ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

MORPHOMETRIC ANALYSIS OF HONEYBEES DISTRIBUTED IN NORTHERN TURKEY ALONG THE BLACK SEA COAST

Türkiye'nin Kuzeyinde Karadeniz Kıyısı Boyunca Dağılış Gösteren Balarılarının Morfometrik Analizi

(Genişletilmiş Türkçe Özet Makalenin Sonunda Verilmiştir)

İbrahim ÇAKMAK[1], Stefan FUCHS[2], Selvinar S.ÇAKMAK[3], Ayça ÖZKAN KOCA[4], Peter NENTCHEV[5], İrfan KANDEMİR[3]

[1]Beekeeping Development-Application and Research Center (AGAM), Mustafakemalpasa MYO, UludagUniversitesi, M.Kemalpasa-Bursa,Turkey
[2]Institut fuer Bienenkunde (Polytechnische Gesellschaft), Faculty of Life Sciences, Goethe-Universitaet Frankfurt am MainKarl-von-Frisch-Weg 2, D-61440 Oberursel, Germany
[3]Department of Biology, Faculty of Science, Ankara University, 06100 Tandogan-Ankara, Turkey
[4]Faculty of Fine Arts, Maltepe University, 34857 Maltepe-Istanbul,Turkey
[5]Faculty of Agriculture, Trakia University,Stara-Zagora, Bulgaria

Geliş Tarihi: 20.05.2015, Kabul Tarihi: 20.07.2015

ABSTRACT

The objective of this study was to discriminate the honeybee populations distributed in different regions of northern Turkey, in a land strip approximately following the Black Sea Coast up into Thrace. To assess the morphological variation between populations, a total of 58 colonies was evaluated in statistical analysis based on standard morphometric measurements using 34 morphometric characters. Discriminant function analysis (DFA) yielded high percentages of correct reclassifications between 6 tentative population groups from geographic regions differing in climatic and ecological characteristics. In particular, results showed a gradual character shift from the Eastern end of the distribution (bordering Georgia) to the Western end (bordering Bulgaria) of the sampling area. To explore relations to adjacent subspecies, we included reference samples obtained fromthe Morphometric Bee Data Bank in Oberursel-Germany. This combined DFA confirmed that *A. m. anatoliaca* is the predominant subspecies in northern part of Turkey extending into Thrace region. *A. m. caucasica* is prevalent in some Eastern Black Sea locations, but allocations to this subspecies were also found scattered westwards up to Northern Thrace indicating the influence of beekeeper activities. Bees in Southern Thrace were *A. m anatoliaca*, while those of North Thrace, though mixed, showed close relations to *A. m. carnica*.

Key words: *Apis mellifera*, honeybees, morphometric, northern Turkey

ÖZ

Bu çalışmanın amacı, Türkiye'nin kuzeyindeki farklı bölgelerde, yaklaşık olarak Karadeniz Bölgesi'nden Trakya'ya devam eden bir kara şeridinde yayılış gösteren balarısı populasyonlarını ayırt etmektir. Populasyonlar arasındaki morfometrik varyasyonu belirlemek için toplam 58 koloni 34 morfomertik karakter kullanılarak standart morfometrik ölçümlere dayalı olarak istatistiksel analizlerde değerlendirilmiştir. Ayrışım fonksiyon analizi (DFA), iklim ve ekolojik özellikleri farklılık gösteren coğrafik bölgelerdeki belirsiz 6 populasyon grubu arasında yüksek doğru sınıflandırma yüzdeleri vermiştir. Özellikle, sonuçlar örnekleme alanının Doğu ucundan (Gürcistan sınırındaki) Batı

ucunakadar (Bulgaristan sınırındaki) kademeli bir karakter kayması göstermiştir. Yakın alttürlerin ilişkilerini araştırmak için Almanya-Oberursel'deki Morfometrik Arı Veri Bankası'ndan elde edilen referans örneklerini analizlere dahil ettik. Bu kombine edilmiş DFA, Trakya bölgesine uzanan Türkiye'nin kuzey kesiminde*A. m. anatoliaca*'nın baskın alttür olduğunu doğrulamıştır. *A.m.caucasica*bazı Doğu Karadeniz lokasyonlarında yaygındır, fakat bu alttürün bölünmesi, ayrıca batıya doğru Kuzey Trakya'ya kadar dağınık halde bulunması arıcı faaliyetlerinin etkisine işaret etmektedir. Trakya'nın güneyindeki arılar *A. m. anatoliaca* iken Trakya'nın kuzeyinde bulunanlar karışık olsa da *A. m. carnica* ile yakın ilişki göstermektedir.

Anahtar kelimeler:*Apis mellifera*, balarıları, morfometri, Kuzey Türkiye

INTRODUCTION

Turkey is situated in a significant geographic position where the three continents Europe, Asia and Africa (via Mid-East) are connected. It encompasses a wide range of different climatic zones and ecological regionswhich are reflected in the diversity of honeybees. Four honeybee subspecies had been described in Turkey, based on multivariate statistical analysis of standard morphometric characters and on six enzyme systems, (Ruttner, 1988; Kandemir et al., 2000). *Apis mellifera anatoliaca* is distributed throughout Central Anatolia, the Aegean and Mediterranean regions, and a large part of the Black Sea region. *A. m. caucasica* resides in North-eastern Anatolia, *A. m. meda* in the southern Anatolia, and *A. m. carnica* in the Thrace region (Ruttner, 1988; Kandemir et al., 2000; Smith et al., 1997). In addition, *A.m. syriaca* is found in the southern part of Turkey near Hatay (Kandemir et al., 2006).Further morphometric, biochemical and genetic research had basically supported this distribution (Güler and Kaftanoğlu, 1999a, 1999b; Palmer et al., 2000; Kandemir et al., 2006; Bodur et al., 2007; Özdil et al., 2009, 2012; Özkan Koca and Kandemir, 2013). Even though extensive migratory beekeeping is practiced in Turkey, native subspecies and their ecotypes are still partly preserved. However, this pattern is endangered because the number of professional beekeepers which transport colonies over wide distances and rely on commercially produced queens increases rapidly.

