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Original article

Morphological characterization of *Apis cerana* in the Yunnan Province of China

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Abstract – Morphological features of *Apis cerana* Fabr. in Yunnan Province of China were studied using morphometrical methods. Samples of *A. cerana* were collected from feral colonies in 14 locations of Yunnan Province, covering the main ecological regions. 38 standard morphometric characters recommended by Ruttner et al. (Apidologie 9, 363–381, 1978) were measured. The data were statistically analysed by factor analysis, discriminant analysis, and cluster analysis and compared to samples from the Oberursel data bank from Beijing, Japan, Korea, Thailand, India, Burma, Vietnam, and Nepal. The results showed a high degree of variation, which correlated to geographical parameters. Bees from the northern high-altitude areas were clearly larger and darker, and showed similarity to data bank samples from Beijing, Nepal, or northern India, whereas bees from lower, southern areas clustered with bees from Thailand and Vietnam.

***Apis cerana* / Yunnan / China / morphometry / biogeography**

1. INTRODUCTION

The Yunnan Province of China has a high degree of botanical and zoological diversity due to its various geographic features and different climate zones. About 90% of its area is mountainous, and more than half of China's plant and animal species are represented. All five honey bee species of China (*Apis cerana* Fabr., *A. florea* Fabr., *A. dorsata* Fabr., *A. andreniformis* Smith and *A. laboriosa* Smith) occur naturally in this province (Li Shao-Wen, 1986). In particular, the cavity-dwelling eastern honey bee, *A. cerana,* is widely distributed throughout the various geographic regions and climatic zones of Yunnan (Cheng Yaochun, 1993), and traditional *A. cerana* beekeeping is rooted in the history of the region.

Peng et al. (1989) reviewed taxonomy studies of China and concluded that the pattern from the northeastern to the southern part of China cannot be reliably constructed because only limited or incompatible character suites were measured, original data were not given and methods of analysis were not clearly described. Thus little is known about the morphological characters of these bees, nor how they relate to the known subspecies of the east Asian mainland.

This study investigates the morphological variation of *A. cerana* in Yunnan Province of China by sampling different regions and using morphometric analysis based on 38 characters recommended by Ruttner et al. (1978). It aims to analyse the relationship of morphological characters to ecological parameters, and to

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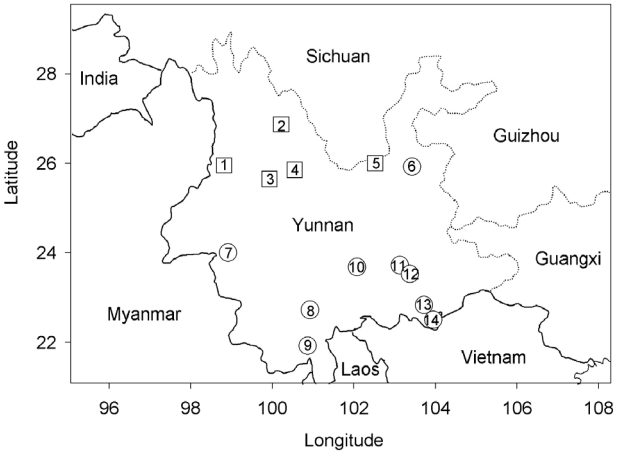

Figure 1. Map of *A. cerana* sampling locations and altitudes: 1 Lushui (1950 m); 2 Lijiang (2680 m); 3 Yuangbi (1810 m); 4 Binchuan (1690 m); 5 Sayinpan (2250 m); 6 Huize (1550 m); 7 Zhenkang (1000 m); 8 Simao (1100 m); 9 Jinghong (600 m); 10 Yuanjian (1500 m); 11 Kaiyuan (1500 m); 12 Caoba (1200 m); 13 Pingbian (1400 m); 14 Hekou (100 m). Altitude ≤ 1600 m circles, > 1600 m squares.

explore the relationship to *A. cerana* samples from adjacent regions using data from the morphometric data bank in Oberursel, Germany.

2. MATERIALS AND METHODS

2.1. Collection of bee samples

Honey bee samples were collected by one of the authors (Tan Ken) from June 1999 to May 2000 from 14 localities throughout Yunnan Province (Fig. 1). The localities were selected to represent different climatic regions, and ranged in altitude from 100 m to 2680 m. Honey bees were collected from natural nests or semi-managed hives such as logs or wall caves. Migratory bee hives have been introduced in some areas only recently, but migration of bee hives is uncommon and collection of bees avoided sampling from hives that may have been trans-located by beekeepers.

