Sociobiology 70(3): e8333 (September, 2023) DOI: 10.13102/sociobiology.v70i3.8333

Sociobiology
An international journal on social insects

RESEARCH ARTICLE - BEES

Determination of Anatolian Honeybee Biodiversity by Wing Characters

Meral Kekeçoğlu[1,4], Songül Bir[2], Merve Kambur Acar[3]

1 - Düzce University, Faculty of Science, Department of Biology, 81620 Düzce, Turkey
2 - Düzce University, Institute of Science, Department of Biology, 81620 Düzce, Turkey
3 - Düzce University, Düzce Vocational School, Beekeeping Program, 81620 Düzce, Turkey
4 - Düzce University, Beekeeping Research Development and Application Centre (DAGEM), 81620 Konuralp, Düzce, Turkey

Article History

Edited by
Evandro Nascimento Silva, UEFS, Brazil
Received 07 July 2022
Initial acceptance 11 December 2022
Final acceptance 16 January 2023
Publication date 31 July 2023

Keywords
Apis mellifera L., biodiversity, morphometry, conservation, Türkiye.

Corresponding author
Meral Kekeçoğlu
Düzce University, Faculty of Science, Department of Biology
81620 Düzce, Türkiye.
meralkekecoglu@duzce.edu.tr

Abstract
In this study, we report that there were five different subspecies and three different ecotypes defined so far in Türkiye, which has a rich biodiversity in terms of honeybee subspecies. However, recently, it has been thought that the current biodiversity is in danger of extinction due to the commercial queen bee supply and the migratory beekeeping activities from a single source. This study uses the morphometric method to reveal the current status of honeybee biodiversity in Türkiye. For this purpose, a total of 3186 worker bees were studied by samplings from 19 different provinces to represent the honeybee races and ecotypes distributed in Türkiye. We made wing preparations and established 19 landmarks on the right forewings using the BAB BsPro200 program. The program automatically obtained the wing's metrics' angle, length, and index values via these 19 landmarks. We used Discriminant function analysis to determine intragroup and intergroup variations by taking the colony averages from data obtained from 31 morphological characters. Given the canonical discriminant function analysis and UPGMA dendrogram, Zonguldak, Düzce, Sakarya, Artvin, Ardahan, and Trabzon constituted a group, and Edirne, Kilis, Van, and Isparta formed a separate group. Hakkari, Kahramanmaraş, and Ordu provinces formed a separate line together. On the other hand, the group centers of Kars and Kırklareli, two different ends of Türkiye, overlapped and formed a close line with Isparta. As a result, this study revealed that, although the protection measures taken at the local level effectively protected the honeybee biodiversity, these measures are insufficient.

Introduction

Honeybees (*Apis mellifera* L.) and bee products have always drawn interest and have been investigated because of their importance as a valuable source of nutrients, healing, and revenue. The pioneering studies, mostly carried out in the Palearctic region, exploring the biodiversity of bees dealt with measuring morphological characteristics in the early 1900s (Buttel-Repeen, 1906). In the following years, by examining the effects of morphological traits on the geographic distribution of races, various studies showed that the morphological characteristics, including tongue length, wing/leg structures, body size, body color, and hair structures, were the distinguishing characteristics (Bodenheimer, 1941; Maa, 1953; Settar, 1983; Ruttner, 1988b; Güler et al., 2002; Kandemir et al., 2005; Kambur, 2017; Kekeçoğlu et al., 2020). Advancing technology and molecular methods to minimize the loss of labor time and providing valuable data regarding inheritance constitute another method utilized in determining the variation in honeybee biodiversity. In addition to the morphometric studies carried out in Turkey, molecular techniques including mtDNA, PCR-RFLP, microsatellite, and sequencing became popular over time (Kandemir et al., 2003; Özdil et al., 2018; Tozkar et al., 2020; Kekeçoğlu et al., 2021).

ISSN: 0361-6525

In addition to its location in the mild temperate zone, the authentic geographical characteristics of Türkiye offer a unique habitat for honeybees. Hosting five of 30 honeybee species identified in the literature to date, Turkey has always drawn the attention of apiculture researchers. Bodenheimer started this process and has continued with morphometric methods in determining the biodiversity of *Apis mellifera* L. seven different ecotypes were discussed first (Bodenheimer, 1941). Identifying the species *Apis mellifera anatoliaca* distributed in the central regions of Turkey for the first time, Maa (1953) stated that there were four different honeybee races and many ecotypes in isolated parts of Turkey. Based on morphological characteristics, Settar (1983) noted that the bee population in the Aegean region was a transition population between the Italian and Caucasian bee races. Ruttner (1988b) also stated that there were four honeybee subspecies in Turkey: *Apis mellifera caucasica* in the region from Samsun to the northeastern part of the country, *Apis mellifera syriaca* in a limited area in the south near the Syrian border, *Apis mellifera meda* in the Southeastern Anatolia, and *Apis mellifera anatoliaca* in the remaining area (Ruttner, 1988b). Besides that, in parallel with Settar (1983) and Bodenheimer (1941), the author also stated that the group in the west of the İstanbul-Bursa-Eskişehir-Isparta line slightly differed from the Anatolian honeybee. Still, the difference was insufficient to identify these bees as a different race (Ruttner, 1988b). In the following years, *Apis mellifera carnica* was reported in the Thrace region of Turkey (Güler & Bek, 2002; Kandemir et al., 2005).

The honeybee population in the Thrace region of Turkey has been a subject of debate for a long time, and it remained uncertain if it was *Apis mellifera carnica* (Smith et al., 1997; Palmer et al., 2000; Kandemir et al., 2006). Examining the race found in the Thrace region, Ünal and Özdil (2018) identified the bee species using the PCR-RFLP technique. They reported that the Thracian honeybee populations were identical to *Apis mellifera carnica* and *Apis mellifera macedonica*. They also had genetic characteristics similar to both species (Ünal & Özdil, 2018). Moreover, in the same study, the honeybees found in the Thrace region of Turkey were registered as the Thracian ecotype of the *A. m. carnica* race by the TR Ministry of Agriculture and Forestry's National Animal Gene Resources Registration Commission (https://www.resmigazete.gov.tr/eskiler/2020/12/20201205-5.htm).

Turkey hosts many honeybee races thanks to its different geographical structure and climatic conditions. Each honeybee race has unique characteristics regarding resistance to diseases, stress, and environmental conditions (Kence, 2006; Tozkar, 2015). However, in the last 20-25 years, migratory beekeeping and the exclusive queen bee trade have become very common in Turkey (Güler, 2010; Kambur & Kekeçoğlu, 2018a.b; Kekeçoğlu et al. 2020). The popularization of these activities poses a threat to the biodiversity of the honeybee populations in Turkey. Due to changing climatic conditions and beekeeping activities, honeybees' unique genetic and morphologic characteristics are at risk of extinction (Kekeçoğlu, 2018). Moreover, unless the Ministry of Agriculture and Forestry takes protective measures regarding both migratory beekeeping and queen bee trade activities, the gene pool of honeybee populations will become homogenized.

The first scientific studies describing honeybee biodiversity used standard morphometric methods. In these studies, many morphological characters were used, such as the length and width of wings and the ratios. Recently, the most used morphological characters in the classification of honeybees are the position of the blood vessels in the wings. The shape and size of some cells formed by these blood vessels and the angles between the vessels show remarkable differences between races. Legal registration programs have used these diagnostic morphometric characters to conserve honeybee diversity. Morphological differences and adaptations give an advantage to honeybees in terms of colony fitness. Honeybee races living in the Northeast of Turkey with cold climates need to conserve as much heat as possible. Thus, it was predicted that they should have evolved wing traits showing less surface area, length, and width, by which they dissipate heat, allowing them to retain more heat. For honeybees living in warm climates, the opposite was predicted.

In this study, we used a geometric morphometric approach based on shape analysis to re-evaluate the status of Anatolian honeybee biodiversity. We hypothesized that Northern honeybee populations have smaller wing dimensions than Southern populations. To test this hypothesis, we performed geometric morphometric techniques on forewing landmarks set on wing photographs from samples representing the honeybee races (*Apis mellifera anatoliaca, Apis mellifera caucasica, Apis mellifera meda, Apis mellifera syriaca,* and *Apis mellifera carnica*) collected from 19 Turkish provinces.

Material and Method

The samples representing the honeybee races and ecotypes in Turkey were collected from 19 different provinces paying attention to obtaining them from settled beekeepers.

We carried out analyses on the right forewings of 3186 worker bees from 136 colonies; 5 colonies from Tekirdağ (N=733), five from Kırklareli (N=83), eight from Edirne (N=18), five from Sakarya (N=134), nine from Düzce (N=134), nine from Zonguldak (N=136), nine from Ordu (N=145), nine from Trabzon (N=136), nine from Artvin (N=297), six from Ardahan (N=249), eight from Kars (N=128), five from Van (N=128), nine from Hakkari (N=74), nine from Gaziantep (N=96), seven from Hatay (N=139), two from Kilis (N=67), eight from Kahramanmaraş (N=139), six from Isparta (N=87), and eight from Muğla (N=263). Transfer, preservation, and preparation processes were conducted as performed previously by Kekeçoğlu (2007). The photos of wing preparations were taken under 1x magnification using a BAB camera system connected to a BAB STR45 stereo-zoom microscope. Nineteen landmark points (Figure 1) were marked on the right forewings using the BAB Bs200ProP program, and the angle, length, and index values of these landmarks were automatically measured (Kambur, 2017). In total, 31 morphological characteristics were examined (Kambur, 2017; Kambur & Kekeçoğlu, 2018 a,b; Bir & Kekeçoğlu, 2021).

