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Systematical studies on the species of the subgenus *Bombus* (*Thoracobombus*) (Hymenoptera: Apidae, *Bombus* Latreille) in Turkey

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Abstract

The aim of this study was to analyze the 12 species which belong to the subgenus *Bombus* (*Thoracobombus*) by identifying, collating and testing the applicability of geometrics morphometrics for distinguishing the species. This was carried out on 133 females and 42 males which were collected from various localities in Turkey. After digitizing landmarks on the right fore wings, 2-dimensional Cartesian coordinates were calculated and by Procrustes analysis the coordinates were standardized and superimposed. Principal Components Analysis (PCA) and Canonical Variates Analysis (CVA) were performed to show the distribution of all species. Then, deformations which appeared in thin-plate splines were observed. Mean values of all the specimens were calculated and Sequential, Agglomerative, Hierarchical, and Nesting clustering method (SAHN) was performed with these data to obtain the dissimilarity trees. It can be concluded that all species were found to have consistently different wing shapes from each other. In females, the species *B. armeniacus*, *B. mesomelas* and *B. pomorum* which resemble each other, were also found to be similar based on their wing morphometry. Both in females and males, the subspecies *B. sylvarum citrinofasciatus* and *B. sylvarum daghestanicus* and the species *B. humilis* and *B. laesus* exposed high similarity in wing morphometry. In males, results showed that the species *B. armeniacus* and *B. mesomelas* and the species *B. humilis* and *B. zonatus* have very similar wing shape.

Keywords: Bumble bees, Systematics, Geometric morphometrics, Principal Components Analysis, Canonical Variates Analysis

Introduction

Bumble bees have always been of interest to biologists' as they are large, colorful and can be found in temperate regions where biologists are mostly active (Williams 1994). They are widely distributed especially in alpine, subalpine, temperate and arctic zones of the Palaearctic, Nearctic, Oriental and Neotropic regions of the world (Williams 1994, Cameron and Williams 2003, Hines 2008). Bumble bees are considered efficient pollinators as they are active foragers even at low temperatures where honey bee activity is limited (Free, 1993). As they have a crucial role in the pollination of many native and cultivated plant species, bumble bees are being commercially produced and are used in greenhouses (Free 1993, Hines et al. 2006).

It is estimated that there are over 250 species of *Bombus* (Williams et al. 2008) and with 47 species, Turkey is considered to be one of the countries with the highest species richness in the West-Palaearctic region (Aytekin et al. 2007, http://zoologie.umh.ac.be/hymenoptera/page.asp?id=103). In order to ease the relationships between the species of bumble bees in *Bombus*, a commonly used system based entirely on morphology was adopted a century ago (e.g., Dalla Torre 1880, Radoszkowski 1884, Robertson 1903, Vogt 1911, Skorikov 1914, 1923, Krüger 1920, Richards 1968). According to this classification, *Bombus* (*Thoracobombus*) was considered a subgenus of the genus *Megabombus* (Aytekin 2002). However, this subgeneric system of bumble bees was found to be rather complicated. This has generated a need to simplify the previously adopted system. According to a newly proposed subgeneric classification, it is suggested that *B.* (*Thoracobombus*) should be studied as one of the 15 main subgenera. As a consequence of this reduction, *B.* (*Tricornibombus*), *B.* (*Exilobombus*), *B.* (*Fervidobombus*), *B.*

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in females, it was found out that *B. sylvarum citrinofasciatus* and *B. sylvarum daghestanicus* coincided with each other. In the UPGMA tree, *B. armeniacus* and *B. mesomelas*; *B. humilis* and *B. zonatus*; and finally *B. sylvarum citrinofasciatus* and *B. sylvarum daghestanicus* were clustered together. *B. humilis* and *B. zonatus* had also formed a cluster in a previous study by Aytekin and Çağatay (2004) where electrophoretic analysis was performed. The species *B. armeniacus*, *B. mesomelas* and *B. pomorum* which resemble each other in showing similar color patterns, were also found to be similar based on their wing morphometry in females. The same cluster was seen in the Bayesian tree based on five different gene sequences (Cameron et al. 2007). The species *B. humilis* and *B. laesus* exposed similar wing morphometry. In males, the species *B. armeniacus* and *B. mesomelas* and the species *B. humilis* and *B. zonatus* showed similar wing morphometry. Both in females and males, the subspecies *B. sylvarum citrinofasciatus* and *B. sylvarum daghestanicus* also showed similar wing morphometry. But to make a decision on their status, a comprehensive study including all subspecies of this species is needed.

In summary, this study revealed promising results for the use of geometric morphometrics in the analyses of *B.* (*Thoracobombus*). All species formed distinct groups concluding that geometric morphometrics is capable of separating and identifying these species. According to the PCA and CVA graphs, species clustering together were mostly close species with similar morphology. Further studies which would integrate geometric morphometrics with molecular methods would help enlighten the relationships within the subgenus.

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