and abroad are as follows: Allahabad (7.960 and 2.850mm) by [8] Udaipur (7.678 and 2.676mm) by [25]**;** Ludhiana (8.19 2.96mm) [26] and Maharashtra (7.62 and 3.07 mm) by [6]. These observations along with the present results suggested that the size of fore wing may be greater in bees of Northern as compared to Southern India, a variation attributed to altitude. In the present investigations, no significant correlation was found between length and breadth of fore wing and length of third and fourth tergite. However, Bornus [27] established a positive correlation between these characters for *A. mellifera* L. Further, a significant and positive correlation was observed between the length of fore wing and hind wing in the present investigation and this was contrary to the results of [12, 28, 29]. Size of radial cell can be an important morphometric character to distinguish among the different races of *A. mellifera* L. [10]. Present morphometric data showed significantly higher values for the length and breadth of radial cell and length of 1st and 2nd abscissa in the bees of mountainous zone as compared to the samples collected from sub mountainous zone of Kashmir region. Kshirsagar [12] also found similar trend in the values of these characters. In Kashmir bees, the length and breadth of radial cell length of 1st and 2nd abscissa were positively correlated with altitude. Similar results were also given by [28]. However, Akahira and Sakagami [21] did not find any significant correlation between length of radial cell and altitude for *A. cerana cerana* F. A significant and positive correlation was found between length and breadth of radial cell and breadth of hind wing. Whereas, length of 1st and 2nd abscissa showed a positive correlation with length of venal lobe. Similar results were given by [28, 29].

3.5 Wing venation Angles

Wing venation is important for the classification and functional stability of the wings in honeybee races [30]. Statistical analysis of the data on different wing venation angles indicated that angle numbers 34 and 35 showed significantly higher values (F = 2.531, $P<0.05$ and F = 3.232, $P<0.01$, respectively) in bees of mountainous zone as compared to sub mountainous zone. Bees collected from Tral area of mountainous zone had higher values (18.32 and 91.56) of angle numbers 34 and 35 respectively than bees collected from other locations of Kashmir region. A significant and positive correlation was established between altitude and angle numbers 34 and 35. However, a significant and positive correlation was established between angle number 34 and length of sixth sternite. These results suggested that wing venation angles and the functional stability of the wings were also affected by the altitude. Similar results were also found by [12, 28, 29, 31] reported significant differences in angle 31 and 34 in bee samples collected during different seasons. Whereas, angle numbers 31 and 35 were significantly different in bee samples at different age groups. These results suggested that most of the wing venation angles did not undergo significant changes with variations in season and age.

3.6 Hind wing

Statistical analysis revealed significant differences in the breadth of hind wing in bee samples collected from different locations of Kashmir region. The character showed

significantly higher values (1.780 and 1.768mm) of bees at Pahalgam and Sonamarg areas respectively of the mountainous zone as compared to the Srinagar and Bandipora areas (1.732 and 1.738mm respectively) of sub mountainous zone. Kshirsagar [12] and Singh [29] also found bigger sizes of hind wing at higher elevations. A significant and positive correlation was found between altitude and breadth of hind wing in mountainous zone, whereas, no such correlation was found in sub mountainous zone of Kashmir region. Also, no correlation was found in the length of hind wing with altitude from Kashmir region. Akahira and Sakagami [21] and Mattu and Verma [28] also did not find any relationship between the altitude and length of hind wing for *A. cerana cerana* F. and *A. cerana indica* F. respectively. Kshirsagar [12] reported lower values for length and breadth of hind wing in bees collected from Mandi (6.15 and 1.24mm respectively) and Kangra (6.31 and 1.75mm respectively) areas of Himachal region as compared to the data collected in the present investigation. Jain and Kushwaha [25]reported that the mean length and breadth of hind wing was 5.247 and 1.932 mm respectively in bees collected from Udaipur. Whereas, Jagannadham and Goyal [26] found mean length and breadth of hind wing as 5.86 and 1.62 mm respectively, for bees found in Ludhiana area. These results suggested that size of hind wing was significantly greater in bees of hilly areas as compared to the plain of Northern India and therefore lend support to present investigators.

