

ORIGINAL ARTICLE

Further geometric morphometric analysis on the genus *Eysarcoris* (Hemiptera: Pentatomidae) from China

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Abstract Further geometric morphometric analysis of the genus *Eysarcoris* was done based on the former studies to classified the nine *Eysarcoris* species from China. In this study, six characters, such as forewing, hindwing, pygophore, head, pronotum and scutellum, were selected to investigate the shape variation of *Eysarcoris*. Significant divergence in the shapes of the six characters was observed among the species ($p < 0.05$). For all methods, phenetic similarity based on the six characters agrees with the current status of the genus. The cluster analysis of eight species are consistent with the traditional morphological studies. CVA analysis also shows that the values of the six characters are not equal in taxonomy. Pygophore, forewing, hindwing and pronotum play more important roles in the classification.

Key words Centroid size, allometry, phylogenetic relationship, canonical variate analysis, cluster analysis.

1 Introduction

The genus *Eysarcoris*, belongs to Pentatominae (Hemiptera: Heteroptera: Pentatomidae), was established by Hahn in 1834, and up to 9 species were recorded in China (Hahn, 1834; Rider *et al.*, 2002; Rider, 2006; Tsai & Rédei, 2009). Some species, such as *E. aeneus* (Scopoli, 1763), *E. ventralis* (Westwood, 1837) and *E. trimaculatus* (Distant, 1881), are important pests of the upland rice, wheat, cotton, soybean, *etc* (Ito, 1978; Learmonth, 1980; Zhang, 1985; Lee *et al.*, 2009; Nasiruddin & Roy, 2012). The rate of pecky rice caused by *E. aeneus* at the milk ripe stage is 10.2% (Lee *et al.*, 2009).

Eysarcoris can be easily distinguished from other genera by its basal angle feature in the scutellum with small, yellow, or pale smooth spots. It also shows inconspicuous morphological differences inter- and intraspecies (Yang, 1962). For instance, *E. guttiger* (Thunberg, 1783) has the levigated angular spots near basal angle of the scutellum various in size (Distant, 1902). The genus is traditional identified mainly based on the male genitalia. However, the divergence of pygophore and paramere is not obvious among species. Thus, geometric morphometrics is introduced to identify *Eysarcoris* species.

Generally, sibling species show high morphological similarities. Geometric morphometrics is sensitive to subtle variations. It is suitable to detect variations inter- and intraspecies or populations (Villegas *et al.*, 2002; Francoy *et al.*, 2011; Márqueza *et al.*, 2011; Bai & Yang, 2014b; Bai *et al.*, 2014c, 2017). The wings of insects are excellent materials for geometric morphometric studies and have been used as a character for such analysis since the 1970s (Plowright & Stephen, 1973; Gumiel *et al.*, 2003; Aytekin *et al.*, 2007). To date, wing features are demonstrated to be suitable characters for taxonomic analysis (Demayo *et al.*, 2011; Campos *et al.*, 2011; Bai *et al.*, 2014a; Barão *et al.*, 2014). Moreover, the shape of

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male genitalia, head, and pronotum were successfully applied in studies of rice black bugs (Dela Cruz *et al.*, 2011).

In our former study, geometric morphometric approach was employed to distinguish sibling species, *E. guttiger*, *E. annamita* and *E. ventralis* by three characters, forewing, hindwing and pygophore (Li *et al.*, 2017). But the inconspicuous morphological differences among inter- and intraspecies of *Eysarcoris* are not solved.

In present study, six characters, such as forewing, hindwing, pygophore, head, pronotum and scutellum, were selected and analyzed to investigate the morphological variation of *Eysarcoris* species by using geometric morphometric methods. The possible use of shape patterns of the six characters for the identification of *Eysarcoris* was tested.

2 Materials and methods

2.1 Taxa sampling

A total of 334 specimens belonging to 9 species of *Eysarcoris* were examined in this study. Its sibling genus, *Carbula* (*C. crassiventris*), was treated as the outgroup (Kobayshi, 1960). Samples were collected mainly by manual pick-up or sweep nets from fields from 1979 to 2016 (Table 1). All specimens were dried or impregnated in ethyl alcohol and deposited in the Insect Collection of Shanxi Agricultural University and Nankai University in China. *E. trigonus*, which was recorded from Tibet and Sichuan Provinces in China formerly (Rider *et al.*, 2002), was collected only one specimen from Yunnan Province. To protect the sample, we only analyzed two characters, pronotum and scutellum of *E. trigonus*, which means the analysis of the forewing, hindwing, pygophore and head, and the cluster analysis based on distant matrices were based on the other 8 species.

2.2 Data acquisition

Six characters, such as forewing, hindwing, pygophore, head, pronotum and scutellum, were analyzed in the geometric morphometric studies. Specimens were fixed with fixative. Forewing and pygophore were removed to get other characters. The images of the head, pronotum and scutellum were obtained using a digital camera (Leica MC120HD), which was mounted on the ocular of a stereo microscope (Leica M165C). The shapes of the head, pronotum and scutellum were represented by one curve (Fig. 1). For the forewing, hindwing and pygophore, the same landmarks selection methods was

