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Multivariate Biometrical Studies on *Vespa* spp. from Himachal Pradesh

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ABSTRACT: Present research work deals with comprehensive biometrical studies conducted on hymenopteran, especially members of family vespidae viz. *Vespa auraria* collected from 10 localities, *V. tropica* from 3 localities, *V. basalis* from 4 localities, *V. orientalis, Polistes hebraeus* and *Ropalidia ferruginea* from one locality respectively sampled from different agroclimatic zones of Himachal Pradesh, situated in the lap of north west Himalayas. Different species were sampled from 14 localities having different altitude and climatic conditions. 59 morphological characters pertaining to mouthparts, antenna, forewing, hindwing, foreleg, hindleg, tergites and sternites were studied. Biometrical data was analysed statistically, using Analysis of variance (ANOVA), Duncan's Multiple Range test, t-test, correlation and Multivariate Discriminant Analysis.

Keywords: Multivariate Discriminant Analysis; Biometrical Studies; *Vespa* spp. and Himachal Pradesh.

INTRODUCTION: Wasps and hornets are social and cosmopolitan insects of great economic importance to mankind. They provide ecosystem services by cross-pollination of several cultivated and wild plant species. In this way, they help in boasting crop productivity, maintenance of biodiversity and in conservation of forest and grassland ecosystems (Crane, 1990; Martin, 1992).

Various species of wasp and hornets have locally adapted populations called ecotypes. The variations within geographical ecotypes are the result of continuous process of natural selection through centuries for a specific niche (Ruttner, 1969, 1971, 1975). The knowledge of these ecotype races is useful for the genetic improvement of wasp and hornets spp. by selection and breeding. In these breeding programmes, geneticists and breeders not only depend on the qualitative characters, but also on the quantitative characters such as different morphological characters that affect the pollination ability.

The biometrical studies based on modern multivariate morphmetrics techniques provide a reliable method in the identification of different sub-species and ecotypes of wasps and hornets. These identification methods are very helpful in the formulation of physical standards for measuring quantitative progress in the genetic improvement of a particular sub-species. The taxonomical status of wasps is still problematical, because of very less information available on its biometrical, behavioural and cytological aspects (Akre and Davis, 1978; Spradbery, 1990 and Sharma, 1996). Therefore, identification of different ecotypes/ geographic populations of *Vespa* spp. is needed. The biometrical studies based on modern multivariate morphometric technique provide a reliable method to identify different sub-species and ecotypes of wasps. These also help in the formulation of physical standards for measuring quantitatively the progress made in genetic improvement of particular sub-species.

Many investigators have studied the multivariate biometrics of *Apis* spp. throughout the world (Daly and Balling, 1978; Ruttner, 1971, 1975, 1976, 1979). Some investigators have studied the biometrics of *Vespa* spp. in Asian and Indian subcontinent (Matsuura and Sakagami, 1973; Sharma, 1996). However, practically no work has been done regarding morphometry, behavioural and foraging ecology of *Vespa* spp in Indian subcontinent. Therefore, it is very important to study the biometrics of *Vespa* spp. so as to evolve suitable methods for identification of various ecotypes/races.

MATERIALS AND METHODS: Wasp samples were collected from different parts of Himachal Pradesh having different altitudes and climatic conditions, during spring, rainy and autumn seasons of the year 1997-99. An attempt has been also made to identify the taxonomically significant biometric characters and their utility in characterizing sub-species/ecotypes of *Vespa auraria* through computer based multivariate discriminant analysis.

Collection of Wasp Samples: Samples of wasp were collected from 15 different localities of Himachal Pradesh having different altitudes, latitudes, longitudes and climatic conditions. Places of collection of golden wasp. *V. auraria* S. samples were, Chamba (1006m), Hamirpur (790m), Harar, Lad Bharol (1219), Longani, Sarkaghat (1100m), Sunder Nagar (900m) in Mandi, Ghumarwin (725m) in Bilaspur, Sainz (1300m) in Kullu, Kunihar (976m) in Solan, Sunni (620m) in Shimla, Nahan (1020m) in Sirmaur areas (Table 1), Whereas, *Vespa basalis* samples were collected from Sunder Nagar (900m), Jandhroo in Mandi (1250m), Hamirpur (790m), Krishna Nagar in Kangra (1050m), whereas, *V. tropica* samples were collected from Kunihar (976m), Sunder Nagar (900m), Chamba (1006m) and *Vespa orientalis* was collected from Daulatpur Chowk in Una (500m). Golden wasps *Polistes hebraeus* and *Ropalidia ferruginea* (Fabr) were sampled from Nalagarh in Solan (500m) and Ner Chowk in Mandi (800m) areas respectively.

Wasp samples were collected with the help of an insect net/aspirator and collections were made during the rainy and autumn seasons. Each sample consisted of fifty field wasps (workers). Wasps were anesthetised with chloroform or with a mixture of chloroform and ether in the ratio of 1:3 and killed in warm water so as to ensure the complete protrusion of proboscis. Dead wasp samples were then preserved in Pamplle's fixative of following composition (Ruttner et al., 1978; Ruttner, 1988).

Distilled water	=	100 ml
95% Alcohol	=	50 ml
Formalin	=	20 ml
Acetic acid	=	10 ml

Dissection and Mounting of Morphological Parts: Different morphological parts were dissected out and mounted in specially prepared Arabic gum medium of following composition**.**

Arabic gum	=	8 gm
Distilled water	=	8 ml
Glycerine	=	5 ml
Acetic Acid	=	3 ml
Thymol	=	1 to 2 crystals

The mountant was prepared in the laboratory by soaking 8 gm of Arabic gum in 8 ml of distilled water and kept overnight in the morning a mixture of glycerine, acetic acid and thymol were added to the above solution and mixed thoroughly in order to get a uniform mixture. The whole mixture was then heated on water bath at about 60 to 70^{o}C for about two hours. It was then filtered while hot, through the glass wool. The filterate was collected and stored as mountant.

All the morphological parts were mounted in between the two glass slides except tergites and sternites. The later were mounted on glass rods so as to retain their natural shape and for simplifying the procedure of measurement. The slides and rods thus prepared were then dried in an oven at 40 to 50°C.

Measurement of Morphological Parts: Different morphological parts were measured with the help of a stereomicroscope equipped with an ocular scale except various wing venation angles. Measurement of different parametres of wing as well as various wing venation angles was taken with the help of a slide projector (Mattu, 1982).

The following 59 morphological characters were studied:

A) Mouthparts (Fig)

1) Length of galea (GlL)
2) Breadth of galea (GlB)
3) Length of maxillary palp (MpL)
4) Length of glossa (GsL)
5) Breadth of glossa (GsB)
6) Length of paraglossa (PgL)
7) Length of labial palp (LpL)
8) Length of hypopharynx (HpL)
9) Breadth of hypopharynx (HpB)
10) Total length of glossa and hypopharynx (GHL)

B) Antenna (Fig)

11) Length of scape (SpL)
12) Length of pedicel (PdL)
13) Length of flagellum (FgL)
14) Total antennal length (AtL)

C) Forewing (Fig)

15) Length of forewing (FwL)
16) Breadth of forewingFwB)
17) Length of radial cell (RcL)
18) Breadth of radial cell (RcB)

19 to 29) Different wing venation angles (Angle 19 to 29)

D) Hindwing (Fig)

30) Length of hindwing (HwL)
31) Breadth of hindwingHwB)
32) Length of basal portion of radial vein (RBL)
33) Length of apical portion of radial vein (RaL)
34) Length of discoidal vein (DcL)
35) Length of indica vein (IdL)
36) Number of hamuli (HmN)
37) Extent of hamuli (HmE)

E) Forelegs (Fig)

38) Length of trochanter (TcL_1)
39) Length of femur (FmL_1)
40) Length of tibia (TbL_1)
41) Length of tibial spur (TsL_1)
42) Length of tarsus (TrL_1)

F) Hindlegs (Fig)

43) Length of trochanter (TcL_3)
44) Length of femur (FmL_3)
45) Length of tibia (TbL_3)
46) Length of tibial spur-I (TsL_{3a})
47) Length of tibial spur-II (TsL_{3b})
48) Length of tarsus (TrL_3)

G) Tergites

a) Third tergite

49) Width of light band (LT_3)
50) Width of dark band (DT_3)
51) Total width of tergite (WT_3)

b) Fourth tergite

52) Width of light band (LT_4)
53) Width of dark band (DT_4)
54) Total width of tergite (WT_4)

H) Sternites

a) Third sternite

55) Width of light band (LS_3)
56) Width of dark band (DS_3)
57) Total width of sternite (WS_3)

b) Sixth sternite

58) Length or depth of sternite (LS_6)
59) Width of sternite (BS_6)

However, in case of *Polistes hebraeus*, a middle light and dark band on third and fourth tergite and on third sternite were also studied.