Present data on the hind wing showed a significant and positive correlation between length of hind wing and breadth of hind wing, length of femur and length of sixth sternite. Whereas breadth of hind wing showed a significant and positive correlation with number of hooks, length of venal lobe, length of vein ML, length of femur, length of third and fourth tergite, length of third and sixth sternite and size of workers etc. These results suggested that size of the hind wing also increased along with other morphological parts. Similar results were also found by [18, 28].

3.7 Length of wing veins RL, ML, VL and IL

Statistical analysis of the data revealed that significant differences existed in the length of wing vein RL and VL of samples collected from different locations of Kashmir region. These veins were significantly longer in the bees of mountainous zone as compared to sub mountainous zone of Kashmir region. Similar observations were also made by [12, 28, 31], who reported longer wing veins at higher elevations as compared to the plain areas. Wing veins VL showed a significant and positive correlation with altitude. Akahira and Sakagami [21]did not find any correlation between altitude and different wing veins for *A. cerana cerana* F. Length of veins RL, VL and IL was significantly greater from mountainous zone as compared to sub mountainous zone of Kashmir region, whereas, no such significant differences were observed for the length of vein ML. These variations in the length of wing vein may be due to the changes in wing shape. Length of vein RL was greater in *A. mellifera ligustica* S. as compared to *A. cerana indica* F., but length of veins ML and VL were shorter in *A. mellifera ligustica* S. as compared to *A. cerana indica* F. [28]. Similar results were also reported by [21].

3.8 Number and extent of hamuli

Statistical analysis indicated significant variations for number of hamuli in bees collected from different locations of Kashmir region. Whereas, extent of hamuli did not show any significant differences in bee samples of Kashmir region. Similar results were reported by [28] but Kapil [8] reported no significant variations in the number of hamuli in plain and hill strains of this species. Fernando [19] also did not find any significant variations in the number of hooks in *A. cerana* F. collected from lowlands and mountainous districts of Sri Lanka. In the present investigations, bees of mountainous zone had significantly more number of hooks as compared to the sub mountainous zone of Kashmir region. Narayanan [32, 33] reported smaller number of hooks in bees at higher altitudes. Hepburn [18] also found smaller number of hooks from Northeast Himalayan region. A significant and positive correlation was established between altitude and number of hooks but, extent of hamuli did not show any correlation with altitude. Singh [29] found a significant correlation between altitude and number of hooks. However, Akahira and Sakagami [21] did not find any significant correlation between altitude and the number of hooks for *A. cerana cerana* F. Present results on the number of hooks for bees collected from Pahalgam area were similar as reported by [28] for hill strain of *A. cerana indica* F. However, the mean value of number of hooks given by [12] for bees of Mandi area (18.40) and Kangra (19.00) areas of Himachal region were smaller than those observed in the present investigations. Other investigators have also reported different mean values of number of hooks for *A. cerana* F. from different parts of India: Madras (18.28) by [32]; Uttar Pradesh (17. 56) by [33]; Udaipur (17.57) by Jain and Kushwaha [25]; Foot hills of Himalayas (18.29) by Singh [29] and Himachal Pradesh and Nepal (19.36 and17.72, respectively) by Hepburn [18] Above results along with the present results suggested that no regular trend existed in the in the number of hooks from North to South of India. There was significant and positive correlation between the number of hooks and length of vannal lobe, length of third and sixth sternite and length of radial cell etc. Similar results were given by [28, 31].

3.9 Length of jugal and vannal lobe

Statistical analysis of the present data suggested significant differences in the length of venal lobe but length of jugal lobe did not show any difference in bees of Kashmir region. This lobe was significantly longer in the bees of mountainous zone as compared to sub mountainous zone of Kashmir region. Further, a significant and positive correlation was established between length of vannal lobe and altitude in bees collected from Kashmir region. Kshirsagar [12] reported higher values of jugal and vannal lobes at higher elevations as compared to bees of plain areas. Similar results were also given by Mattu and Verma [28] from higher elevations of Himachal region.