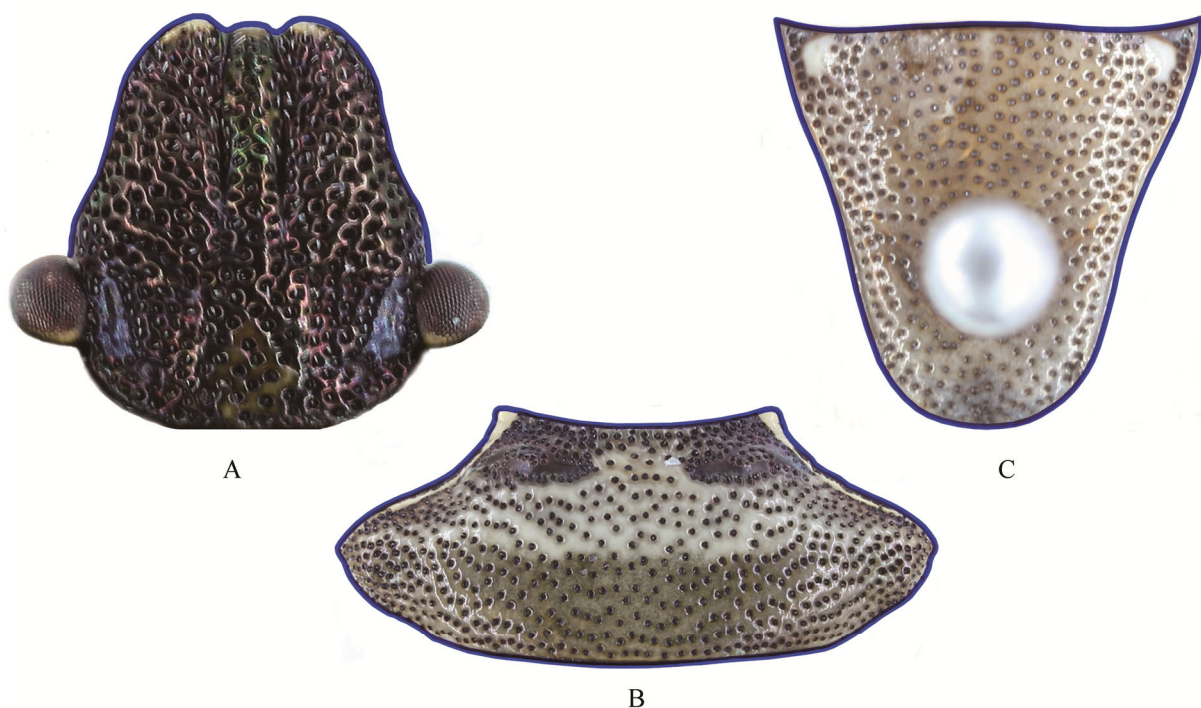


Figure 1. Curves selection of three characters, resampled into 30, 100 and 50 semi-landmarks respectively. A. Head, outline curved of the tylus and jugum. B. Pronotum, outline curved. C. Scutellum, outline curved.

used as the former work (Li *et al.*, 2017). The forewing included six landmarks and one curve. For the hindwing, eight landmarks and one curve were used. The shape of pygophore was represented by one curve. Each photo was labeled with a unique code. Curves and landmarks were digitized with tpsDig Ver.2.05 (Rohlf, 2006) and all semi-landmarks were converted to landmarks. All pictures and digital procedures were operated by the same person.

Table 1. Materials used in the geometric morphometric analyses*.

Species	Locality	Forewing	Hindwing	Pygophore	Head	Pronotum	Scutellum
<i>Eysarcoris aeneus</i>	Shandong	24	27	18	41	38	40
	Shanxi	16	39	19	64	64	62
	Tianjin	1	-	-	-	-	-
	Shannxi	2	1	-	-	-	-
	Zhejiang	1	1	-	-	-	-
<i>Eysarcoris aenescens</i>	Yunnan	22	16	24	25	26	26
<i>Eysarcoris annamita</i>	Zhejiang	4	7	-	5	6	6
	Yunnan	-	3	-	3	3	3
	Sichuan	3	9	3	8	11	7
	Guangxi	-	5	-	7	7	7
	Jiangxi	-	2	-	3	1	1
	Guizhou	10	9	2	14	14	14
	Hunan	1	8	5	5	5	4
	Guangdong	2	3	3	5	5	4
	<i>Eysarcoris guttiger</i>	Guizhou	-	-	-	2	1
Zhejiang		4	3	1	4	5	5
Hunan		1	2	2	3	3	2
Sichuan		5	7	4	6	3	7
Shannxi		1	1	-	3	7	2
Gansu		4	4	-	3	4	4
Hubei		1	1	-	1	1	1
<i>Eysarcoris montivagus</i>	Guizhou	2	2	-	2	3	4
	Yunnan	3	2	3	4	5	4
<i>Eysarcoris rosaceus</i>	Yunnan	7	35	45	72	71	73
<i>Eysarcoris ventralis</i>	Shandong	32	14	14	30	30	29
	Shanxi	1	1	1	1	1	1
	Zhejiang	3	1	1	4	4	4
	Hebei	4	-	-	2	2	2
	Hubei	1	-	-	2	2	2
	Beijing	1	-	-	-	-	-
	Hunan	1	-	-	-	-	-
	Tianjin	1	-	-	-	-	-
<i>Eysarcoris gibbosus</i>	Shanxi	6	9	5	10	10	10
	Heilongjiang	5	-	3	6	6	5
<i>Eysarcoris trigonus</i>	Yunnan	-	-	-	-	1	1
<i>Carbula crassiventris</i>	Yunnan	10	15	11	23	26	25

*The data is partly from Li *et al.* (2017).

2.3 Geometric morphometric analyses

To explore shape variation, the raw coordinates were scaled, translated, and rotated against the consensus configuration using the generalized least-squares procrustes superimposition method to remove the variance caused by the scale, position, and orientation (Bookstein, 1991). Centroid size was used to examine size variation. It is the square root of the summed

squared distance of each landmark from the center of the form (Zelditch *et al.*, 2004). A one-way ANOVA method was conducted to assess size differences of the six characters among species using Paleontological Statistics software (PAST) Ver.3.06 (Hammer *et al.*, 2001). A multivariate regression of Procrustes coordinates against centroid size was conducted to test for the presence of allometry using MorphoJ 1.06d (Klingenberg, 2011). The significance of the allometry was calculated with a permutation test with 10,000 iterations.

Canonical variate analysis (CVA) was performed using MorphoJ 1.06d. The Procrustes distances and Mahalanobis distances were computed during canonical variate analysis. Procrustes distance is a measure of the absolute magnitude of the shape deviation and indicates how big the differences are between the average group shapes. Mahalanobis distance provides an indication of how different an individual is relative to the others in the sample, and how distinctly groups are separated from one another (Li *et al.*, 2015). Distant matrices obtained from the coriandis 1.2 beta (Márquez & Knowles, 2007) are used in cluster analysis through PAST Ver.3.06.

3 Results

Multivariate regression of shape variables on centroid size was calculated. No allometry was found in the forewing, head and scutellum ($p = 0.0713$, $p = 0.1871$ and $p = 0.3653$, respectively), and the null hypothesis of isometry was rejected (allometry was present) in pygophore, hindwing and pronotum ($p < 0.0001$, $p = 0.0385$ and $p = 0.0005$, respectively) and accounted for 11.3023%, 1.0598% and 2.4287% of the overall shape variation. To remove allometry effects in pygophore, hindwing and pronotum, size-corrected shape variables (the residuals from the regression) were used in subsequent shape analysis. The smallest centroid size was that of *E. ventralis* for pygophore, *E. gibbosus* for head, and *E. guttiger* for other four characters (Fig. 2). For all the six characters, there was no predictable pattern in pairwise comparisons of size divergence (Tables 1S).