Statistical Analysis of Data: Biometrical data on different *Vespa* spp. was analysed statistically in order to calculate mean, standard deviation, standard error about means and Coefficient of Variation (Snedcor and Cochran, 1993). In case of *V. auraria* one way analysis of variance (ANOVA) and multivariate discriminant analaysis were applied. However, in case of other *Vespa* spp., *V. tropica*, *V. basalis*, *V auraria*, *V. orientalis*, *Polistes hebraeus* and *Ropalidia ferruginea* data could not be analysed by analysis of variance due to less number of locatily studied. Hence, overall mean values of different morphological characteristic of *Vespa* spp. collected from different localities of Himachal Pradesh were compared by *Duncan's* multiple range test and T-test and differences observed in the mean values were expressed as percentage difference (P.D.).

Multivariate Discriminant Analysis of *Vespa auraria* Populations: Multivariate discriminant analysis was performed on an IBMPC- AT micro computer at computer center of Himachal Pradesh University, Shimla. For the discriminant analysis, the programme "DISCRIMINANT' from the SPSS statistical package for the Social Sciences was utilized (Norusis, 1985). For the unweighted pair-group cluster analysis, the NTSYS-PC (Rohlf, 1987) was used with arithmetic averages (UPGMA) as described by Sneath and Sokal (1973). The analysis was made with the direct options (all characters entered in the analysis) and equal prior probabilities of classification.

The statistical analysis was performed in four phases. Only selected statistical results have been reproduced here because of the large number of characters and localities. The purpose of the first phase was to make an initial discriminant analysis of the localities and to determine how the *V. auraria* wasps from 10 localities could be clustered into a smaller number of biometrically similar groups. There were different regions in which measurement of all the characters for the collections were grouped by locality and entered as 10 groups in a discriminant analysis. It was followed by the reclassification of 500 individual wasps with coefficients from the analysis to get the extent to which the analysis discriminated among the localities. Wasps were assigned to the groups for which it had the highest probability of membership. With 10 groups of equal prior probability each could be correctly classified by chance alone.

For each character at each locality, the mean value was used to compute the coordinates of the centriods with respect to canonical determinant functions. The square roots of the Euclidean distances between each pair of localities were then computed from the coordinates of centroides. The similarities of the biometerics of the wasps collected at two localities are dependent upon the distances. The smaller the distance, the more similar are the biometrics of the wasps collected at two localities. A three dimensional graphs and a hierarchic UPGMA cluster analysis was made of the Euclidean distances of the localities (Sneath and Sokal, 1973) and 2 biometric groups were recognized on this basis.

In the second phases, the discrimination among the 2 biometric groups were evaluated using all the 59 characters. All the measurements of the collections were regrouped into 2 biometric groups and entered in a discriminant analysis. It was followed by the reclassification of the individual wasps into 2 biometric groups. With 2 groups of equal prior probabilities 50% of the wasps could be correctly classified by chance only.

In third phase, evaluation of the contribution of the different character for discrimination into 2 biometric groups was carried out. This was done by following two methods. Firstly by ranking of the absolute values of the standardized discrimination function coefficients and secondly by ranking the absolute values of the correlations of the 59 characters with single discriminant function. As a result of these comparisons, a reduced number of characters was selected to provide a quick method for identification of the biometric groups.

In the fourth phase, the correlations between all the localities and altitudes were determined with the means values for each of 59 character as well as the canonical discriminant functions for the 10 localities of phase one.

RESULTS AND DISCUSSION:

Multivariate Discriminant Analysis of *Vespa auraria* Populations: Multivariate statistical analyses were made of 59 characters of golden wasp, *Vespa auraria* collected from 10 different localities of Himachal Pradesh.

i) Univariate Biometrics of Vespa auraria and Correlation with Altitudes

Mouth Parts: Analysis of variance showed significant differences (P<0.01) in various characters of mouth parts such as length of galea, maxillary palp, glossa, paraglossa, labial palp, length and breadth of hypopharynx and total length of glossa and hypopharynx in *Vespa auraria* samples collected from various localities of Himachal Pradesh (Table 1). These results are in conformity with the earlier findings of Sharma (1996) for *V. velutina* samples collected from different parts of Himachal Pradesh. But Mattu and Verma (1983) could not find any significant differences (P>0.05) in different characters of tongue in bee samples from different agroclimatic zones of Himachal Pradesh.

Coefficient of variation showed high values for all the characters of mouth parts in different *V. auraria* samples analysed (Table 1). These results are in agreement with the earlier observations of Mattu (1982), Sharma (1996) and Sharma (2000) who also observed high values of coefficient of variation for honeybees, wasps and bumblebee samples collected from different area of Himachal Pradesh.

Statistical analysis of biometrical data showed a significant (P<0.01, P<0.05) positive correlation between altitude and length and breadth of galea, whereas, a significant (P<0.01) negative correlation was observed between altitude and length and breadth of hypopharynx and total length of glossa and hypopharynx in wasp samples from different localities of Himachal Pradesh (Table 1). These observations corroborate the earlier findings of Sharma (1996) who also observed such relationship in *V. velutina* samples from different zones of northwest Himalayas. However, length of maxillary palp, length and breadth of glossa, length of paraglossa and labial palp of *V. auraria* showed no correlation with altitude (Table 1). These results are in agreement with the earlier studies of Mattu and Verma (1983), who also could not find any such relationship in bee samples from Himachal Pradesh.

Antenna: Statistical analyses of biometrical data on wasps revealed significant (P<0.01) differences in most of the parameters of antenna except the length of pedicel (Table 1). These results corroborate the earlier findings of Mattu and Verma (1983) for bee samples and Sharma (1996) for wasp samples collected from different parts of Himachal Pradesh. Such significant differences were also observed in the characters from bees from the eastern Himalayan region by Singh (1989). Recently, Sharma (2000) also reported similar significant (P<0.01) differences in different antennal characters except length of scape in bumblebees samples collected from different localities of Himachal Pradesh.

Coefficient of variation was high for scape and pedicel, but, it was low for length of flagellum and total antennal length in wasp samples collected from different parts of Himachal Pradesh (Table 1). These results are in conformity with the earlier observations of Sharma (1996) for wasps from the north western Himalayan region. Similar results were also observed by Mattu (1982) and Singh (1989) for bees from western and eastern Himalayan regions respectively.

Statistical analysis of biometrical data showed a significant (P<0.01, 0.05) positve correlation between altitude and length of flagellum and total antennal length except for length of pedicel and scape (Table

1). These results are in accordance with the earlier findings of Mattu and Verma (1983) who also found significant positive correlation between altitude and all the parameters of antenna in different honey bee samples from Himachal Pradesh. But Sharma (1996, 2000) found significant negative correlation between altitude and all morphological characters of antenna except length of pedicel in the wasp and bumblebee samples from Himachal Pradesh.

Table 1: Biometrical data on different morphological characters of *Vespa auraria* S. collected from different localities of Himachal Pradesh.

