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Full Length Research Paper

Use of wing morphometry for the discrimination of some *Cerceris* (Insecta: Hymenoptera: Crabronidae species)

Serdar Yüksel[1] and Ayla Tüzün[2]*

[1]Ankara Dr.Zekai Tahir Burak Hospital Department of Genetics, Ankara, Turkey.
[2]Department of Biology, Faculty of Science, University of Ankara, Tandogan / Ankara 06100, Turkey.

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In this study, the wing morphology analyses of *Cerceris arenaria, Cerceris circularis dacica, Cerceris eryngii, Cerceris media, Cerceris quinquefasciata Cerceris ruficornis, Cerceris rybyensis* and *Cerceris sabulosa* (Philanthinae) species, were obtained from Niğde province between 2006 and 2008, by using discrimination, relative warp, Fourier and thin plate spline methods. The mean deviation graphics and values of prior wing vein characteristics which enable the differences in the discrimination analysis were presented by marking them on the wing pictures. Furthermore, the landmarks caused by the wing characteristics that enable variations were determined by using the relative warp analysis. The outline analysis, in which geometric and traditional morphometry potentials are insufficient, was performed by using the Fourier transformation. As a result of the comprehensive wing morphometry study, it was found that both *Cerceris* species can be distinguished according to their wing structures and the metric characteristics enabling this discrimination were identified. Within this context, a contribution to the *Cerceris* taxonomy was enabled by the use of obtained concrete results.

Key words: Niğde, apoid wasps, fauna, wing morphometry, discrimination, relative warp, Fourier, thin plate spline.

INTRODUCTION

Geometric morphometry was used for the discrimination of species, identification of the group variations, display of the evolutionary relations, discrimination of sexes and determination of the relationships between growth and figure (O'Higgins, 2000; Harda et al., 2000; Waleed et al., 2000; MacLeod, 2002; Rosas and Bastir, 2002; Claude et al., 2004; Kassam et al., 2004; Lieberman et al., 2004; Tatsuta et al., 2004; Bruner et al., 2005; Cardini and O'Higgins, 2005; Monteiro et al., 2005; Pretorius 2005; Schillaci et al., 2005; Bastir and Rosas, 2006; Crews and Hedin, 2006; Hiller et al., 2006; Pérez et al., 2006; Pizzo et al., 2006).

Nowadays, the definition of biometry is also used along with the definition of the morphometry. The researchers, who studied biometry in 1960's and 1970's, attempted to, determine the morphometric variations within a group and between the groups by using all of the possibilities of the multivariate statistical methods.

This approach is nowadays termed as traditional morphometry (Marcus, 1990; Reyment, 1991) or multivariate morphometry (Blackith and Reyment, 1971). Also, in this day and age, the traditional morphometry approach is applied by many researchers. Some studies conducted by Nagamitsu and Inoue, (1998), Sueli and Alves (2002), Lehmann et al. (2005), Arizaga et al. (2006), Francoy et al. (2006), Meixner et al. (2007) and Özkan et al. (2009) can be considered as examples of the traditional works.

In the traditional morphometry studies, generally using the length units, enumerations, angular values and ratios are also used. principal components analysis (PCA), canonic variation analysis (CVA), discrimination function analysis (DFA), and factor analyses can be presented as

*Corresponding author. E-mail: atuzun@science.ankara.edu.tr. Tel: +903122126720/1061or +905337741968.

the statistical method examples to be used in the traditional studies.

In this study, the discrimination of some species of the genus *Cerceris* latreille, 1802 was aimed by using all the possibilities of the geometric and traditional wing morphometry. Moreover, the outline analysis, a situation in which traditional and geometrical morphometry methods cannot be performed, was realized with Fourier transformation. As a result of the study, measuremental wing characteristics were identified by combining the results obtained by geometric and traditional morphometry methods.

MATERIALS AND METHODS

Wing morphometry method

The samples obtained from the land were prepared by taking out their fore wings. The wings were located on the lamina over which Canadian balsam was dribbled. The wing was suitably stretched and its upper surface was covered with 20 × 20 mm lamella by removing the air bubbles inside it. The preparations derived by using the abovementioned methods, were left on to dry at room temperature. The photographs of the samples were taken by using Leica macro microscope system. The photographs were saved with the use of a computer in JPEG (joint photographic expert group) format, 24 bit depth and high resolution with 150 dpi 2088 x 1552 pixel dimensions. In the traditional morphometry study, the binary data at A(x, y) form were transformed into single dimensional data by calculating the length, angle and ratios between the landmarks. In the geometric study however, the landmark approach was applied. The procrustes superimposition method was used for the standardization of the landmarks. The geometric morphometry method, respectively, consists of the phases: the list of the photographs to be used in the TPSutil software was created (Rohlf, 2006). The photograph lists were run over in the TPSdig software and the landmark measurements were respectively performed (Rohlf, 2003). The landmark data, obtained as a consequence of the measurements, at the TPS format were standardized with CoordGen6f (Sheets, 2001). The discrimination function analysis was performed by using CVAGen6o.

Statistical analyses

Superimposition

The most developed method for the standardization of the coordinate data obtained from the landmark markings is the procrustes method. This method is based on the smallest square estimation of the translation, rotation and scaling parameters that includes the sorted sets of the landmark coordinates for the sample pair (Özden, 2008). For the application of this method, CoordGen6f (Sheets, 2001), among the IMP series software, was utilized. Within the scope of this thesis, generalized procrustes analysis (GPA) was used for the translation and rotation of each sample. The samples were individually scaled and their landmark coordinations were transferred to the general coordinate system (superimposition). Thus, the landmark coordinate differences caused by several figure configurations were surpassed and the landmark coordinate data were standardized before the application of the relative warp analysis. The GPA method, on the other hand, exists inside the TPSRelw software (Özden, 2008).

Thin plate spline

Thin plate splines (grates) enable the comparison of the groups according to the position of the landmarks. It attempts to define the variation between the groups by displaying on which landmarks the deformation intensifies (Özden, 2008). In this study, figure differences of the fore wings belonging to different *Sphecidae* species were reflected on the thin plate splines by using the TPSspline (Rohlf, 2005b) program and the points in which the differences were sourced from was revealed accordingly.

Relative warp

Relative warps are displayed with the data obtained from the wings by using an orthogonal sequential projection method. The consensus configurations, variations and relative contributions of the landmarks are determined by means of relative warp analyses (Özden, 2008). The relative warp analysis in this study was actualized by using TPSrelw program (Rohlf, 2005a).