A total of 120 samples were collected. In most of the 14 localities 10 colonies were sampled. Each sample contained 30 worker bees, which were killed and preserved in 75% ethanol. Samples were split and one half was deposited in the Eastern Bee Research Institute of Yunnan Agricultural University of China, the other half in the bee collection of the Institute für Bienenkunde, Oberursel.

2.2. Preparations and measurements

From each locality, two randomly selected colony samples were analysed at the Institut für Bienenkunde, except in two localities from which only one sample was analysed. From each sample 15 worker bees were dissected for morphometric analysis and measured according to the methods described by Ruttner et al. (1978) and Ruttner (1988). Of the 41 morphometric characters listed in Ruttner et al. (1978) 38 were measured, excluding length of proboscis (Nr. 5) and cubital veins left (Nr. 29 and 30), resulting in 16 size characters, 11 wing angles, 7 colour characters, 3 hair characters, and number of hamuli. Measurements and colour scaling were performed using a stereomicroscope and a computer-aided measuring system based on a video system and measuring program developed by Meixner (1994).

2.3. Statistical analysis of the data

Colony sample means, standard deviation, and standard error were computed for each character from the samples by the morphometric measuring program, representing estimates for the colony. Colony means were submitted to factor analysis together with data from samples from Beijing (4), Myanmar (2), Japan (8), Korea (5), Nepal (4), Thailand (8), Vietnam (17) and India (5) taken from the data base in the Bee Institute in Oberursel, Germany. For visualisation, sample scores were plotted on principal component (PC) coordinates. Sample reallocation to the different groups was performed by discriminant analysis, with the Yunnan samples either as their own group or forced to be allocated into one of the adjacent groups. Morphometric relations were additionally investigated by cluster analysis, which included sampling location means for the Yunnan samples and group means for the bee groups of adjacent regions. Morphometric relations to environmental variables including altitude, latitude, longitude, mean annual temperature and rainfall were investigated by correlation analysis. All calculations were performed using the SPSS for Windows 8.0.0. statistical package.

3. RESULTS

Group means and standard deviation of colony means are shown in Table I for the morphometric characters of the bees from Yunnan together with those of Japan, Nepal, Vietnam, Thailand, and Beijing. Differences were significant in 30 of the characters with $P < 0.0005$, and not different with $P > 0.05$ in 4 characters. The bees from Yunnan took extreme positions in 8 of the measures, and showed the highest values in the width of sternum 6, width of metatarsus, width of wax mirror and length of the cubital vein 2. They showed the lowest values for the width of tomentum and the wing venation angles G18, J 16 and N3. Differences were confirmed by post-hoc comparisons (Bonferroni-adjusted), and all were significant ($P < 0.05$) with the exceptions of Bejing in case of width of tomentum and width of metatarsus, of Nepal in case of length of cubital vein 2, of Japan in case of wing venation angles G18 and N23, and of Japan, Nepal and Beijing in case of the width of the wax mirror.

In most of the other size measures (length of forewing, hind tibia, tergum 3, tergum 4 and wax mirror) the bees from Yunnan were significantly smaller than the bees from Japan but significantly larger than those of Thailand. They were significantly smaller than the bees of Nepal and bigger than those of Vietnam in some of the size measures.

In the pigmentation measures the Yunnan bees were significantly lighter colored than the bees of Japan (tergum 2, 3 and scutellum 2) and of Bejing (tergum 2, 3), but significantly darker than the bees from Thailand (tergum 3).

Principal component analysis (PCA) of the 38 morphometric characters performed on the 26 sample means yielded 2 factors with high eigenvalues (> 2.5),which accounted for 61.7% of the total variation in the data. The first factor accounted for 37.2% of the total variation in the data and was predominantly associated ($r > 0.6$) positively with the size measures length terga 3 and 4, length sterna 3 and 6, length of wax mirror, length and width of forewing, length of hind leg femur and tibia, length and width of metabasitarsus, length of cubital vein 1, and hair length. The second factor accounted for 17.7% of total variation in the data, and was positively associated with the distance of the wax mirrors, the width of the dark stripe of the tomentum, the length of the cubital vein 2, the pigment on tergum 3 and the wing venation angle A4 but was negatively associated with the width of the tomentum and wing venation angle B4. The third factor accounted for 6.9% of the total variation in the data and was positively associated with the width of sternum 6, the width of the wax mirror and wing venation angle O26, but negatively with the wing venation angles N23 and J16.

