



## Distance Between Turkish Pigeon Breeds in terms of Behavioral, Morphological, and Some Genetic Characteristics

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### ABSTRACT

In terms of pigeon diversity, Anatolia is culturally and biologically rich. This study aimed to classify twenty-two local Turkish pigeon breeds based on their phenotypic and genetic characteristics using multiple correspondence analysis (MCA) and hierarchical cluster analysis (HCA). A total of seventy-six qualitative and quantitative traits were coded in binary form (presence/absence) to reveal inter-breed relationships. The first three MCA dimensions explained 40.92% of the total variation and effectively reflected similarities among breeds. According to the MCA results, short-beaked breeds formed a distinct cluster, while diving-spinning breeds grouped separately. The Takla breed, on the other hand, appeared clearly distinct from all others, consistent with its unique flight performance and widespread distribution. HCA using Ward's method and Euclidean distance produced four clusters; however, evaluation criteria indicated limited clustering accuracy, suggesting that binary data were insufficient for robust hierarchical grouping. Overall, MCA provided a more reliable representation of phenotypic and genetic similarities than HCA. In particular, the grouping of short-beaked pigeon breeds and diver-spinner breeds, based on the results of Euclidean distance calculation using three-dimensional coordinates from the MCA, shows that Turkish pigeon breeds tend to group themselves according to their functional characteristics, while the shared geographical origin should also not be disregarded. This study contributes to the understanding of behavioural, morphological, and genetic relationships among native pigeon breeds in Turkey and offers a methodological framework for their characterization and conservation of these cultural assets.

## Davranışsal, Morfolojik ve Bazı Genetik Özellikler Bakımından Türk Güvercin Irkları Arasındaki Farklılıklar

### MAKALE BİLGİSİ

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### ÖZ

Güvercin çeşitliliği açısından Anadolu, kültürel ve biyolojik bir zenginliğe sahiptir. Bu çalışma, çoklu uyum analizi (MCA) ve hiyerarşik kümeleme analizi (HCA) kullanarak yirmi iki yerel Türk güvercin ırkını fenotipik ve genetik özelliklerine göre sınıflandırmayı amaçlamıştır. Irklar arası ilişkileri ortaya çıkarmak için toplam yetmiş altı nitel ve kantitatif özellik ikili biçimde (var/yok) kodlanmıştır. İlk üç MCA boyutu, toplam varyasyonun %40,92'sini açıklamış ve ırklar

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**Anahtar Kelimeler**

Genetik mesafe  
Yerel güvercin  
Morfometri  
Çok değişkenli

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arasındaki benzerlikleri etkili bir şekilde yansıtmıştır. MCA sonuçlarına göre, kısa gagalı ırklar ayrı bir küme oluştururken, dalış-dönme ırkları ayrı bir grupta yer almıştır. Bursa ve Mülakat ırkları ortak kökenlerini yansıtmak üzere yakın ilişkilidir. Öte yandan Takla ırkı, benzersiz uçuş performansı ve yaygın dağılımıyla tutarlı olarak diğerlerinden açıkça farklı görünmektedir. Ward yöntemi ve Öklid mesafesi kullanılarak yapılan HCA, dört küme oluşturmuştur; Ancak, değerlendirme kriterleri sınırlı kümeleme doğruluğunu gösterdi ve bu da ikili verilerin sağlam hiyerarşik gruplama için yetersiz olduğunu düşündürmüştür. Genel olarak, MCA, HCA'ya göre fenotipik ve genetik benzerliklerin daha güvenilir bir temsilini sağlamaktadır. Özellikle, MCA'dan elde edilen üç boyutlu koordinatlar kullanılarak yapılan Öklid mesafesi hesaplamasının sonuçlarına dayalı olarak kısa gagalı güvercin ırkları ve dalıcı-dönücü ırklarının gruplandırılması, Türk güvercin ırklarının işlevsel özelliklerine göre gruplanma eğiliminde olduğunu, ancak ortak coğrafi kökenin de göz ardı edilmemesi gerektiğini göstermektedir. Bu çalışma, Türkiye'deki yerli güvercin ırkları arasındaki davranışsal, morfolojik ve genetik ilişkilerin anlaşılmasına katkıda bulunmakta ve bu kültürel varlıkların karakterizasyonu ve korunması için metodolojik bir çerçeve sunmaktadır.