We obtained the raw data using the morphometric analysis software BAP Bs200Pro. Cross-Validation Test (CVT) was used to determine the distribution of samples by wing characteristics. The statistical significance level of the morphometric characteristics was determined using the colony averages. The raw data about the wing characteristics obtained using the colony averages were analyzed using the Discriminant Function Analysis (DFA). We performed a one-way analysis of variance (ANOVA) to determine the characteristics playing an effective role in discriminant functions. The intragroup and intergroup variances were determined using multivariate variance analysis (MANOVA), in which all the characteristics are combined to classify the groups. We performed the analyses using the statistical software SPSS.15.

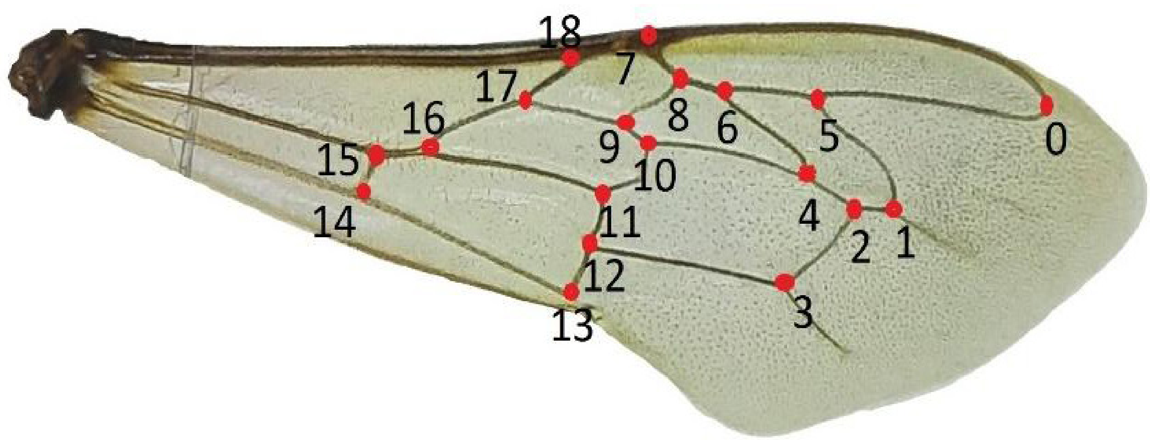

Fig 1. Marking the landmark points on the right forewings.

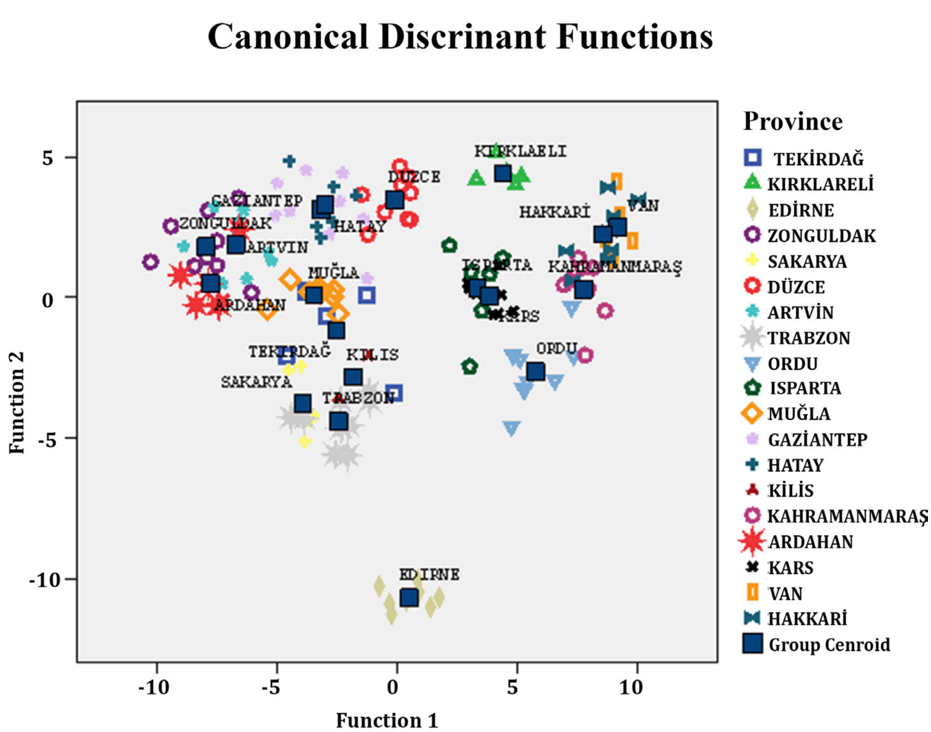

Fig 2. 2D dispersion diagram of samples representing the populations.

Results

The descriptive statistics of (means, standard errors, and minimum and maximum values) of 31 (A1: 24.17, A4: 33.78, B3: 78.44, B4: 99.63, D7: 100.32, E9: 19.87, G7: 24.04, G18: 89.39, H12: 16.90, J10: 53.63, J16: 91.28, K19: 77.95, L13: 12.80, M17: 35.59, N23: 89.67, O26: 38.51, Q21: 37.92, DA: 11.63, CI: 2.23, PCI: 2.71, DBI: 0.96, RI: 1.75, DiscS: 0.35, DiscsL: 1.71, RADL: 3.55, A: 0.56, B: 0.26, C: 0.93, D: 2, IWL: 4.54, IWW: 2.13) morphometric characteristics of the populations are presented in three categories as angle, length, and index. The mean, min-max, and standard error values of the 31 standard morphometric characteristics are presented in Tables 1-3.

Given the results obtained from ANOVA, we examined the intergroup variations of these morphological characteristics. We found a statistically significant difference between the groups in at least one of the 31 morphological characteristics ($p<0.05$). The characteristics found to be significant in distinguishing the populations by provinces were as follows; B3 for Van, B4 for Isparta and Van, D7 for Sakarya, Van, and Edirne, E9 for Muğla and Kilis, G7 for Kırklareli and Van, G18 for Kahramanmaraş, H12 for Edirne, J16 for Hakkari, K19 for Edirne, Artvin, and Van, L13 and M17 for Hakkari, N23 for Kırklareli, O26 for Kırklareli, Kahramanmaraş, and Hakkari, Q21 for Gaziantep and Kilis, A for Kırklareli, B for Kahramanmaraş and Van, C for Tekirdağ, Kırklareli, and Düzce, D for Tekirdağ, Kırklareli, and Van, the cubital index for Kırklareli, Sakarya, Kahramanmaraş, and Van, the precubital index for Kırklareli and Hakkari, the dumb-bell index for Düzce, Artvin, and Sakarya, the radial index for Tekirdağ and Artvin, the positive discoidal shift (PDK) for Kırklareli, and the discoidal angle (DA) for Kırklareli ($p<0,05$).

We determined eighteen functions in the discriminant analysis and found 11 statistically significant ($p<0.05$). The first function explains 41.4% of the total variation, the second explains 15%, and the third explains 10.2%. Combined, the first three functions explain 66.6% of the total variation. Moreover, examining the structure of canonic correlation coefficients between each variable and any discriminant function, we verified that the highest canonic correlation characteristics were radial length, inner wing length, and D length in the first function and O26 angle in the third function.

Regarding the distribution of samples, we drew a 2D dispersion diagram based on the first two discriminant functions. We calculated the colony averages of the data obtained according to this diagram, a discriminant function analysis, and the intragroup and intergroup variances. In conclusion, the provinces of Düzce, Sakarya, Trabzon, Tekirdağ, Edirne, Kilis, Van, and Isparta remarkably distinguished themselves from the others. The group centers of Zonguldak and Ardahan overlapped and clustered near Artvin. Muğla, Gaziantep, and Hatay distributed into each other and constituted a separate group. Kars and Kırklareli overlapped and formed a line near Isparta. On the other hand, Hakkari, Kahramanmaraş, and Ordu clustered closely and constituted a separate line (Şekil 2).

The populations constituted two main groups in the UPMGA dendrogram drawn by the Mahalanobis distances (Figure 3). Given the results achieved here, the Tekirdağ, Trabzon, and Ardahan group and the populations of Zonguldak, Sakarya, and Artvin constituted a group in the first line. In the second line, Kırklareli, Gaziantep, Hakkari, Kahramanmaraş, Kars, Düzce, Isparta, and Ordu formed a close group, and Edirne and Hatay and Muğla and Kilis clustered a near group. Van population was in the second line but constituted a separate group from all the populations in its line.