Discrimination function analysis (DFA)

This is also known as multi dimensional discrimination analysis. When it happens in PCA, it reveals the distribution of the groups in relation with the correlation between the characters. Differing from PCA, the species are grouped before the analysis.

In DFA analysis, the differences between the groups are increased, while the differences within them are decreased; thus, axes, which do not display correlation in the linear plane inside the new space, are obtained or Eigen vectors are normalized, while the distribution of the groups inside the space are evaluated, accordingly (Özden, 2008).

In other words, the results of the analysis show that the distribution of the groups, were displayed on a two dimensional plane in the form of graphics. CVAGen6o and SPSS package program were used for the DFA analysis. Before the discrimination analysis, the covariance matrix equivalences were evaluated by using Box M test. The multivariate relation problems between the variables were determined by calculating the correlation matrixes. The variables that show high correlation were removed from the analysis.

Wilks' lambda statistics, in the discrimination analysis, display the ratio of the total variance in the discrimination scores that could not be explained with differences between the groups (Cengiz, 2008). The condition of the Wilks' lambda value being very close to zero is an indication that, mean values of the group were totally different (Oğuzhan and Aydin, 2000). It was determined whether the distinctive functions of abovementioned Wilks' lambda statistics, at the significance level of Barlett's chi-square statistics, were significant or not. Within this scope, the discrimination functions with p value < 0.05 were accepted as significant.

The higher value of the degree existing between the canonic correlation coefficient and abovementioned discrimination function show that, it has the ability to discriminate the groups. The condition of having a lower value of coefficient is an indication that the discrimination function has a very low ability or no ability of discriminating the groups (Oğuzhan and Aydin, 2000). The square of the canonical correlation value of the discrimination function display which percentage of the variance for the related variable can be explained by using the discrimination function (Cengiz, 2008). The ratio or percentage of the variances corresponds to the percentage of total change between the groups for the discrimination functions (Oğuzhan and Aydin, 2000). In this study, the canonic correlation coefficients of 0.7 or higher, were accepted as high values.

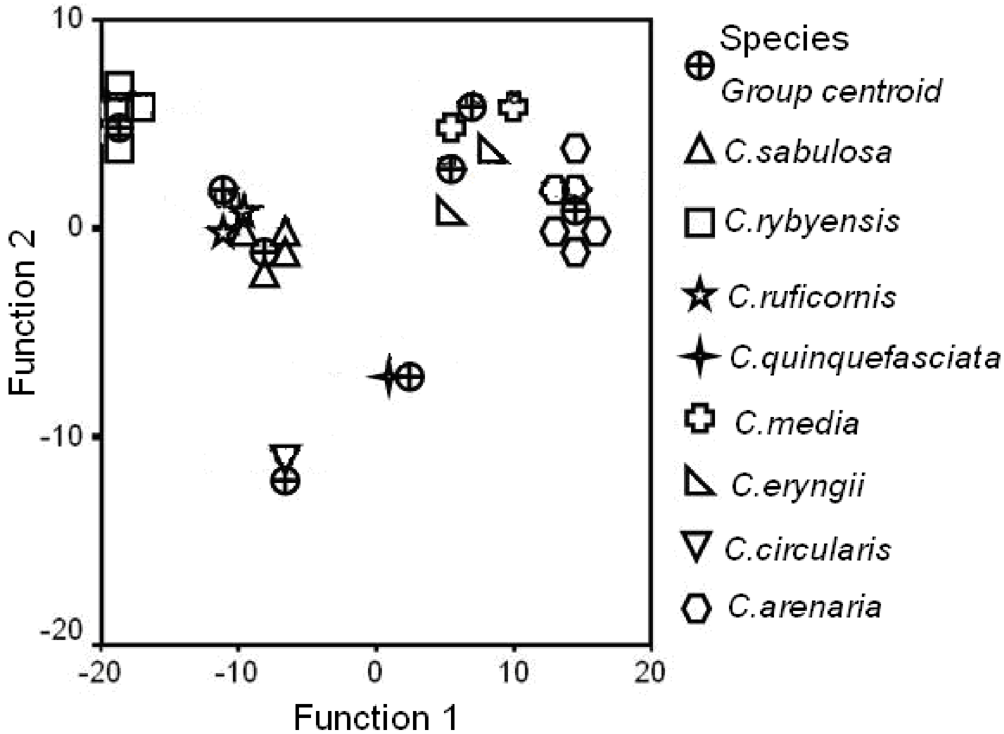


Figure 1. Discrimination analysis graphic of *C. sabulosa*, *C. rybyensis*, *C. ruficornis*, *C. quinquefasciata quinquefasciata*, *C. media*, *C. eryngii*, *C. circularis dacia* and *C. arenaria*.

Table 1. Eigen values and Wilks' lambda statistics of the *Cerceris* species.

Function	Eigen Value	% of the variance	Cumulative (%)	Canonic correlation
1	187.142	78.1	78.1	0.997
2	28.403	11.8	89.9	0.983
Test of the function	**Wilks' Lambda**	**Chi-square**	**Open % variance**	**Significance**
1	0.000	211.958	99.4	0.000
2	0.000	141.256	96.6	0.040

Factor analyses

The factor analysis was performed by using PCA (principle component analysis) technique. In this study, vectors that define the maximum change between the groups were calculated. These vectors provide convenience for the discrimination of the groups. Kaiser-Meyer-Olkin (KMO) test was used in order to determine the suitability of the data set for the Factor analysis.

RESULTS

As a result of the traditional wing morphometry study, it can be observed that the first discrimination analysis, conducted by using the wing morphometry data on some *Cerceris* species, placed *C. rybyensis* in the first group, while it placed *C. sabulosa, C. ruficornis* and *C. circularis* dacia in the third group. *C. quinquefasciata quinquefasciata* was placed in the fourth group*, C. media, C. eryngii*, and *Cerceris arenaria* were placed, respectively, in groups 5 and 6. Second function, on the other hand, placed these species in the same groups like the first function and moreover, it discriminated *C. sabulosa, C. ruficornis, C. media,* and *C. eryngii* species from each other (Figure 1).

The Eigen values, for calculated discrimination functions were found, respectively, as 187.142 and 28.403 in the first and second functions. When Table 1 is evaluated, it can be observed that there exist two significant discrimination functions calculated for eight species. The first function obtained explains 99.4% of the variance, while the second function explains 96.6% of it.