3.10 Hind leg

Size of hind leg especially metatarsus affect the pollen carrying capacity of honeybee [10]. In Kashmir region, significant differences were observed only in length of femur and breadth of metatarsus. Bees of mountainous zone showed significantly higher values for these characters as compared to bees of sub mountainous zone of Kashmir region. Kapil [8] and Verma [31] also found bigger size of hind leg at higher elevations as compared to the plain areas. Present results showed that length of tibia and metatarsus in bees of Kashmir region was greater (3.217 and 2.027mm respectively) as compared to *A. cerana cerana* F. (3.005 and 1.899 mm respectively) [21]. Jagannadham and Goyal [26] reported the length of tibia and metatarsus as 2.65 and 2.12 mm respectively for *A. cerana indica* F. collected from plain areas of Punjab. So, the size of hind leg may be bigger in hilly areas

as compared to those present in plains of Northern India. A significant and positive correlation was found to exist between altitude and length of femur and breadth of metatarsus, but no such correlation was found with other characters of hind leg. A significant and positive correlation existed between length of femur and length and breadth of metatarsus, length of third and sixth sternite and size of workers etc. Similar observations were also made by [28] and [18] who reported a positive correlation between length of femur and metatarsus at higher elevations as compared to the plain areas and therefore lend support to present investigations.

3.11 Tergites (Third and Fourth)

Third and fourth tergites were taken as the indicators of abdominal size [27]. In Kashmir region, significant differences were observed in the length of third and fourth tergites. Length of both third and fourth tergites was significantly smaller in bees of sub mountainous zone as compared to the mountainous zone of Kashmir region. Kshirsagar [12] also reported bigger size of third and fourth tergites at the higher altitudes. Present results showed that length of third and fourth tergites in bees of Kashmir region was greater (2.124 and 2.095mm respectively) as compared to *A. cerana indica* F. (1.98 and 1.90 mm respectively from Himachal region [18] **t**hus supporting the argument that bees of Kashmir region have bigger abdominal size than the bees of same species existed in Himachal Pradesh. A significant and positive correlation was found between altitude and length of third and fourth tergites. Also a significant and positive correlation was found between length of third and fourth tergite and length of third sternite. Similar observations were also made by [34, 18] who reported a positive correlation of length of third and fourth tergites with the length of third sternite at higher elevations as compared to the plain areas.

3.12 Sternites (third and sixth)

Statistical analysis of the data revealed significant differences in the length of third and sixth sternites in bees of Kashmir region. Further, these parameters showed significantly higher values in the bees of mountainous zone as compared to sub mountainous zone of Kashmir region. Kshirsagar [12] also reported bigger size of sternites at the higher altitudes. A significant and positive correlation was found between altitude and length of third and sixth sternites. Also a positive correlation was found to be existing between length of third and sixth sternite and size of workers. Similar observations were also made by [34, 18] who reported the positive correlation between the length of third and sixth sternite at higher elevations as compared to the plain areas. Longer sternites in the bees at higher elevations could be attributed to the larger abdominal size of such bees as compared to the bees found in plains. For many social insects a tendency has been found that the higher the altitude and latitude, the bigger is the body size and the colony population [35]. This relationship is the rule for *A. mellifera* [36] for *A. cerana* [31] for *A. florea* [37] and for some stingless bee species [38]. A high degree of variation in size reflects the ecological diversity of *A. cerana*. Based on essentially morphological and behavioural analysis and the aid of different genetic techniques, the classification systematic of the true honey bees has obtained great achievements in the last two decades of the twentieth century. Present studies confirmed that the morphometric features of honeybees in Kashmir region show a wide range of variation in measurements of size. This high variation reflects the ecological diversity from different locations of Kashmir region, where the samples were taken. The results confirmed that the bees get bigger and darker at higher elevation, also found in former studies on *A. mellifera, A. cerana* and *A. florea* [36, 31, 37, 39].

3.13 Body colour pattern of *A. cerana*

Honeybee, *A. cerana* is a vital component of natural ecosystem. Its decline may have serious consequences for various entomophilous plant species. The variations in the colour pattern of various morphological traits of the worker bees of *A. cerana* collected from various locations at different altitudes of Kashmir are presented in Table-3. From the data, it is evident that colour variations existed in the bees at different altitudes. General body colour of *A. cerana* F. was yellow dirty to blackish brown in sub mountainous zone, whereas, it was dirty yellow blackish brown in bees of mountainous zone. Colour of thorax was light brown and dark brown in the bee samples collected from sub mountainous and mountainous zones respectively. Hind legs were light blackish brown in the bees of sub mountainous zone and blackish brown in the bees present in the mountainous zone. Other morphological parts such as antennae, wings and sixth sternite were similar in colour pattern in both the zones, however, these parts showed slightly darker shades in the bees of mountainous zone. All the locations of sub mountainous and mountainous zones showed a similar colour pattern of yellow blackish brown of third and fourth tergite except at Bandipora which showed light yellow blackish brown colouration. Similarly, colour of third and sixth sternite was yellowish black in all the areas of sub mountainous and mountainous zone except Bandipora which showed light yellowish black colour. Studies on the colour patterns indicated differences in the general body colour of honeybee, *A. cerana* F. collected from sub mountainous and mountainous zones of Kashmir region. Bees of mountainous zone showed dark colouration as compared to the sub mountainous zone, although bees of adjacent altitudes could not be differentiated clearly. However, major body parts showed different colouration of bees in different zones.