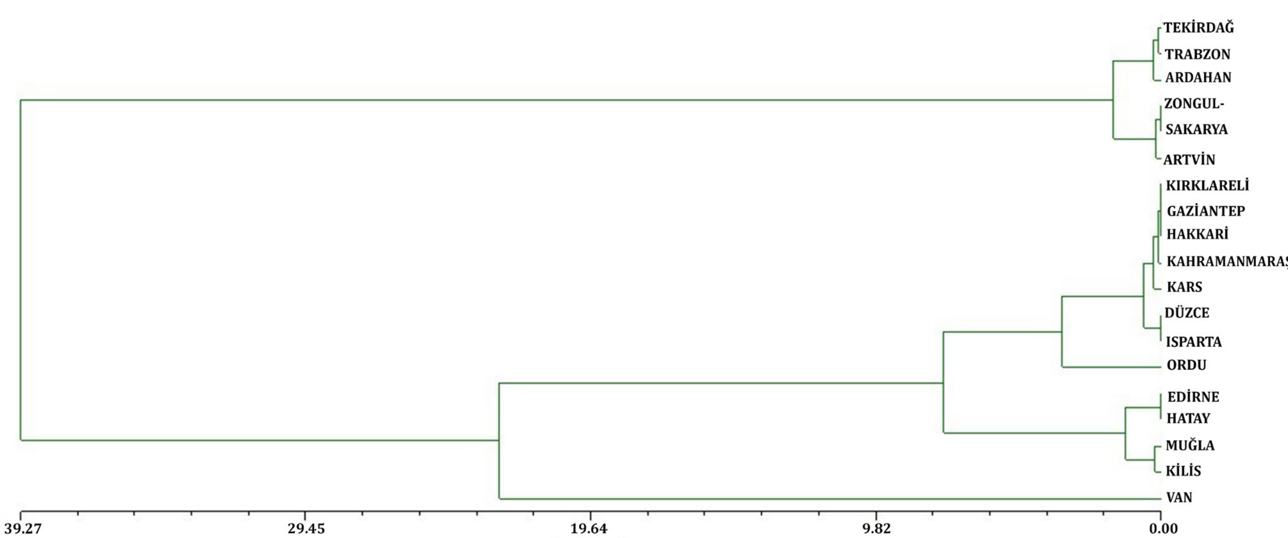

Fig 3. UPGMA dendrogram of populations.

Among two lines, the first consists of Black Sea populations, except Tekirdağ. The other one includes the honeybee populations from the cities representing every region in Turkey.

Discussion

The pioneering studies on the distribution of Anatolian honeybee populations were carried out by Buttel-Reepen (1906) in limited areas of the Aegean and Marmara regions. Then, Bodenheimer (1941) divided Turkey into seven regions. Maa (1953) was the first taxonomist who characterized and identified the *Apis mellifera anatoliaca*. Examining the honeybees in Anatolia, Adam (1983) specified four subspecies and many Anatolian ecotypes and reported results similar to Bodenheimer (1941). Many researchers studying the Anatolian honeybees with allozyme variations supported the results achieved by Ruttner (1988b) (Darendelioglu & Kence, 1992; Kandemir & Kence, 1995; Güler & Kaftanoglu, 1999a,b,c; Güler et al., 1999; Kandemir et al., 1995, 2000; Güler et al., 2002; Kandemir et al., 2003).

Morphometry and allozyme studies identified 5 *Apis mellifera* subspecies in Turkey, which are *Apis mellifera anatoliaca, Apis mellifera caucasica, Apis mellifera carnica, Apis mellifera syriaca,* and *Apis mellifera meda*; *Apis mellifera anatoliaca* (Ruttner, 1988a; Smith et al., 1997; Palmer et al., 2000; Kandemir et al., 2006a), *Apis mellifera caucasica* (Smith et al., 1997; Ruttner, 1988a; Palmer et al., 2000; Kandemir et al., 2006a), *Apis mellifera carnica (*Bodenheimer, 1941; Smith et al., 1997; Palmer et al., 2000; Kandemir et al., 2006a), *Apis mellifera syriaca* (Ruttner, 1988a; Palmer et al., 2000; Kandemir et al., 2006a,c), *Apis mellifera meda* (Ruttner, 1988b). The rich honeybee genetic diversity found in Turkey plays an important role in the sustainable future of beekeeping in the country. Estimating which bee race would adapt better to recently increasing bee diseases and pests, global warming, and changing climatic factors is difficult.

Each race and each ecotype have different morphometric and genetic characteristics. The Anatolian bee (*Apis mellifera anatoliaca*) has a wide abdomen and tarsis, longer forewings, and short legs and wings compared to the body size. The length of the forewing is approx. 9.18 mm. Anatolian bees are generally yellow, but the abdomen rings are usually orange but turn brown at the backward segment. The most important characteristic was reported to be the difference in vein angles and wing veins (Maa, 1953; Adam, 1983).

A. m. caucasica Gorb. (Grey Caucasian Mountain bee) is one of the four most known and preferred honeybees throughout the world. It naturally exists in the eastern Black Sea, Russia, and a part of Azerbaijan but was reported to distribute from Caucasian mountains to Samsun on Black Sea shores (Alpatov, 1948; Bilash et al., 1976; Awetisjan, 1978; Ruttner, 1988b). Examining the performance of this race, the Grey Caucasian mountain bee showed its best performance in the Eastern Black Sea region (Ruttner, 1988b). As a result of morphometric analyses, Ruttner (1988a) stated that the bees that were similar to *A. m. caucasica* were found on Black Sea shores (in the Samsun province). However, since the Caucasian bee has many varieties, it has been debated whether these bees were related to the Caucasian race (Ruttner, 1988a). In the following years, the *Apis mellifera* population in the Artvin region, known as the Caucasian region, was examined using morphometric methods. It was reported that the bees in this region were an ecotype of the Caucasian race, which has adapted to the region (Güler, 2001). In a study examining the Turkish honeybees in terms of mtDNA variation, Smith et al. (1997) found that 77% of samples taken from near the Georgian border, 29% of those obtained from near Erzurum province, and 25% of those obtained from Van province were in concordance with mtDNA haplotype of *A. m. caucasica*. The samples taken from the Thrace region were found to have a 24% similarity with the *A. m. carnica* mtDNA haplotype (Smith et al., 1997). There also are studies reporting that the honeybee races distributed alongside the northern shores of Turkey were *Apis mellifera anatoliaca* or an ecotype of this subspecies (Kandemir et al., 2000; Kekeçoğlu, 2007; Kekeçoğlu & Soysal, 2010b; Çakmak et al., 2014). In a morphometric study in which Kastamonu, Sinop, and Artvin provinces constituted a group, it was pointed out that there might be bee species or varieties other than *Apis mellifera caucasica* on the northern shores of Turkey (Kambur & Kekeçoğlu, 2018a). In the 2D diagram and UPGMA dendrogram provided in the same study, Artvin and Ordu were in a group, whereas Ardahan and Trabzon constituted separate independent groups (Kambur & Kekeçoğlu, 2018a). In the present study, similarly, Ardahan and Artvin, which are Caucasian bee breeding regions, grouped together with Trabzon and Zonguldak provinces. In the UPGMA dendrogram, Black Sea populations (except for Ordu province) formed a group together. This finding contradicts the finding about the presence of *A. m. caucasica* only in northeastern Turkey. Moreover, the involvement of the Tekirdağ population in this group indicates the intermixture of populations.

Italian bees (*A. m.ligustica*) and Carniolan bees (*A. m. carnica*), having the highest economic value, are in the Eastern Europe group. *A. m. carnica* naturally distributes from Wien to Austria and Dalmatian shores, entire Yugoslavia, and south of the Alps (Ruttner, 1965). Together with *A. m. caucasica*, *A. m. carnica* is one of the biggest bees among the *Apis mellifera* races. Although *A. m. carnica* can be easily distinguished from *A. m. caucasica* with its short and dense hair cover, high cubital index value, and especially the differences in wing vein angles, it is very difficult to distinguish it from Balkan bee *Apis mellifera macedonica*. As with *A. m. caucasica*, it was determined that *A. m. carnica* had various varieties depending on geographical locations. While the populations at low altitudes in Austria and northern Slovenia were found to be original *A. m. carnica*, the ones in Romania, Yugoslavia, and Hungary were determined to be Banat bees that are similar to *A. m. carnica* (Adam 1983). In our country, even though it was tried to clarify the presence of *Apis mellifera carnica* found to be in Thrace by making use of molecular methods, the disputes continued for a long time (Smith et al., 1997; Palmer et al., 2000; Kandemir et al., 2006; Ünal & Özdil., 2018, Tozkar, 2020, Karabağ et al., 2020; Kekeçoğlu et al., 2021). In the year 2018, Ünal and Özdil identified the race in the region by using the PCR-RFLP method and reported that the Thracian honeybee populations showed similar characteristics to the Carniolan honeybee populations (*Apis mellifera carnica*), as well as *Apis mellifera macedonica*, *A. m. caucasica*, and *Apis mellifera anatoliaca* honeybees and their crossbreeds. In the present study, although they are in the same line as the honeybees from 7 different regions of Anatolia, the samples taken from Edirne and Kırklareli constituted distant groups. Still, they were in the same cluster as Tekirdağ Black Sea populations. The fact that Thracian populations were in the same group as both Anatolian and Caucasian populations support the results reported by Ünal and Özdil (2018). These results might suggest that Thrace, which is a point of interest for beekeepers thanks to the plants such as sunflower and canola, was affected by the migratory beekeeping activities, or they are the results of commercial beekeeping activities.

In a previous morphometric study, Özbakır (2011) emphasized that the honeybee populations in Hatay might be *Apis mellifera syriaca* and those in Van and Hakkâri showed similar characteristics as *Apis mellifera meda*. Kambur and Kekeçoğlu (2018a) stated that the results they achieved in their morphometric studies were exactly overlapping with those reported by Özbakır (2011) and in harmony with those reported by Bodenheimer (1941). Koca (2012) compared the samples taken from Hatay and Hakkâri to those taken from Iran and Northern Iraq and determined that 1.7% of the samples taken from Iran overlapped with those taken from Eastern and Southeastern Anatolia. A previous mtDNA study found that the samples taken from southern Turkey were *Apis mellifera meda* (Kandemir et al., 2006a). Kambur and Kekeçoğlu (2018a), in their morphometric study, reported that the Southeastern Anatolia region remarkably distinguished from the other regions of Turkey and, thus, there was a difference in the south, but further studies were needed to reveal if this difference arose from being *Apis mellifera meda* or *Apis mellifera syriaca*. Given the DFA results of the present study, the fact that Hatay and Kilis were in the same group as all the other honeybee populations in Turkey, except for Black Sea populations, suggests that Southeastern Anatolia honeybee populations might be *A. m. anatoliaca*.