	Name of Character		**Locality**										
	Mouth Parts		1	2	3	4	5	6	7	8	9	10	F ratio
1.	Length of galea	R.V.	1.675-1.725	1.625-2.100	1.525-1.925	1.500-1.900	1.700-1.900	1.325-1.550	1.600-1.820	1.500-1.850	1.500-2.100	1.325-1.825	75.036**
		X±S.E.	1.773±0.006	1.926±0.019	1.711±0.009	1.734±0.011	1.790±0.006	1.491±0.009	1.715±0.008	1.731±0.008	1.758±0.021	1.618±0.021	
		C.V.	2.425	6.957	3.565	4.322	2.458	4.292	3.381	3.408	8.418	8.961	
2.	Breadth of galea	R.V.	0.600-0.850	0.700-0.900	0.600-0.750	0.650-0.950	0.600-0.800	0.600-0.850	0.650-0.800	0.600-0.800	0.600-0.900	0.600-0.850	14.485**
		X±S.E.	0.734±0.009	0.785±0.008	0.701±0.006	0.767±0.011	0.698±0.008	0.713±0.011	0.723±0.006	0.700±0.006	0.746±0.010	0.689±0.009	
		C.V.	8.344	6.878	5.706	10.169	8.452	10.518	5.394	6.285	9.383	8.853	
3.	Length of maxillary palp	R.V.	2.350-2.900	2.050-2.550	2.000-2.450	1.850-2.100	2.050-2.400	1.650-1.900	1.700-2.300	1.700-2.300	1.850-2.900	1.650-2.300	127.959**
		X±S.E.	2.611±0.014	2.331±0.022	2.255±0.017	1.959±0.010	2.236±0.014	1.773±0.010	2.013±0.025	2.010±0.024	2.232±0.036	1.919±0.028	
		C.V.	3.906	6.563	5.321	3.471	4.516	4.004	8.693	8.606	11.469	10.369	
4.	Length of glossa	R.V.	1.400-1.700	1.350-1.750	1.400-1.550	1.400-1.600	1.250-1.700	1.000-1.300	1.200-1.600	1.100-1.700	1.350-1.700	1.000-1.450	106.130**
		X±S.E.	1.563±0.011	1.491±0.017	1.498±0.007	1.518±0.008	1.490±0.018	1.147±0.013	1.383±0.012	1.343±0.010	1.487±0.011	1.265±0.017	
		C.V.	5.054	7.385	3.137	3.754	8.456	8.020	6.146	5.137	5.110	9.249	
5.	Breadth of glossa	R.V.	1.200-1.450	1.000-1.300	1.150-1.450	1.000-1.200	1.000-1.350	0.650-0.950	0.800-1.350	0.700-1.450	1.000-1.450	0.650-1.200	119.566**
		X±S.E.	1.272±0.009	1.178±0.012	1.307±0.010	1.126±0.009	1.138±0.010	0.780±0.013	1.033±0.019	1.015±0.025	1.215±0.017	0.868±0.021	
		C.V.	4.874	7.385	5.585	5.861	5.887	12.179	13.068	17.536	10.041	17.050	
6.	Length of paraglossa	R.V.	0.950-1.200	0.950-1.300	1.000-1.250	1.000-1.250	1.000-1.200	0.700-1.000	0.700-1.250	0.950-1.200	0.950-1.200	0.750-1.200	46.002**
		X±S.E.	1.063±0.009	1.116±0.015	1.148±0.009	1.136±0.010	1.111±0.008	0.868±0.010	1.074±0.016	1.061±0.010	1.108±0.010	0.984±0.021	
		C.V.	5.832	9.408	5.313	6.161	5.310	8.410	10.893	6.974	6.227	14.735	
7.	Length of labial palp	R.V.	1.950-2.350	2.750-3.000	2.400-3.100	2.400-2.850	2.600-3.000	2.100-2.300	2.350-2.700	2.200-2.700	1.950-3.000	2.100-2.750	146.026**
		X±S.E.	2.153±0.013	2.895±0.014	2.794±0.021	2.599±0.018	2.755±0.015	2.200±0.010	2.493±0.012	2.489±0.019	2.622±0.041	2.354±0.024	
		C.V.	4.226	3.316	5.332	4.848	3.883	3.227	3.529	5.504	11.022	7.094	
8.	Length of hypopharynx	R.V.	1.950-2.400	1.800-2.700	2.050-2.950	2.300-2.800	2.500-3.000	1.550-2.100	1.800-2.500	1.700-2.150	1.800-2.050	1.550-2.150	139.704**
		X±S.E.	2.234±0.018	2.101±0.027	2.689±0.027	2.469±0.017	2.612±0.026	1.754±0.018	2.133±0.035	2.002±0.017	2.355±0.038	1.912±0.025	
		C.V.	5.819	8.995	7.130	4.900	6.928	7.354	11.626	6.143	11.380	9.152	
9.	Breadth of hypopharynx	R.V.	1.050-1.900	1.300-1.450	1.200-1.700	1.000-1.300	1.350-1.700	1.200-1.350	1.100-1.550	1.100-1.450	1.300-1.900	1.200-1.450	84.010**
		X±S.E.	1.585±0.019	1.394±0.007	1.536±0.021	1.193±0.012	1.581±0.012	1.253±0.007	1.265±0.014	1.266±0.014	1.421±0.029	1.301±0.012	
		C.V.	8.328	3.730	9.765	7.041	5.186	4.229	8.063	7.661	14.356	6.302	
10.	Total length of glossa and hypopharynx	R.V.	3.350-4.450	3.150-4.400	3.900-4.450	3.650-4.300	3.550-4.450	2.450-3.400	3.150-4.100	2.900-3.500	3.500-4.450	2.300-3.550	174.648**
		X±S.E.	3.820±0.027	3.608±0.038	4.200±0.023	3.980±0.022	4.166±0.037	2.852±0.027	3.523±0.044	3.342±0.024	3.859±0.041	3.128±0.042	
		C.V.	5.026	7.483	3.928	3.894	6.337	6.626	8.856	5.086	7.488	9.430	
	Antenna												
11.	Length of scape	R.V.	1.550-1.850	1.550-2.200	1.600-1.900	1.650-1.900	1.750-1.900	1.500-1.550	1.500-1.900	1.750-1.900	1.500-2.250	1.500-1.950	30.972**
		X±S.E.	1.757±0.014	1.876±0.033	1.777±0.009	1.729±0.009	1.816±0.008	1.527±0.007	1.707±0.015	1.820±0.010	1.792±0.022	1.709±0.024	
		C.V.	5.691	12.260	3.714	3.817	3.083	3.405	6.092	3.791	8.872	9.771	
12.	Length of pedicel	R.V.	0.250-0.300	0.250-0.250	0.200-0.300	0.250-0.300	0.200-0.300	0.250-0.250	0.200-0.300	0.250-0.250	0.250-0.300	0.250-0.250	2.030
		X±S.E.	0.252±0.003	0.250±0.000	0.251±0.003	0.253±0.002	0.248±0.002	0.250±0.000	0.258±0.003	0.250±0.000	0.255±0.003	0.250±0.000	
		C.V.	9.523	0.000	9.561	4.743	5.645	0.000	7.364	0.000	8.235	0.000	
13.	Length of flagellum	R.V.	5.250-6.750	5.750-7.200	4.750-6.600	5.650-6.150	5.000-6.250	5.050-6.050	5.350-6.900	5.600-6.750	4.750-6.900	5.050-6.600	24.246**
		X±S.E.	6.299±0.049	6.523±0.053	6.095±0.053	6.070±0.015	5.998±0.040	5.585±0.028	6.243±0.069	6.201±0.042	6.087±0.070	5.899±0.059	
		C.V.	5.492	5.748	6.611	1.713	4.734	3.509	7.832	4.805	8.115	7.035	
14.	Total antennal length	R.V.	7.100-8.850	7.550-9.550	6.650-8.650	7.700-8.350	7.000-8.300	6.800-7.850	7.150-9.100	7.650-8.850	6.650-9.250	6.800-8.650	25.616**
		X±S.E.	8.300±0.060	8.641±0.082	8.125±0.062	8.064±0.017	8.012±0.048	7.363±0.030	8.118±0.093	8.222±0.049	8.136±0.085	7.839±0.077	
		C.V.	5.096	6.712	5.366	1.450	4.231	2.906	8.117	4.220	7.423	6.965	
	Fore Wing												
15.	Length of forewing	R.V.	15.230-18.760	14.900-20.000	17.100-18.500	16.300-18.300	15.800-18.600	12.900-15.600	15.500-19.400	16.100-19.500	15.420-19.800	13.500-19.500	38.749**
		X±S.E.	17.123±0.145	17.976±0.218	17.858±0.060	17.583±0.088	17.708±0.089	14.057±0.279	18.026±0.131	17.998±0.105	17.642±0.144	16.317±0.419	
		C.V.	5.980	8.572	2.374	3.540	3.535	14.014	5.120	4.122	5.787	18.140	
16.	Breadth of forewing	R.V.	4.100-5.100	3.950-6.200	4.000-5.250	4.350-4.900	4.400-5.400	3.650-4.250	4.200-5.200	4.150-5.100	3.950-6.000	3.650-5.150	36.425**
		X±S.E.	4.764±0.040	4.991±0.099	4.905±0.029	4.607±0.023	4.792±0.036	3.912±0.020	4.760±0.038	4.834±0.036	4.829±0.064	4.432±0.073	
		C.V.	5.919	14.065	4.179	3.494	5.369	3.553	5.672	5.295	9.380	11.642	
17.	Length of radial cell	R.V.	6.350-4.750	3.500-5.400	3.850-4.400	3.200-4.200	3.750-4.350	3.150-3.600	3.550-4.400	3.650-4.400	3.500-5.250	3.150-4.300	42.304**
		X±S.E.	4.191±0.040	4.402±0.092	4.241±0.019	4.055±0.024	4.177±.023	3.383±0.018	4.028±0.034	4.123±0.027	4.279±0.057	3.795±0.056	
		C.V.	6.680	14.766	3.230	4.148	3.878	3.665	5.958	4.535	9.441	10.355	
18.	Breadth of radial cell	R.V.	0.900-1.050	0.850-1.250	0.950-1.050	0.9001.000	0.950-1.050	0.800-0.900	0.900-1.050.	0.900-1.150	0.850-1.250	0.800-1.150	27.963**
		X±S.E.	0.984±0.007	1.013±0.019	0.989±0.005	0.956±0.006	0.999±0.006	0.848±0.002	1.006±0.006	0.992±0.007	0.992±0.012	0.928±0.012	
		C.V.	4.776	13.524	3.437	4.184	4.004	1.179	4.075	5.241	8.568	9.159	
19.	Angle 19	R.V.	63.000-71.000	58.000-72.000	60.000-70.000	58.000-72.000	60.000-75.000	58.000-78.000	59.000-73.000	61.000-71.000	58.000-72.000	61.000-74.000	2.881*
		X±S.E.	66.880±0.345	65.420±0.542	65.300±0.392	67.320±0.466	67.240±0.579	66.640±0.588	66.460±0.495	65.900±0.423	65.000±0.480	66.240±0.438	
		C.V.	3.645	5.860	4.254	4.898	6.088	6.240	5.266	4.538	5.220	4.670	
20.	Angle 20	R.V.	67.000-78.000	62.000-80.000	59.000-80.000	61.000-77.000	66.000-82.000	62.000-76.000	67.000-79.000	67.000-82.000	69.000-80.000	65.000-82.000	5.595**
		X±S.E.	72.500±0.384	71.860±0.636	73.100±0.623	70.540±0.627	73.500±0.538	69.940±0.528	72.480±0.472	73.880±0.543	73.180±0.406	71.780±0.562	
		C.V.	3.740	6.255	6.024	6.282	5.099	5.337	4.608	5.193	3.920	5.532	
21.	Angle 21	R.V.	110.000-127.000	119.000-130.000	120.000-130.000	117.000-126.000	120.000-130.000	114.000-126.000	122.000-128.000	118.000-126.000	117.000-130.000	117.000-126.000	10.997**
		X±S.E.	123.460±0.582				124.540±0.327						