Among the morphological characters besides the size of different body parts, colour patterns also assume diagnostic value to a certain extent [10]. These colour patterns not only enable to distinguish among different races but are frequently used in selection and breeding programmes [10, 41]. Present morphometric studies on the honeybee, *A. cerana* F. revealed differences in the colour patterns of bee samples collected from different locations of Kashmir region. Honeybees from mountainous zone were darker in colour than those collected from sub mountainous zone. Kshirsagar [12] reported bees of darker colour at higher altitudes as compared to plains. Bees collected from different locations of Kashmir were significantly different in colour patterns. For example, general body colour of bees from mountainous zone was dirty yellow blackish brown, whereas, it was light dirty yellow blackish brown in sub mountainous zone. Similarly, colour of thorax was dark brown in mountainous zone, whereas, it was light brown in sub mountainous zone. Other morphological parts such as hind legs, veins of wings, tergites and sternites etc. also showed differences in their colouration. These observations suggested that bees of Kashmir region showed significant differences not only in morphological parts but also in their colour pattern. Also colour pattern of the body and its parts was found variable with altitudes. These results suggested that the bees in Kashmir region particularly those

existing at higher altitudes were different from other parts of the country.

A high degree of colour variation reflects the ecological diversity of *A. cerana*. Verma [31] reported that bees were darker at higher altitudes under lower rainfall conditions, whereas, Kshirsagar [40] found that queen bees of *A. cerana indica* F. were darker at higher altitudes and lighter at lower altitudes. Narayanan [33, 33, 42] reported the bees of leaden grey and leather golden colour from Indian hills and plains respectively. They described variation in colour patterns as racial cum geographical characteristics. Tan [39] reported that the bees from higher altitudes and cold temperate regions were markedly darker than bees from lower altitudes and warm subtropical regions. Based on essentially morphological and behavioural analysis and the aid of different genetic techniques, the classification systematic of the true honey bees has obtained great achievements in the last two decades of the twentieth century. Present studies confirmed that the morphometric features of honeybees in Kashmir region show a wide range of variation in measurements of size, and colour pattern. This high variation reflects the ecological diversity from different locations of Kashmir region, where the samples were taken. The results confirmed that bees get bigger and darker at higher elevation, also found in former studies on *A. mellifera, A. cerana* and *A. florea* [36, 31, 37, 39].

Table 2: Comparative morphometric traits of honeybee, *Apis cerana* F. collected from different regions having altitudinal variations.