When Wilks' lambda statistics are evaluated in Table 1, the significance level is 0.000 and 0.04 for the first and second functions, respectively. Wilks' lambda value, on

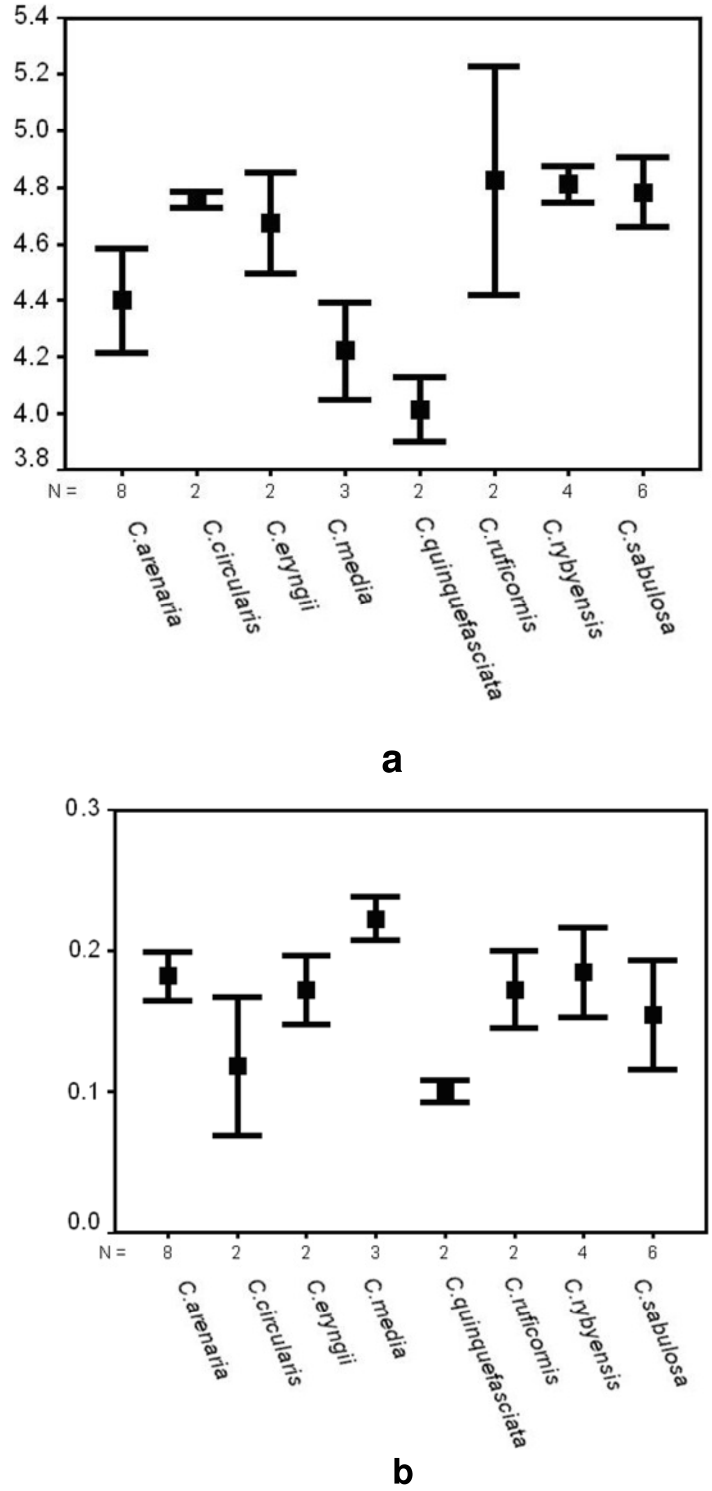
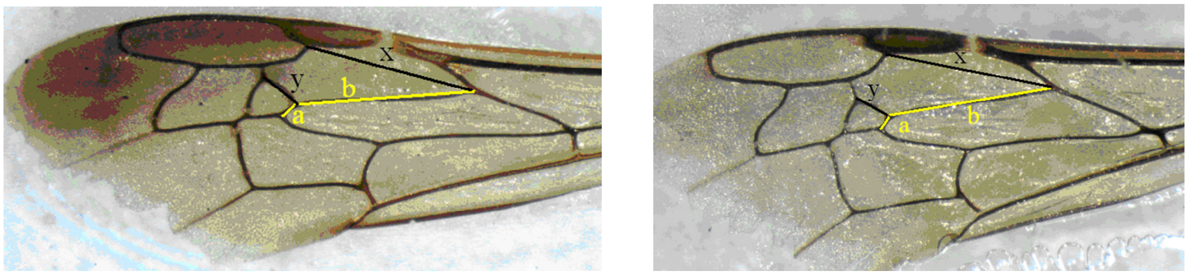


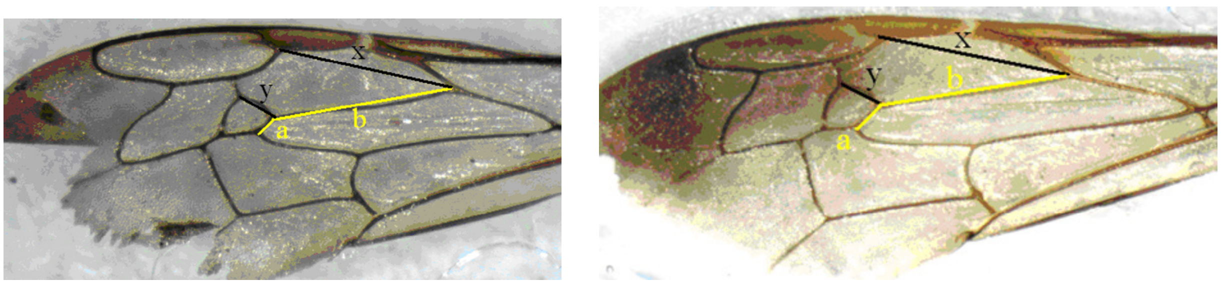
Figure 2. Mean and standard deviation graphics of (a) x/y; (b) a/b ratios for *Cerceris* species.

the other hand, is 0.000 for the first function, while the second function calculated the value again as 0.000. Within this context, 0% of the total variance could not be explained by the differences between the groups for the first and second functions. The graphics belonging to x/y (Figure 2a) and a/b (Figure 2b) ratios are presented as follows: the x/y ratio (2r + stigmal vein / Submarginal II. Medial - anterior vein) values (Figure 2a) were found as



A B

Figure 3. Fore wing of *C. arenaria* (A) and *C. circularis dacia* (B).