Figure 2a, b present the plots of sample factor scores on the three principal component axes. The graphs show that the samples from Yunnan exhibit a wide range of variety in relation to the field covered by *A. cerana* from the other groups. In factor 1, mainly representing size variation, they extend almost over the complete range of the samples from the other 8 countries or regions. In factor 2 they overlap with the bees of Vietnam and Nepal, are close to the bees of Beijing, overlap with the range of the bees of Myanmar and Thailand but are distant from those of India, Korea and Japan. In factor 3 (Fig. 2b), most of them are distant from the bees of other regions, but the bigger bees overlap with the bees of Japan and Korea. Samples from Yunnan also show a within-group pattern where the bees from the northern high-altitude areas (> 1600 m, < 25° latitude) are positioned towards the relatively higher values of factor 1 and lower values of factor 3, in comparison to the southern – low-altitude bees.

Discriminant analysis reallocated all samples to their pre-assigned regions with post-hoc probability of $P > 0.999$. In particular, if Yunnan bees were split into a high-altitude northern and a low-altitude southern group, they were also reallocated into the correct regions with post-hoc probability of $P > 0.999$. When forced to be classified into the other regions, 15 colonies of Yunnan bees (55%) were assigned to Myanmar, with the majority (12) coming from low-altitude southern regions, nine (33%) were assigned to Beijing, all except one coming from the northern high-altitude regions, and three colonies (11%) were assigned to Nepal, one from the high-altitude northern and one from low-altitude southern regions.

Table I. Means and standard deviation of morphometric characters of bees from Yunnan (China), Japan, Nepal Vietnam, Thailand, and Beijing (China).