S. No.	Trait	Location						Percentage Difference (P.D.)
		Mountainous region			Sub- Mountainous region			
		Pahalgam	Sonamarg	Average (M1)	Srinagar	Bandipora	Average (M2)	
1	Total tongue length	5.459	5.465	5.463	5.338	5.342	5.340	2.25*
2	Length of scape	1.260	1.249	1.254	1.243	1.245	1.244	0.79 ns
3	Length of pedicel	0.244	0.240	0.242	0.240	0.240	0.240	0.82 ns
4	Length of flagellum	2.740	2.738	2.739	2.710	2.709	2.709	1.06*
5	Total length of antenna	4.335	4.329	4.332	4.285	4.277	4.281	1.18*
6	Length of forewing	8.789	8.764	8.776	8.732	8.728	8.730	0.52 ns
7	Breadth of fore wing	3.121	3.117	3.119	3.058	3.052	3.055	2.05*
8	Length of radial cell	3.217	3.215	3.216	3.169	3.175	3.172	1.36*
9	Breadth of radial cell	0.432	0.430	0.431	0.422	0.418	0.420	2.55*
10	Length of 1st abscissa	0.565	0.578	0.571	0.551	0.550	0.550	3.67**
11	Length of 2st abscissa	0.157	0.162	0.159	0.152	0.154	0.153	3.77**
12	Angle number 31	33.09	33.07	33.08	32.85	32.80	32.82	0.78 ns
13	Angle number 32	108.05	107.92	107.98	107.40	107.02	107.21	0.71 ns
14	Angle number 33	96.00	96.10	96.05	95.82	95.88	95.85	0.20 ns
15	Angle number 34	18.08	18.17	18.12	17.62	17.78	17.70	2.31*
16	Angle number 35	91.32	91.28	91.30	90.45	89.95	90.20	1.20*
17	Angle number 36	43.58	43.75	43.66	42.80	43.63	43.21	1.03*
18	Length of hind wing	6.448	6.437	6.442	6.380	6.374	6.370	1.11*
19	Breadth of hind wing	1.780	1.768	1.774	1.732	1.738	1.735	2.19*
20	Length of vein RL	1.486	1.489	1.487	1.455	1.449	1.452	2.35*
21	Length of vein ML	1.230	1.223	1.226	1.220	1.224	1.222	0.32ns
22	Length of vein VL	1.274	1.281	1.277	1.257	1.259	1.258	1.48*
23	Length of vein IL	0.439	0.436	0.437	0.428	0.426	0.427	2.28*
24	Number of hooks	20.43	20.73	20.58	18.58	20.03	19.03	7.53**
25	Extent of hamuli	1.288	1.312	1.30	1.291	1.297	1.294	0.46 ns
26	Length of jugal lobe	1.829	1.828	1.828	1.825	1.816	1.820	0.43 ns
27	Length of venal lobe	1.256	1.246	1.251	1.229	1.238	1.233	1.43*
28	Length of femur	2.595	2.597	2.596	2.555	2.560	2.557	1.50*
29	Length of tibia	3.218	3.217	3.217	3.204	3.207	3.206	0.34 ns
30	Length of metatarsus	2.014	2.027	2.020	2.008	2.012	2.010	0.49 ns
31	Breadth of metatarsus	1.125	1.104	1.114	1.098	1.102	1.100	1.25*
32	Length of third tergite	2.124	2.112	2.118	2.090	2.095	2.092	1.22*
33	Length of Fourth tergite	2.095	2.079	2.087	2.040	2.045	2.042	2.10*
34	Length of third sternite	2.590	2.604	2.597	2.546	2.550	1.88	1.88*
35	Length of sixth sternite	2.429	2.405	2.417	2.378	2.372	2.375	1.73*

(ns) $P>0.05$ = Not significant, (*) $P<0.05$ = Significant, (**) $P<0.01$ = Highly significant

Table 3: Colour pattern of honeybee, *Apis cerana* F. (workers) collected from different locations of Kashmir region.

Character	Location				
	Mountainous zone			Sub-mountainous zone	
	Pahalgam	Tral	Sonamarg	Srinagar	Bandipora
General body colour	Dirty yellow blackish brown	Dirty yellow blackish brown	Dirty yellow blackish brown	Light dirty yellow blackish brown	Light dirty yellow blackish brown
Antenna	Dark brown	Dark brown	Dark brown	Dark brown	Dark brown
Thorax	Dark brown	Dark brown	Dark brown	Light brown	Light brown
Wings	Clear hyaline with veins of dark amber colour	Clear hyaline with veins of dark amber colour	Clear hyaline with veins of dark amber colour	Clear hyaline with veins of dark amber colour	Clear hyaline with veins of dark amber colour
Hind leg	Blackish brown	Blackish brown	Blackish brown	Light blackish brown	Light blackish brown
Third tergite	Yellow blackish brown	Yellow blackish brown	Yellow blackish brown	Yellow blackish brown	Light yellow blackish brown
Fourth tergite	Yellow blackish brown	Yellow blackish brown	Yellow blackish brown	Yellow blackish brown	Light yellow blackish brown
Third sternite	Yellowish black	Yellowish black	Yellowish black	Yellowish black	Light yellowish black
Sixth sternite	Yellowish black with dark posterior end	Yellowish black with dark posterior end	Yellowish black with dark posterior end	Yellowish black with dark posterior end	Light yellowish black with dark posterior end

4. Conclusion

During the investigations, important findings summarized and various conclusions have been drawn from the experimental findings. The bees of Kashmir region showed a wide range of variation reflects the ecological diversity from different locations. Since these morphological characters affect the flight ability, nectar and pollen collection activity and sense perception. The results also confirmed the trend that bees get darker at higher elevation. Expression of body colour in *A. cerana* depends upon the sexuality and may be considered as an adaptation to the environmental living conditions. Thus morphometric and colour pattern variations found in *A. cerana* F. viz-a-viz altitudes could have a significant impact in future bee breeding programmes with respect to *A. cerana* F. in Kashmir.