Except for the specified races, it was reported that there was a Muğla ecotype in several isolated parts of the Aegean Regions and a Yığılca ecotype in the Western Black Sea region and its surroundings (Güler & Kaftanoğlu, 1999a,b; Kekeçoğlu, 2007; Kekeçoğlu, 2010; Kekeçoğlu and Soysal, 2010; Bouga et al., 2011; Kekeçoğlu et al., 2020). Muğla honeybee is an ecotype collecting the secretions of *Marchalleina hellenica* living on *Pinus brutia* and adapted to the bug's lifecycle (Güler & Kaftanoğlu, 1999a,b). Yığılca honeybee was, however, defined as an ecotype of the Anatolian honeybee (*A. m. anatoliaca*) since it has a relatively dark color and long legs and wings in comparison to the other races, as well as early spring development and high capacity of honey collection (Kekeçoğlu, 2010; Gösterit et al., 2012, 2016). The Düzce samples in the present study were from Yığılca. In parallel with the literature, the fact that Düzce was different from the Black Sea populations and close to the group of other provinces of Turkey corroborates an ecotype of Anatolian (*A. m. anatoliaca*) honeybee in this region.

On the other hand, Muğla has a very high potential and hosts Turkish beekeepers producing honeydew honey. In the present study, the fact that Muğla clustered with Gaziantep contradicts the studies reporting that there was a different ecotype in Muğla. Furthermore, it also suggests that, as in Thrace, the national beekeeping industry was affected by migratory beekeeping and queen bee breeding activities (Kekeçoğlu. 2018). Besides migratory beekeeping and queen bee breeding activities, the other factors negatively affecting the honeybee biodiversity were natural events such as seasonal changes and wrong beekeeping practices. The events related to global warming, such as seasonal changes and false spring, cause the loss of bees and are among the critical factors endangering the honeybee biodiversity. The races and ecotypes that are not resistant to such negative environmental conditions face the danger of extinction.

The honeybee biodiversity in Turkey is the most important national wealth and food security for the future. For this reason, besides carrying out studies on identifying the current subspecies and ecotypes, it is imperative to take necessary measures to preserve these gene sources. Purely breeding the subspecies and ecotypes, which are resistant to different geographies, in facilities to be established in isolated regions, especially banning the international queen bee trade and legally supervising the national migratory beekeeping and queen bee breeding activities would contribute to the preservation of honeybee biodiversity in Turkey the most.

Authors' Contributions

MK: conceptualization, writing - original draft, writing-review & editing.
SB: methodology, investigation, formal analysis, writing-original draft, writing-review & editing.
MKA: investigation, writing-original draft, writing-review & editing.

Table 1. Angle values of forewings.

Province	Serial number	N	A1 X ± Sx (Min.-Max.)	A4 X ± Sx (Min.-Max.)	B3 X ± Sx (Min.-Max.)	B4 X ± Sx (Min.-Max.)	D7 X ± Sx (Min.-Max.)	E9 X ± Sx (Min.-Max.)	G7 X ± Sx (Min.-Max.)	G18 X ± Sx (Min.-Max.)	H12 X ± Sx (Min.-Max.)
Tekirdağ	1	733	25.67±0.80 (23.60-28.53)	32.76±0.82 (31.30-34.83)	78.19±1.56 (75.16-83.69)	102.37±1.76 (96.93-107.60)	100.72±1.39 (96.92-104.50)	20.17±0.51 (18.68-21.15)	24.39±0.47 (23.00-25.56)	90.14±0.63 (88.70-92.29)	17.84±0.95 (15.02-20.64)
Kırklareli	2	83	21.34±0.31 (20.77-22.29)	33.80±0.15 (33.42-34.20)	81.23±0.52 (79.71-82.73)	102.37±0.30 (100.30-101.92)	100.61±0.40 (99.41-101.42)	20.06±0.16 (19.42-20.32)	22.62±0.14 (22.25-22.91)	89.73±0.41 (88.27-90.69)	18.78±0.13 (18.32-19.14)
Edirne	3	18	22.94±2.08 (15.31-34.08)	33.47±0.88 (30.45-38.44)	77.30±0.83 (74.04-80.06)	96.94±2.27 (87.53-104.66)	98.48±1.24 (93.16-102.16)	19.92±0.39 (18.51-21.56)	23.54±0.25 (22.47-24.52)	89.10±0.75 (85.53-92.39)	18.92±0.72 (15.10-21.24)
Zonguldak	4	136	24.28±0.84 (21.35-28.65)	33.86±0.37 (31.79-34.94)	78.42±0.65 (75.16-81.83)	99.12±0.59 (96.16-101.21)	101.02±0.68 (98.40-104.06)	19.54±0.29 (18.08-20.65)	24.18±0.19 (23.39-25.06)	90.10±0.85 (86.90-94.01)	18.07±0.58 (14.31-20.05)
Sakarya	5	134	24.13±1.16 (21.60-27.28)	34.38±0.30 (33.67-35.42)	80.63±0.97 (77.75-82.87)	102.95±1.09 (99.68-105.33)	103.67±0.55 (102.19-105.25)	19.10±0.27 (18.63-20.10)	22.87±0.27 (22.19-23.73)	89.38±1.27 (86.35-93.78)	16.38±0.70 (14.62-17.75)
Düzce	6	134	21.00±0.76 (18.18-23.94)	35.21±0.48 (32.86-36.75)	80.49±0.58 (78.26-82.99)	98.86±1.28 (94.10-105.4)	101.69±0.56 (99.21-104.41)	20.02±0.47 (17.68-21.77)	23.54±0.22 (22.85-24.80)	91.84±1.66 (86.85-100.77)	18.34±0.36 (17.14-20.02)
Artvin	7	297	22.92±0.58 (19.90-24.96)	35.92±0.29 (34.36-37.25)	79.99±0.40 (77.84-81.62)	96.50±1.26 (92.12-102.46)	101.94±0.39 (100.15-103.68)	19.18±0.30 (17.38-20.04)	23.17±0.08 (22.89-23.56)	91.47±0.95 (87.29-96.05)	15.74±0.20 (14.98-16.94)
Trabzon	8	136	23.20±1.20 (18.64-29.61)	33.95±0.65 (31.10-36.39)	79.53±1.51 (72.10-85.22)	101.10±0.64 (98.33-104.64)	100.22±1.17 (94.23-103.35)	19.83±0.68 (17.90-23.03)	23.54±0.31 (22.24-25.00)	89.48±0.09 (84.36-92.98)	16.70±0.68 (13.79-19.60)
Ordu	9	145	22.46±0.36 (20.52-23.80)	34.37±0.37 (32.66-36.00)	79.77±0.54 (77.87-82.39)	99.36±1.11 (94.74-104.96)	101.26±0.47 (98.77-103.57)	20.82±0.39 (18.86-22.39)	24.09±0.39 (22.44-25.91)	89.17±1.51 (83.57-95.73)	17.56±0.49 (15.16-19.54)
Isparta	10	87	22.88±0.70 (20.75-25.58)	34.35±0.25 (33.16-34.84)	79.11±0.40 (78.04-80.34)	95.38±2.07 (89.30-101.86)	99.64±0.76 (97.26-101.98)	19.75±0.20 (18.92-20.38)	24.69±0.37 (23.82-25.66)	92.91±0.88 (90.47-95.50)	16.45±0.16 (15.90-16.85)
Muğla	11	263	24.47±1.53 (19.72-30.38)	34.27±0.52 (32.73-36.62)	79.48±0.36 (78.20-81.57)	97.98±1.22 (94.28-102.68)	101.25±0.51 (99.25-103.74)	18.77±0.65 (16.67-21.85)	23.17±0.17 (22.08-23.69)	91.25±0.79 (88.25-93.80)	15.62±0.52 (12.79-17.23)
Gaziantep	12	96	25.42±0.48 (23.50-27.71)	32.05±0.55 (30.17-35.59)	77.01±0.62 (74.43-80.73)	100.13±0.97 (95.30-104.71)	100.27±062 (98.06-104.06)	19.23±0.27 (18.57-21.10)	24.46±0.24 (23.58-25.50)	87.24±1.19 (82.94-93.88)	17.27±0.91 (13.24-20.89)
Hatay	13	139	24.84±0.33 (23.93-26.23)	32.46±0.46 (31.44-34.94)	76.87±0.82 (74.38-81.17)	101.50±1.07 (97.55-105.77)	100.06±0.81 (97.05-103.65)	19.98±0.35 (19.05-21.79)	24.04±0.23 (22.78-24.65)	90.64±0.45 (89.17-92.22)	16.88±0.77 (14.60-19.90)
Kilis	14	67	24.40±2.90 (21.50-27.29)	31.52±0.99 (30.52-32.51)	75.62±2.83 (72.79-78.44)	105.35±0.36 (104.99-105.70)	99.22±4.17 (95.05-103.38)	21.41±0.15 (21.26-21.55)	24.51±1.54 (22.97-26.04)	88.42±2.48 (85.94-90.90)	14.84±2.15 (12.69-16.98)
K.maraş	15	139	26.54±0.39 (24.38-28.18)	33.88±0.17 (33.10-34.55)	79.26±0.34 (77.38-80.31)	99.73±0.38 (98.21-101.36)	102.15±0.30 (100.76-102.95)	20.07±0.18 (19.01-20.79)	24.58±0.11 (24.28-25.22)	83.57±0.82 (80.41-86.54)	16.73±0.29 (16.00-18.62)
Ardahan	16	249	24.99-0.38 (23.90-26.30)	35.71±0.61 (34.52-38.56)	79.38±1.04 (76.48-83.87)	97.62±0.83 (94.96-100.06)	100.79±0.93 (97.39-103.92)	19.71±0.26 (18.78-20.57)	23.61±0.20 (22.97-24.27)	91.50±0.42 (90.47-92.90)	15.79±0.94 (12.07-18.03)
Kars	17	128	23.41±1.00 (19.74-27.61)	32.81±0.42 (31.07-34.38)	77.27±0.85 (73.42-80.07)	102.30±1.41 (96.24-107.16)	99.20±1.11 (94.03-103.12)	20.49±0.41 (19.23-22.31)	24.68±0.27 (23.76-25.93)	85.90±1.07 (81.19-89.86)	16.89±0.86 (12.43-20.02)
Van	18	128	28.27±0.41 (27.19-29.33)	33.91±0.61 (32.28-35.40)	73.26±0.46 (72.35-74.87)	92.33±1.86 (87.70-97.23)	93.80±0.41 (93.08-95.38)	19.74±0.17 (19.43-20.39)	26.24±0.13 (25.86-26.54)	89.66±0.48 (88.46-90.78)	16.89±0.09 (16.78-17.31)
Hakkari	19	74	26.05±1.21 (20.03-31.35)	33.14±0.40 (31.84-35.15)	77-52±1.32 (69.77-82.58)	102.34±1.49 (96.00-108.55)	100.06±0.96 (94.70-104.46)	19.82±0.23 (18.86-20.86)	24.85±0.20 (23.78-25.59)	86.99±1.60 (79.66-91.32)	15.34±0.78 (12.27-17.98)
Total		3186	24.17±0.91 (21.29-27.53)	33.78±0.49 (32.23-35.62)	78.44±0.87 (75.53-81.44)	99.63±1.16 (95.50-103.84)	100.32±0.92 (97.32-103.11)	19.87±0.33 (18.68-21.19)	24.04±0.30 (23.16-24.95)	89.39±1.01 (86.04-92.97)	16.90±0.65 (14.59-18.93)