The northern parts of Turkey stretching along the Black Sea coast cover a range of honeybee subspecies, from *A. m. caucasica* at the Georgian border over *A. m. anatoliaca* in north Anatolia to *A. m. carnica* in Thrace. This area encompasses several regions differing in climatic and ecological conditions. Eastern Anatolia is a predominantly mountainous region with some forest, mostly covered by grassland and an alpine zone at higher elevations.The region is known for longfreezng cold winters with heavy snow fall and short hot summers. The Eastern Black Sea is a temperate humid rainforest region in the lower parts, but steep mountains rise immidiately at the coast, frequently separated by rivers between these mountains. The winters are mild and long in the coast and cold on the mountains. The Western Black Sea region, though basically similar to the east, is less humid and mountains are much lower. The Marmara region in the West is divided by the Marmara Sea and has two parts. South Marmara in Asia Minor, where Blacksea, Aegean and Central Anatolia meet, is considered a transition zone between Europe and Asia Minor. Here, winters are rather mild and summers are moderate. Thrace is situated at the European side and comprised of mostlygrassland with short mild winters and moderate or hot summers.

The common method to distinguish honeybee subspecies is the study of morphometric characters on the body parts, using wing venation angles, lenght measures of body parts, and pigmentation patterns (Reviewed in Ruttner, 1988, Meixner et al., 2013), to be evaluated by multivariate statistical anaysis. The objective of our research is to investigate the extent of morphometric variation of honeybee populations distributed in the northern Turkey including South Marmara and Thrace regions.

MATERIALS AND METHOD

Honeybee samples were collected in May-August of 2002-2005 from 58 colonies in northern Turkey ranging from sea level up to 3000 m to the Bulgarian border in Turkey, includingthe adjacent Bulgarian region(Figure 1, Table 1). Bee samples were taken from remote villages with no or only minor

short-distance migratory beekeeping. Areas with intense migratory beekeeping were mostly avoided but in few cases some samples were included to improve representation of the region. Some of the sampling points in both Georgian (Camili-Artvin) and Bulgarian border (Armutveren-Kirklareli) were situated in native bee preservation areas and sampling permission was obtained from authorities. Bee samples were shaken from a brood comb into a plastic bag containing a chloroform sucked cotton ball to obtain a fully stretched out proboscis. Samples were then transferred into a plastic bottle containing 70% ETOH. A total of 10 worker bees per colony were measured for a total of 34 morphometric characters (Ruttner, 1988) using a stereomicroscope and a PC-based video measuring system developed by Meixner and Meixner (2004). Multivariate morphometric analyses were performed on this measured data of 58 colonies obtained from different regions in northern Turkey.

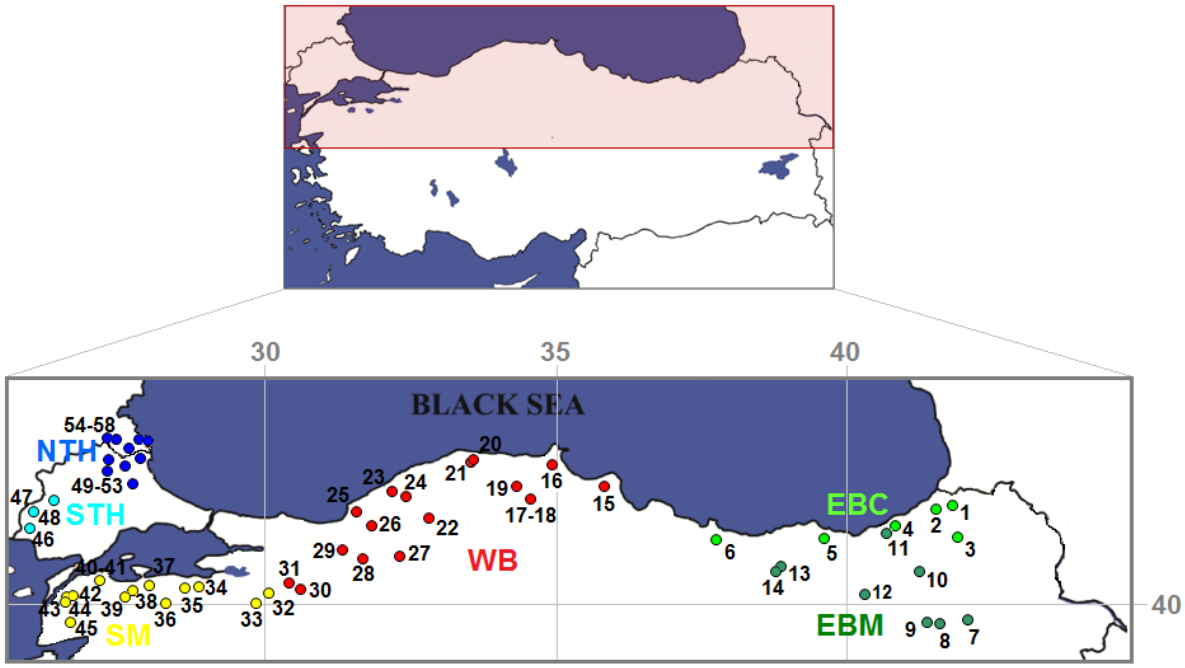


Figure 1. Sampling locations of honeybee samples from northern Turkey. Names for numbered localities are given in Table 1.