5. Acknowledgement

The authors are highly thankful to the insect systematic laboratory, Division of Entomology SKUAST Kashmir for providing the necessary facilities for the completion of the research work.

6. References

1. Smith DR, Villafuerte L, Otis G, Palmer MR. Biogeography of *Apis cerana* F. and *A. nigrocincta* Smith: insights from mtDNA studies. Apidologie 2000; 31:265-279.
2. Cornuet JM, Fresnaye J, Tassencourt L. Discrimination and classification of honeybee populations by means of biometric characters. Apidologie. 1975; 6:145-187.
3. Tomassone R, Fresnaye J. A biometrical and statistical method to distinguish successive generations of honeybee populations. Apidologie. 1971; 2:49-65.
4. Ruttner F, Tassencourt L, Louveaux J. Biometrical statistical analysis of the geographical variability of *Apis mellifera* L. I. Material and Methods. Apidologie 1978; 9:363-381.
5. Ruttner F. Biogeography and Taxonomy of Honeybees, Springer- Verlag, Berlin, 1988.
6. Deodikar GB, Thakar CV, Tonapi KV. Evolution of genus *Apis.* Indian bee journal. 1961; 23:86-91.
7. Verma LR. Honeybees in Mountain Agriculture. Oxford and IBH Publishing Co., New Delhi 1992b, 274.
8. Kapil RP. Variation in biometrical characters of the Indian honeybee (*Apis indica* F.). Indian J. Entomol. 1956; 18:440-457.
9. Kshirsagar KK. Morphometric studies on the Indian hive bee *Apis cerana indica* F. I-morphometric characters useful in identification of intraspecific taxa, Proc. 2nd Int. Conf. Apic. Trop. Clim., New Delhi. 1983, 254-261.
10. Ruttner F. Races of bees. From the hive and the honeybee (ed. Dadant and Sons). Hamilton, Illinois Dadant and Sons, 1979.
11. Woyke J. The heredity of colour patterns in the honey bee. Genetics, Selectian and Reproduction of the Honey Bee. Symp. on Bee Biology in Moscow, Bucharest 1977, 49-55
12. Kshirsagar KK. Studies on Indian Apidae with special reference to Indian hive bee, *Apis cerana indica* F. Ph.D. thesis in Zoology University of Poona, Pune, 1976.
13. Morse RA, Laigo FM. *Apis dorsata* in the Philippines. Philipp. Assoc. Entomol. 1969; 1:1 -96
14. Okada I. Biological characteristics of the Japanese honey bee, *Apis cerana* japonica. Proc. 30th Int. Apic. Congr., Apimondia, Nagoya, 1986, 119-122
15. Szabo TI. Morphometric characteristics of *Apis cerana* from Sri Lanka. Amarican Bee Journal. 1990; 130(12):815.
16. Matsuka M, Sasaki T. Temperature as a causative factor of the seasonal colour dimorphism in *Apis cerana* japonica. In: Proceedings of the 31st International Apiculture Congress, Apimondia, Warsaw. 1987, 186.
17. Morimoto H. The use of the labial palpus as a measure of proboscis length in worker honeybees, *Apis mellifera ligustica* and *Apis cerana cerana.* Journal of Apiculture Research. 1968; 7:147-150.
18. Hepburn HR, Radloff SE, Verma S, Verma LR. Analysis of *Apis cerana* populations in the southern Himalayan region. Apidologie. 2001; 32:435-447.
19. Fernando EFW. Some biometrical features of *Apis cerana* F. from Sri Lanka. Indian Bee Journal 1979, 2001; 41:5-8.
20. Hassanein MH, El-Banby MA. Studies on the biometrics of the Egyptian honeybee, *Apis mellifera fasciata* L. (Hymenoptera: Apoidae). Bulletin Society Entomological Egypt. 1956; 40:127-130.
21. Akahira Y, Sakagami SF. A biometrical study on the Japanese honeybee, observations upon some populations of Kyushu (studies on the Japanese honey bee, *Apis cerana cerana* F.). Journal of the Faculty of Science, Hokkaido University 1959a; 10:353-362.
22. Antontseva PV. Seasonal changes in external characters of local bees of the Dzhungarskii Alatau (mountains). *Temat. Sborn. Nauch. Trud.* Alma-Atin I Semipal,