Canonical variate analyses (CVA) were conducted to assess the differences among *Eysarcoris* species quantitatively. In the analysis of the forewing, four species, *E. rosaceus*, *E. guttiger*, *E. aenescens* and *E. montivagus* were overlapped, while others were clearly separated (Fig. 3A). In the analyses of the hindwing, *E. guttiger*, *E. annamita* and *E. rosaceus* were overlapped, while others were clearly separated (Fig. 3B). Most of the species were clearly separated in the analysis of pygophore, except *E. aeneus* and *E. annamita* were slightly overlapped (Fig. 3C). In the analysis of pronotum, *E. guttiger* and *E. annamita*, *E. ventralis* and *E. gibbosus* were overlapped, respectively, while *E. ventralis* slightly overlapped with *E. gibbosus* (Fig. 3E). In the analyses of the head and scutellum, most species were overlapped, excepted *E. aeneus* (in both analyses; Fig. 3D), *E. trigonus* and *E. ventralis* (only in the latter analysis, Fig. 3F). *E. trigonus* was clearly separated from the other groups in pronotum and scutellum (Figs 3E–F).

The Mahalanobis and Procrustes distances among species were calculated (Tables 2S–7S). All obtained p -values from the permutation test (1000 permutation rounds) for the Mahalanobis distance of all the six characters among the species were smaller than 0.05. Most of the obtained p -values from the permutation test (1000 permutation rounds) for the Procrustes distance based on the morphology of the six characters among the species were smaller than 0.05.

Figure 4 shows the relationship of the eight species of *Eysarcoris*. All *Eysarcoris* species were clustered together and separated into two groups, *E. gibbosus*, *E. ventralis*, *E. aeneus*, *E. guttiger* and *E. annamita* as the first group and *E. aenescens*, *E. montivagus* and *E. rosaceus* as the second, with 52% and 85% posterior probability, respectively.

4 Discussion

Morphological features, such as the male genitalia, head, pronotum, scutellum and the color of abdomen beneath, are commonly used in the traditional morphological studies of *Eysarcoris* (Hsiao, 1977; Zhang, 1985). Some characters, e.g., the color of abdomen beneath, which are difficult to quantify, are not selected. Significant shape divergences of the six characters were observed among the nine species. This finding indicates that the morphological boundaries of the species based on the sample specimens were obvious.

According to CVA analysis (Fig. 3), all six characters were more or less with overlapping samples. Among them, the eight/nine species can be separated roughly by pygophore, while five species in hindwing and pronotum, four in forewing and three in scutellum, respectively. This may indicate that the value of the six characters was not equal in taxonomy. The pygophore provides the most important role for the identification of the *Eysarcoris*, which was in accordance with the

former studies (Li et al., 2017). Most of the species can be separated by pygophore, except *E. aeneus* and *E. annamita*.

The forewing, hindwing and pronotum are also informative in the taxonomy of *Eysarcoris* based on this study. In former works, the forewing, especially the venation patterns of the membrane part of the hemelytra, which was usually used in the family level (Zheng & Gui, 1999), has been proved to be useful to identify species by using the geometric morphometric methods (Gumiel et al., 2003; Campos et al., 2011). In our study, species were separated better in the analysis of hindwing than the forewing. It may indicate that the hindwing is evolving faster than the forewing, which is also found in *Calopteryx* damselflies (Outomuro et al., 2012). Thus, the evolution pattern of the forewing and hindwing in Pentatomidae should be evaluated in future. Pronotum is widely used in the taxonomy of the stink bug. It has been proved by DNA barcoding in the genus *Pentatoma*, which was divided into four groups by pronotum (Ling & Zheng, 1987; Liang, 2009).

The head, especially the relative length of tylus and jugum, is various in *Eysarcoris*, and the shape of scutellum has been used in tribe level taxonomic studies of Pentatomidae (Yang, 1962). However, The head and scutellum contained the least morphological variation among the six characters in this study. The taxonomic value of the head and scutellum are not highly supported.

In the comparative analyses, significant shape divergences are observed among the nine species for all the six characters, while the size divergence follows no rhyme. Compared to size difference, the performance of shape divergence