Şekil 1. Kuzey Türkiye'deki balarısı örneklerinin lokasyonları. Numaralandırılmış lokasyon isimleriTablo 1 verilmiştir.

Honeybee samples were assignedto six groups (Eastern Black Sea Coast, EBC; Eastern Black Sea Mountain, EBM; Western Black Sea, WB; South Marmara, SM; North Thrace, NTH; South Thrace, STH) according to geographic regions of apparent climatic and ecological differences. To assess the morphological variation between these six groups, first an analysis of variance (ANOVA) was carried out on the mean values of the colony sample measurements. Then a discriminant function analysis (DFA) was carried out, and reclassification rates were estimated using leave-one-out (cross-validation) classification and cross validation tests to check the accuracy in identifying the colonies. To investigate the clinal structure along the northern parts of Turkey, regression distribution of DA function over longitude was applied. In a second DFA, reference samples representing *A. m. anatoliaca*, *A. m. carnica*, *A. m. caucasica*, *A. m. cecropia*, *A. m. ligustica, A. m. macedonica* and *A. m. Mellifera* from the Morphometric Bee Data Bank in Oberursel were included into analysis and samples were force-allocated into these subspecies. All of the statistical analyses were carried out using SPSS 13.0 (SPSS, 2004) software.

RESULTS

Morphometric Analysis of Honeybee Populations

Analysis of variance (ANOVA) of morphological characters showed that all of the measured morphological characters displayed statistically significant differences among honeybee populations ($P<0.05$). The DFA confirmed reliable separation of the honeybee populations from the six regions. Of five relevant DFA axesthe first, the second and the third represented 63.4%,15.2% and 9.1% of the total variation, respectively. Scatter plot of the first two DFA axes showed three major groups: the first group included the colonies of NTH, the second group included the colonies of STH, and the third group included the colonies of EBC, EBM, WB and SM (Figure 2). The members of these third group regions, however, showed some overlapping with each other, with the colonies of SM somewhat more separate. Cross validation tests based on these discriminant functions re-assigned 86% of the colonies to their correct original group, and all regional population except the WB population colonies were correctly re-classified to their assigned groups. In the WB population, 12 of 17 samples (70.6%) were correctly re-allocated into the WB population, while 1 (5.9%), 2 (11.8%) and 2 (11.8%) were assigned to the EBC, EBM and SM populations, respectively. The geographic distribution of re-allocations is shown in Figure 3a. In particular, a clear relation to the geographic position is apparent indicating a clinal, transitional pattern along the coast, with NTH set apart. This gradual East-West transition is clearly supported by regression analysis of the first three DFA axis sample scores over longitude, yielding significant slopes (F1: Beta=-0.593 $p<0.0005$; F2: Beta=0.426 $P<0.001$; F3: Beta=-0.319 $P=0.013$, NTH excluded). This transition can be visualized in Figure 3b, where sample RGB color values are computed from the first three DFA axis scores, thus reflecting their morphometric positioning.