Characters	Yunnan		Japan		Nepal		Thailand		Vietnam		Beijing	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Length of hair on tergum 5	24.78	6.57	28.18	1.31	26.64	6.42	18.91	1.41	18.89	2.81	29.93	0.62
Width of tomentum on tergum 4	35.45	5.48	62.37	2.44	47.88	2.16	45.84	5.15	40.47	1.82	41.07	1.24
Width of dark stripe on tergum 4	79.18	3.80	64.37	1.98	76.65	7.34	68.70	6.75	80.76	3.19	83.74	1.67
Length of femur, hind leg	242.3	7.04	251.4	2.55	245.0	10.5	225.7	4.33	237.9	5.36	248.3	1.64
Length of tibia, hind leg	304.6	8.89	318.1	3.26	308.9	16.1	284.5	5.91	298.9	5.36	313.4	1.33
Length of metabasitarsus, hind leg	190.7	6.51	197.1	2.81	191.7	8.68	175.0	2.61	185.6	5.06	193.2	1.51
Width of metabasitarsus, hind leg	109.1	3.62	103.5	2.06	103.6	3.50	96.55	3.12	103.8	2.06	107.5	1.34
Pigment of tergum 2	6.850	2.19	4.585	0.96	7.035	0.94	7.102	0.91	7.858	1.19	4.084	1.03
Pigment of tergum 3	7.259	0.84	5.019	0.75	6.824	0.25	6.377	0.50	6.651	0.72	5.000	0.00
Pigment of tergum 4	5.988	0.86	5.025	0.71	5.500	1.00	5.308	0.69	6.275	0.97	5.000	0.00
Length of tergum 3	186.7	7.52	203.9	3.31	198.5	8.60	177.9	2.56	188.1	6.63	119.2	2.23
Length of tergum 4	182.4	7.99	199.4	3.12	194.5	9.52	174.4	1.98	184.5	6.27	194.3	1.16
Length of sternum 3	242.9	10.5	251.5	5.26	243.7	9.90	223.1	2.23	237.0	7.39	246.9	4.16
Length of wax mirror	105.0	6.90	115.4	3.22	105.2	5.19	91.59	6.39	96.06	4.41	105.7	1.49
Width of wax mirror	231.6	28.0	218.1	4.75	208.2	12.1	188.7	3.32	198.1	7.04	210.6	3.12
Distance of wax mirror	38.56	7.50	27.70	2.07	34.23	4.01	33.68	2.71	36.54	3.18	33.70	1.77
Length of sternum 6	228.6	9.76	235.3	2.32	230.3	9.51	211.1	2.73	222.3	6.85	235.8	2.98
Width of sternum 6	328.0	38.4	289.9	6.86	282.4	18.8	248.9	5.96	264.2	8.89	285.0	6.35
Length of forewing	834.5	29.0	855.5	18.5	843.7	30.2	777.9	9.96	804.6	20.7	876.5	8.85
Width of forewing	296.3	10.4	292.1	6.24	293.7	11.0	271.4	4.20	278.3	6.30	301.7	2.61
Pigment of scutellum 1	6.510	1.03	5.250	1.92	5.577	1.23	6.205	1.50	6.554	0.76	5.617	1.15
Pigment of scutellum 2	3.989	0.48	2.162	1.67	2.644	1.36	3.312	2.10	3.167	1.94	4.100	0.54
Pigment of labrum 1	6.995	0.03	7.000	0.00	7.000	0.00	7.000	0.00	7.000	1.94	7.000	0.00
Pigment of labrum 2	5.740	2.05	5.550	2.83	4.407	3.38	6.429	2.47	7.148	1.14	6.250	2.84
Length of cubital vein 1	53.22	2.85	55.27	1.19	53.04	8.18	43.95	2.73	49.87	1.14	50.71	0.99
Length of cubital vein 2	14.29	1.35	8.986	0.77	12.60	0.54	11.94	1.39	12.45	1.14	12.17	0.96
Angle A4	31.75	0.88	27.46	1.75	33.13	1.69	31.13	1.02	31.13	1.14	30.87	0.58
Angle b4	107.6	2.02	113.3	2.42	105.9	1.60	110.3	2.07	109.5	1.14	110.3	1.05
Angle D7	95.47	1.56	93.36	1.84	94.81	1.36	95.90	1.36	95.23	1.20	95.88	1.07
Angle E9	19.51	0.62	20.05	0.31	19.82	0.67	20.40	0.85	19.77	0.70	19.87	0.49
Angle G18	88.41	1.67	89.98	0.87	91.81	2.26	91.14	2.01	89.72	0.70	93.98	0.95
Angle J10	46.74	1.24	44.95	1.09	47.60	2.53	48.85	1.19	47.03	1.74	45.82	0.64
Angle J16	100.4	1.86	103.3	1.23	104.9	1.40	105.7	1.30	106.4	1.93	105.1	1.62
Angle K19	78.34	1.53	82.89	0.94	81.67	4.25	78.06	2.11	77.91	1.82	79.92	0.60
Angle L13	14.49	0.99	14.99	0.65	14.24	1.63	15.14	1.11	14.20	1.30	14.73	0.13
Angle N23	77.22	2.26	78.06	2.08	82.45	3.46	82.39	2.52	84.14	1.80	83.72	0.75
Angle O26	34.73	2.59	34.23	2.27	31.16	2.14	34.04	3.32	32.22	1.65	33.35	1.38
Number of hamuli	18.05	0.79	18.50	0.73	18.05	1.22	17.92	0.46	17.83	0.56	-	-

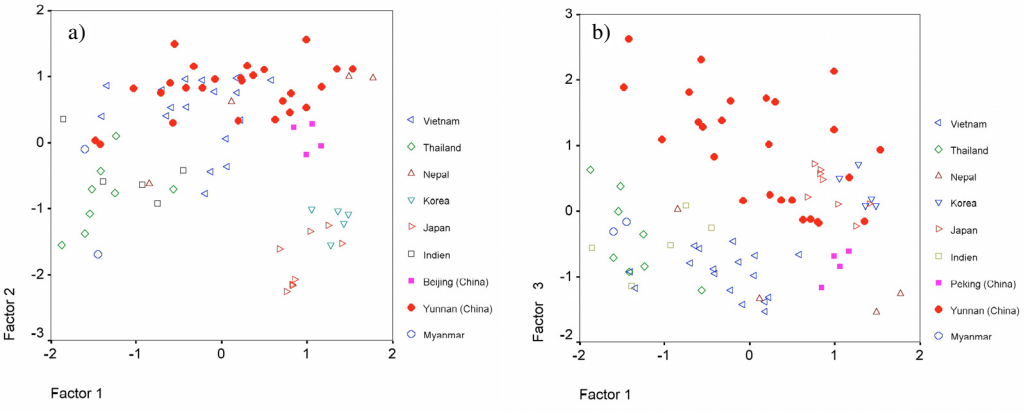

Figure 2. Characterisation of *A. cerana* colony samples from Yunnan and adjacent regions by factor analysis. Axes show sample means factor 1 scores (x-axis, a, b) plotted against factor 2 scores or factor 3 scores ((y-axis, a or b, respectively).