		C.V.	3.334	124.920±0.358 2.025	123.880±0.324 1.849	122.560±0.408 2.355	1.858	121.680±0.468 2.720	125.140±0.241 1.360	121.820±0.364 2.115	123.600±0.441 2.521	121.760±0.372 2.160	
22.	Angle 22	R.V.	17.000-22.000	17.000-25.000	17.000-24.000	17.000-23.000	17.000-24.000	15.000-21.000	16.000-22.000	17.000-24.000	17.000-23.000	15.000-24.000	3.470*
		X±S.E.	19.340±0.247	19.860±0.284	20.360±0.266	19.760±0.217	20.740±0.247	19.160±0.256	19.740±0.210	20.260±0.237	20.140±0.257	19.960±0.300	
		C.V.	9.022	10.120	9.243	7.758	8.423	9.451	7.507	8.272	9.026	10.616	
23.	Angle 23	R.V.	100.000-112.000	99.000-117.000	9.000-114.000	7.000-114.000	101.000-117.000	102.000-118.000	101.000-114.000	100.000-112.000	9.000-116.000	2.000-116.000	4.095*
		X±S.E.	106.640±0.469	106.340±0.880	105.200±0.665	106.220±0.498	106.120±0.582	109.040±0.541	106.144±0.595	104.080±0.651	107.320±0.704	106.360±0.660	
		C.V.	3.111	5.854	4.470	3.317	3.876	3.505	3.965	4.425	4.635	4.401	
24.	Angle 24	R.V.	78.000-104.000	82.000-96.000	1.000-105.000	3.000-104.000	87.000-100.000	3.000-105.000	2.000-102.000	1.000-109.000	8.000-104.000	1.000-109.000	4.164*
		X±S.E.	92.380±0.799	89.040±0.611	92.700±0.907	91.980±0.662	92.480±0.464	91.840±0.944	95.140±0.886	90.360±0.836	91.440±0.822	90.720±0.899	
		C.V.	6.114	4.855	6.920	5.092	3.544	7.266	6.582	6.540	6.358	7.003	
25.	Angle 25	R.V.	92.000-108.000	94.000-106.000	5.000-108.000	7.000-109.000	92.000-109.000	4.000-107.000	8.000-106.000	4.000-111.000	4.000-108.000	4.000-108.000	6.906**
		X±S.E.	99.080±0.549	100.480±0.610	100.940±0.577	103.320±0.424	99.060±0.532	99.820±0.564	101.860±0.777	103.320±0.563	100.880±0.614	101.460±0.524	
		C.V.	3.836	4.294	4.044	2.903	3.795	3.995	5.391	3.854	4.303	3.650	
26.	Angle 26	R.V.	47.000-68.000	52.000-69.000	51.000-62.000	51.000-65.000	50.000-61.000	49.000-68.000	57.000-65.000	49.000-94.000	52.000-62.000	49.000-72.000	12.028**
		X±S.E.	57.460±0.689	59.900±0.573	57.380±0.445	57.480±0.473	57.220±0.511	62.860±0.641	59.920±0.366	56.180±0.501	57.360±0.384	59.060±0.903	
		C.V.	8.395	6.767	5.487	5.821	6.319	7.216	4.315	6.308	4.735	10.814	
27.	Angle 27	R.V.	10.000-15.000	11.000-15.000	10.000-15.000	12.000-17.000	11.000-20.000	10.000-18.000	13.000-17.000	10.000-16.000	10.000-17.000	9.000-18.000	7.913**
		X±S.E.	12.960±0.189	13.160±0.177	13.160±0.195	13.860±0.171	13.840±0.259	14.720±0.232	14.460±0.177	13.060±0.206	13.020±0.226	13.400±0.304	
		C.V.	10.339	9.506	10.455	8.744	13.244	11.154	8.637	14.464	12.265	16.029	
28.	Angle 28	R.V.	107.000-126.000	112.000-136.000	110.000-126.000	110.000-123.000	112.000-124.000	110.000-131.000	115.000-124.000	115.000-126.000	110.000-126.000	111.000-131.000	6.078**
		X±S.E.	115.220±0.662	120.340±0.698	117.140±0.696	117.120±0.580	118.980±0.405	118.480±0.780	118.580±0.492	119.340±0.542	116.660±0.600	119.320±0.709	
		C.V.	4.064	4.100	4.203	3.504	2.404	4.658	2.936	3.252	3.639	4.200	
29.	Angle 29	R.V.	25.000-45.000	25.000-43.000	25.000-51.000	27.000-50.000	24.000-46.000	28.000-43.000	29.000-47.000	28.000-55.000	27.000-51.000	28.000-52.000	10.328**
		X±S.E.	33.480±0.758	32.980±0.824	36.640±0.786	36.980±0.913	35.080±0.667	34.920±0.609	36.860±0.674	41.960±0.872	34.600±0.907	37.520±0.905	
		C.V.	16.003	17.665	15.169	17.460	13.443	12.339	12.924	14.699	18.537	17.054	
	Hind Wing												
30.	Length of hindwing	R.V.	9.550-11.400	10.100-13.000	10.700-12.200	10.150-11.400	10.000-12.300	8.350-9.700	9.900-11.950	10.400-12.200	9.750-13.000	8.450-12.100	72.025**
		X±S.E.	10.736±0.062	11.225±0.097	11.686±0.067	10.838±0.048	11.245±0.069	8.957±0.050	10.842±0.088	11.433±0.055	11.227±0.100	10.405±0.182	
		C.V.	4.098	6.111	4.039	3.164	4.339	3.929	5.727	3.393	6.324	12.378	
31.	Breadth of hindwing	R.V.	1.750-2.350	1.800-2.600	2.000-2.350	1.900-2.200	1.800-2.350	1.500-1.800	2.000-2.400	1.800-2.350	1.900-2.550	1.550-2.350	51.192**
		X±S.E.	2.031±0.021	2.166±0.042	2.272±0.024	2.029±0.010	2.221±0.024	1.671±0.012	2.256±0.017	2.156±0.019	2.139±0.023	1.963±0.038	
		C.V.	7.188	13.619	7.438	3.647	7.564	5.086	5.274	6.168	7.667	13.805	
32.	Length of basal portion of radial vein	R.V.	2.500-3.400	2.750-4.400	2.850-3.350	2.900-3.150	2.950-3.500	2.300-2.700	2.600-3.350	2.850-3.450	2.850-3.650	2.300-3.450	53.643**
		X±S.E.	3.070±0.033	3.482±0.063	3.140±0.019	3.101±0.018	3.204±0.018	2.498±0.016	3.144±0.025	3.249±0.022	3.129±0.033	2.916±0.059	
		C.V.	7.557	12.808	4.331	4.095	4.057	4.643	5.566	4.863	7.382	14.300	
33.	Length of apical portion of radial vein	R.V.	0.950-1.250	1.000-1.500	1.000-1.400	0.950-1.150	1.000-1.250	0.950-1.050	1.000-1.250	0.850-1.250	0.950-1.300	0.950-1.250	15.630**