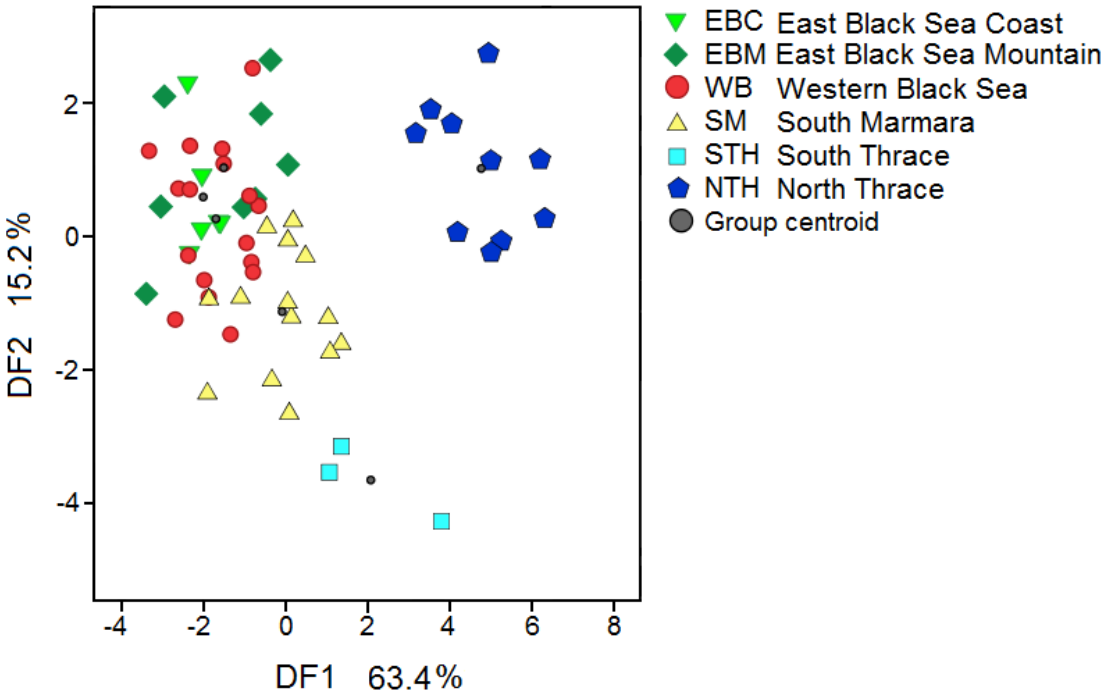
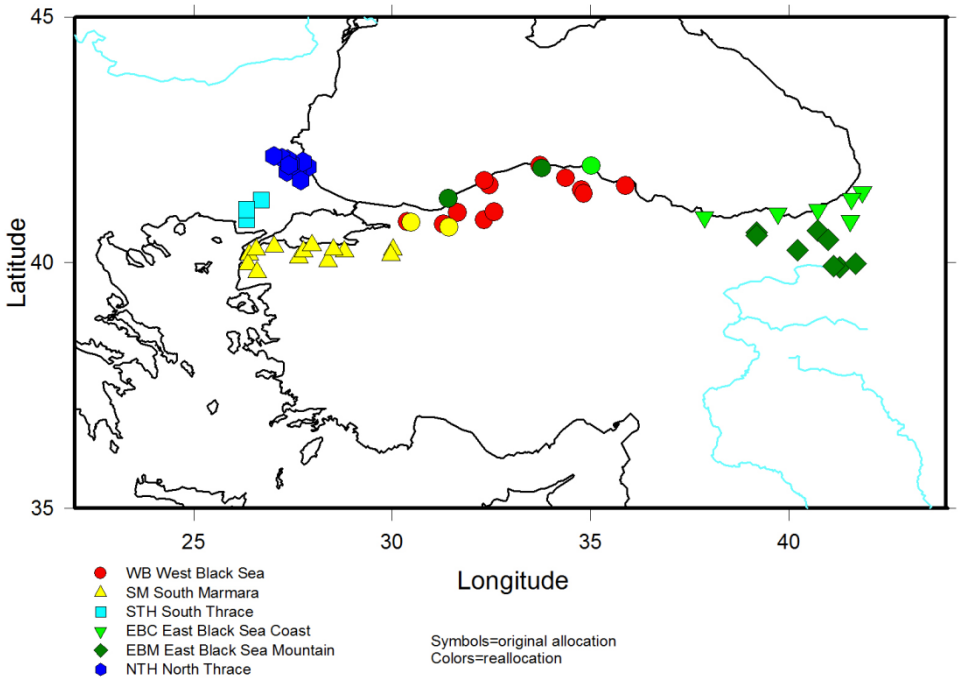


Figure 2. Scatter plot of DFA based on morphometric characters of honeybee populations from six geographic regions.

Şekil 2. Altı coğrafik bölgeden toplanan balarısı örneklerinin morfometrik karakterlere dayalı DFA dağılım grafiği.

a



b

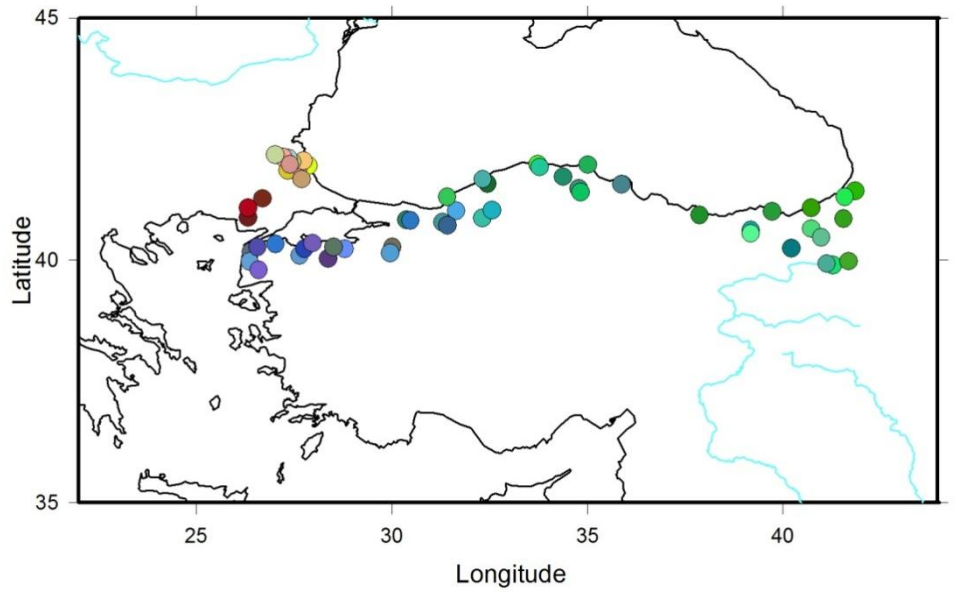


Figure 3. a) Geographic distribution of colony re-allocations into six regional groups. **b)** Visualization morphometric positioning of colony samples. Sample plot RGB color values are computed from the first three DFA axis scores.

Şekil 3. a) Kolonilerin 6 bölgesel gruba yeniden yerleştirilmesinin coğrafik dağılımı **b)** Koloni örneklerinin morfometrik pozisyonlarının gözlenmesi. Örnek grafik RGB renk değerleri ilk 3 DFA eksenlerinden hesaplanmıştır.