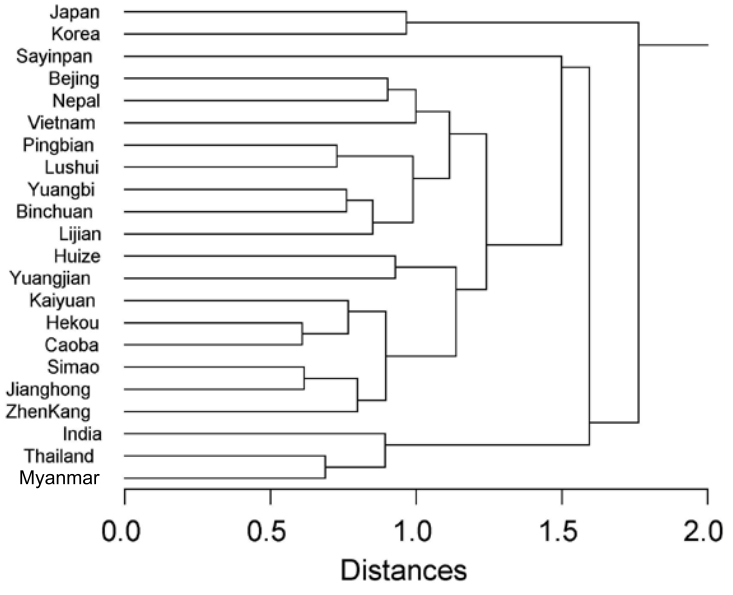

Figure 3. Characterisation of *A. cerana* from Yunnan locations and of adjacent regions derived from cluster analysis using the average linkage method on z-normalized location means of morphometric characters.

A cluster analysis was performed using average linkage between groups, based on z-normalised group means of the characters. The resulting dendrogram (Fig. 3) supports that Yunnan bees are divided into two branches. The first branch encompasses the bees from the low altitude southern locations. The second branch is composed by the bees from high altitude locations, and associates with the bees of Nepal, Vietnam and Beijing. However, one location (Sayinpan) is placed outside these two branches but tended to cluster with the northern bees in other analyses.

Table II. Correlation coefficients between morphometric characters and environmental variables.

Characters	Environmental variables				
	Altitude	Rainfall	Temperature	Latitude	Longitude
Length of hair on tergum 5	.75**	-.53**	-.78**	.78**	-.10
Width of tomentum on tergum 4	.62**	-.71**	-.45*	.71**	.02
Width of dark stripe on tergum 4	.18	-.18	-.17	.33	.09
Length of femur, hind leg	.66**	-.64**	-.60**	.56**	.40*
Length of tibia, hind leg	.61**	-.43*	-.63**	.50**	.40*
Length of metabasitarsus, hind leg	.72**	-.59**	-.67**	.68**	.23
Width of metabasitarsus, hind leg	.64**	-.48*	-.63**	.63**	.08
Pigment of tergum 2	-.75**	.57**	.57**	-.74**	.13
Pigment of tergum 3	-.69**	.63**	.48*	-.71**	.13
Pigment of tergum 4	-.48*	.53**	.38	-.50**	-.05
Length of tergum 3	.66**	-.51**	-.63**	.60**	.34
Length of tergum 3	.69**	-.55**	-.63**	.64**	.25
Length of sternum 3	.37	-.38	-.37	.40*	.30
Length of wax mirror	.65**	-.22	-.67**	.63**	.01
Width of wax mirror	-.31	-.01	.22	-.29	.48*
Distance of wax mirror	-.57**	.10	.46*	-.47*	.23
Length of sternum 6	.75**	-.42*	-.70**	.77**	-.15
Width of sternum 6	-.37	.06	.27	-.34	.43*
Length of forewing	.76**	-.66**	-.67**	.77**	.12
Width of forewing	.80**	-.59**	-.72**	.79**	-.02
Pigment of scutellum 1	-.47*	.18	.44*	-.41*	.11
Pigment of scutellum 2	-.16	.03	.06	-.05	.19
Pigment of labrum 1	-.08	.31	-.08	-.20	.12
Pigment of labrum 2	-.71**	.36	.-.56**	-.65**	.36
Length of cubital vein 1	.60**	-.55**	-.01	.61**	-.03
Length of cubital vein 2	.01	.06	-.22	-.09	.53**
Angle A4	.02	.12	.12	-.03	.34
Angle b4	.09	-.24	.06	.14	-.44*
Angle D7	.04	-.16	-.01	.07	.08
Angle A9	.08	-.02	-.07	.09	-.36
Angle G18	.20	-.35	.28	.12	-.01
Angle J10	-.26	.16	.37	-.22	.16
Angle J16	-.40*	.23	-.19	-.33	.16
Angle K19	.27	-.36	.42*	.30	.07
Angle L13	-.41*	.48*	-.04	-.40*	-.10
Angle N23	.15	-.14	.02	.26	-.02
Angle = 26	-.12	.21	.13	-.18	-.08
Number of hamuli	-.01	.08	.13	-.08	-.08