		X±S.E.	1.091±0.012	1.184±0.018	1.168±0.015	1.052±0.009	1.117±0.013	1.008±0.005	1.120±0.009	1.097±0.015	1.136±0.019	1.068±0.013	
		C.V.	7.699	10.472	8.989	6.083	8.325	3.768	5.892	9.845	11.883	8.520	
34.	Length of discoidal vein	R.V.	1.850-2.400	2.200-2.800	1.950-2.400	1.900-2.200	1.900-2.450	1.600-1.850	1.800-2.450	1.850-2.550	1.950-2.350	1.600-2.450	53.122**
		X±S.E.	2.132±0.020	2.327±0.036	2.233±0.013	2.039±0.010	2.193±0.017	1.762±0.010	2.268±0.018	2.215±0.021	2.181±0.015	2.026±0.039	
		C.V.	6.754	11.087	4.228	3.433	5.471	3.916	5.643	6.591	4.768	13.672	
35.	Length of indica vein	R.V.	0.900-1.200	1.000-1.400	1.100-1.350	0.950-1.150	0.950-1.250	0.900-1.050	1.000-1.250	0.950-1.300	0.950-1.400	0.900-1.250	24.973**
		X±S.E.	1.094±0.014	1.151±0.015	1.208±0.010	1.061±0.010	1.132±0.013	0.961±0.005	1.130±0.010	1.112±0.013	1.117±0.017	1.049±0.013	
		C.V.	8.775	9.296	6.043	6.597	8.127	3.642	6.283	8.183	10.832	8.960	
36.	Number of hamuli	R.V.	24.000-40.000	30.000-61.000	25.000-32.000	27.000-38.000	22.000-32.000	19.000-29.000	25.000-33.000	26.000-36.000	29.000-40.000	26.000-35.000	95.807**
		X±S.E.	30.340±0.587	43.840±0.990	28.060±0.213	33.180±0.409	26.840±0.337	26.380±0.354	29.240±0.341	30.500±0.346	32.280±0.660	27.780±0.498	
		C.V.	13.688	15.967	5.359	8.710	8.885	9.499	8.248	8.009	14.464	12.663	
37.	Extent of hamuli	R.V.	1.250-1.800	1.400-2.150	1.400-1.750	1.350-1.700	1.350-1.850	1.100-1.350	1.140-1.750	1.350-1.800	1.350-2.150	1.100-1.800	47.160**
		X±S.E.	1.516±0.018	1.763±0.030	1.574±0.012	1.512±0.013	1.587±0.016	1.235±0.009	1.583±0.017	1.643±0.015	1.573±0.021	1.463±0.034	
		C.V.	8.311	12.081	5.273	6.084	6.931	5.101	7.454	6.390	9.408	16.267	
	Fore Leg												
38.	Length of trochanter	R.V.	0.950-1.050	1.000-1.100	0.950-1.100	1.050-1.100	1.100-1.250	1.000-1.100	1.000-1.100	1.000-1.200	0.900-1.100	1.000-1.200	44.259**
		X±S.E.	1.004±0.006	1.054±0.014	1.012±0.009	1.080±0.004	1.179±0.002	1.050±0.005	1.032±0.004	1.062±0.007	1.036±0.007	1.068±0.006	
		C.V.	3.884	9.487	6.027	2.500	4.240	3.047	2.713	4.613	5.019	3.745	
39.	Length of femur	R.V.	3.500-4.100	3.500-4.500	3.650-4.250	3.650-4.450	3.650-4.350	3.300-3.650	3.550-4.250	3.650-4.300	3.500-4.300	3.350-4.300	26.190**
		X±S.E.	3.879±0.026	4.134±0.067	4.024±0.024	3.995±0.028	4.112±0.022	3.492±0.011	3.927±0.030	4.054±0.029	3.901±0.034	3.900±0.051	
		C.V.	4.743	11.441	4.249	5.006	3.696	2.262	5.398	5.056	6.254	9.230	
40.	Length of tibia	R.V.	2.700-3.250	2.950-4.100	2.850-3.600	3.050-3.650	2.850-3.750	2.650-2.900	2.750-3.700	2.900-3.500	2.800-4.000	2.700-3.200	38.072**
		X±S.E.	3.069±0.022	3.504±0.050	3.185±0.020	3.229±0.017	3.288±.026	2.785±0.011	3.312±0.037	3.252±0.023	3.203±0.035	3.089±0.040	
		C.V.	4.952	10.159	4.427	3.716	5.656	2.692	7.850	5.043	7.805	9.226	
41.	Length of tibial spur	R.V.	0.900-1.200	0.900-1.450	0.850-1.100	0.950-1.250	0.950-1.300	1.000-1.100	1.100-1.250	0.950-1.300	0.900-1.200	1.000-1.300	24.210**
		X±S.E.	1.101±0.011	1.190±0.016	1.031±0.013	1.118±0.011	1.167±0.011	1.045±0.004	1.147±0.009	1.186±0.010	1.059±0.015	1.131±0.013	
		C.V.	6.811	9.495	8.632	7.245	6.940	2.966	5.666	6.078	9.726	7.957	
42.	Length of tarsus	R.V.	3.600-4.200	3.500-5.000	3.600-4.350	3.750-4.400	3.550-4.250	3.400-3.750	3.700-4.600	3.700-4.750	3.550-4.450	3.400-4.300	35.401**
		X±S.E.	3.921±0.020	4.214±0.068	3.747±0.024	4.106±0.026	4.025±0.026	3.531±0.009	4.174±0.027	4.115±0.032	3.909±0.038	3.901±0.048	
		C.V.	3.647	11.366	4.456	4.456	4.521	1.869	4.575	5.492	6.804	8.741	
	Hind Leg												
43.	Length of trochanter	R.V.	1.450-1.550	1.450-2.000	1.300-1.600	1.300-1.550	1.450-1.650	1.100-1.250	1.450-1.550	1.500-1.600	1.300-1.750	1.100-1.600	71.561**
		X±S.E.	1.508±0.005	1.627±0.024	1.501±0.008	1.510±0.008	1.523±0.007	1.209±0.006	1.505±0.006	1.544±0.005	1.520±0.016	1.390±0.025	
		C.V.	2.387	10.510	3.930	3.642	3.080	3.391	2.591	2.137	7.302	12.877	
44.	Length of femur	R.V.	4.050-4.950	3.900-5.550	4.350-5.000	4.250-4.750	4.300-5.050	3.700-4.500	4.250-5.100	3.950-5.000	4.050-5.400	3.700-5.000	56.250**
		X±S.E.	4.558±0.032	4.649±0.058	4.778±0.022	4.536±0.002	4.770±0.021	3.853±0.018	4.708±0.039	4.810±0.026	4.655±0.044	4.333±0.066	
		C.V.	5.002	8.883	3.223	3.483	3.060	3.218	5.904	3.866	6.702	10.777	
45.	Length of tibia	R.V.	4.350-4.600	4.200-6.100	4.550-5.450	4.600-4.950	4.700-5.700	3.800-4.450	4.500-5.900	4.400-5.450	4.350-6.000	3.850-5.050	45.083**
		X±S.E.	4.958±0.043	4.941±0.070	5.024±0.025	4.791±0.015	4.872±0.032	4.109±0.020	5.051±0.044	5.108±0.026	4.945±0.050	4.629±0.069	
		C.V.	6.091	9.977	3.582	2.233	4.659	3.407	6.157	3.582	7.219	10.563	
46.	Length of	R.V.	1.600-2.150	1.700-2.450	1.750-2.300	3.700-4.200	1.700-2.150	1.500-1.750	1.700-2.250	1.700-2.150	1.750-2.450	1.500-2.150	