Zoovet, Institov. 1975; 36:31-32.
23. Lindauer M. Communication among the honeybees and stingless bees of India. Bee World. 1957; 38:521.
24. Mattu VK, Verma LR. Comparative morphometric studies on the Indian honeybee of the north-west Himalayas. 2. Wings. Journal Apiculture Research, 1984a; 23:3-10.
25. Jain PC, Kushwaha KS. Morphometrics of bees, *Apis dorsata* F., *Apis cerana* F., *Apis florea* F., *Trigona* Smith (Hymenoptera: Apidae) and their foraging habitat at Udaipur. M. Sc. Thesis Univ. of Udaipur, Udaipur, 1967.
26. Jagannadham B, Goyal NP. Morphological and behavioural characteristics of honeybee workers reared in combs with large cells. Khadigramodyog, 1980, 369-377.
27. Bornus L. Investigations on the size of honeybee body and some of its parts. Pszcz. Zesz. Nauk. 1960; 4:175-182.
28. Mattu VK, Verma LR. Comparative morphometric studies on introduced European bee *Apis mellifera* L. and Indian honeybee *Apis cerana indica* F. in Himachal Pradesh, Proc. 2nd Int. Conf. Apic. Trop. Clim., New Delhi. 1983a, 262-277.
29. Singh MP, Verma LR, Daly HV. Morphometric analysis of the Indian honeybee in the northeast Himalayan region. Journal Apiculture Research. 1990; 29:3-14.
30. Louis J. Studies of wings of Hymenoptera III, the wings of Apoidae. Apidologie. 1970c; 1:375-400.
31. Verma LR, Mattu VK, Daly HV. Multivariate morphometrics of the Indian honeybee in the northwest Himalayan region. Apidologie. 1994; 25:203-223.
32. Narayanan ES, Sharma PL, Phadke KG. Studies on 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. 1961a; 23:3-9.
33. Narayanan ES, Sharma PL, Phadke KG. Studies on biometry of the Indian bees. IV. Tongue length and number of hooks on the hind wings of *Apis indica* F. collected from Uttar Pradesh. Indian Bee Journal. 1961b; 23:69-74.
34. Mattu VK, Verma LR. Comparative morphometric studies on the Indian honeybee of the north-west Himalayas. 1. Tongue and antenna Journal Apiculture Research. 1983b; 22:79-85.
35. Niem NV, Ha TD, Thai LD. Preliminary observation on morphological data of *Apis cerana* F in Vietnam. Paper presented at the XIXth. International Congress of Entomology; Beijing, 1992.
36. Hepburn HR, Radloff SE, Oghiake S. Mountain bees of Africa. Apidologie. 2000; 31:205-221.
37. Ruttner F, Mossadegh MS, Kauhausen D. Distribution and variation in size of *Apis florea* F. in Iran. Apidologie, 1995; 26:477-486.
38. Pereboom ZJM, Biesmeijer JC. Thermal constraints for stingless bee foragers: the importance of body size and coloration. Oecologia. 2003; 137(1):42-50.
39. Tan K, Fuchs S, Koeniger N, Ruiguang Z. Morphological Characterization of *Apis cerana* in the Yunnan Province of China. Apidologie. 2003; 34(6):553-561.
40. Kshirsagar KK. Comparative biometric studies on Indian honeybees. III. Preliminary observations on biometry of *Apis cerana* F. queen. Indian Bee Journal. 1973; 35:21-26.
41. Woyke J. The heredity of colour patterns in the honeybee. Proc. Int. Sym. Bee Genetics, Selection and Reproduction, Moscow. 1976b, 49-55.
42. Narayanan ES, Sharma PL, Phadke KG. Tongue length and number of hooks on the hind wings of *Apis indica* F. Indian Bee Journal. 1960; 22:81-88.