* Significant at $P < 0.05$.

** Significant at $0.05 > P < 0.01$.

Colony means of the Yunnan samples were correlated with environmental variables. 13 of the 38 characters were significantly correlated to the four environmental parameters altitude, rainfall, temperature and latitude (Tab. II). These contained nine size measures and hair length, which were consistently positively correlated with altitude and latitude and negatively with rainfall and temperature. This trend is also represented by a clear correlation of the first factor scores from factor analysis with altitude ($r = 0.78$, $P < 0.0005$) and latitude ($r = 0.76$, $P < 0.0005$) (Fig. 4a, b). Two pigmentation characters showed the opposite association. No strong associations were apparent with longitude except in the length of

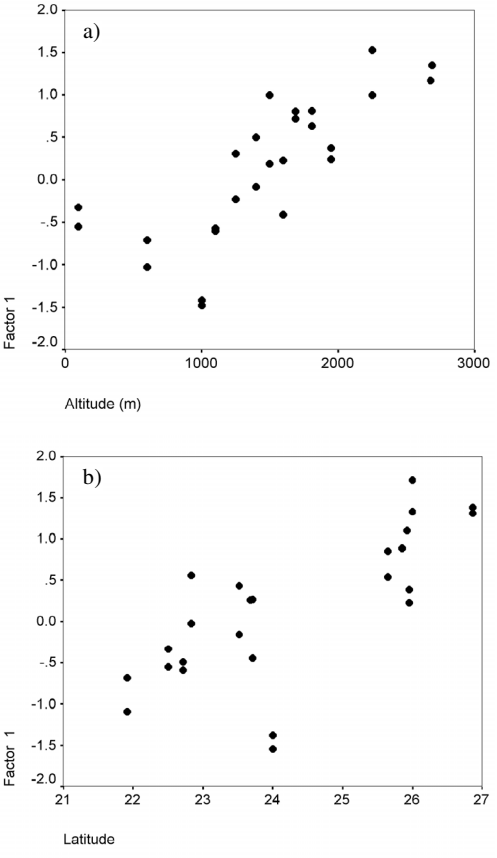

Figure 4. Correlation between factor analysis PC1 scores and the environmental variables altitude (a) or latitude (b).

the cubital vein 2 which increased from west to east. Wing venation angles showed no association with any of the variables.

4. DISCUSSION

Morphometric features of Yunnan bees vary considerably, showing a high degree of variation in size and coloration measures. This high variation reflects the ecological diversity of the Yunnan Province which encompasses zones of subtropical character in the south to high-altitude mountainous regions in the north. Accordingly, many of the measured morphological traits correlate significantly with the environmental variables altitude, rainfall, temperature and latitude. Generally, size characters were positively correlated with altitude and latitude and negatively with rainfall and temperature while the pigment characters showed the opposite trend. The bees from high altitude and cold temperate regions were markedly bigger and darker than bees from low altitude and warm subtropical regions. The strong inter-correlation between the environmental variables did not allow further differentiation between these. Yunnan bees thus give further support to the rule that bees are bigger and darker in high-altitude areas, which has repeatedly been found in *A. mellifera* (Ruttner, 1988; Ruttner et al., 2000; Hepburn et al., 2000) but also in *A. cerana* (Verma et al., 1994) and *A. florea* (Ruttner et al., 1995).