Morphometric Analysis of Honeybee Samples in Relation to Adjacent Subspecies Reference Samples

When reference samples from the Oberursel Data Bank were included in DFA, four DFA axes were included in the calculations, and the first, the second and the third axes represented 62.3%, 21.2% and 6.9% of the total variation, respectively. All colonies from five geographic region (EBC, EBM, WB, SM and STH) clustered with *A. m. anatoliaca* and *A. m.caucasica* reference data, thus representing members of the O honeybee lineage except one from EBC region which was allocated to *A. m. carnica* Figure 4). Though allocations to *A. m. anatoliaca* was found in 3 locations in the eastmost Black Sea regions, this subspecies was also found in 5 locations scattered in the WB and SM region. The presence of this subspecies far from its Caucasian origin area in these regions of intense and advanced beekeeping clearly indicated the effect of beekeepers colony transport or queen breeding efforts. We did not find *A. m. caucasica* in the Thrace locations. While bees in South Thrace region were still allocated to *A. m. anatolica,* the bees in the North Thrace / Bulgarian border region were mostly allocated to *A. m. carnica* (5 out of 10 samples). However, even in that region a substantial portion (3 out of 10) were more close to *A. m. anatoliaca* then to any of the other tested subspecies, with the remaining 2 samples allocated to *A. m. ligustica* or *A. m. macedonica*.

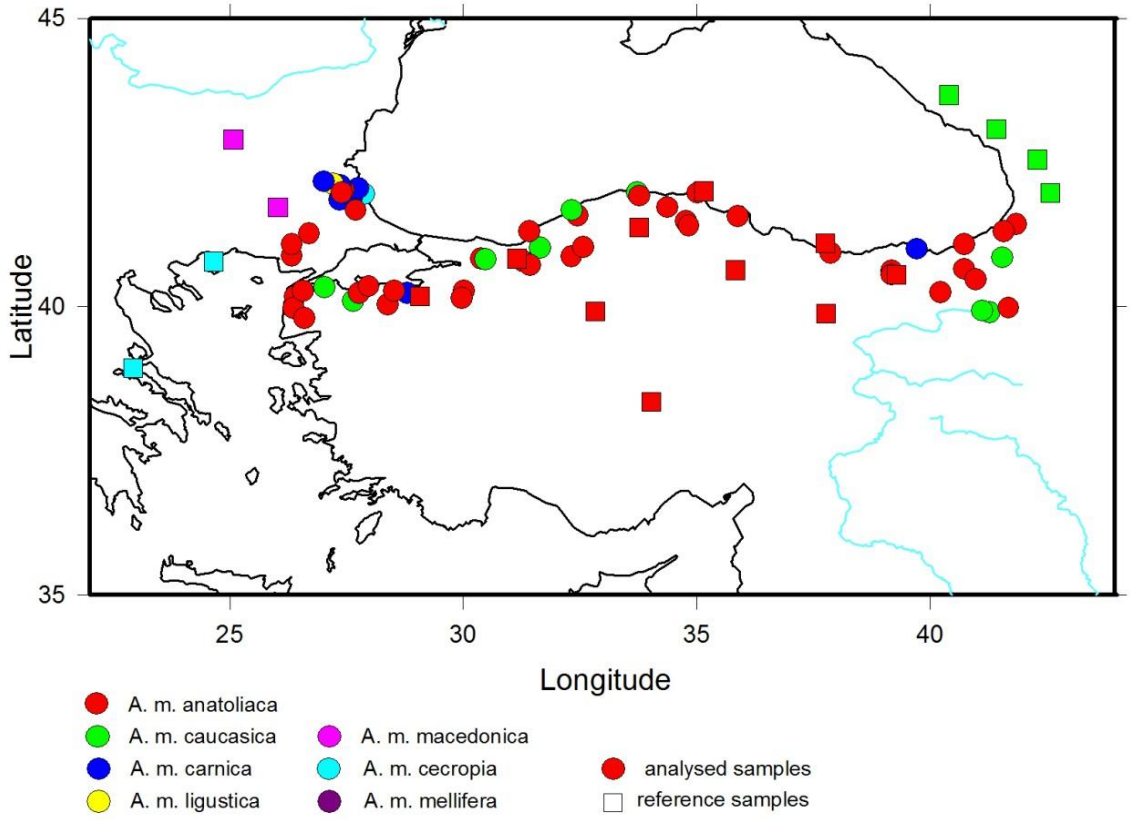


Figure 4. Geographic distribution of DFA force allocation of colony samples into seven adjacent subpecies represented by reference samples from the Oberursel Data Bank. Geographic positions of these reference samples if within the map range are also shown.

Şekil 4. Koloni örneklerinin DFA zorlaması ile Oberusel veri bankası'ndaki referans 7 yakın alttür örneklerine göre yerleştirmesi. Eğer harita alanı içerisinde ise bu referans örneklerinin coğrafik pozisyonu da gösterilmiştir.

DISCUSSION

The morphometric method we used here to study populations distributed in the northern Turkey including South Marmara and Thrace regions is commonly applied to study variation in honeybees.The results showed, that bees differed in their morphometric characters between the six local population groups proposed from climatic and ecological differences, and colonies could be reliably resampledinto their respective groups using DFA. Moreover, the placements of these groups in DFA plots, as well as regressions of the first three DA functionson longitude displayed a structured pattern which supported an east-west population transition. This concurs with results of Kandemir et al. (2000) who had applied multiple regression analysis on latitude and longitude to morphometric and electrophoretic variables, also showing that somemorphometric characters and gene frequencies were significantly related to geographic position (latitude and longitude). Our study also showed that colonies from Thrace region as well as part of the colonies from south Marmara formed separate clusters, with the NTH cluster closely affiliated to *A. m. carnica.*Colonies in Eastern Black Sea, where honeybees are more preserved compared to other regions in Turkey, overlap with colonies in Western Black Sea coastal areas. This suggested that *A. m. caucasica* is prevalent in some Eastern Black Sea locations and its influence may extend to Western Black Sea.