Table 1. Angle values of forewings. (Continued)

Province	Serial number	N	J10 X ± Sx (Min.-Max.)	J16 X ± Sx (Min.-Max.)	K19 X ± Sx (Min.-Max.)	L13 X ± Sx (Min.-Max.)	N17 X ± Sx (Min.-Max.)	N23 X ± Sx (Min.-Max.)	O26 X ± Sx (Min.-Max.)	Q21 X ± Sx (Min.-Max.)	DA X ± Sx (Min.-Max.)
Tekirdağ	1	733	55.28±0.98 (52.31-58.19)	93.19±1.33 (88.77-95.70)	77.61±1.73 (71.62-81.18)	13.76±0.50 (11.97-15.01)	38.88±1.45 (33.93-42.62)	92.95±0.73 (90.94-95.39)	40.69±1.92 (37.02-47.02)	37.36±0.64 (35.03-38.73)	11.63±1.06 (8.37-13.99)
Kırklareli	2	83	50.65±0.32 (49.76-51.74)	93.42±0.64 (91.18-95.17)	75.92±0.38 (74.63-76.70)	12.96±0.25 (12.16-13.66)	45.22±1.05 (42.46-47.85)	95.53±0.63 (93.85-97.56)	44.39±0.62 (42.49-45.86)	37.22±0.42 (36.39-38.59)	7.68±0.18 (7.08-8.13)
Edirne	3	18	54.68±2.11 (49.09-64.94)	95.50±1.06 (92.05-99.69)	82.19±0.64 (79.05-84.02)	14.17±0.48 (12.16-15.91)	39.11±1.46 (31.69-43.42)	91.96±1.31 (87.37-98.79)	36.00±0.66 (33.58-38.35)	36.44±0.52 (34.82-38.83)	12.22±0.58 (9.45-13.70)
Zonguldak	4	136	54.77±0.70 (51.42-57.15)	90.37±0.92 (87.95-96.91)	80.47±0.75 (75.99-83.98)	10.29±0.28 (8.48-11.09)	24.96±0.78 (22.44-29.07)	90.68±0.76 (87.96-95.04)	35.86±0.78 (32.62-40.38)	37.80±0.28 (36.57-38.90)	9.49±0.42 (7.92-11.80)
Sakarya	5	134	53.65±1.71 (49.97-58.53)	92.98±2.68 (85.55-98.13)	78.79±099 (76.23-80.90)	13.71±0.24 (13.21-14.41)	29.97±0.57 (27.96-31.48)	90.15±0.57 (89.08-92.21)	34.02±0.44 (32.93-35.39)	37.56±0.47 (36.65-39.26)	9.72±1.08 (7.81-12.85)
Düzce	6	134	52.65±0.55 (50.64-55.86)	91.06±1.20 (85.50-96.78)	78.41±1.00 (73.80-82.48)	11.12±0.24 (10.22-12.42)	26.17±1.14 (21.40-31.58)	88.54±1.16 (83.79-93.13)	38.50±1.65 (33.11-47.40)	7.14±0.43 (35.34-39.32)	11.90±0.47 (10.02-13.49)
Artvin	7	297	53.81±0.56 (50.88-56.21)	89.26±1.09 (84.82-95.08)	75.09±0.55 (71.79-77.45)	11.24±0.32 (9.73-12.78)	25.01±0.90 (20.11-28.49)	88.26±0.57 (85.59-91.16)	38.37±0.96 (34.53-43.29)	37.87±0.15 (37.34-38.56)	9.59±1.10 (5.62-14.10)
Trabzon	8	136	53.17±0.8 (48.71-55.58)	91.27±1.28 (86.05-97.32)	78.75±0.23 (77.72-79.89)	13.33±0.36 (11.78-14.51)	38.47±2.53 (27.98-46.45)	91.16±1.30 (87.77-97.29)	35.89±0.57 (34.01-39.03)	36.91±0.70 (34.73-40.45)	10.51±0.79 (8.18-14.95)
Ordu	9	145	55.21±0.55 (52.55±57.51	92.32±1.37 (86.22-97.86)	80.15±0.52 (77.84-82.88)	14.10±0.20 (13.57-15.31)	40.37±0.61 (36.52-42.22)	86.26±1.08 (80.02-89.40)	38.34±1.17 (33.96-43.45)	37.85±0.16 (37.04-38.89)	11.72±0.73 (7.98-14.02)
Isparta	10	87	54.67-0.15) (54.27±55.06)	91.52±1.09 (88.92-95.71)	78.95±0.34 (77.51-79.64)	13.65±0.30 (12.70-14.75)	37.02±0.86 (33.16-39.30)	90.26±1.36 (87.33-94.94)	39.17±1.71 (34.32-43.60)	37.64±0.59 (36.45-40.48)	12.12±0.55 (11.08-14.32)
Muğla	11	263	(53.33-0.55 50.46±55.58)	91.95±0.62 (88.51-94.29)	75.19±0.54 (72.99-77.33)	10.87±0.29 (10.14-12.38)	26.45±1.48 (20.80-30.97)	90.94±0.56 (87.63-93.06)	37.33±0.48 (35.47-39.06)	37.51±0.35 (35.23-38.35)	9.59±0.52 (8.08-11.75)
Gaziantep	12	96	52.42±0.64 (49.05-55.64)	89.87±1.55 (83.72-97.58)	79.80±0.93 (76.06-85.31)	10.40±0.17 (9.73-11.06)	24.74±0.45 (22.71-26.63)	88.57±1.41 (81.96-95.60)	36.42±0.82 (32.24-40.64)	39.58±1.09 (37.65-48.20)	7.91±0.70 (4.73-10.76)
Hatay	13	139	51.93±0.93 (48.26-54.85)	89.60±1.32 (85.91-96.06)	78.61±0.57 (76.74-80.42)	10.08±0.26 (8.81-10.69)	23.44±0.75 (19.52-25.62)	87.81±0.76 (84.98-90.62)	36.44±1.01 (32.02-39.79)	39.03±0.73 (37.57-42.85)	6.74±1.17 (3.14-10.83)
Kilis	14	67	52.98±1.115 (51.83-54.13)	86.79±1.23 (85.56-88.02)	77.49±1.78 (75.71-79.27)	12.66±0.36 (12.30-13.01)	33.66±0.43 (33.23-34.08)	88.03±2.47 (85.56-90.50)	34.14±1.13 (33.01-35.27)	40.20±0.79 (39.41-40.99)	11.61±2.97 (8.64-14.57)
K.maraş	15	139	53.18±0.43 (51.38-55.16)	96.02±0.64 (93.96-98.91)	76.48±0.53 (75.23-79.59)	14.07±0.32 (13.06-15.70)	42.91±0.70 (39.75-45.54)	88.03±0.63 (85.98-91.16)	41.37±0.71 (37.39-43.03)	36.93±0.46 (34.89-38.31)	12.18±0.19 (11.15-12.69)
Ardahan	16	249	55.63±0.71 (52.19-57.07)	90.97±1.118 (87.56-96.23)	76.54±1.30 (70.64-80.06)	10.38±0.26 (9.51-11.33)	23.55±0.56 (22.34-25.73)	87.61±0.91 (85.15-91.71)	36.96±1.21 (34.16-42.16)	37.98±0.29 (36.78-38.89)	9.59±0.95 (6.57-12.10)
Kars	17	128	53.60±0.85 (50.83-58.09)	90.25±1.55 (82.75-96.47)	79.24±1.04 (74.55-83.63)	13.88±0.37 (12.40-15.65)	41.55±0.62 (38.35-43.13)	86.76±1.93 (73.83-90.74)	40.10±0.82 (35.57-43.02)	38.80±0.37 (37.51-40.43)	10.37±0.65 (7.83-13.21)
Van	18	128	52.15±0.56 (50.83-53.68)	95.52±0.55 (93.61-96.55)	74.65±0.40 (73.70-76.04)	15.52±0.22 (14.87-16.07)	45.00±0.60 (43.09-46.73)	90.75±0.53 (89.35-91.82)	39.81±0.74 (37.11-41.48)	38.48±0.55 (36.49-39.55)	9.79±0.14 (9.46-10.21)
Hakkari	19	74	55.34±0.93 (50.43-59.45)	82.49±4.73 (62.01-97.43)	76.73±1.115 (72.06-81.33)	17.01±3.29 (11.21-42.91)	69.64±12.29 (40.36-119.24)	88.99±0.34 (87.45-90.41)	47.99±1.58 (41.51-54.13)	38.08±0.40 (36.21-39.47)	11.56±1.04 (7.33-16.17)
Total		3186	53.63±0.80 (50.78-56.55)	91.28±1.37 (86.35-96.31)	77.95±0.81 (74.94-80.64)	12.80±0.46 (11.47-15.19)	35.59±1.54 (30.41-41.06)	89.67±1.00 (86.08-93.19)	38.51±1.00 (35.11-42.23)	37.92±0.49 (36.43-39.95)	10.24±0.79 (7.89-12.76)