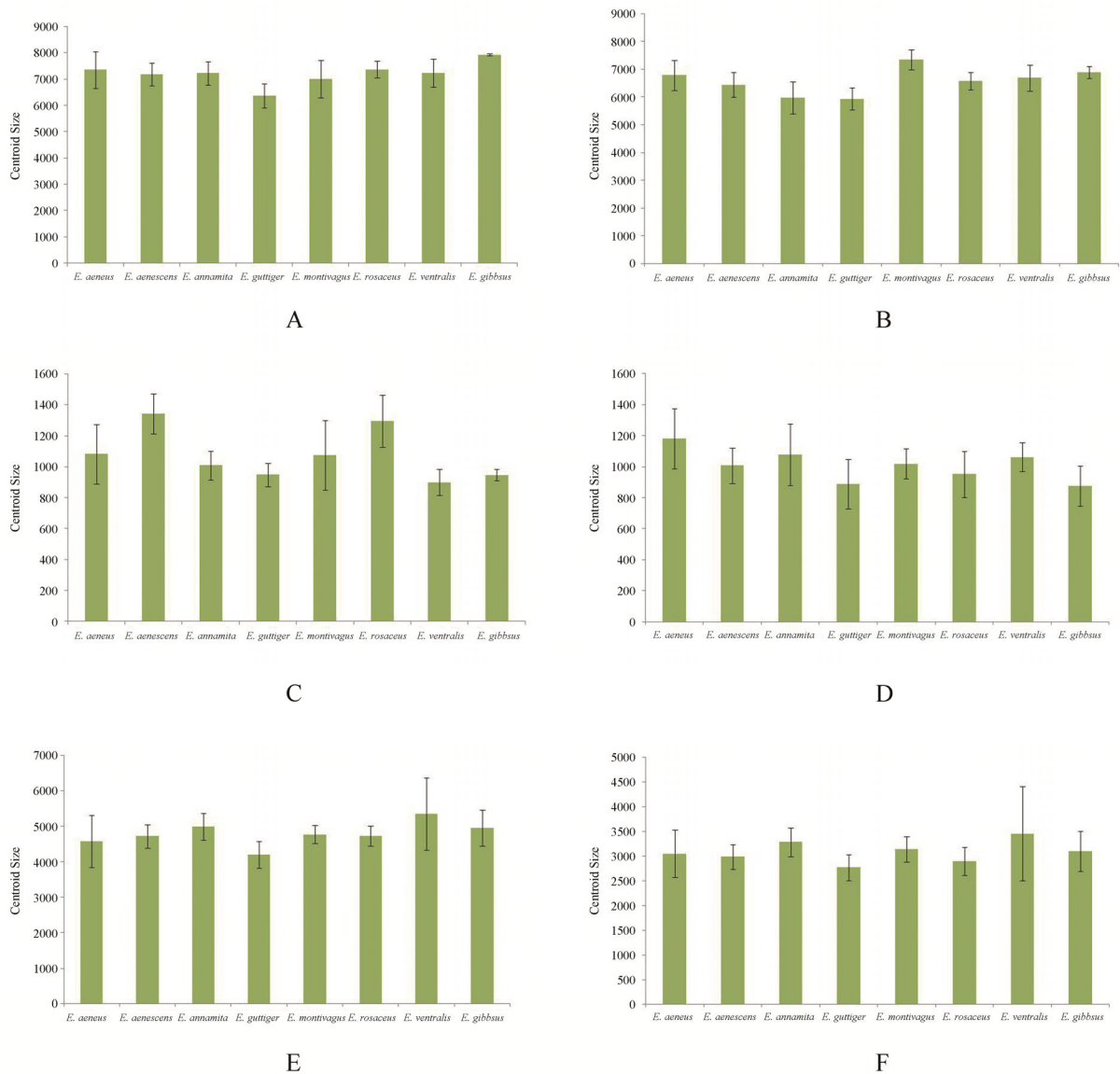


Figure 2. Comparisons of CS variables among species of *Eysarcoris*. A. Forewing. B. Hindwing. C. Pygophore. D. Head. E. Pronotum. F. Scutellum.

among species was more stable. Therefore, an analysis of shape is more sensitive for detecting differences.

The study analyzed the phylogenetic relationships of *Eysarcoris* species. As the morphological similarity of the sibling species caused difficulty in traditional classification (Yang, 1962), we present a quantitative method and easy way to distinguish them. The cluster analysis reflected the morphological similarity of these species. The species which are similar in morphology were clustered together (Distant, 1902; Yang, 1934, 1962; Zhang, 1985, 1995; Bu & Zheng, 1997), such as *E. aeneus* and *E. ventralis*, *E. guttiger* and *E. annamita* in the first group, *E. montivagus* and *E. rosaceus* in the second.

The results indicate that geometric morphometric methods are useful in detecting subtle differences between species of *Eysarcoris*. Among the six characters, pygophore is the most important character in taxonomy, then the forewing, hindwing, and pronotum. The shape of head and scutellum are less informative in this study.

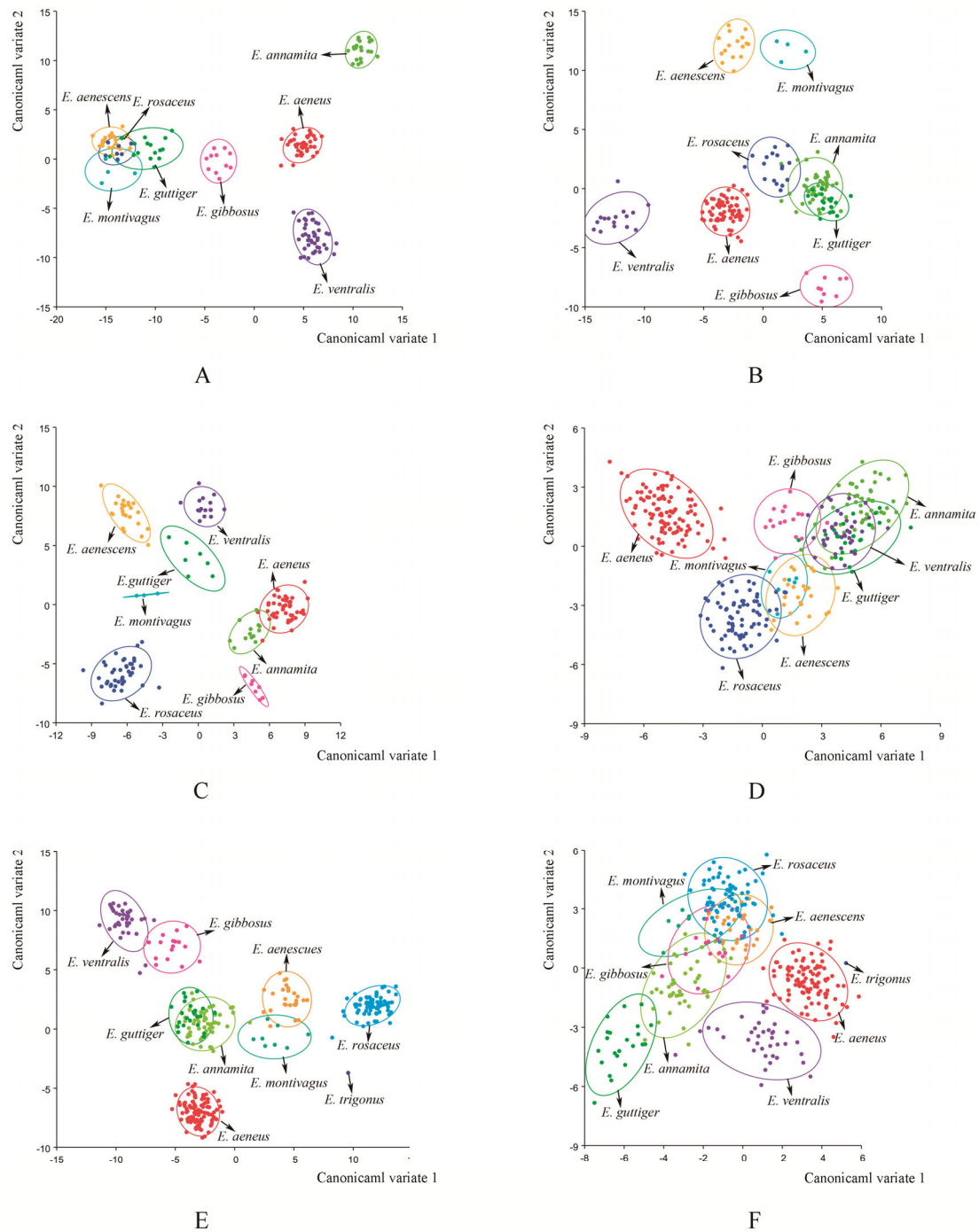


Figure 3. Canonical variate analysis (CVA) based on the shape variables of different characters showing 90% confidence ellipses of population means. A. Forewing, B. Hindwing. C. Pygophore. D. Head. E. Pronotum. F. Scutellum.