A B

Figure 4. Fore wing of *Cerceris eryngii* (A) and *C. media* (B).

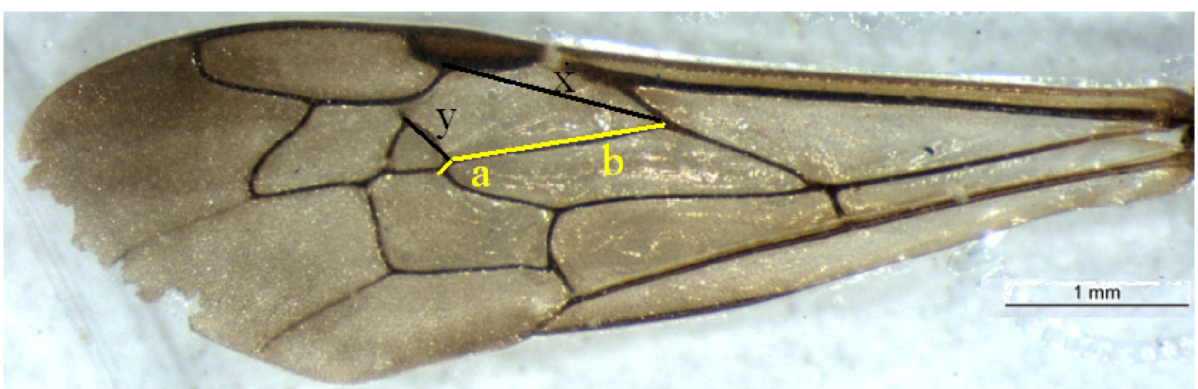


Figure 5. Fore wing *of C. quinquefasciata quinquefasciata.*

4.3996 ± 0.2628 (n = 8) in *C. arenaria* (Figure 2a); as 4.7560 ± 0.0198 (n = 2) in *C. circularis dacia* (Figure 4b); as 4.6740 ± 0.1272 (n = 2) in *C. eryngii* (Figure 4a); as 4.222 ± 0.1494 (n = 3) in *C. media* (Figure 4b); as 4.0150 ± 0.0806 (n = 2) in *C. quinquefasciata quinquefasciata* (Figure 5); as 4.8235 ± 0.2849 (n = 2) in *C. ruficornis* (Figure 6); as 4.8108 ± 0.0651 (n = 4) in *C. rybyensis* (Figure 7); 4.7822 ± 0.1486 (n = 6) in *C. sabulosa* (Figure 8). It was observed that, x/y ratio finely distinguished *C. circularis*, *C. quinquefasciata* and *C. arenaria* from each other, while this ratio displayed values that are very close to each other for *C. rybyensis*, *C. sabulosa*, *C. ruficornis* and *C. circularis dacia* species and subspecies. The ratio of a/b (submarginal II. medial vein/ discoidal I. RS + M vein) values (Figure 2b) were calculated as 0.1116 ± 0.0172 (n = 8) in *C. arenaria* (Figure 2a); as 0.0760 ± 0.2121 (n = 2) in *C. circularis dacia* (Figure 3b); as 0.1140 ± 0.0141 (n = 2) in *C. eryngii* (Figure 4a); as 0.1617 ± 0.0136 (n = 3) in *C. media* (Figure 4b); as 0.0650 ± 0.0000 (n = 2) in *C. quinquefasciata quinquefasciata* (Figure 5); as 0.1055 ± 0.0049 (n = 2) in *C. ruficornis* (Figure 6); as 0.1170 ± 0.0281 (n = 4) in *C.*