Table 2. Index values of forewings.

Province	Serial number	N	CI	PCI	DBI	RI
			X ± Sx (Min.-Max.)	X ± Sx (Min.-Max.)	X ± Sx (Min.-Max.)	X ± Sx (Min.-Max.)
Tekirdağ	1	733	2.23±0.19 (1.77-2.68)	2.71±0.03 (2.61-2.79)	0.96±0.02 (0.91-1.04)	1.75±0.02 (1.71-1.81)
Kırklareli	2	83	1.68±0.01 (1.64-1.71)	2.95±0.03 (2.87-3.04)	0.96±0.01 (0.92-0.99)	1.57±0.00 (1.57-1.58)
Edirne	3	18	2.21±0.08 (1.95-2.57)	2.77±0.09 (2.25-3.05)	0.92±0.01 (0.88-0.98)	1.62±0.01 (1.60-1.64)
Zonguldak	4	136	2.07±0.09 (1.67-2.63)	2.75±0.01 (2.69-2.78)	0.94±0.02 (0.85-1.02)	1.70±0.01 (1.64-1.77)
Sakarya	5	134	1.82±0.06 (1.62-1.97)	2.78±0.03 (2.69-2.85)	0.86±0.01 (0.82-0.88)	1.70±0.02 (1.66-176)
Düzce	6	134	2.11±0.10 ()1.71-2.53(	2.80±0.02 (2.74-2.89)	0.86±0.01 (0.83-0.93)	1.59±0.01 (1.55-1.62)
Artvin	7	297	1.96±0.07 (1.72-2.29)	2.75±0.02 (2.67-2.84)	0.85±0.01 (0.82-0.88)	1.69±0.00 (1.67-1.71)
Trabzon	8	136	1.94±0.11 (1.59-2.56)	2.70±0.03 (2.59-2.84)	0.96±0.01 (0.91-1.01)	1.72±0.01 (1.66-1.77)
Ordu	9	145	2.10±0.07 (1.85-2.40)	2.69±0.03 (2.57-2.82)	0.93±0.01 (0.88-1.03)	1.61±0.01 (1.58-1.67)
Isparta	10	87	2.15±0.02 (2.06-2.22)	2.68±0.03 (2.60-2.80)	0.94±0.01 (0.92-0.96)	1.61±0.01 (1.57-1.64)
Muğla	11	263	2.03±0.05 (1.80-2.23)	2.80±0.04 (2.65-2.97)	0.92±0.01 (0.89-0.96)	1.60±0.01 (1.57-1.64)
Gaziantep	12	96	2.13±0.07 (1.86-2.38)	2.75±0.01 (2.70-2.81)	0.99±0.02 (0.91-1.05)	1.60±0.01 (1.57-1.67)
Hatay	13	139	2.20±0.04 (2.04-2.35)	2.76±0.03 (2.66-2.90)	0.97±0.01 (0.93-1.01)	1.61±0.01 (1.56-1.67)
Kilis	14	67	2.34±0.44 (1.90-2.77)	2.66±0.13 (2.53-2.78)	0.99±0.02 (0.97-1.01)	1.68±0.04 (1.64-1.71)
Kahramanmaraş	15	139	2.46±0.04 (2.27-2.61)	2.82±0.02 (2.75-2.92)	0.91±0.02 (0.84-0.96)	1.62±0.00. (1.61-1.63)
Ardahan	16	249	2.08±0.07 (1.90-2.33)	2.72±0.02 (2.68-2.83)	0.88±0.03 (0.77-0.98)	1.72±0.01 (1.69-1.75)
Kars	17	128	2.15±0.08 (1.83-2.44)	2.73±0.03 (2.63-2.84)	0.93±0.03 (0.83-1.05)	1.62±0.01 (1.58-1.66)
Van	18	128	2.70±0.01 (2.65-2.73)	2.70±0.02 (2.66-2.76)	0.96±0.01 (0.94-0.99)	1.58±0.01 (1.56-1.60)
Hakkari	19	74	2.75±0.11 (1.98-2.94)	2.44±0.12 (1.99-2.94)	0.98±0.05 (0.77-1.23)	1.56±0.02 (1.46-1.64)
Total		3186	2.14±0.09 (1.88-2.44)	2.73±0.04 (2.61-2.87)	0.93±0.02 (0.87-1.00)	1.64±0.01 (1.60-1.68)

Table 3. Lengths values of forewings.

