

Geometric morphometric analysis of honey bee (*Apis mellifera* L.) subspecies distributed in Turkey

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Honey bee subspecies in Turkey include the subspecies *Apis mellifera anatolica*, *A. m. caucasica*, *A. m. meda*, *A. m. syriaca* and *A. m. carnica* which were revealed by traditional morphometric and genetic studies. In this study, we used a new methodology “geometric morphometric” in order to discriminate honey bee subspecies from different geographic regions in Turkey.

A total of 191 colonies evaluated from different subspecific distributional areas in Turkey. All colonies were described by means of 10 workers and 20 type I landmarks (venation intersections) on the fore wings were identified. Landmarks were digitized by using tpsDIG to obtain 40 x, y cartesian coordinates. Landmark configurations were scaled, translated and rotated against the consensus configuration by GLS procrustes superimposition method. After superimposition the aligned landmark coordinates were used as a data set for assigned subspecies groups and Multivariate Analysis of Variance and Pairwise tests were applied using Morpheus. Geometric morphometric data were also used as the data set for discriminant function analysis and UPGMA cluster analysis based on Mahalanobis distances. Differences in wing shape among different honey bee groups were also visualized by deformation grids using Thin Plates Splines. 33 out of 40 cartesian coordinates of landmarks, displayed statistical significant differences among proposed grouping ($P < 0.05$). MANOVA result demonstrated that subspecies were significantly different for individual and colony consensus average wing shapes ($P < 0.001$) In the discriminant analysis, colonies of Aegean region, colonies of Thrace region, colonies of North-East Anatolia region were clearly separated from other groups. However, colonies of Central Anatolia region and colonies of South-east Anatolia region showed overlapping. Pairwise resulted in a similar findings honey bee groups except colonies of Central Anatolia region and colonies of South-east Anatolia region were found to be statistically different each others ($P < 0.001$). Total shape variation was explained in 4 axis. The contribution of the first, second, third and fourth axes were 47.7%, 29.9%, 17.0% and 5.3% respectively. All honey bee groups were correctly classified 82.7% to their original groups. Discriminant function analysis of subspecies were also supported by the UPGMA clustering based on Mahalanobis distances.