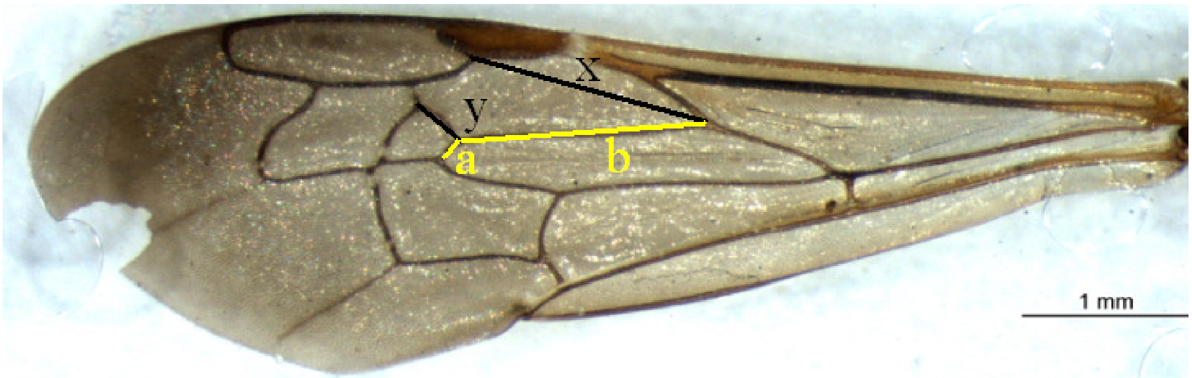


Figure 6. Fore wing of *C. ruficornis*

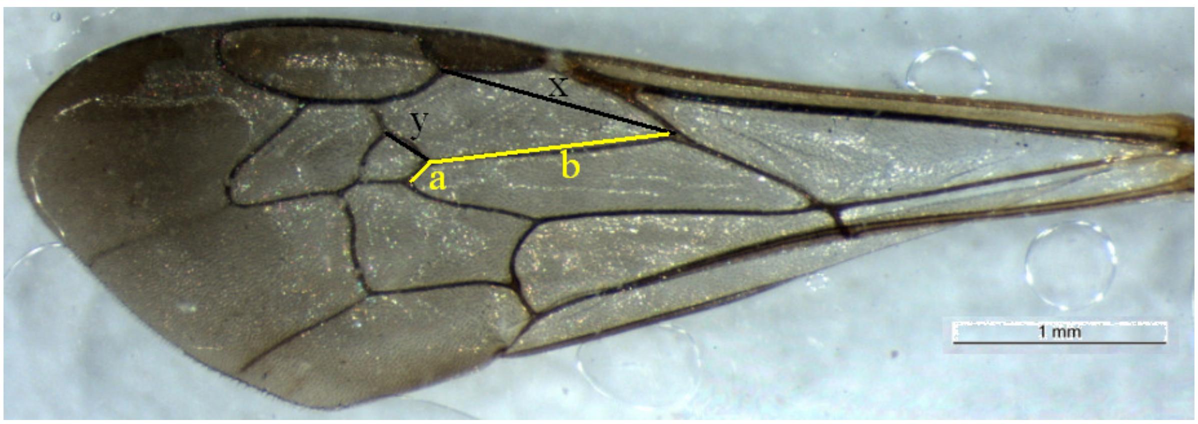


Figure 7. Fore wing of *C. rybyensis.*

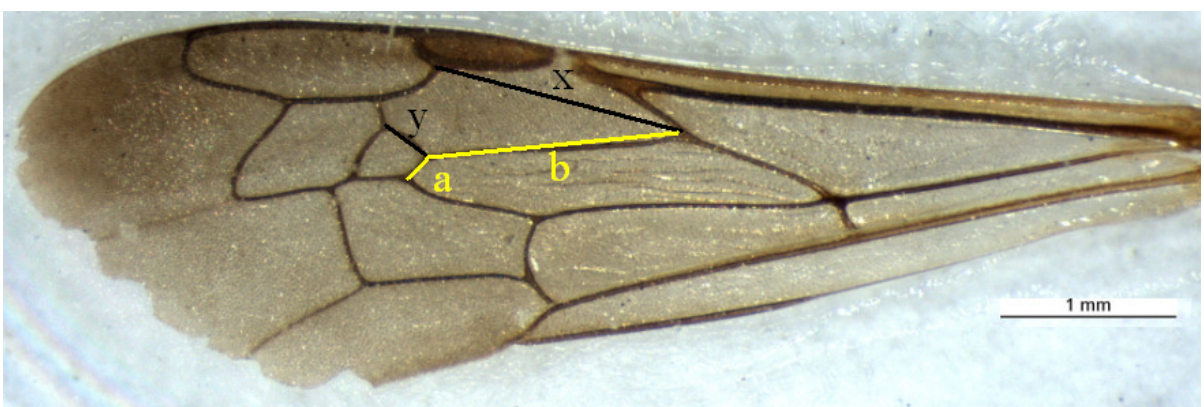


Figure 8. Fore wing of *C. sabulosa.*

rybyensis (Figure 7); as 0.0990 ± 0.0317 (n = 6) in *C. sabulosa* (Figure 8).

The ratio of a/b distinguished *C. arenaria*, *C. circularis dacia*, *C. media* and *C. quinquefasciata* species from each other. This value was found very close to the species of *C. eryngii* and *C. ruficornis*.

For the *Cerceris* species and subspecies, in which geometric wing morphometry methods were applied, the Eigen values were calculated as 11957.4040 in the first function (X axis), while they were 207.4837 in the second function (Y axis). For the first function, the values for Wilk's lambda, chi square SD and significance was calculated respectively, as 0.0000, 320.2463, 140 and 3.33067e-016; Wilks' lambda chi square SD and significance values occurred respectively, as 0.0000, 188.7977, 114 and 1.33496e-005 for the second function and for the third function; the values for Wilks' lambda, chi square SD. and significance were calculated as 0.0003, 114.0396, 90 and 0.0443793, respectively. The calculated discrimination analysis functions were statistically significant and its Eigen values were high. As can be seen from the discrimination analysis graphics in Figure 9, the discrimination function classified eight *Cerceris* species into five groups. *C. circularis dacia* falls into the first group; *C. sabulosa* and *C. ruficornis* fall into the second group; *C. rybyensis, C. arenaria* and *C. quinquefasciata quinquefasciata* are located in the third group; *C. media* and *C. eryngii* species fall into the fourth and fifth groups, respectively. Second function on the other hand, distinguished *C. sabulosa* and *C. ruficornis* species, which fall into the second group and *C. rybyensis*, *C. arenaria* and *C. quinquefasciata quinquefasciata* species, fall into the third group, from each other (Figure 9). *C. ruficornis* and *C. sabulosa* species, which could not be distinguished from each other in the traditional wing morphometry discrimination analysis graphics; were also placed at close coordinates in the geometric morphometry discrimination analysis.

Therefore, since their discrimination could be difficult by using both methods, their discrimination was enabled by using another morphometry method; the outline method. In the outline method, applied for the discrimination of these two species, elliptical Fourier transformation data were used. As the statistical method, the results of the factor analysis (principal component analysis), applied by using Fourier transformation data (Figure 10) are presented further (Figure 11).

When the PCA graphics presented in Figure 11 is evaluated, it can be observed that the first PCA functions that are calculated for the discrimination of *C. sabulosa* and *C. ruficornis* from each other were also used. First, second and third functions correspond to X, Y and Z functions, respectively. The polar coordinates of these two species used in the outline method were distinguished from each other according to the results of PCA statistics performed by using Fourier transformation data (Table 2).

The fore wing figure variations of species of *Cerceris* were reflected on the thin plate spline and the points in which the deformations intensified were revealed by using tpspline program.

First and second functions of the geometric (Figure 9) and traditional (Figure 1) morphometry discrimination analyses finely distinguished the *Cerceris* species from each other.

It was observed that, the discrimination strength of the traditional morphometry analysis was lesser than the geometric morphometry. The Eigen values of the geometric morphometry analysis were higher, while the analysis had lesser significance values than the traditional one. This condition can be accepted as a statistical indicator that, the geometric morphometry analysis performed a better discrimination for the *Cerceris* species.

It was found out that the x/y ratio (2r + stigmal vein / submarginal II. Media- anterior vein) (Figure 2a) finely distinguished *C. circularis*, *C. quinquefasciata quinquefasciata* and *C. arenaria* from each other. The ratio of x/y is related with the fourth, fifth, tenth and fourteenth landmarks. It was observed that, the relative contribution of the fourth, fifth and fourteenth landmarks were low. Therefore, it can be stated that, x/y proportional variance was caused by tenth landmark (Table 3).

On the other hand, the ratio of a/b (submarginal II. medial vein / discoidal I. RS + M vein) (Figure 4b), distinguished *C. arenaria*, *C. circularis, C. media* and *C. quinquefasciata quinquefasciata* from each other. The a/b ratio was related with ninth, tenth and fourteenth landmarks.