Province	Serial number	N	DiscS	DiscsL	RADL	A	B	C	D	IWL	IWW
			X ± Sx (Min.-Max.)	X ± Sx (Min.-Max.)	X ± Sx (Min.-Max.)	X ± Sx (Min.-Max.)	X ± Sx (Min.-Max.)	X ± Sx (Min.-Max.)	X ± Sx (Min.-Max.)	X ± Sx (Min.-Max.)	X ± Sx (Min.-Max.)
Tekirdağ	1	733	0.35±0.03 (0.26-0.42)	1.71±0.02 (1.66-1.77)	3.55±0.02 (3.47-3.58)	0.56±0.02 (0.49-0.60)	0.26±0.01 (0.23-0.29)	0.93±0.01 (0.90-0.95)	2.00±0.02 (1.96-2.04)	4.54±0.03 (4.42-4.61)	2.13±0.02 (2.07-2.21)
Kırklareli	2	83	0.21±0.01 (0.19-0.22)	1.57±0.00 (1.57-1.58)	3.19±0.01 (3.16-3.21)	0.46±0.00 (0.46-0.47)	0.28±0.00 (0.28-0.28)	0.82±0.00 (0.81-0.83)	1.85±0.01 (1.82-1.87)	4.21±0.01 (4.18-4.24)	1.94±0.00 (1.93-1.95)
Edirne	3	18	0.35±0.02 (0.26-0.40)	1.60±0.01 (1.58-1.62)	3.41±0.01 (3.35-3.43)	0.54±0.02 (0.49-0.61)	0.25±0.01 (0.22-0.28)	0.85±0.01 (0.82-0.88)	1.89±0.01 (1.86-1.94)	4.42±0.02 (4.37-4.50)	1.97±0.02 (1.93-2.07)
Zonguldak	4	136	0.28±0.01 (0.23-0.35)	1.68±0.01 (1.62-1.73)	3.63±0.02 (3.52-3.68)	0.55±0.01 (0.50-0.63)	0.27±0.00 (0.25-0.30)	0.93±0.01 (0.90-0.95)	1.96±0.02 (1.87-2.03)	4.56±0.02 (4.45-4.63)	2.06±0.02 (1.97-2.16)
Sakarya	5	134	0.29±0.04 (0.23-0.39)	1.68±0.02 (1.65-1.73)	3.53±0.03 (3.45-3.60)	0.50±0.02 (0.44-0.53)	0.27±0.00 (0.26-0.28)	0.90±0.01 (0.87-0.92)	1.96±0.03 (1.90-2.03)	4.53±0.04 (4.44-4.63)	2.08±0.02 (2.04-2.14)
Düzce	6	134	0.33±0.01 (0.27-0.37)	1.55±0.01 (1.53-1.58)	3.41±0.02 (3.34-3.49)	0.49±0.01 (0.45-0.53)	0.24±0.01 (0.22-0.26)	0.84±0.01 (0.82-0.87)	1.86±0.01 (1.81-1.93)	4.25±0.02 (4.18-4.35)	1.91±0.01 (1.89-1.95)
Artvin	7	297	0.28±0.03 (0.17-0.41)	1.66±0.01 (1.61-1.70)	3.65±0.02 (3.54-3.70)	0.51±0.00 (0.50-0.54)	0.27±0.01 (0.24-0.30)	0.89±0.00 (0.88-0.90)	1.97±0.01 (1.93-2.04)	4.49±0.01 (4.43-4.53)	2.04±0.01 (2.00-2.07)
Trabzon	8	136	0.32±0.03 (0.24-0.46)	1.69±0.01 (1.66-1.72)	3.53±0.02 (3.43-3.59)	0.53±0.02 (0.47-0.63)	0.28±0.01 (0.25-0.30)	0.90±0.01 (0.86-0.95)	1.99±0.01 (1.96-2.03)	4.46±0.01 (4.52-4.63)	2.10±0.01 (2.05-2.16)
Ordu	9	145	0.33±0.02 (0.22-0.40)	1.59±0.01 (1.57-1.64)	3.22±0.02 (3.09-3.29)	0.49±0.01 (0.46-0.52)	0.24±0.01 (0.22-0.26)	0.85±0.01 (0.85-0.89)	1.82±0.01 (1.77-1.85)	4.17±0.03 (4.00-4.26)	1.96±0.01 (1.91-2.01)
Isparta	10	87	0.34±0.01 (0.32-0.40)	1.59±0.02 (1.53-1.62)	3.31±0.01 (3.28-3.34)	0.53±0.01 (0.50-0.57)	0.25±0.000 (0.24-0.26)	0.87±0.01 (0.84-0.88)	1.86±0.00 (1.85-1.87)	4.25±0.01 (04.22-4.28)	1.94±0.01 (1.91-1.99)
Muğla	11	263	0.27±0.01 (0.22-0.33)	1.59±0.01 (1.55-1.63)	3.49±0.01 (3.46-3.52)	0.52±0.00 (0.49-0.53)	0.26±0.00 (0.24-0.28)	0.86±0.00 (0.84-0.88)	1.91±0.00 (1.89-1.93)	4.39±0.02 (4.31-4.41)	1.94±0.01 (1.89-199)
Gaziantep	12	96	0.22±0.02 (0.13-0.30)	1.59±0.01 (1.56-1.67)	3.46±0.02 (3.37-3.53)	0.54±0.01 (0.51-0.58)	0.26±0.01 (0.22-0.29)	0.87±0.01 (0.84-0.89)	1.85±0.01 (1.81-1.91)	4.31±0.02 (4.22-4.41)	1.92±0..02 (1.86-2.01)
Hatay	13	139	0.19±0.03 (0.09-0.30)	1.60±0.02 (1.56-1.66)	3.47±0.02 (3.40-3.59)	0.54±0.01 (0.50-0.56)	0.25±0.00 (0.24-0.26)	0.87±0.01 (0.84-0.89)	1.89±0.03 (1.81-2.01)	94.36±0.03 (4.28-4.50)	1.95±0.02 (1.89-2.02)
Kilis	14	67	0.34±0.08 (0.26-0.42)	1.65±0.05 (1.60-1.70)	347±0.07 (3.40-3.54)	0.55±0.005 (0.50-0.59)	0.24±0.02 (0.22-0.26)	0.90±0.03 (0.87-0.92)	1.93±0.01 (1.92-1.93)	4.39±0.00 (4.38-4.39)	2.04±0.01 (2.03-2.05)
K.maraş	15	139	0.35±0.01 (0.31-0.36)	1.59±0.00 (1.58-1.60)	3.28±0.01 (3.25-3.34)	0.52±0.01 (0.50-0.55)	0.22±0.00 (0.20-0.23)	0.86±0.00 (0.85-0.87)	1.85±0.02 (1.79-1.90)	4.19±0.02 (4.11-4.28)	1.94±0.00 (1.92-1.95)
Ardahan	16	249	0.29±0.03 (0.20-0.37)	1.70±0.01 (1.65-1.72)	3.69±0.02 (3.62-3.74)	0.54±0.01 (0.50-0.57)	0.27±0.01 (0.25-0.28)	0.92±0.01 (0.89-0.94)	1.98±0.01 (1.95-2.02)	4.54±0.02 (4.49-4.61)	2.07±0.01 (2.04-2.09)
Kars	17	128	0.29±0.02 (0.22-0.38)	1.60±0.01 (1.56-1.62)	3.29±0.01 (3.24-3.33)	0.51±0.01 (0.46-0.56)	0.24±0.01 (0.22-0.26)	0.86±0.01 (0.84-0.91)	1.84±0.01 (1.78-1.88)	4.22±0.01 (4.17-4.28)	1.96±0.01 (1.94-1.97)
Van	18	128	0.27±0.01 (0.26-0.29)	1.56±0.01 (1.55-1.58)	3.14±0.01 (3.11-3.17)	0.58±0.01 (0.56-0.59)	0.22±0.00 (0.21-0.22)	0.87±0.00 (0.86-0.88)	1.77±0.01 (1.75-1.79)	4.06±0.02 (4.02-4.12)	1.89±0.01 (1.87-1.90
Hakkari	19	74	0.32±0.03 (0.20-0.44)	1.57±0.02 (1.49-1.63)	3.13±0.04 (2.95-3.27)	0.52±0.02 (0.42-0.56)	0.23±0.01 (0.19-0.27)	0.85±0.01 (0.83-0.87)	1.85±0.01 (1.79-1.91)	4.12±0.03 (3.92-4.20)	1.89±0.04 (1.74-1.98))
Total		3186	0.30±0.02 (0.23-0.37)	1.62±0.01 (1.58-1.66)	3.41±0.02 (3.34-3.47)	0.53±0.01 (0.48-0.56)	0.25±0.01 (0.23-0.27)	0.87±0.01 (0.85-0.90)	1.90±0.01 (1.85-1.94)	4.35±0.02 (4.27-4.42)	1.99±0.01 (1.94-2.04)

References

Adam, B. (1954). Bee breeding. Bee World, 35: 4-13. https://doi.org/10.1080/0005772X.1954.11094836

Adam, B. (1983). In search of the best strains of bees. Hebden Bridge: Northern Bee Books, 206 p.

Alpatov, W.W. (1929). Biometrical studies on variation and races of the honeybee *Apis mellifera.* The Quarterly Review of Biology, 4: 1-58. https://doi.org/10.1086/394322

Alpatov, W.W. (1948). The races of honeybees and their use in agriculture. Sredi Prirodi, 4: 1-65.

Awetisjan, G.A. (1978). Selection of Carpathian bees. In G.A. Awetisjan, W.A. Gubin & I.K. Davydenko (Eds.), International beekeeping congress (pp. 366-371). Bucharest: Apiculture, Apimondia Publishing House.

Bilash, G.D., Makarov, H. & Sedich, A.W. (1976). Geographic classification of honeybee races in the USSR. In Apimondia Symposium of Genetics Selection and Reproduction (pp. 140-150).

Bodenheimer, F.S. (1941). Studies on the honeybee and beekeeping in Türkiye. Ankara: Merkez Ziraat Mücadela Enstitüsü Numune Matbaası.

Bodur, C., Kence, M. & Kence, A. (2006). Microsatellıte analysıs revealed the maintenance of genetic ıdentıty of subspecies of *Apis mellifera* L. In Türkiye in spıte of intensive migratory beekeeping. Second European Conference of Apidology. Prague, Czech Republic: 10-14 September.

Bouga, M., Harizanis, P., Kılıas, G. & Alahıotıs, S. (2005). Genetic divergence and phylogenetic relationships of honeybee *Apis mellifera* (Hymenoptera: Apidae) populations from Greece and Cyprus using PCR-RFLP analysis of three mtDNA segments. Apidologie, 36: 335-344. https://doi.org/10.1051/apido:2005021

Brown, W.M. (1985). The mitochondrial genome of animals. In R.J. MacInterre (Eds.), Molecular Evolutionary Genetics (pp. 95-130). New York: Plenum Press. https://doi.org/10.1007/978-1-4684-4988-4_2

Buttel-Reepen, H. (1906). Apistica. Beitrage zur Systematic, Biologie, sowie zur geschichtlichen und Geographischen Verbreitung der Honigbiene (*Apis mellifera* L), ihrer Varietaten und der übrigen Apis-Arten (pp. 118-120). Berlin: Veroff. Zoology Museum. https://doi.org/10.1002/mmnz.4830030201

Cornuet, J. & Fresnaye, J. (1989). Biometrical study of honey bee populations from Spain and Portugal. Apidologie, 20: 93-101. https://doi.org/10.1051/apido:19890109

Daly, H.V. (1985). Insect morphometrics. Annual Review of Entomology, 30: 415-438. https://doi.org/10.1146/annurev.en.30.010185.002215

Daly, H.V., Danka, R.G., Hoelmer, K., Rinderer, T.E. & Buco, S.M. (1995). Honey bee morphometrics: linearity of variables with respect to body size and classification tested with European worker bees reared by varying number of nurse bees. Journal of Apicultural Research, 34: 129-145. https://doi.org/10.1080/00218839.1995.11100898

Daly, H.V., Hoelmer, K. & Gambino, P. (1991). Clinal geographic variation in feral honey bees in California, USA. Apidologie, 22: 591-609. https://doi.org/10.1051/apido:19910603

Darendelioglu, Y. & Kence, A. (1992). Morphometric study on population structure on honeybee, *Apis mellifera* L. (Hymenoptera: Apidae). In Türkiye 2. Entomoloji Kongresi Bildirileri (pp. 387-396). Adana: Çukurova Üniversitesi Yayınları.

DuPraw, E. (1965). Non-Linnear taxonomy and the systematics of honey bees. Systematic Zoology, 14: 1-24. https://doi.org/10.2307/2411899

Goetze, G. (1940). Die beste Biene: Züchtungs- u. Rassen-Kunde d. Honigbiene nach d. heutigen Stand von Wiss. u. Praxis. Leipzig: Liedloff Loth und Michaelis.