Accordingly, factor analysis and cluster analysis suggested that Yunnan bees could be subdivided into two groups, one from low altitude(≤ 1600 m) subtropical regions at latitude less than 25°N, another from high altitude (> 1600 m) temperate zone regions at latitude greater than 25°N. This grouping was supported by discriminant analysis showing that each colony sample was correctly reallocated into one of these two groups.

The subdivision of *A. cerana* into different subspecies is still controversial (reviewed by Hepburn et al., 2001) and is unlikely to be resolved until better coverage of samples, analysed with compatible methods, is available for the regions of China. However, with further substructuring pending, a conservative approach would place *A. cerana indica* Fabr. in the southern, *A. cerana cerana* Fabr. in the northern and *A. c. scorikovi* Engel in the uplift Himalayan regions. Geographically, Yunnan is positioned in the transition zone between *A. cerana* south or north of the Himalaya in its eastern foothills. Factor analysis places the high-altitude northern Yunnan samples close to the samples from Bejing and Nepal and the southern Yunnan bees close to Vietnam, Myanmar and Thailand. In particular, discriminant analysis forcing the allocation of Yunnan bees into the adjacent groups allocates almost all high-altitude northern samples into the Bejing group and the low-altitude southern samples into the Myanmar group, supporting a split of the Yunnan bees which might be related to the greater pattern of geographical

distribution of *A. cerana* subspecies. However, as is apparent from cluster analysis and discriminant analysis, the Yunnan bees are still separate from the rest of other Asian samples of *A. cerana*, which is also supported by the high number characters in which they display extreme values, as the high values in the width of sternum 6, wax mirror, metabasitarsus width and cubital vein 2 length, as well as the narrow tomentum.

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Résumé – Caractérisation morphologique d'*Apis cerana* dans la province de Yunnan en Chine. Les caractères morphologiques d'*Apis cerana* Fabr. dans la province chinoise de Yunnan ont été étudiés selon les méthodes morphométriques de Ruttner et al. (1978). Des échantillons ont été prélevés dans 14 localités qui représentent la majeure partie de la variabilité écologique de la province (Fig. 1). Pour chaque échantillon, on a mesuré 38 caractères : 16 caractères de taille, 11 de vénation alaire, 7 de pigmentation, 3 de pilosité ainsi que le nombre d'hamulus. À titre de comparaison on a prélevé dans la banque de données d'Oberursel des échantillons du Japon, du Népal, du Vietnam, de Thaïlande, du Myanmar et de Pékin. Les abeilles du Yunnan ont des valeurs extrêmement hautes pour la largeur du sternite 6, du métatarse, du miroir à cire et pour la longueur de la veine cubitale 2 et des valeurs extrêmement faibles pour la largeur du tomentum et pour les angles alaires G18, J16 et N23. Pour la plupart des autres mesures de taille, les abeilles du Yunnan étaient plus petites que celles du Japon mais plus grandes que celles de Thaïlande ; en ce qui concerne la pigmentation, elles étaient plus claires que les abeilles du Japon, mais plus foncées que celles de Thaïlande.
L'analyse en composantes principales a montré une variabilité extrêmement grande des abeilles (Fig. 2a, b). Dans le facteur 1 (principalement les caractères de taille) elles s'étendaient sur presque l'ensemble des échantillons provenant des autres régions. Dans le facteur 2 elles chevauchaient les abeilles du Vietnam et du Népal, mais étaient éloignées des abeilles d'Inde, de Corée et du Japon. Dans le facteur 3 elles étaint nettement séparées de la plupart des autres abeilles.
Les abeilles des régions plus septentrionales (> 1600 m, < 25° de latitude nord) avaient des valeurs relativement plus élevées du facteur 1 et plus basses du facteur 3 que les abeilles des régions plus méridionales et de faible altitude. Treize des caractères présentaient une corrélation significative avec des facteurs du milieu tels que l'altitude, les précipitations, la température et la latitude (Tab. II). On a en particulier trouvé une corrélation positive entre la taille et l'altitude (Fig. 4a). Une analyse discriminante a confirmé l'existence de deux groupes, l'un du nord et d'altitude plus élevée, l'autre du sud et d'altitude plus faible. L'analyse de groupes a fourni un résultat semblable (Fig. 3).
Les résultats suggèrent que les abeilles de la partie nord du Yunnan sont morphométriquement plus proches des abeilles de Pékin et du Népal, tandis que celles du sud du Yunnan se rapprochent plus des abeilles du Myanmar, de Thaïlande et du Vietnam. Cela suggère que la subdivision des abeilles du Yunnan en deux groupes, l'un du nord et l'autre du sud, est en relation avec le modèle plus général de répartition d'*Apis cerana* entre *A. c. indica* au sud et *A. c. cerana* au nord. Pourtant les abeilles du Yunnan présentent des valeurs extrêmes pour un certain nombre de caractères qui les séparent d'*Apis cerana* des autres pays asiatiques (Tab. I).