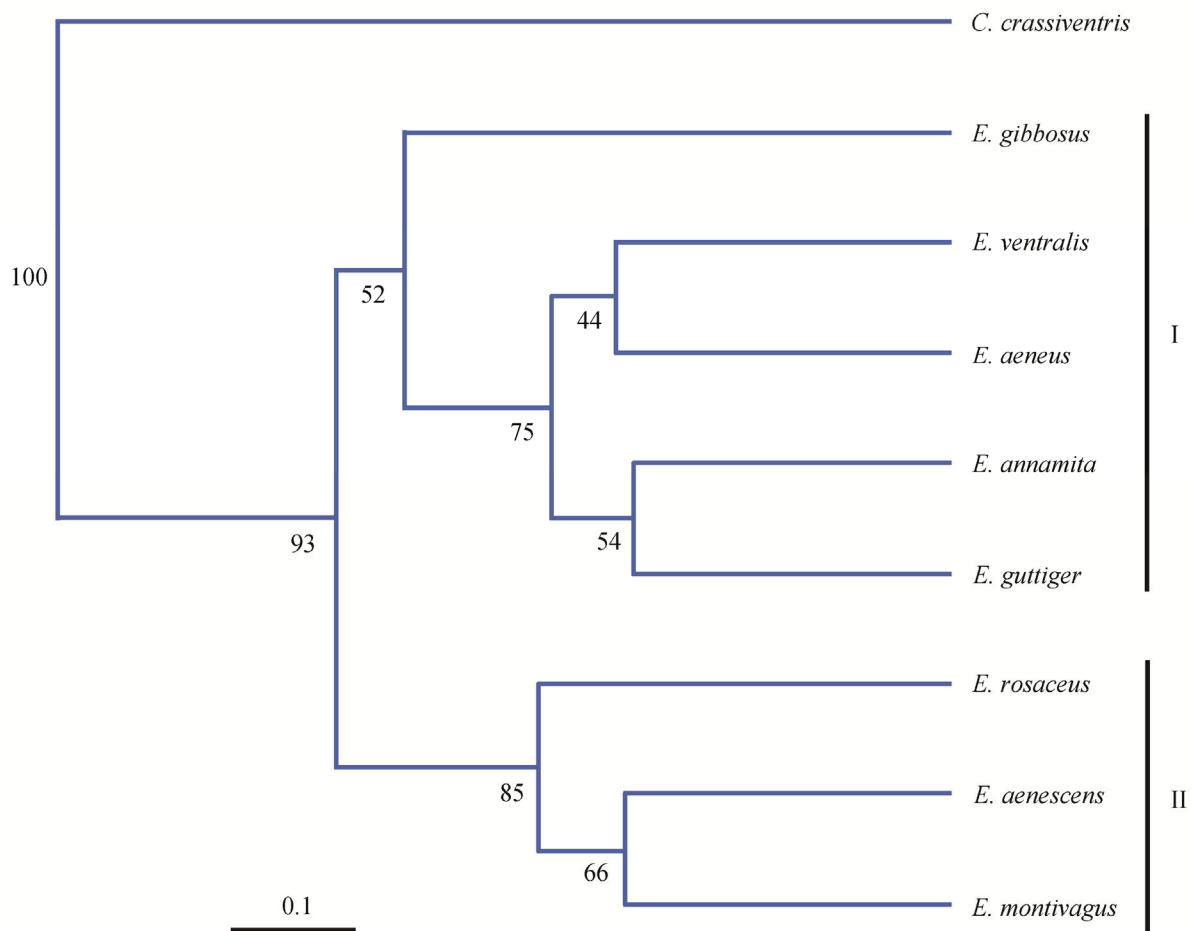


Figure 4. A dendrogram showing the relationship of the eight species of *Eysarcoris*.

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Table 1S. Tukey HSD for the CS among different species of *Eysarcoris*: *p*-values (above) and Studentized Range Statistic *q* (below).

	<i>E. aeneus</i>	<i>E. aenescens</i>	<i>E. annamita</i>	<i>E. guttiger</i>	<i>E. montivagus</i>	<i>E. rosaceus</i>	<i>E. ventralis</i>	<i>E. gibbosus</i>
Forewing								
<i>E. aeneus</i>		0.9970	0.9993	0.0007	0.8110	1.0000	0.9994	0.2289
<i>E. aenescens</i>	0.9900		1.0000	0.0109	0.9935	0.9962	1.0000	0.0377
<i>E. annamita</i>	0.7919	0.1982		0.0066	0.9828	0.9990	1.0000	0.0571
<i>E. guttiger</i>	5.9440	4.9540	5.1520		0.1197	0.0006	0.0062	<0.0001
<i>E. montivagus</i>	2.1130	1.1230	1.3210	3.8310		0.7958	0.9809	0.0023
<i>E. rosaceus</i>	0.0396	1.0300	0.8315	5.9840	2.1530		0.9992	0.2424
<i>E. ventralis</i>	0.7685	0.2215	0.0234	5.1760	1.3440	0.8081		0.0598
<i>E. gibbosus</i>	3.4300	4.4200	4.2200	9.3740	5.5430	3.3900	4.1990	
Hindwing								
<i>E. aeneus</i>		0.7321	0.0034	0.0015	0.1467	0.9738	0.9998	0.9997
<i>E. aenescens</i>	2.3050		0.3620	0.2478	0.0006	0.9986	0.9412	0.3970
<i>E. annamita</i>	5.3930	3.0870		1.0000	<0.0001	0.0930	0.0184	0.0005
<i>E. guttiger</i>	5.6800	3.3750	0.2879		<0.0001	0.0530	0.0091	0.0002
<i>E. montivagus</i>	3.7130	6.0180	9.1050	9.3930		0.0069	0.0422	0.3966
<i>E. rosaceus</i>	1.4220	0.8834	3.9710	4.2590	5.1350		0.9994	0.8063
<i>E. ventralis</i>	0.6546	1.6510	4.7380	5.0260	4.3670	0.7673		0.9798
<i>E. gibbosus</i>	0.7034	3.0090	6.0960	6.3840	3.0100	2.1250	1.3580	
Pygophore								
<i>E. aeneus</i>		0.0044	0.9650	0.5367	1.0000	0.0464	0.1477	0.5324
<i>E. aenescens</i>	5.3020		0.0001	<0.0001	0.0027	0.9972	<0.0001	<0.0001
<i>E. annamita</i>	1.4980	6.8000		0.9890	0.9825	0.0010	0.7720	0.9890
<i>E. guttiger</i>	2.7160	8.0180	1.2180		0.6214	0.0001	0.9970	1.0000
<i>E. montivagus</i>	0.1730	5.4750	1.3250	2.5430		0.0320	0.1951	0.6171
<i>E. rosaceus</i>	4.3220	0.9802	5.8200	7.0380	4.4950		<0.0001	0.0001
<i>E. ventralis</i>	3.7090	9.0110	2.2110	0.9930	3.5360	8.0310		0.9970
<i>E. gibbosus</i>	2.7250	8.0270	1.2270	0.0088	2.5520	7.0470	0.9842	