A DFA together with subspecies reference samples (Oberursel Data Bank) confirmed that *A. m. anatoliaca* is the predominant subspecies in the northern part of Turkey, with its influence extending into the Thrace region. Some samples were found in North Thrace, which predominantly was shown to be affiliated to C lineage subspecies, mainly *A. m. carnica*. The overall east-west transient pattern indicated that the original natural distribution is still apparent. However, even though the bee samples were taken from stationary beekeepers and native populations, a significant degree of mixing was also apparent throughout the region, particularly evidenced by scattered occurrences of *A. m. caucasica* rigth into the westmost beekeeping areas. Since the highest number of migratory beekeepers are located in middle Black Sea area, eastern bees were apparently transported along the coastal region and mixed, or by introduction of purchased queens from other regions. Genetic studies could help to clarifythis situation.

Table 1. Locations and collection date of the samples of honeybees analyzed in northern Turkey. Location as indicated on the map shown in Figure 1.

Tablo 1. Kuzey Türkiye'den analiz edilen balarısı örneklerinin toplanma zamanı ve lokasyonları. Lokasyonlar Şekil 1'de harita üzerinde gösterilmiştir.

Location	Latitude	Longitude	Altitude (m)	Date
Eastern Black Sea Coast (EBC)				
1. Camili-Borçka-Artvin	41° 26′ N	41° 51′ E	1500-1750	2002
2. Kabaca-Murgul-Artvin	41° 18′ N	41° 35′ E	750-1000	2002
3. Morkaya-Yusufeli-Artvin	40° 51′ N	41° 33′ E	1250-1500	2002
4. Kemer-Cayeli-Rize	41° 05′ N	40° 44′ E	0-250	2002
5. Çilekli-Trabzon	41° 00′ N	39° 43′ E	0-250	2002
6. Yokuşdibi-Ordu	40° 56′ N	37° 52′ E	250-500	2002
Eastern Black Sea Mountain (EBM)				
7. Pasinler-Erzurum	39° 59′ N	41° 41′ E	1500-1750	2002
8. Erzurum	39° 54′ N	41° 17′ E	2000-2250	2002
9. Ilıca-Erzurum	39° 56′ N	41° 07′ E	1750-2000	2002
10. İspir-Erzurum	40° 28′ N	40° 59′ E	1000-1250	2002
11. Ballıkoy-Anzer-Rize	40° 39′ N	40° 44′ E	2500-2750	2002
12. Bayburt	40° 15′ N	40° 13′ E	1500-1750	2002
13. Akçal-Kürtün-Gümüşhane	40° 37′ N	39° 11′ E	1500-1750	2002
14. Söğuteli-Kürtün-Gümüşhane	40° 33′ N	39° 11′ E	1750-2000	2002
Western Black Sea (WB)				

15. Kuşcular-Bafra-Samsun	41º 34′ N	35º 53′ E	0-250	2002
16. İğnesoküğü-Erfelek-Sinop	41º 58′ N	35º 01′ E	0-250	2002
17. Boyabat-Sinop	41º 29′ N	34º 47′ E	250-500	2005
18. Boyabat-Sinop	41º 24′ N	34º 50′ E	500-750	2005
19. Yılanlı-Hanönü-Kastamonu	41º 43′ N	34º 23′ E	1250-1500	2005
20. Belören-İnebolu-Kastamonu	41º 55′ N	33º 47′ E	500-750	2002
21. İnebolu-Kastamonu	41º 59′ N	33º 44′ E	0-250	2005
22. Hacıözköy-Karabük	41º 02′ N	32º 34′ E	1000-1250	2005
23. Bartın	41º 40′ N	32º 20′ E	0-250	2002
24. Derbent-Bartın	41º 35′ N	32º 27′ E	500-750	2005
25. Kdz.Ereğli-Zonguldak	41º 18′ N	31º 25′ E	0-250	2002
26. Karakavuz-Kdz. Ereğli-Zonguldak	41º 01′ N	31º 39′ E	1250-1500	2005
27. Gerede-Bolu	40º 52′ N	32º 19′ E	1250-1500	2005
28. Bolu	40º 43′ N	31º 26′ E	1250-1500	2002
29. Kaynaşlı-Düzce	40º 47′ N	31º 18′ E	250-500	2005
30. Akçapınar-Sakarya	40º 50′ N	30º 23′ E	0-250	2005
31. Taraklı-Sakarya	40º 49′ N	30º 29′ E	0-250	2005
South Marmara (SM)				
32. Bilecik	40º 16′ N	30º 01′ E	500-750	2005
33. Pazaryeri-Bilecik	40º 09′ N	29º 58′ E	500-750	2005
34. Görükle-Bursa	40º 14′ N	28º 48′ E	0-250	2002
35. Ikizce-Bursa	40º 16′ N	28º 31′ E	0-250	2002
36. Güllüce-M.Kemalpaşa-Bursa	40º 02′ N	28º 23′ E	0-250	2002
37. Bandırma-Balıkesir	40º 21′ N	27º 59′ E	0-250	2002
38. Üzümlü-Gönen	40º 06′ N	27º 39′ E	0-250	2002
39. Çalıoba-Bandırma-Balıkesir	40º 14′ N	27º 46′ E	0-250	2002
40. Balıklıçeşme-Balıkesir	40º 20′ N	27º 02′ E	0-250	2005
41. Balıklıçeşme-Çanakkale	40º 20′ N	27º 02 E	0-250	2002
42. Karacaören-Çanakkale	39º 58′ N	26º 22′ E	250-500	2005
43. Kepez-Çanakkale	40º 10′ N	26º 24′ E	0-250	2005
44. Güzelyalı-Çanakkale	40º 16′ N	26º 34′ E	0-250	2002
45. Bayramiç-Çanakkale	39º 48′ N	26º 36′ E	0-250	2002
South Thrace (STH)				
46. Sarıcaali-İpsala-Edirne	40º 53′ N	26º 20′ E	0-250	2002
47. Omurca-Meriç-Edirne	41º 05′ N	26º 20′ E	0-250	2002
48. Uzunköprü-Edirne	41º 16′ N	26º 42′ E	0-250	2002
North Thrace (NTH)				
49. Dereköy-Tr-Bg Border	41º 59′ N	27º 24′ E	750-1000	2005
50. Düzorman-Tr-Bg Border	41º 51′ N	27º 21′ E	500-750	2005
51. Boztaş-Tr-Bg Border	41º 55′ N	27º 38′ E	500-750	2005
52. Sisliova-Tr-Bg Border	41º 57′ N	27º 53′ E	250-500	2005
53. İslambeyli-Tr-Bg Border	41º 40′ N	27º 42′ E	500-750	2005
54. Tsarevo-Tr-Bg Border	42º 10′ N	27º 01′ E	250-500	2005
55. S.Sinemorets-Tr-Bg Border	42º 08′ N	27º 13′ E	250-500	2005
56. S.Kosti-Tr-Bg Border	42º 03′ N	27º 45′ E	0-250	2005
57. M.Turnovo-Tr-Bg Border	42º 01′ N	27º 27′ E	500-750	2005
58. S.Zvezdets-Tr-Bg Border	42º 06′ N	27º 22′ E	500-750	2005