	tibial spur-I	X±S.E. C.V.	1.910±0.020 7.225	2.003±0.030 10.683	1.955±0.019 6.854	3.995±0.019 3.429	1.886±0.012 4.665	1.598±0.008 3.692	2.061±0.025 8.588	2.043±0.011 3.964	2.529±0.123 34.361	1.826±0.033 12.705	240.600**
47.	Length of tibial spur-II	R.V. X±S.E. C.V.	1.100-1.350 1.224±0.011 6.617	1.050-1.800 1.370±0.027 13.722	1.100-1.450 1.288±0.015 7.996	1.000-1.500 1.241±0.019 10.797	1.200-1.450 1.261±0.009 4.837	1.000-1.100 1.061±0.005 3.204	1.100-1.550 1.325±0.018 9.509	1.200-1.400 1.274±0.007 4.003	1.050-1.450 1.290±0.018 10.000	1.000-1.400 1.197±0.019 11.361	27.046**
48.	Length of tarsus	R.V. X±S.E. C.V.	7.300-8.750 8.144±0.049 4.248	7.700-9.400 9.018±0.044 3.481	7.250-8.800 8.115±0.048 4.140	1.600-8.350 8.034±0.025 2.178	7.500-8.750 8.174±0.033 2.826	6.300-7.100 6.623±0.029 3.095	7.000-8.900 8.084±0.076 6.630	7.300-8.800 8.471±0.033 2.774	7.300-9.100 8.347±0.070 5.931	6.350-8.750 7.635±0.128 11.879	102.308**
	Third Tergite												
49.	Width of light band	R.V. X±S.E. C.V.	0.700-1.850 1.130±0.035 21.858	0.750-2.150 1.255±0.050 28.286	0.850-1.800 1.126±0.031 17.927	1.200-1.800 1.581±0.024 11.638	0.850-1.600 1.346±0.029 15.304	0.800-1.100 0.966±0.013 9.627	1.500-3.400 1.422±0.029 14.486	0.800-1.350 1.127±0.019 11.978	0.750-1.350 1.327±0.049 25.923	0.750-1.350 1.050±0.022 14.857	32.362**
50.	Width of dark band	R.V. X±S.E. C.V.	1.650-2.850 2.233±0.039 12.360	1.400-3.000 2.267±0.081 25.276	1.800-2.750 5.390±0.029 3.821	1.500-2.000 1.754±0.024 9.578	1.900-2.500 2.172±0.030 9.622	1.100-1.850 1.574±0.028 12.515	0.850-2.000 1.978±0.061 21.638	2.000-2.500 2.247±0.030 9.345	1.500-3.000 2.241±0.071 22.489	1.100-2.500 1.954±0.066 24.053	26.670**
51.	Total width of tergite	R.V. X±S.E. C.V.	2.850-3.700 3.325±0.032 6.706	2.950-4.200 3.530±0.062 12.379	3.200-4.000 3.588±0.031 6.127	2.750-3.600 3.277±0.028 11.231	3.000-3.850 3.515±0.025 5.007	2.050-2.900 2.532±0.028 7.938	3.000-3.500 3.296±.024 5.248	3.000-3.850 3.413±0.037 7.647	2.750-4.200 3.548±0.050 10.005	2.050-3.950 3.062±0.086 19.790	50.743**
	Fourth Tergite												
52.	Width of light band	R.V. X±S.E. C.V.	0.700-1.900 1.371±0.049 25.091	1.100-2.300 1.579±0.042 18.682	1.400-2.000 1.662±0.023 9.747	1.100-1.800 1.533±0.021 9.719	1.300-1.750 1.591±0.016 7.120	0.900-1.700 1.182±0.024 14.297	1.300-1.950 1.633±0.025 11.022	1.250-1.850 1.551±0.034 15.409	0.700-1.900 1.486±0.046 21.938	0.900-1.700 1.390±0.046 23.165	17.954**
53.	Width of dark band	R.V. X±S.E. C.V.	1.200-2.050 1.658±0.027 11.338	1.200-2.500 1.684±0.045 18.883	1.400-1.850 1.622±0.017 7.400	1.200-1.500 1.335±0.014 7.265	1.300-1.900 1.595±0.020 8.777	1.100-1.500 1.260±0.008 4.365	1.200-1.800 1.383±0.025 12.725	0.900-2.000 1.700±0.024 10.058	1.200-2.050 1.494±0.032 15.127	1.100-2.000 1.496±0.041 19.251	31.770**
54.	Total width of tergite	R.V. X±S.E. C.V.	2.200-3.500 3.050±0.041 9.606	2.550-4.000 3.229±0.063 13.905	3.000-3.550 3.284±0.023 4.933	2.400-3.150 2.838±0.027 6.730	2.350-3.500 3.078±0.040 9.226	2.150-3.000 2.439±0.026 7.421	2.750-3.250 3.028±0.021 4.986	2.200-3.550 3.213±0.031 6.784	2.200-3.500 2.983±0.049 11.632	2.150-3.450 2.847±0.065 16.051	35.582**
	Third Sternite												
55.	Width of light band	R.V. X±S.E. C.V.	1.250-1.700 1.518±0.024 11.198	1.000-1.950 1.361±0.028 14.621	1.200-1.650 1.484±0.014 6.805	1.150-1.750 1.487±0.920 9.482	1.200-1.650 1.413±0.016 8.067	1.000-1.300 1.126±0.011 7.193	1.250-1.900 1.532±0.025 11.684	1.250-1.850 1.440±0.023 11.319	1.060-1.650 1.463±0.020 9.432	1.000-1.850 1.318±0.029 15.781	30.919**
56.	Width of dark band	R.V. X±S.E. C.V.	0.750-1.100 0.903±0.014 10.631	0.750-1.250 0.930±0.019 14.193	0.700-1.100 0.913±0.014 10.514	0.750-1.000 0.848±0.012 9.669	0.8501.100 0.951±0.009 6.834	0.600-0.850 0.726±0.010 9.504	0.550-1.300 0.762±0.014 12.860	0.850-1.150 0.988±0.011 7.995	0.750-1.200 0.900±0.018 14.111	0.550-1.150 0.878±0.024 19.134	30.686**
57.	Total width of sternite	R.V. X±S.E. C.V.	2.250-3.000 2.424±0.022 6.518	1.850-2.950 2.317±0.040 12.257	2.200-2.550 2.405±0.011 3.326	2.100-2.550 2.329±0.018 5.538	2.150-2.550 2.360±0.016 4.915	1.650-2.050 1.851±0.016 6.266	2.050-2.500 2.301±0.022 6.692	2.250-2.850 2.430±0.025 7.325	2.050-2.950 2.412±0.029 8.374	1.700-2.850 2.201±0.048 15.265	41.438**
	Sixth Sternite												
58.	Length or depth of stenite	R.V. X±S.E. C.V.	2.250-2.600 2.479±0.027 7.745	2.200-3.050 2.697±0.041 10.715	2.400-2.900 2.631±0.015 4.028	2.800-3.250 3.070±0.016 3.583	2.400-2.700 2.592±0.013 3.433	2.100-2.250 2.186±0.006 1.967	2.400-2.750 2.594±0.019 5.088	2.300-2.800 2.649±0.017 4.530	2.450-3.600 2.813±0.039 9.811	2.100-2.800 2.426±0.033 9.727	86.352**
59.	Width of sternite	R.V. X±S.E. C.V.	3.100-4.100 3.668±0.037 7.115	3.000-4.250 3.538±0.064 12.719	3.100-3.850 3.378±0.027 5.654	5.100-5.700 5.470±0.024 3.144	3.050-3.800 3.273±0.036 7.852	2.750-3.250 2.875±0.020 4.869	3.400-4.100 3.756±0.037 7.002	2.800-3.500 3.295±0.063 13.414	3.100-5.500 3.620±0.037 7.154	2.250-3.350 3.007±0.038 8.846	313.457**