Table 1S (continued)

	<i>E. aeneus</i>	<i>E. aenescens</i>	<i>E. annamita</i>	<i>E. guttiger</i>	<i>E. montivagus</i>	<i>E. rosaceus</i>	<i>E. ventralis</i>	<i>E. gibbosus</i>
Head								
<i>E. aeneus</i>		0.0169	0.4821	<0.0001	0.0333	0.0002	0.2900	<0.0001
<i>E. aenescens</i>	4.7730		0.8687	0.2769	1.0000	0.9533	0.9633	0.1442
<i>E. annamita</i>	2.8280	1.9450		0.0052	0.9415	0.1985	1.0000	0.0016
<i>E. guttiger</i>	8.0680	3.2960	5.2400		0.1789	0.9283	0.0156	1.0000
<i>E. montivagus</i>	4.4770	0.2959	1.6490	3.5910		0.8891	0.9895	0.0850
<i>E. rosaceus</i>	6.3520	1.5800	3.5250	1.7160	1.8760		0.3604	0.7994
<i>E. ventralis</i>	3.2620	1.5110	0.4339	4.8070	1.2150	3.0910		0.0053
<i>E. gibbosus</i>	8.4960	3.7230	5.6680	0.4276	4.0190	2.1430	5.2340	
Pronotum								
<i>E. aeneus</i>		0.9918	0.2360	0.3423	0.9561	0.9904	0.0002	0.3951
<i>E. aenescens</i>	1.1660		0.7588	0.0488	1.0000	1.0000	0.0067	0.8969
<i>E. annamita</i>	3.4090	2.2430		0.0001	0.8970	0.7715	0.4479	1.0000
<i>E. guttiger</i>	3.1330	4.2990	6.5420		0.0203	0.0457	<0.0001	0.0003
<i>E. montivagus</i>	1.5620	0.3961	1.8470	4.6950		1.0000	0.0180	0.9706
<i>E. rosaceus</i>	1.1960	0.0306	2.2130	4.3290	0.3655		0.0073	0.9049
<i>E. ventralis</i>	6.3080	5.1430	2.8990	9.4410	4.7460	5.1120		0.2770
<i>E. gibbosus</i>	3.0130	1.8470	0.3961	6.1460	1.4510	1.8170	3.2950	
Scutellum								
<i>E. aeneus</i>		0.9999	0.6942	0.4966	0.9983	0.9625	0.0686	1.0000
<i>E. aenescens</i>	0.6176		0.3978	0.7848	0.9617	0.9984	0.0179	0.9936
<i>E. annamita</i>	2.3890	3.0070		0.0060	0.9667	0.1046	0.9229	0.8853
<i>E. guttiger</i>	2.7980	2.1800	5.1870		0.1492	0.9856	0.0001	0.2760
<i>E. montivagus</i>	0.9050	1.5230	1.4840	3.7030		0.6790	0.3043	1.0000
<i>E. rosaceus</i>	1.5170	0.8995	3.9060	1.2810	2.4220		0.0017	0.8452
<i>E. ventralis</i>	4.1300	4.7480	1.7410	6.9280	3.2250	5.647		0.1682
<i>E. gibbosus</i>	0.5003	1.1180	1.8890	3.2980	0.4047	2.017	3.630	

Table 2S. Difference in the forewing shapes among the species of *Eysarcoris*.

	<i>E. aeneus</i>	<i>E. aenescens</i>	<i>E. annamita</i>	<i>E. guttiger</i>	<i>E. montivagus</i>	<i>E. rosaceus</i>	<i>E. ventralis</i>	<i>E. gibbosus</i>
Mahalanobis distance (below) and <i>p</i> -value from permutation test for Mahalanobis distance among species (above)								
<i>E. aeneus</i>		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
<i>E. aenescens</i>	21.1941		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
<i>E. annamita</i>	14.0049	28.0781		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
<i>E. guttiger</i>	20.4578	18.0245	26.2850		<0.0001	<0.0001	<0.0001	<0.0001
<i>E. montivagus</i>	21.5934	14.5041	29.8040	14.5277		0.0001	<0.0001	0.0001
<i>E. rosaceus</i>	20.9763	13.6673	28.6136	14.8817	12.5775		<0.0001	<0.0001
<i>E. ventralis</i>	11.3397	23.6429	19.7244	22.0436	23.6273	23.6820		<0.0001
<i>E. gibbosus</i>	14.7336	16.0439	21.1413	19.0420	18.2199	17.6909	16.1011	
Procrustes distance (below) and <i>p</i> -value from permutation test for Procrustes distance among species (above)								
<i>E. aeneus</i>		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
<i>E. aenescens</i>	0.0768		<0.0001	<0.0001	0.0004	<0.0001	<0.0001	<0.0001
<i>E. annamita</i>	0.0330	0.1040		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
<i>E. guttiger</i>	0.0520	0.0841	0.0568		0.0001	<0.0001	<0.0001	<0.0001
<i>E. montivagus</i>	0.0662	0.0399	0.0873	0.0516		0.0247	<0.0001	0.0022
<i>E. rosaceus</i>	0.0719	0.0592	0.0915	0.0477	0.0322		<0.0001	0.0001
<i>E. ventralis</i>	0.0507	0.1033	0.0616	0.0698	0.0934	0.0844		<0.0001
<i>E. gibbosus</i>	0.0575	0.0480	0.0829	0.0850	0.0670	0.0779	0.0821	

Table 3S. Difference in the hindwing shapes among the species of *Eysarcoris*.