*Turkey (Tr), Bg (Bulgaria)

Acknowledgement

We thank Nikolaus Koeniger for supporting this research, and Beate Springer for invaluable help taking the measurements. The Project was funded by NATO project No. CLG 981340 and also supported by TÜBİTAK and DFG through Research Exchange program. We are grateful to Mustafa Civan and Civan Beekeeping Company and beekeepers for helping during bee sample collection.

REFERENCES

Bodur, C., Kence, M., Kence, A. 2007. Genetic structure of honeybee, *Apis mellifera* L. (Hymenoptera: Apidae) populations of Turkey inferred from microsatellite analysis. *Journal of Apicultural Research*, 46: 50–56.

Güler, A., Kaftanoğlu, O. 1999a. Morphological characters of some important races and ecotypes of Turkish honey bees (*Apis mellifera* L.) - I. *TurkishJournal of Veterinary Animal Sciences*, 23: 565–570.

Güler, A., Kaftanoğlu, O. 1999b. Morphological characters of some important races and ecotypes of Turkish honeybees (*Apismellifera* L.) - II. *TurkishJournal of Veterinary Animal Sciences*, 23: 571–575.

Kandemir, I., Kence, M., Kence, A. 2000. Genetic and morphometric variation in honeybee (*Apis mellifera* L.) populations of Turkey. *Apidologie*, 31: 343–356.

Kandemir, I., Kence, M., Sheppard, W.S., Kence, A. 2006. Mitochondrial DNA variation in honey bee (*Apis mellifera* L.) populations from Turkey. *Journal of Apicultural Research,* 45: 33–38.

Meixner, A., Meixner, M.D. 2004. BEE2 Morphometric Software © 1997–2004. Frankfurt, Germany.

Meixner, M.D., Pinto, M.A., Bouga, M., Kryger, P., Ivanova, E., Fuchs, S. 2013.Standard methods for characterising subspecies and ecotypes of *Apis mellifera*.*Journal of Apicultural Research,*52 (4).

Özdil, F., Yıldız, M.A., Hall, G.H. 2009. Molecular characterization of Turkish honey bee populations (*Apis mellifera*) inferred from mitochondrial DNA RFLP and sequence results. *Apidologie*, 40: 570–576.

ÖzkanKoca, A.,Kandemir, İ. 2013. Comparison of two morphometric methods for discriminating honey bee populations (*Apis mellifera* L.) in Turkey. *Turkish Journal of Zoology*,37(2), 205-210.

Palmer, M.R., Smith, D.R., Kaftanoğlu, O. 2000. Turkish honey bees: genetic variation and evidence for a fourth lineage of *Apismellifera* mtDNA. *Journal of Heredity*, 91: 42–46.

Ruttner, F. 1988. *Biogeography and taxonomy of honeybees*. Springer, Berlin, Heidelberg.

Smith, D.R., Slaymaker, A., Palmer, M., Kaftanoğlu, O. 1997. Turkish honey bees belong to the east Mediterranean mitochondrial lineage. *Apidologie*, 28: 269–274.

SPSS, 2004. SPSS for Windows, Release 13.0, standard version. SPSS Inc., Chicago, IL, USA.