The relative contributions of nineth and tenth landmarks to the RW analyses were at high levels, while the contribution of fourteenth landmark is less. Therefore, fourteenth landmark can be accepted as the reference point for x/y ratio (Table 3).

The deformations at thirth fourth and sixth landmark regions do exist in such a way that it could directly effect the ratios x/y and a/b (Figure 12).

It was observed that, the results of traditional and geometric morphometry methods are in harmony. According to the results obtained from the traditional morphometry analyses, the ratios of a/b and x/y can be used for the discrimination of most evaluated *Cerceris* species. Landmarks, which are decisive for the ratios of a/b and x/y, displayed high relative contributions and deformations also in the RW analysis and thin plate spline methods. Within this scope, geometric and traditional morphometry methods can be stated to be in harmony both for the discrimination analyses and definitive (angle, ratio, length, landmark irregularities and deformations) analyses.

For the discrimination of *C. ruficornis* and *C. sabulosa*, which were positioned at close locations in the traditional morphometry analysis, submarginal II cell periphery elliptical Fourier transformation analysis was performed. Submarginal II cell had a different appearance in both species.

If there exists a requirement for displaying this difference statistically, then it would not be possible by using traditional (length, angle, ratio) and geometric (landmark) morphometry approaches. In order to define the structures with no distinctive geometric shapes, polar coordinates or elliptical Fourier transformation should be used.

The first 3 basic elements, which are calculated by PCA statistics performed by using the elliptical Fourier transformation data, discriminate these two species, according to the shape of the submarginal II cell periphery on the 3 dimensional graphics (Figure 11).

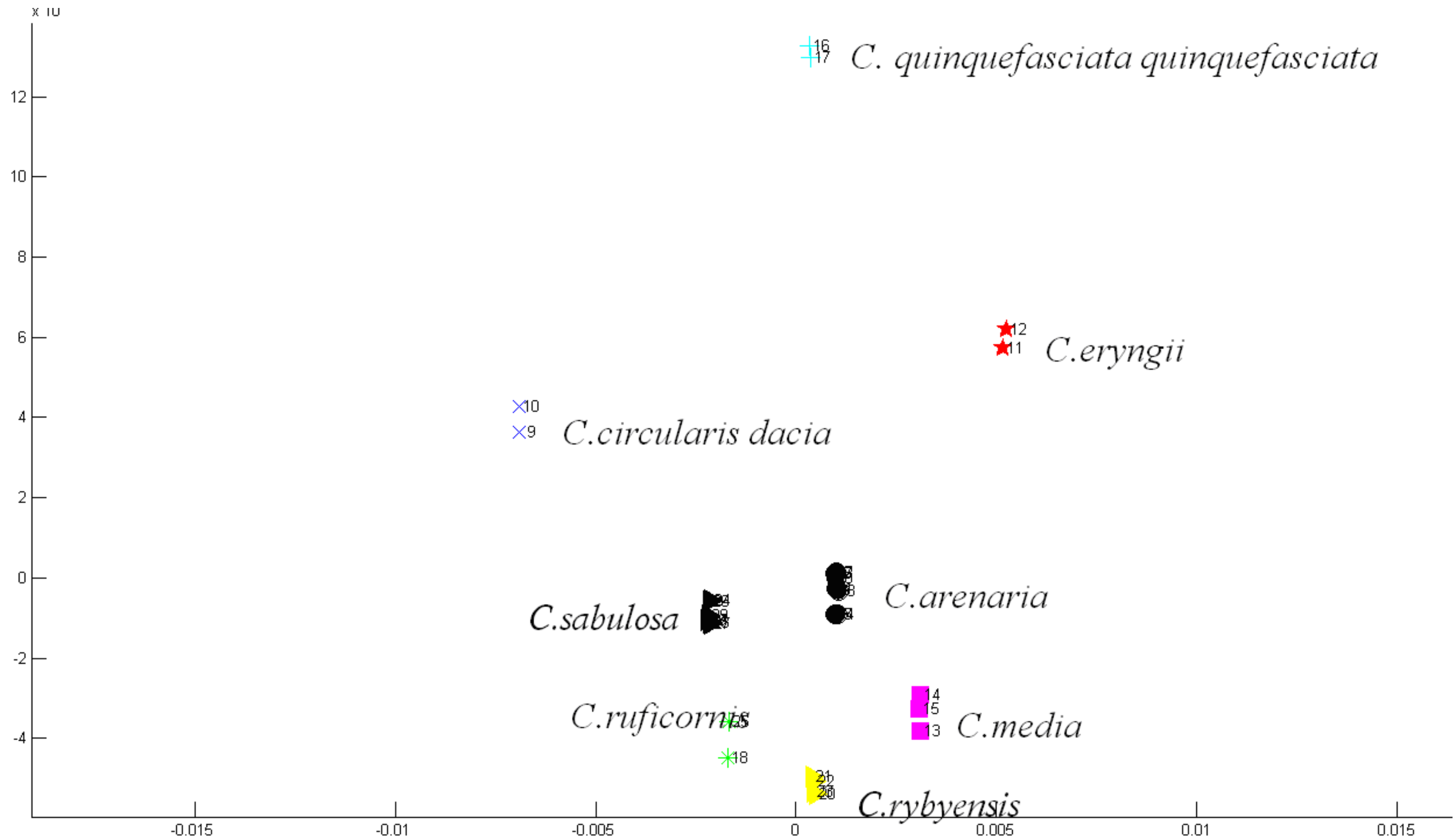


Figure 9. Geometric morphometry discrimination analysis graphic for *Cerceris* species and subspecies.

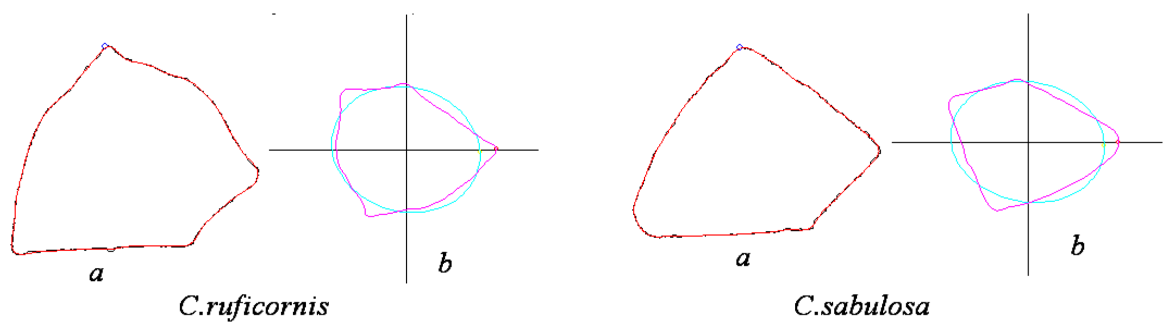


Figure 10. (a) Original structure of submarginal II cell periphery; (b) elliptical Fourier transformation of the original structure.