***Apis cerana* / Yunnan / Chine / morphométrie / biogéographie**

Zusammenfassung – Morphologische Charakterisierung von *Apis cerana* in der Provinz Yunnan, China. Die morphologischen Merkmale von *Apis cerana* Fabr. in der chinesischen Provinz Yunnan wurden unter Anwendung der morphometrischen Methoden von Ruttner et al. (1978) untersucht. Es wurden Proben von 14 Sammelorten genommen, die den größten Teil der ökologischen Variabilität der Provinz repräsentieren (Abb. 1). An den Proben wurden 38 Merkmale vermessen, diese umfassten 16 Größenmerkmale, 11 Flügelwinkel, 7 Farbmerkmale, 3 Behaarungsmerkmale sowie die Anzahl der Hamuli. Zum Vergleich wurden Daten von Proben aus Japan, Nepal, Vietnam, Thailand, Myanmar und Peking aus der Oberurseler Datenbank herangezogen. Die Bienen von Yunnan wiesen in der Breite von Sternum 6, des Metatarsus, des Wachspiegels und der Länge der Cubitalader 2 extrem hohe und bei der Breite des Tomentums und den Flügelwinkeln G18, J16 und N23 extrem niedrige Werte auf. Sie waren in den meisten Längenmessungen kleiner als die Bienen aus Japan, aber größer als die aus Thailand, bei den Farbmessungen waren sie heller als die Bienen aus Japan, aber dunkler als die aus Thailand.
Eine Faktoranalyse (PCA) zeigte eine außerordentlich große Variabilität der Bienen (Abb. 2a, b). In Faktor 1 (im wesentlichen Größenmerkmale) umspannten sie den Bereich der Vergleichsgruppen. Bei Faktor 2 überschnitten sie sich mit den Bienen aus Vietnam, Nepal, Myanmar und Thailand, lagen

aber entfernt von den Bienen von Indien, Korea und Japan. In Faktor 3 hoben sie sich von den meisten anderen Bienen deutlich ab.

Die Bienen aus den nördlichen Bereichen (> 1600 m, < 25° nördlicher Breite) waren eher mit hohen Werten von Faktor 1 und niedrigen Werten von Faktor 3 verbunden. Eine Anzahl (13) der Charaktere (13) waren mit Umgebungsvariablen wie Höhe, Niederschlag, Temperatur und geografischer Breite korreliert (Tab. II), insbesondere bestand ein positiver Zusammenhang von Größe und Höhe (Abb. 4a). Eine Diskriminanzanalyse bestätigte eine Gruppe von nördlichen in größerer Höhe und südlichen in niedrigerer Höhe lebenden Bienen, ein ähnliches Ergebnis erbrachte eine Clusteranalyse (Abb. 3).

Die Analysen legen nahe, dass die nördlichen Bienen morphometrisch nahe zu den Bienen aus Peking und Nepal stehen, während die südlichen Bienen eher eine Nähe zu den Bienen aus Myanmar, Thailand und Vietnam aufweisen. Dies legt nahe, dass die Unterteilung der Bienen von Yunnan in eine nördliche und südliche Gruppe zu dem größeren Verteilungsmuster von *A. cerana* im Übergang von *A. c. indica* im Süden und *A. c. cerana* im Norden in Beziehung steht. Darüber hinaus weisen die Bienen von Yunnan dennoch in einigen Charakteristika extreme Werte auf, die sie von *A. cerana* der anderen asiatischen Länder unterscheiden (Tab. I).

***Apis cerana* / China / Yunnan / Morphometrie / Biogeographie**

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