	<i>E. aeneus</i>	<i>E. aenescens</i>	<i>E. annamita</i>	<i>E. guttiger</i>	<i>E. montivagus</i>	<i>E. rosaceus</i>	<i>E. ventralis</i>	<i>E. gibbosus</i>
Mahalanobis distance (below) and <i>p</i> -value from permutation test for Mahalanobis distance among species (above)								
<i>E. aeneus</i>		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
<i>E. aenescens</i>	15.4643		<0.0001	<0.0001	0.0003	<0.0001	<0.0001	<0.0001
<i>E. annamita</i>	10.1145	15.5806		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
<i>E. guttiger</i>	11.0092	16.8312	7.6455		<0.0001	<0.0001	<0.0001	<0.0001
<i>E. montivagus</i>	21.1838	18.4789	19.5207	20.2240		<0.0001	0.0002	0.0004
<i>E. rosaceus</i>	10.5448	13.9226	10.1562	9.7883	20.9394		<0.0001	<0.0001
<i>E. ventralis</i>	14.8534	20.0145	18.5792	19.2433	25.6289	17.3425		<0.0001
<i>E. gibbosus</i>	17.2580	23.5199	16.0962	15.1620	27.2804	17.3385	22.5679	
Procrustes distance (below) and <i>p</i> -value from permutation test for Procrustes distance among species (above)								
<i>E. aeneus</i>		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
<i>E. aenescens</i>	0.0360		<0.0001	<0.0001	0.0029	0.0002	<0.0001	<0.0001
<i>E. annamita</i>	0.0388	0.0508		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
<i>E. guttiger</i>	0.0366	0.0492	0.0202		<0.0001	<0.0001	<0.0001	<0.0001
<i>E. montivagus</i>	0.0569	0.0428	0.0513	0.0562		0.0641	0.0001	0.0011
<i>E. rosaceus</i>	0.0397	0.0283	0.0449	0.0457	0.0301		<0.0001	<0.0001
<i>E. ventralis</i>	0.0370	0.0356	0.0630	0.0597	0.0610	0.0412		<0.0001
<i>E. gibbosus</i>	0.0744	0.0826	0.0543	0.0530	0.0853	0.0824	0.0891	

Table 4S. Difference in the pygophore shapes among the species of *Eysarcoris*.

	<i>E. aeneus</i>	<i>E. aenescens</i>	<i>E. annamita</i>	<i>E. guttiger</i>	<i>E. montivagus</i>	<i>E. rosaceus</i>	<i>E. ventralis</i>	<i>E. gibbosus</i>
Mahalanobis distance (below) and <i>p</i> -value from permutation test for Mahalanobis distance among species (above)								
<i>E. aeneus</i>		<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001
<i>E. aenescens</i>	16.5524		<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001
<i>E. annamita</i>	12.7473	17.6964		<0.0001	0.0010	<0.0001	<0.0001	<0.0001
<i>E. guttiger</i>	13.5298	13.5710	17.4889		0.0018	<0.0001	<0.0001	<0.0001
<i>E. montivagus</i>	17.4110	15.8781	19.4298	15.7639		<0.0001	0.0004	0.0004
<i>E. rosaceus</i>	15.1212	14.8970	15.3195	15.4605	14.4412		<0.0001	<0.0001
<i>E. ventralis</i>	16.2277	14.6186	16.3003	16.2622	17.0782	18.1218		<0.0001
<i>E. gibbosus</i>	21.5859	24.8512	18.9385	24.3567	23.5179	21.8492	22.6281	
Procrustes distance (below) and <i>p</i> -value from permutation test for Procrustes distance among species (above)								
<i>E. aeneus</i>		<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001
<i>E. aenescens</i>	0.0809		<0.0001	<0.0001	0.0070	<0.0001	<0.0001	<0.0001
<i>E. annamita</i>	0.1220	0.1171		0.0002	0.0266	0.0023	<0.0001	0.1032647
<i>E. guttiger</i>	0.0841	0.0779	0.1730		0.0165	<0.0001	0.0342	0.0001
<i>E. montivagus</i>	0.1044	0.0638	0.1387	0.0935		0.0002	0.1445	0.0026
<i>E. rosaceus</i>	0.1363	0.1221	0.0625	0.1795	0.1555		<0.0001	<0.0001
<i>E. ventralis</i>	0.1094	0.1042	0.1786	0.0846	0.0945	0.2050		0.0001
<i>E. gibbosus</i>	0.1191	0.1203	0.0591	0.1759	0.1335	0.0980	0.1711	

Table 5S. Difference in the head shapes among the species of *Eysarcoris*.

	<i>E. aeneus</i>	<i>E. aenescens</i>	<i>E. annamita</i>	<i>E. guttiger</i>	<i>E. montivagus</i>	<i>E. rosaceus</i>	<i>E. ventralis</i>	<i>E. gibbosus</i>
Mahalanobis distance (below) and <i>p</i> -value from permutation test for Mahalanobis distance among species (above)								
<i>E. aeneus</i>		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
<i>E. aenescens</i>	8.2276		<0.0001	<0.0001	0.0029	<0.0001	<0.0001	<0.0001
<i>E. annamita</i>	10.2267	6.3110		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
<i>E. guttiger</i>	9.7608	5.1388	3.6382		<0.0001	<0.0001	<0.0001	<0.0001
<i>E. montivagus</i>	7.9633	4.8461	7.3696	6.1188		<0.0001	<0.0001	<0.0001
<i>E. rosaceus</i>	6.4797	4.2690	8.5926	7.3647	4.8380		<0.0001	<0.0001
<i>E. ventralis</i>	9.8938	6.6029	7.0089	6.0448	6.9492	8.1372		<0.0001
<i>E. gibbosus</i>	7.3994	6.2861	6.8265	5.9486	6.4937	6.7282	5.7651	
Procrustes distance (below) and <i>p</i> -value from permutation test for Procrustes distance among species (above)								
<i>E. aeneus</i>		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
<i>E. aenescens</i>	0.0561		<0.0001	<0.0001	0.0099	<0.0001	<0.0001	<0.0001
<i>E. annamita</i>	0.0556	0.0570		0.0008	<0.0001	<0.0001	<0.0001	<0.0001
<i>E. guttiger</i>	0.0523	0.0440	0.0162		<0.0001	<0.0001	<0.0001	<0.0001
<i>E. montivagus</i>	0.0637	0.0244	0.0595	0.0462		<0.0001	<0.0001	<0.0001
<i>E. rosaceus</i>	0.0660	0.0294	0.0809	0.0682	0.0325		<0.0001	<0.0001
<i>E. ventralis</i>	0.0608	0.0631	0.0339	0.0312	0.0669	0.0884		<0.0001
<i>E. gibbosus</i>	0.0459	0.0729	0.0348	0.0393	0.0774	0.0940	0.0323	

Table 6S. Difference in the pronotum shapes among the species of *Eysarcoris*.