DISCUSSION

When the results obtained from this study were compared with the other studies, it was observed that, traditional wing morphometry was used for the discrimination of *Cochliomyia hominivorax* ve *Cochliomyia macellaria* (Diptera: Calliphoridae) (Lyra et al., 2010), *Anopheles* subspecies of *Nyssorhynchus* (Diptera: Culicidae) (Calle et al., 2002) and species of the genus *Liriomyza* (Diptera: Agromyzidae) (Shiao, 2004). For the discrimination of *Rhagoletis pomonella* and *Rhagoletis zephyria* (Diptera: Tephritidae) (Yee et al., 2009), geometric wing morphometry was used. The only study on Sphecids, in which discrimination of species is enabled, conducted by using wing morphometry belongs to Tüzün (2009). In that study, wing morphometry was applied for the discrimination of species of the genus *Sphex* Linnaeus where successful results were obtained. The wing morphometry practice to which the traditional method used within the study best corresponds can be

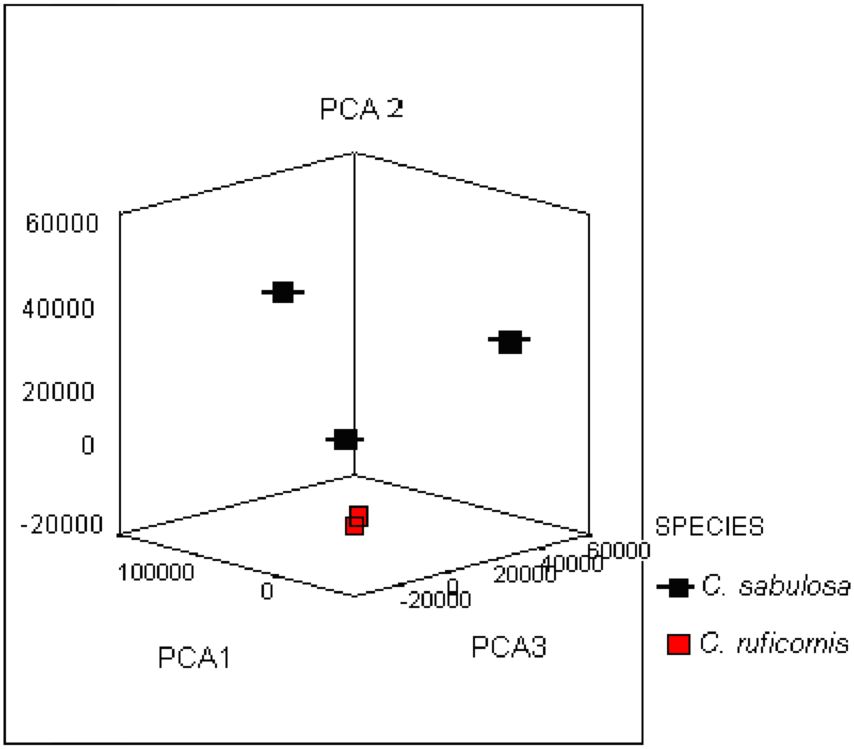


Figure 11. PCA graphic of the elliptical Fourier transformation data belonging to the submarginal II cells of *C. ruficornis* and *C. sabulosa*.

Table 2. Eigen value statistics of the elliptical Fourier transformation.

PCA function	Eigen value	% of the variance	Cumulative (%)
1	3.44E-03	63.0694	63.0694
2	9.89E-04	18.1151	81.1845
3	8.99E-04	16.4673	97.6518
4	1.28E-04	2.3482	100

Table 3. Relative contribution and variations of 14 landmarks belonging to the fore wings of *Cerceris* species.

Landmark number	Relative warp	Landmark variance
1	0.00067	0.00038933
2	0.00632	0.00015491
3	0.02431	0.00009997
4	0.03896	0.00011365
5	0.02012	0.00025168
6	0.00316	0.00013497
7	0.18344	0.00011370
8	0.30863	0.00010599
9	0.22293	0.00011326
10	0.17792	0.00008844
11	0.00407	0.00017306
12	0.00847	0.00011192
13	0.00013	0.00012684
14	0.00086	0.00015519

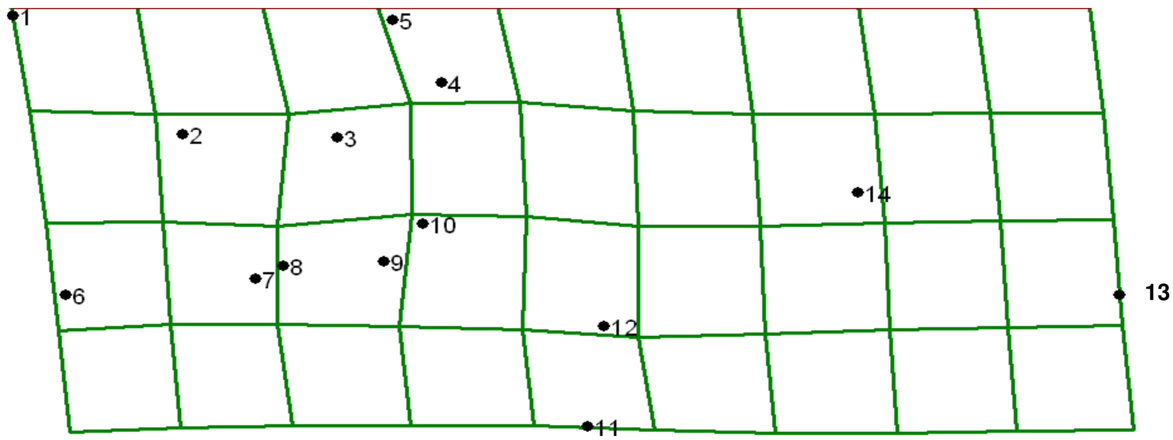


Figure 12. Thin spline plate graphics for the species belonging to the genus *Cerceris*.