R. V. = *Range of variation.*
X±S.E. = *Mean ± Standard error about mean.*
C.V. = *Coefficient of Variation.*
* = *Significant, P<0.05.*
** = *Highly significant P<0.01*
All the mean values are in mm. except wing venation angles which are in degrees.

Forewing: Analysis of Variance showed significant differences (P<0.01) in length and breadth of forewing, length and breadth of radial cell and all wing venation angles in different wasp samples collected from Himachal Pradesh (Table 1). Similar findings were also reported by Sharma (1996) in *V. velutina* samples from Himachal Pradesh. These results also corroborate the earlier findings of Mattu and Verma (1984a) and Singh (1989), who also found significant differences in length and breadth of forewings and all the wing venation angles in bee samples colleced from the western and eastern Himalayan regions respectively. Sharma (2000) also found similar results for *Bombus tunicatus* samples from Himachal Pradesh.

Coefficient of variation was low for length of forewing, breadth of radial cell and most of the wing venation angles except 19, 20, 22, 24, 26, 27 and 29 (Table 1). These results support the earlier findings of Mattu (1982) and Singh (1989) for bee samples from western and eastern Himalayan regions.

Correlation data showed a significant (P<0.01) negative correlation between altitude and angle 19, whereas, it was positively correlated (P<0.05) with wing venation angle 26 (Table 1). However, Mattu and Verma (1984 a) reported a significant positive correlation between altitude and most of the wing venation angles in bee samples from different parts of Himachal Pradesh. But Sharma (1996) reported significant negative correlation between altitude and length of forewing, radial cell and angle 20, whereas, it was positively correlated with breadth of radial cell and other wing venation angles in wasps collected from Himachal Pradesh.

Hindwing: Statistical analysis of biometrical data revealed significant (P<0.01) differences in all the characters of hindwings of *V. auraria* samples collected from different parts of Himachal Pradesh (Table 1). These results corroborate the earlier findings of Sharma (1996), who also found significant differences in various *V. velutina* samples collected from different parts of Himachal Pradesh. Similar variations have also been reported earlier in honeybee and bumblebee samples collected from different parts of Himachal Pradesh (Mattu and Verma, 1984a; Sharma, 2000).

Coefficient of variation was high for all the characters of hindwing (Table 1). These findings are in agreement with the earlier findings of Sharma (1996, 2000), who also reported high values of coefficient of variation for hindwings except its length in wasp and bumblebees collected from Himachal Pradesh. But, Mattu (1982) and Singh (1989) have reported low values of coefficient of variations for hindwing characters of honeybees from western and eastern Himalayan regions.

In present investigations, altitude showed a significant positive correlation with number of hamuli (Table 1). However, Sharma (1996) reported a significant (P<0.01) negative correlation between altitude and length of basal and apical portion of radial vein and length of discoidal vein, but a significant (P<0.05) positive correlation was stablished between altitude and length and breadth of hindwing in *V. velutina* samples from North West Himalayas.

Foreleg: Statistical analyses of biometrical data revealed significant differences (P<0.01) in all the parameters of foreleg in *V. auraria* samples collected from different parts of Himachal Pradesh (Table 1). Similar variations were also observed in foreleg characters by Sharma (1996, 2000) in wasps and bumblebee samples collected from different parts of the north west Himalayan region.

Statistical analyses revealed high values of coefficient of variation for all the morphological characters of foreleg, thus indicating heterogeneity in wasp populations.

Altitude showed a significant positive correlation (P<0.05) with length of tibia and tarsus but it was negatively correlated (P<0.01) with length of trochanter in wasp populations from different agroclimatic zones of Himachal Pradesh (Table 1). But, Sharma (1996) showed a significant negative (P<0.01) correlation between altitude and foreleg charcters in *V. velutina* from Himachal Pradesh.

Hindleg: Analyses of variance revealed significant differences (P<0.01) in all characters of hindleg of *Vespa auraria* samples (Table 1). These results are in conformity with the earlier findings of Sharma (1996) for wasp populations; Mattu and Verma (1984a) for honeybees and Sharma (2000) for bumblebees populations from different regions of Himachal Pradesh.

All the biometric characters of hindleg showed high values of coefficient of variation in *V. auraria* populations of Himachal Pradesh (Table 1). Similar results were also reported by earlier authers for wasps (Sharma, 1996) and bumble bee (Sharma, 2000) populations from Himachal Pradesh.

Correlation analyses showed a significant (P<0.05) negative correlation between altitude and length of trochanter and tibia in wasp populations from different parts of Himachal Pradesh (Table 1). These results do not agree with the earlier observations of some of the investigators who established a significant positve correlation between altitude and different hindleg characters for wasps (Sharma, 1996), honey bees (Singh, 1989) and bumble bees (Sharma, 2000).

