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Morphometric studies of Sphecid wasps of Karnataka, India

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Abstract
Apoidea super-family, which includes four families: Ampulicidae, Crabronidae, Heterogynaidae, and Sphecidae. Apoid wasps are closely related to bees in terms of morphology, wherein ecologically and behaviourally they are diverse in many habitats. In the present study we carried out a PCA analysis to determine which variable contributed more with its variance to total variance observed in the apoid wasp's morphology. First and second components with 59.55% total variation were found positively correlated with twenty-seven characters except the length of pedicle which was negatively correlated. Second component with 8.48% positively correlated with width of forewing and length of first submarginal cell and negatively correlated with length of forewing and length of metasoma. Third component with 6.55% positively correlated with length of propodeum, length of petiole and length of first metasomal segment.

Keywords: Sphecidae, morphometry, PCA, apoid

Introduction
Sphecidae (mud-dauber and thread-waisted wasps or digger wasps) (Latreille 1802) is a cosmopolitan family of wasps. Traditionally, all sphecid wasps were included in a single family, Sphecidae. Apoid wasps are closely related to bees in terms of morphology, where in ecologically and behaviourally they are diverse in many habitats. They are placed under super-family Apoidea, which includes four families: Ampulicidae, Crabronidae, Heterogynaidae, and Sphecidae. The family Sphecidae contains a vast array of genera and species that, collectively, are exceedingly diverse morphologically, ecologically and behaviourally [1, 2, 3]. They are worldwide in distribution, mainly occupying arid and semi arid areas, but are most numerous in warm and more or less dry habitats. While adult wasps feed on flowers, females hunt insects or spiders to provision their progeny. They are mostly specialized hunters of specific insect prey, but many species prey on a wide array of spiders. Females nest in the ground, in wood borings or plant stems, and some build exposed mud nests attached to stones or wood. A few genera consist of cleptoparasitic species. Most are active in summer months [4].
The Sphecinae wasps can be recognized by many diagnostic characters such as; gaster with cylindrical elongate petiole composed of sternum only unless it has two section as in *Ammophila* Kirby, inner orbits of eyes without notch, mandibles without a notch on externo-ventral margin, notauli on scutum absent but weak and short when present, jugal lobe of hind wing large containing an anal vein, no pygidial plate, male with 13 and female with 12 antennal segments [5, 6]. They are generally black-bodied insects or black marked with white, yellow or red; some are tinged with metallic blue or green. They range in size from about 2mm up to 51 mm long [7]. In this study 28 quantitative morphometric characters of sixty five species of the Apoidea super-family from south India were identified. Then obtained data were coded and analysed by principal component analysis (PCA) test.

Materials and Methods
The collected specimens were brought to the laboratory, sorted, relaxed and pinned using insect pins (size no. 1, 2 and 3). An adequate number of samples were preserved in 70 per cent or 90 per-cent ethanol and kept for molecular studies in a -20 °C refrigerator. To facilitate identification of tiny sized wasps, they were mounted on paper points on the right side of the thorax. Before mounting the pointed end of each piece of paper point was mildly bent using forceps to enable gluing to the right part of the thorax so that head, wings, and abdomen could be examined. Tongue, mandibles, antennae, legs, and wings were stretched properly.

The specimens were dried using a hot air oven at 40 ℃. The processed samples were permanently labelled with locality information, collection date, and collector's name.

Morphometric measurements were made using a standardized micrometre fixed in the eyepiece of a stereo binocular microscope. Five male and five female specimens were used for measurement in most species. In species with fewer specimens, all the available samples were measured. All measurements are given in millimeters. Below are the detailed characters used for measurements.

Measurements of different parts

i. Head length
ii. Head width
iii. Thorax length
iv. Abdomen length
v. Forewing length
vi. Total body length

Details of measurements

1. Total body length: Distance between the anterior-most point of vertex and the posterior tip of the abdomen
2. Length of head: Length of anterior and posterior margin of the head
3. Width of head: Distance between the points where eyes projected most at the sides
4. Length of scape
5. Width of scape
6. Length of pedicel
7. Width of pedicel
8. Length of the first flagellomere
9. Width of the first flagellomere
10. Inter-antennal distance
11. Clypeo-ocellar distance
12. Inter ocellar distance(median)
13. Inter ocellar distance (lateral and median)
14. Width of eye
15. Length of clypeus
16. Width of clypeus
17. Clypeo-antennal distance
18. Length of mesosoma: Distance between the anterior and posterior margin of the thorax
19. Length of propodeum
20. Width of propodeum
21. Length of forewing: Length from tegula to the tip of the wing.
22. Width of forewing
23. Length of hindwing
24. Length of first submarginal cell
25. Length of metasoma: Distance between the anterior margin of the first visible metasomal segment and the posterior margin of the last visible metasomal segment.
26. Width of metasoma
27. Length of the first metasomal segment(T1)
28. Length of a second metasomal segment(T2)

Analysis of morphometric data

The morphometric data were subjected to principal component analysis (PCA). PCA involves a mathematical procedure that transforms several (possibly) correlated variables into a (smaller) number of uncorrelated variables called principal components. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible. The objectives of PCA are to discover or to reduce the dimensionality of the data set and to identify new meaningful underlying variables [8].