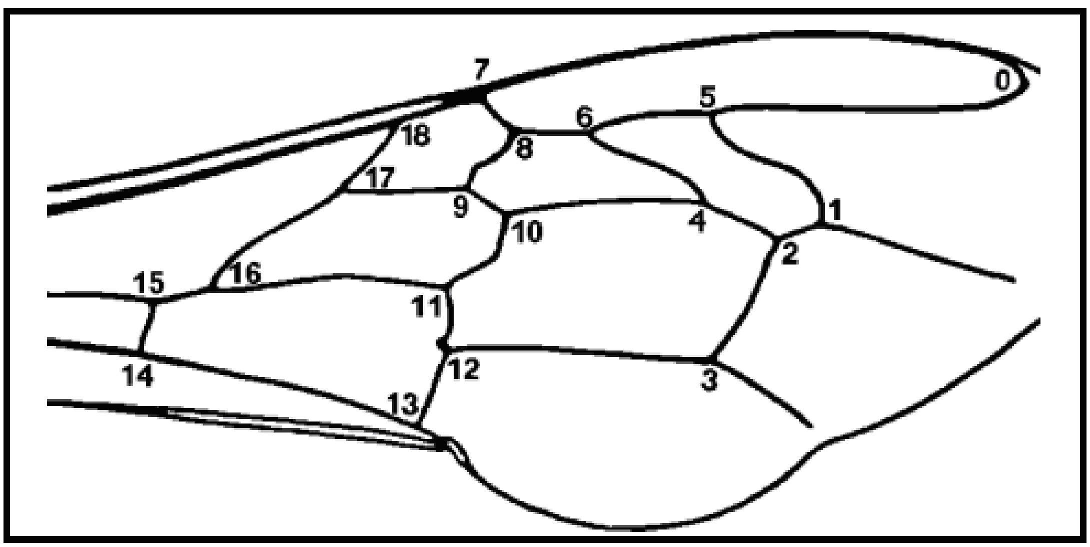


Figure 13. Fore wing landmarks of the significant wing characteristics in the honeybee *Apis mellifera Linnaeus*.

stated as the traditional wing morphometry that enables the practical discrimination of the honeybee (*Apis* sp.) by using the wing angle, ratio and length values. The wing characteristics of honeybees, according to Ruttner (1988) and Nazzi (1992) are angle, length and ratio (discoidal shift, cubital 2;4/1;2, precubital 4;9/8;10, dumb-bell 1;4/5;6) values (Figure 13). These values were used in many studies about the honeybees (Gençer and Firatli, 1999; Özkan et al., 2009). In this respect, they can be stated as being significant morphometric characters. Since no sufficient studies exist regarding the wing morphometry of crabronids, the results obtained within this study cannot be compared with any previous study. If there is to be a comparison, the wing characteristics of honeybees, which is the most compatible among the existing studies, can be used. Nonetheless, among the landmarks that are related to these values, the ones related to 7, 15 and 18 were not included in the analysis, considering that there might be problems regarding the marking of the crabronid wing. Likewise, to decrease the marking errors to minimum, angular values belonging to some cells were also not included in the analysis. Consequently, the most constant characters which can be applied on the analysis of crabronids, among the wing characters that are used for *Apis* sp., were found as; discoidal shift angle, angle (2-5-6) B3 1;4;3, angle (5-6-11), D7 4;3;13, angle (6-11-12) G18 12;13;14, angle (12-17-18), length A 2;4, U(6-7) B 1;2, U(5-6), D 11;15, ratio cubital index, hantel index, and dumb-bell 1;4/5;6 ratio (2-3/5-6) values.

These *Apis* species wing characteristics, in the literature, were found not to be effective on the discrimi-

Table 4. Discriminative wing morphometric characteristics of the examined *Cerceris* species.

Species	x/y (2r + stigmal vein / submarginal II. medial – anterior vein) ratio		a/b (submarginal II. medial vein / discoidal I. RS + M vein) ratio	
	Mean	Standard deviation	Mean	Standard deviation
Cerceris arenaria	4.399	0.2628	0.1116	0.0172
Cerceris circularis dacia	4.756	0.0198	0.076	0.2121
Cerceris eryngii	4.674	0.1272	0.114	0.0141
Cerceris media	4.223	0.1494	0.1617	0.0136
Cerceris quinquefasciata quinquefasciata	4.015	0.0806	0.065	0
Cerceris ruficornis	4.823	0.2849	0.1055	0.0049
Cerceris rybyensis	4.81	0.0651	0.117	0.0281
Cerceris sabulosa	4.782	0.1486	0.099	0.0317

nation of *Cerceris* species. The wing characteristics which were effective are presented in Table 4.

This study can be evaluated in relation with the wideness of its scope, as the first study in which both traditional and geometric morphometry methods are applied on the same sample group. In this sense, the evaluation of both methods was enabled within the scope of the study. The significance values of Wilks' lambda statistics and the values belonging to the calculated discrimination functions were used during this evaluation. Stepwise discrimination analysis definitive statistics used in the traditional morphometry studies, enabled the determination of the most effective characteristics in the discrimination of the groups. These characteristics are presented *en masse* in Table 4. In this context, not only the enablement situation of wing characteristics regarding the discrimination of species was determined, but also the deterministic characteristics that have distinguishing features that were identified. It is considered that the use of only these characteristics without using any other morphometry method, would contribute to the discrimination of the species from each other. The wing morphometry characteristics presented in Table 4 consist of three landmarks of angle, four landmarks of ratio and two landmarks of length. The geometric morphometry method does not present any information about angle, ratio or length values. On the other hand, it was revealed with the relative warp analysis, the landmark/landmarks were more effective than the others on determining the identified values for angle, ratio and length.

Consequently, this study is the first in which traditional and geometric morphometry methods are compared comprehensively. By using descriptive statistics belonging to the traditional morphometry method, it was possible to confirm and support the distinctive characteristics (Table 4). Differing from the other morphometry studies, geometric and traditional morphometry methods supported each other and accordingly, their deficiencies were attempted to be overcome in this study. It can be stated within this context that, the results of geometric and traditional morphometry methods were optimally combined. As a conclusion, it is suggested that the concurrent use of both methods would be most compatible in the morphometry studies.

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