Goetze, G. (1964). Die Honigbiene in natürlicher und künstlicher Zuchtauslese. 2 Beurteilung und züchterische Auslese von Bienenvölkern. Hamburg: Hamburg Parey.

Güler, A. & Kaftanoglu, O. (1999a). Türkiye'deki önemli bal arısı ırk ve ekotiplerinin morfolojik özellikleri-I. Turkish Journal of Veterinary and Animal Sciences, 23: 565-575.

Güler, A. & Kaftanoglu, O. (1999b). Türkiye'deki önemli bal arısı ırk ve ekotiplerinin morfolojik özellikleri-II. Turkish Journal of Veterinary and Animal Sciences, 23 (Suppl. 3): 571-575.

Güler, A. & Kaftanoglu, O. (1999c). Türkiye'deki önemli bal arısı (*Apis mellifera* L.) ırk ve ekotiplerinin morfolojik karakterler açısından iliskilerinin diskriminant analiz yöntemiyle saptanması. Turkish Journal of Veterinary and Animal Sciences, 23: 565-575.

Güler, A. (1999). Türkiye'nin bazı bal arısı (*Apis mellifera* L.) genotiplerinde verimi etkileyen mofolojik ve fizyolojik karakterler üzerinde araştırmalar. Turkish Journal of Veterinary and Animal Sciences, 23 (Suppl. 2): 393-399.

Güler, A. (2001). Artvin Borçka Camili (Macahel) yöresi bal arısı (*Apis mellifera* L.)'nın morfolojik özellikleri. Turkish Journal of Veterinary and Animal Sciences, 25: 473-481.

Güler, A., Akyol, E., Gökçe, M. & Kaftanoglu, O. (2002). Artvin ve Ardahan yöresi bal arıları (*Apis mellifera* L.)'nın bazı morfolojik özellikler yönünden iliskilerinin belirlenmesi. Turkish Journal of Veterinary and Animal Sciences, 26: 595-603.

Güler, A., Kaftanoglu, O., Bek, Y. & Yeninar, H. (1999). Türkiye'deki önemli bal arısı (*Apis mellifera* L.) ırk ve ekotiplerinin göçer arıcılık kosullarında performanslarının karsılastırılması, Turkish Journal of Veterinary and Animal Sciences, 23 (Suppl. 3): 565-575.

Kandemir, İ. & Kence, A. (1995). Allozym variability in a central Anatolian honeybee (*Apis mellifera* L.) population. Apidologie, 26: 503-510. https://doi.org/10.1051/apido:19950607

Kandemir, İ., Kandemir, G., Kence, M., İnci, A. & Kence, A. (1995). Morphometrical and electrophoretical discrimination of honeybees from different regions of Turkey. In XXXIV. International Apicultural Congress in Apimondia (pp. 14-19). Lausanne, Switzerland.

Kandemir, İ., Kence, M. & Kence, A. (2000). Genetic and Morphometric variation in honeybee (*Apis mellifera*) population of Türkiye. Apidologie, 31: 343-356. https://doi.org/10.1051/apido:2000126

Kandemir, İ., Kence, M. & Kence, A. (2005). Morphometric and electrophoretic variation in different honeybees (*Apis mellifera*) population. Turkish Journal of Veterinary and Animal Sciences, 29: 885-890.

Kandemir, İ., Kence, M., Sheppard, W.S. & Kence, A. (2006a). Mitochondrial DNA variation in honey bee (*Apis mellifera* L.) populations from Türkiye. Journal of Apicultural Research and Bee World, 45: 33-38. https://doi.org/10.1080/00218839.2006.11101310

Kandemir, İ., Pinto, M.A., Meixner, M.D. & Sheppard, W.S. (2006b). Hinf-I digestion of cytochrome oxidase I region is not a diagnostic test for *A. m. lamarckii*. Genetics and Molecular Biology, 29: 747-749. https://doi.org/10.1590/S1415-47572006000400027

Kandemir, İ., Meixner, M.D., Özkan, A. & Sheppard, W.S. (2006c). Genetic characterization of honey bee (*Apis mellifera cypria*) populations in northern Cyprus. Apidologie, 37: 547-555. https://doi.org/10.1051/apido:2006029

Karabağ, K., İvgin Tunca, R., Tüten, E. & Doğaroğlu, T. (2020). Current genetic status of honey bees in Anatolia in terms of thirty polymorphic microsatellite markers. Turkish Entomology Journal, 44: 333-346. https://doi.org/10.16970/entoted.678808

Kekeçoğlu, M. (2018). Morphometric divergence of Anatolian honey bees through loss of original traits: A dangerous outcome of Turkish apiculture. Sociobiology, 65: 232-243. https://doi.org/10.13102/sociobiology.v65i2.1895

Kekeçoğlu, M. & Sosysal, M.İ. (2010). Genetic diversity of bee ecotypes in Türkiye and evidence for geographical differences. Romanian Biotechnological Letters, 15: 5646-5653.

Maa, T.C. (1953). An inquiry into the systematics of the Tribe Apidini or honeybees (Hymenoptera). Treubia, 21: 525-640.

Kekeçoğlu, M., Kambur Acar, M., Bir, S., Uçak, M. & Çaprazlı, T. (2020). Biodiversity of honey bees (*Apis mellifera* L.) in Turkey by geometric morphometric analysis. Biological Diversity and Conservation, 13: 282-289. https://doi.org/10.46309/biodicon.2020.773984

Rinderer, T.E. (1986). Bee Genetics and Breeding. Orlando, Florida: Academic Press, 426p.

Rinderer, T.E., Daly, H.V., Sylvester, H.A., Collins, M., Buco, S.M., Helmıch, R.L. & Danka, R.G. (1990). Morphometric differences among Africanized and European honey bees and their hybrids (Hymenoptera: Apidae). Annals of the Entomological Society of America, 83: 346-351. https://doi.org/10.1093/aesa/83.3.346

Rothenbuhler, W.C. & Kerr, W.E. (1968). Bee genetics. Annual Review of Genetics, 2: 413-438. https://doi.org/10.1146/annurev.ge.02.120168.002213

Ruttner, F. (1965). Versuch einer Charakterisierung der Carnica-Biene nach ihrem Flügelgeader. Praha: Ustav Vedeckotech Inf MZLVH, 165-172.

Ruttner, F. (1980). *Apis mellifera adami*. Apidologie, 11: 385-400. https://doi.org/10.1051/apido:19800407

Ruttner, F. (1984). Races of bees. In Dadant and Sons (Eds), The Hive and the Honey Bee (pp. 19-38). Illinois: Dadant and Sons. Inc.

Ruttner, F. (1987). Breeding techniques and selection for breeding of honeybee. Derby, UK: British Isles Bee Breeders' Association, 152 p.

Ruttner, F. (1988a). Biogeography and taxonomy of honeybees. Berlin: Springer Verlag, 310 p. https://doi.org/10.1007/978-3-642-72649-1

Ruttner, F. (1988b). Breeding technique and selection for Breeding of Honey bee. Brighton UK: G.bread and Sons. Led.

Ruttner, F. (1992). Naturgeschichte der Honigbienen. Münich, Germany: Ehrenwirth Verlag, 360 p.

Ruttner, F., Tassencourt, L. & Louveaux, J. (1978). Biometrical-Statistical analysis of the geographic variability of *Apis mellifera* L. Apidologie, 9: 363-381. https://doi.org/10.1051/apido:19780408

Smith, D. R., Taylor, O. R. & Brown, W. M. (1989). Neotropical Africanized honey bees have African mitochondrial DNA. Nature, 339: 213-215. https://doi.org/10.1038/339213a0

Smith, D.R. & Brown, W.M. (1988). Mitochondrial DNA restriction site polymorphism American and Africanized honey bees (Apis mellifera). Experientia, 44: 257-260. https://doi.org/10.1007/BF01941730

Smith, D.R. & Brown, W.M., (1990). Restriction endonuclease cleavage site and length polymorphism in mitochondrial DNA of *Apis mellifera mellifera* and *Apis mellifera carnica* (Hymenoptera: Apidae). Annals of the Entomological Society of America, 83: 81-88. https://doi.org/10.1093/aesa/83.1.81

Smith, D.R. (1991). Mitochondrial DNA and honey bee biogeography. In D.R. Smith, (Eds.), Diversity in the genus Apis. Boulder. New York: CRC Press, 46 p.

Smith, D.R. (2002). Genetic diversity in Turkish honey bees. Uludağ Arıcılık Dergisi, 2: 10-17.

Smith, D.R., Slaymaker, A., Palmer, M. & Kaftanoglu, O. (1997). Turkish honey bees belong to the east Mediterranean mitochondrial lineage. Apidologie, 28: 269-274. https://doi.org/10.1051/apido:19970503

Smith, D.R., Vıllafuerte, L., Otıs, G. & Palmer, M.R. (2000). Biogeography of *Apis cerana* F. and *A. nigrocincta* Smith: insight from mtDNA studies. Apidologie, 31: 265-279. https://doi.org/10.1051/apido:2000121

Tozkar, C.Ö. (2020). Genetic structure of honey bee (Apis mellifera Linnaeus, 1758) subspecies based on tRNAleu-COX2 and ND5 regions of mtDNA. Applied Ecology and Environmental Research, 18: 2269-2284. https://doi.org/10.15666/aeer/1802_22692284

Ünal, G. & Özdil, F. (2018). Genetic characterization of Thrace honey bee populations of Türkiye: restriction and sequencing of inter cytochrome C oxidase I-II (CoxI-CoxII) genes. Journal of Apicultural Research, 57: 213-218. https://doi.org/10.1080/00218839.2018.1426347