The mathematical technique used in PCA is called eigen analysis in which the eigenvalues and eigenvectors of a square symmetric matrix with sums of squares and cross products are determined. The eigenvector associated with the largest eigenvalue has the same direction as the first principal component. The eigenvector associated with the second largest eigenvalue determines the direction of the second principal component. The sum of the eigenvalues equals the trace of the square matrix and the maximum number of eigenvectors equals the number of rows (or columns) of this matrix [9].

Results and Discussion

In the present study we carried out a PCA analysis to determine which variable contributed more with its variance to total variance observed in the apoid wasp's morphology. For this, twenty eight characteristics were measured as mentioned in the material and methods. All the measurements were recorded in millimeters (mm). Factor analysis on results of morphometric characters and variance table (Table 1 and 2) showed that the first six factors describe about 86% of total variance.

First and second components with 59.55% total variation were found positively correlated with twenty-seven characters except the length of pedicle which was negatively correlated. Second component with 8.48% positively correlated with width of forewing and length of first submarginal cell and negatively correlated with length of forewing and length of metasoma. Third component with 6.55% positively correlated with length of propodeum, length of petiole and length of first metasomal segment. The last three components with 10% total variance were positively correlated with length of pedicle, inter ocellar distance and negatively correlated with length of propodeum.

Table 1: Total variance explained using principal component analysis for studied apoid wasp's characters

Total Variance						
Component	Initial Eigen values			Rotation sums of squared loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	17.270	59.550	59.550	17.270	59.550	59.550
2	2.459	8.480	68.030	2.459	8.480	68.030
3	1.901	6.556	74.585	1.901	6.556	74.585
4	1.188	4.096	78.681	1.188	4.096	78.681
5	1.099	3.789	82.470	1.099	3.789	82.470
6	1.024	3.531	86.001	1.024	3.531	86.001
7	.778	2.684	88.685			
8	.651	2.245	90.930			
9	.497	1.714	92.644			

10	.444	1.532	94.176	
11	.344	1.186	95.362	
12	.269	0.927	96.289	
13	.233	.804	97.093	
14	.188	.649	97.741	
15	.132	.455	98.196	
16	.108	.372	98.567	
17	.101	.347	98.915	
18	.083	.287	99.202	
19	.055	.188	99.390	
20	.047	.161	99.551	
21	.034	.118	99.669	
22	.029	.101	99.770	
23	.023	.080	99.849	
24	.013	.046	99.895	
25	.010	.034	99.929	
26	.007	.025	99.954	
27	.006	.022	99.976	
28	.004	.015	99.991	
29	.003	.009	100.000	

Table 2: Six components of PCA test and correlating morphometric characters of studied apoid taxa

	Component Matrix[a]						
	Characters measured	**Components**					
		1	**2**	**3**	**4**	**5**	**6**
1	Total body length	0.971					
2	Length of head	0.974					
3	Width of head	0.982					
4	Length of scape	0.707					
5	Width of scape	0.943					
6	Length of pedicle				0.594	0.565	0.406
7	Width of pedicle	0.802					
8	Length of F1	0.846					
9	Width of F1	0.782					
10	Inter antennal distance	0.591					
11	Clypeo-ocellar distance	0.898					
12	Inter ocellar distance (lateral)	0.424			0.431		-0.516
13	Inter ocellar distance (m and l)					0.486	
14	Width of eye	0.918					
15	Length of clypeus	0.908					
16	Width of clypeus	0.905					
17	Clypeo antennal distance	0.590					
18	Length of mesosoma	0.962					
19	Length of propodeum			0.544	-0.437		
20	Width of propodeum	0.783					
21	Length of forewing	0.831	-0.503				
22	Width of forewing	0.710	0.671				
23	Length of hindwing	0.886					
24	Length of 1st SMCell	0.726	0.648				
25	Length of metasoma	0.778	-0.429				
26	Width of metasoma	0.824	0.465				
27	Length of petiole	0.542		0.620			
28	Length of 1st metasomal segment (T1)	0.620		0.612			
29	Length of 2nd metasomal segment (T2)	0.876					

*Bold values are positive significant (P<0.05)

Hence the results of this particular analysis provide information about the importance of the twenty-eight morphological characters recorded among all apoid wasps studied. All the selected morphological characters that contribute highly are more valuable tools for differentiating the species [10, 11]. Used morpho-biometrical characters for separation and identification of Sphecidae genera [12]. used 26 quantitative and 15 qualitative morpho-biometric characters to know total variance and also generated keys based on the characters. The study of Sphecidae species using morphometrical characters showed Dorsal surface propodeum with or without U-shaped groove, antenna and foot colour, basal veinlet/anterior veinlet, pulvilli presence or absence between nails, nail characters and presence or absence of angle between first abdominal tergite and petiole are the most valuable and representative characters for separation of Sphecidae taxa. We know morphology was for a long time the only discipline contributing the characters for systematics and phylogenetic reconstruction [13].

Conclusion

Morphometric measurement is used most often to seek

patterns of relationship at lower levels in the taxonomic hierarchy, where mosaic patterns make intuitive pattern recognition difficult, if not possible, and in which concepts of holophyly are inappropriate [14]. Therefore study of morpho-meteric characters are useful to distinguish the genera and species and they contribute significantly to apoid morphology.

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