	<i>E. aeneus</i>	<i>E. aenescens</i>	<i>E. annamita</i>	<i>E. guttiger</i>	<i>E. montivagus</i>	<i>E. rosaceus</i>	<i>E. trigonus</i>	<i>E. ventralis</i>	<i>E. gibbosus</i>
Mahalanobis distance (below) and <i>p</i> -value from permutation test for Mahalanobis distance among species (above)									
<i>E. aeneus</i>		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0089	<0.0001	<0.0001
<i>E. aenescens</i>	15.0993		<0.0001	<0.0001	<0.0001	<0.0001	0.0168	<0.0001	<0.0001
<i>E. annamita</i>	10.7175	12.1688		<0.0001	<0.0001	<0.0001	0.0151	<0.0001	<0.0001
<i>E. guttiger</i>	11.3651	13.1719	6.4633		<0.0001	<0.0001	0.0290	<0.0001	<0.0001
<i>E. montivagus</i>	13.7074	13.5591	10.7187	12.7510		<0.0001	0.0004	<0.0001	0.0001
<i>E. rosaceus</i>	17.2807	12.6704	16.0363	17.1409	13.4117		0.0010	<0.0001	<0.0001
<i>E. trigonus</i>	39.5189	39.5756	38.9820	40.1891	37.6959	37.8430		0.0098	0.0499
<i>E. ventralis</i>	17.6742	18.8213	14.9132	14.1761	19.6990	22.4606	43.5855		<0.0001
<i>E. gibbosus</i>	17.8274	17.9080	14.8678	14.5506	18.9627	20.9286	42.9219	15.1717	
Procrustes distance (below) and <i>p</i> -value from permutation test for Procrustes distance among species (above)									
<i>E. aeneus</i>		<0.0001	<0.0001	<0.0001	0.0711	<0.0001	0.0184	<0.0001	<0.0001
<i>E. aenescens</i>	0.0811		<0.0001	<0.0001	<0.0001	<0.0001	0.0279	<0.0001	<0.0001
<i>E. annamita</i>	0.0475	0.0815		0.0739	<0.0001	<0.0001	0.0129	<0.0001	<0.0001
<i>E. guttiger</i>	0.0527	0.0886	0.0107		<0.0001	<0.0001	0.0384	<0.0001	<0.0001
<i>E. montivagus</i>	0.0311	0.0594	0.0304	0.0474		<0.0001	0.1118	<0.0001	<0.0001
<i>E. rosaceus</i>	0.0836	0.0506	0.1077	0.1153	0.0719		0.0269	<0.0001	<0.0001
<i>E. trigonus</i>	0.1111	0.1153	0.1488	0.1550	0.1176	0.0802		0.0227	0.0589
<i>E. ventralis</i>	0.0920	0.1350	0.0590	0.0520	0.0961	0.1623	0.1955		<0.0001
<i>E. gibbosus</i>	0.0841	0.0998	0.0412	0.0393	0.0769	0.1358	0.1081	0.0497	

Table 7S. Difference in the scutellum shapes among the species of *Eysarcoris*.

	<i>E. aeneus</i>	<i>E. aenescens</i>	<i>E. annamita</i>	<i>E. guttiger</i>	<i>E. montivagus</i>	<i>E. rosaceus</i>	<i>E. trigonus</i>	<i>E. ventralis</i>	<i>E. gibbosus</i>
Mahalanobis distance (below) and <i>p</i> -value from permutation test for Mahalanobis distance among species (above)									
<i>E. aeneus</i>		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0028	<0.0001	<0.0001
<i>E. aenescens</i>	6.2445		<0.0001	<0.0001	<0.0001	<0.0001	0.0259	<0.0001	<0.0001
<i>E. annamita</i>	7.0440	6.1107		<0.0001	<0.0001	<0.0001	0.0026	<0.0001	<0.0001
<i>E. guttiger</i>	10.4703	10.2177	7.5505		<0.0001	<0.0001	0.0293	<0.0001	<0.0001
<i>E. montivagus</i>	8.3429	6.5766	6.5094	9.5180		<0.0001	0.0148	<0.0001	<0.0001
<i>E. rosaceus</i>	6.4281	5.5122	6.5893	9.9521	5.4945		0.0028	<0.0001	<0.0001
<i>E. trigonus</i>	16.9493	18.1263	18.8734	20.7168	19.5190	18.2747		0.0256	0.0050
<i>E. ventralis</i>	6.7866	8.3776	7.7580	9.9738	9.0606	8.1372	18.5742		<0.0001
<i>E. gibbosus</i>	7.5105	7.4453	6.3188	9.4669	8.0068	5.7775	17.8806	7.9971	
Procrustes distance (below) and <i>p</i> -value from permutation test for Procrustes distance among species (above)									
<i>E. aeneus</i>		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0096	<0.0001	<0.0001
<i>E. aenescens</i>	0.0293		<0.0001	<0.0001	0.0002	<0.0001	0.0111	<0.0001	0.0001
<i>E. annamita</i>	0.0488	0.0317		<0.0001	<0.0001	<0.0001	0.0123	<0.0001	<0.0001
<i>E. guttiger</i>	0.0816	0.0662	0.0497		<0.0001	<0.0001	0.0398	<0.0001	<0.0001
<i>E. montivagus</i>	0.0474	0.0360	0.0303	0.0419		0.0024	0.0993	0.0073	0.0005
<i>E. rosaceus</i>	0.0356	0.0296	0.0409	0.0565	0.0198		0.0052	<0.0001	<0.0001
<i>E. trigonus</i>	0.0633	0.0741	0.0861	0.1275	0.0963	0.0891		0.0055	0.0097
<i>E. ventralis</i>	0.0344	0.0396	0.0430	0.0569	0.0264	0.0223	0.0887		<0.0001
<i>E. gibbosus</i>	0.0345	0.0249	0.0282	0.0598	0.0278	0.0261	0.0727	0.0312	