GENİŞLETİLMİŞ ÖZET

Giriş

Türkiye balarılarında çeşitliliği yansıtan farklı iklim zonlarını ve ekolojik bölgelerini kapsayan üç kıtanın (Avrupa, Asya ve Afrika) birbirine bağlandığı önemli bir coğrafi konumda bulunmaktadır. Standart morfometrik karakterlerin çok değişkenli istatistiksel analizi ve enzim sistemlerine bağlı olarak yapılan analizlerde Türkiye'de dört farklı balarısı alttürü tanımlanmıştır.*Apis melliferaanatoliaca* Orta Anadolu, Ege ve Akdeniz Bölgesi ve Karadeniz Bölgesi'nin büyük bir kısmında dağılmaktadır. *A. m. caucasica* Kuzeydoğu Anadolu'da, *A. m. meda* Güneydoğu Anadolu'da ve *A. m. carnica* Trakya'da bulunmaktadır. Ayrıca *A. m. syriaca* Hatay yakınındaki Türkiye'nin güney kesiminde bulunmaktadır. Morfometrik, biyokimyasal ve genetik olarak yapılan diğer çalışmalar bu dağılımı desteklemiştir. Karadeniz'in kıyı kesimi boyunca uzanan, Türkiye'nin kuzey kesimlerinde farklı alttürler (*A. m. caucasica*, *A. m. anatoliaca* ve *A. m. carnica*) yayılış göster-

mektedir. Bu araştırmanın amacı, Güney Marmara ve Trakya Bölgeleri de dahil olmak üzere, Türkiye'nin kuzeyinde bulunan balarısı populasyonlarında morfometrik varyasyonu araştırmaktır.

Materyal ve Metot

Çalışma için balarısı örnekleri 2002-2005 yıllarında Mayıs ve Ağustos ayları arasında, Türkiye'nin kuzeyinde bulunan ve Türkiye sınırına yakın Bulgaristan bölgesinden kolonileri de içeren toplam 58 koloniden toplanmıştır (Şekil 1, Tablo 1). Her bir koloniden toplam 10 işçi arıda morfometrik karakterler Meixner ve Meixner (2004) tarafından geliştirilen ölçüm sistemi ile ölçülmüş ve çok değişkenli morfometrik analizler bu ölçülen veriler ile gerçekleştirilmiştir. Analizler için balarısı örnekleri, bulundukları coğrafik bölgelerin belirgin iklimsel ve ekolojik farklılıklarına göre altı ana gruba (Doğu Karadeniz-Kıyı Bölgesi, EBC; Doğu Karadeniz-Dağlık Bölge, EBM; Batı Karadeniz, WB; Güney Marmara, SM; Kuzey Trakya, NTH; Güney Trakya, STH) ayrılmış olup gruplar arasındaki ayrımı görmek için ayrışım fonksiyon analizi (DFA) yapılmıştır. Çapraz doğrulama testi ile kolonilerin diğer gruplara dağılımı ve kendi orginal gruplarına yerleşme yüzdelikleri kontrol edilmiştir.Oberursel Morfometrik Arı Bankası'ndan elde edilen *A. m. anatoliaca*, *A. m. carnica*, *A. m. caucasica*, *A. m. cecropia*, *A. m. ligustica, A. m. macedonica* ve *A. m. mellifera* alttürlerine ait referans örneklerinin verileri DFA'ya dahil edilerek örneklerin hangi alttür gruplarına dahil olduğu belirlenmiştir. Ayrıca Türkiye'nin kuzey bölgeleri boyunca klinal yapıyı araştırmak için, örneklerin bulunduğu lokasyonların boylamları üzerinde DA fonksiyonlarının regresyon dağılımı uygulanmıştır. Tüm istatistiksel analizler SPSS 13.0 programı kullanılarak gerçekleştirilmiştir.

Sonuçlar ve Tartışma

Balarısı Populasyonlarının Morfometrik Analizi: DFA altı bölgedeki balarısı populasyonlarının güvenilir ayrılmasını doğrulamıştır. DFA'nın ilk iki eksenindeki dağılım grafiğinde, üç temel grup ayrılmıştır: İlk grup NTH kolonilerini, ikinci grup STH kolonilerini ve üçüncü grup EBC, EBM, WB ve SM kolonilerini içermektedir (Şekil 2). Ancak üçüncü grup bölgelerinin üyeleri birbirleri ile bazı örtüşmeler göstermekte olup SM kolonileri diğerlerinden biraz daha fazla ayrılmaktadır. Ayrışım fonksiyonlarına bağlı olarak çapraz doğrulama testi, WB kolonileri hariç kolonilerin %86'sını kendi orijinal grupları içerisinde sınıflandırmıştır. Kolonilerin yeniden gruplara ayrılmalarının coğrafik dağılımı Şekil 3a'da görülmektedir. Örneklerin bulunduğu lokasyonların boylamları üzerinde DA fonksiyonlarının regresyon dağılımına göre örnekleme alanının doğu ucundan (Gürcistan sınırındaki) batı ucuna kadar (Bulgaristan sınırındaki) kademeli bir geçiş görülmektedir (Şekil 3b).

Balarısı Örnekleri ile Yakın Alttürlerin Referans Örneklerinin Morfometrik Analizi: Oberursel Veri Bankası'ndaki referans örnekler DFA'ya dahil edildiğinde, analiz Trakya bölgesine kadar uzanan Türkiye'nin kuzey kesiminde *A. m. anatoliaca*'nın baskın alttür olduğunu doğrulamıştır. *A. m. caucasica* bazı Doğu Karadeniz lokasyonlarında yaygındır, fakat bu alttürün bölünmesi, ayrıca batıya doğru Trakya'nın kuzeyine kadar dağınık halde bulunması arıcı faaliyetlerinin etkisine işaret etmektedir. Trakya'nın güneyindeki arılar *A. m. anatoliaca* iken Trakya'nın kuzeyinde bulunanlar karışık olsa da *A. m. carnica* ile yakın ilişki göstermektedir (Şekil 4).