Tergites: Statistical analysis of biometrical data showed significant differences in all the characters of third and fourth tergites in wasp samples from Himachal pradesh (Table 1). Similar results were also reported by Sharma (1996) for *Vespa* sp.; Mattu and Verma (1984b) and Singh 1989 for honeybees and Sharma (2000) for bumblebee samples from different zones of the Himalayan region.

Present results showed high values of coefficient of variation for third and fourth tergites in wasp samples collected from different localities of Himachal Pradesh. These results corroborate the earlier observations of Mattu (1982) and Singh (1989) for bee samples from western and eastern Himalayan region respectively and Sharma (1996) for wasp samples from Himachal Pradesh.

Altitude showed a significant negative correlation (P<0.01) with width of light band as well as dark band of third tergite and width of dark band of fourth tergite. Sharma (1996) also found a significant negative correlation between altitude and different characters of third and fourth tergites in *Vespa velutina* samples collected from different parts of Himachal Pradesh. However, Mattu and Verma (1984b) and Sharma (2000) established a positive correlation between altitude and tergite characters of honeybees and bumblebees sample from Himalayan region.

Sternites: Biometrical data showed significant variations (P<0.01) in all the characters of sternites in *V. auraria* samples collected from different parts of Himachal Pradesh. Similar variations were also observed in *Vespa velutina* (Sharma, 1996); *Apis cerana* (Mattu and Verma, 1984b, Singh, 1989) and *Bombus tunicatus* Sharma (2000) samples collected from different zones of Himalayan region.

Coefficient of variation was high for all characters of third and sixth sternites of *Vespa auraria* (Table 1). Some of the earlier investigators have also reported high values of coefficient of variation for *Vespa velutina, Apis cerana* and *Bombus tunicatus* samples from different region of Himachal Pradesh (Sharma, 1996; Mattu and Verma, 1984b, Singh, 1989 and Sharma, 2000).

Altitude showed a significant negative correlation (P<0.01) with width of dark band and total width of third sternite, however, a significant (P<0.01) positive correlation was established between altitude and width of sixth sternite (Table 1). However, Sharma (1996) reported a significant positive correlation (P<0.01) between altitude and width of dark band as well as total width of third sternite for wasp samples collected from different regions of north west Himalayas. Recently, Sharma (2000) also reported a significant negative correlation between altitude and width of sixth sternite in *Bombus tunicatus* samples from Himachal Pradesh.

Univariate biometrics and correlation analyses of biometrical data on golden wasp, *Vespa auraria* sampled from different agroclimatic zones of Himachal Pradesh. That most of morphological characters pertaining to length of maxillary palp, glossa, paraglossa, hypopharynx and total length of glossa and hypopharynx and breadth of glossa and hypopharynx of mouth parts, length of scape and pedicel of antenna, length and breadth of forewing and hindwing, length of trochanter and femur of foreleg and hindleg etc. showed a negative relationship with the altitudinal gradient. These results are in confirmily with Allen's Rule that protruding body parts are relatively shorter in the colder then warmer climates.

***ii) Geographic Populations/Ecotypes of V. auraria S. Multivariate discriminant function analysis*:** (DFA) clustered all 10 wasp samples into 2 biometric groups. The 2 samples from northeast of Himachal Pradesh formed one biometric group arbitrarly named NEHP and 8 samples from southwest Himachal Pradesh formed the second group arbitrarily named as SWHP. NEHP is separated from SWHP primarily on discriminant canonical function 1. But the morphometric gap between the groups was quite distinct. Samples from localities along the boundary between the groups did not appear to form a transitional cline. For example, wasps from locality 3 taken at a lower elevation in Himachal Pradesh did not cluster with wasps from locality 7 also at lower elevations. Similarly, wasps from locality 7 located at higher elevation did not cluster with wasps from locality 8, also at a high elevation.

Although no striking physiographic feature separates the regions of these biometric groups yet a major climatic boundary does found a barrier. Analyses of future collection along this climatic boundary will be necessary to discover where the transition from one biometric type to other occurs or if the two groups coexist symparically. In the latter case, an appropriate taxonomic action would be in order.

The two biometric groups were distinguished by significant differences in 46 of the 59 characters. Wasps of NEHP group were larger, on the average than those of SWHP in most of length and breadth measurements, exceptions were character 11 (length of scape), 12 (length of pedicel), 16 (breadth of forewing), 20 (angle 20), 22 (angle 22), 24 (angle 24), 26 (angle 26), 27 (angle 27), 29 (angle 29), 30 (length of hindwing), 31 (breadth of hindwing), 33 (length of apical portion of radial vein), 35 (length of indica vein), 37 (extent of hamuli), 38 (length of trochanter), 41 (length of tibal spur of foreleg), 43 (length of trochanter of hindwing), 50 (width of dark band of third tergite), 52 (width of light band of fourth tergite), 53 (width of dark band of fourth tergite), 55 (width of light band) and 56 (width of dark band of third sternite), in which *V. auraria* of NEHP group are smaller. Wasp of NEHP group also had larger depth of sixth sternite and width of sixth sternite. However, characters of tongue are complex. Breadth of galea and breadth of hypopharynx were not different between the groups, length of galea, length palp and total length of glossa and hypopharynx were larger in NEHP group.

iii) Taxonomically Significant Morphometric Characters: Univariate and multivariate discriminant analysis of 59 characters of *V. auraria* wasps collected from Himachal Pradesh revealed that following 3 characters could be used as the important discriminators for distinguishing different biometric groups of wasps (Table 1). These pertain to hind wing (number of hamuli) and sternites (length and width of sixth sternite). Singh (1989) has identified 12 morphological characters, i.e. forewing (length of radial cell and apical portion of radial cell), hindwing (length of hindwing and jugal to be) and abdomen (width of light and dark bands of third and fourth tergites, total width of third and fourth tergites, length of wax mirror, depth of sixth sternite) as the important discriminators for classifying bees from Himalayan region, whereas, Verma et al. (1994) found only 2 morphological characters viz. length of hindwing and length of wax mirror on third sternite as important discriminators for classifying bees from western Himalayan region. Singh (1989), Sharma (1995) found 16 characters helpful in discriminating biometric groups of bees from the Hindu Kush Himalayas, These results also corroborate the finding of Sharma (1996) for *V. velutina*, who found 3 characters pertain to hindwing (length of hindwing) and sternites (length and width of sixth sternite). Sharma (2000) found 3 characters viz. extent of hamuli of hindwing and length of dark band of third and fourth tergites useful for discriminating biometric groups of bumble bees samples from Himachal Pradesh.

2. Biometric Comparison of *Vespa* spp.: Comparative biometrical studies showed all morphological except, length of scape; wing venation anlge 19, 24, 25, 26; tibial spur – II, width of light band of third and fourth the tergite and length or depth of sixthe sternite were significantly greater in *V. tropica* and *V. auraria* than *V. auraria*, *V. basalis* and *V. orientalis*. But a few characters like length of paraglossa, length of labial palp, total length of glossa and hypopharynx; wing venation angle 19, 24, 26, 27, 28; length and breadth of hindwing; length of basal portion of radial vein, length of discoidal vein, extent of hamuli of hindwing; length of trochanter, length of femur, length of tarsus of foreleg; length of tibal spur – II of hindleg, etc., were significantly higher in *V. basalis* and *V. orientalis* than *V. auraria*. These results corroborate the earlier findings of Sharma (1996) for different *Vespa* sp. collected from Himachal Pradesh.

CONCLUSION: In this work of comprehensive biometrical studies on hymenopteran, especially members of family vespidae viz. *Vespa auraria* collected from 10 localities, *V. tropica* from 3 localities, *V. basalis* from 4 localities, *V. orientalis, Polistes hebraeus* and *Ropalidia ferruginea* from one locality respectively sampled from different agroclimatic zones of Himachal Pradesh, situated in the lap of north west Himalayas, the study revealed the following trend in the body size of different wasps and hornets:

V.tropica>V. auraria> V. orientalis> V. basalis.

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