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**Introduction**

The pigeon is among the most ancient domesticated avian species, occupying a distinctive position in the annals of cultural history (Haag-Wackernagel, 1998). In the contemporary era, the primary purpose of pigeon husbandry is recreational, with the meat of these birds utilised as a specialty product in certain countries (Kokoszyński et al., 2020; Lan et al., 2025). Especially, Homing pigeon races have become an important economic sector with their organizations and activities all over the world (Mostert and Donaldson, 2024).

Pigeons offer an enormous diversity within their species compared to most mammal and bird species. This diversity can be easily observed between geographies, and the presence of many local breeds in the same geography also contributes to this diversity. In this context, Anatolia has a great cultural and biological richness in terms of pigeon diversity (Savaş and Erdem, 2021). In Turkey, there are local pigeon breeds that are specific to geographical regions, and even local pigeon breeds that are not commonly encountered outside their cities of origin. Six of these breeds have been officially registered (Bursa, Hünkâri, Edremit Kelebek, Alabadem, Trakya, Muğla).

The pigeon, which inspired the theory of evolution, has been regarded as a good model for molecular genetic studies in recent years (Domyan and Shapiro, 2017; Pacheco et al., 2020). Yakubu and Ibrahim (2011) argue that phenotypic comparisons based on morphological differences can be used to reveal genetically based differences. Many pigeon breeds can be easily distinguished from one another morphologically (color, pattern, size, feather structures). However, even if some breeds resemble each other in this respect, they can be distinguished from each other by their behavior, particularly their flight characteristics and flight performance. Therefore, the morphological and morphometric characteristics used to describe pigeons may not be sufficient to distinguish one pigeon breed from another.

Nowadays, molecular genetic methods are used to determine the genetic distance between breeds. However, these methods require special laboratories, experts, and are also quite

costly. On the other hand, low sample size and the number of loci examined, or sampling that does not fully reflect the genetic variation in the population, may lead to errors in genetic distance estimates (Reed and Frankham, 2001; Landguth et al., 2012). In particular, overlooking rare alleles or failing to fully represent the genetic structure within a population is a significant problem (Frankham et al., 2010). On the other hand, the inability to use numerous molecular markers due to many constraints may lead to genomic variation not being represented, and consequently, to incorrect genetic distance estimates. Moreover, if neutral markers cannot be selected, the effect of adaptive selection may confound genetic distance calculations (Allendorf et al., 2010).

Monogenic inheritance systems obtained through classical genetic studies can also be used in breed differentiation. In this context, the inheritance of many feather colours in pigeons has been established through classical breeding and crossbreeding studies dating back to the beginning of the last century (Horton, 1909; Doncaster, 1912; Cole and Kelley, 1919; Walker, 1925; Miller and Hollander, 1995). In addition, some plumage characteristics, feather structures, and behavioral traits are known to be inherited similarly (Metz and Savaş, 2004; Anonymous, n.d.). Besides these details, other characteristics used to define breeds can be used to distinguish breeds from one another and to show the relationships between breeds. Indeed, in this sense, efforts have been made in the literature on both pigeons and different domestic species (Jordana and Ribo, 1991; Jordana et al., 1993; Parés I Casanova, 2013).

In order to classify pigeon breeds, all qualitative and quantitative characteristics that define pigeons can be considered together. The presence or absence of these characteristics in a breed can be used to determine the relationship between breeds. This requires the evaluation of data containing numerous categorical variables. Multiple Correspondence Analysis (MCA), which can be used in this context, analyzes the relationships between multiple categorical variables as a whole (Abdi and Valentin, 2007). Correspondence analysis summarizes multiple categorical variables into a small number of components, and using these components as coordinates, distances between the resulting 2 or 3-dimensional points can be calculated. Thus, multiple features can be evaluated simultaneously to interpret the relationships between dependent variables. The components (coordinates) obtained from multiple regression analysis can also be used to visualize the relationships between dependent variables.

Hierarchical cluster analysis, another multivariate statistical technique, is used to classify groups into consistent categories based on several variables (Cornell et al., 2008). Hierarchical clustering produces a dendrogram from a data set by applying a classifier or divisive strategies (Nguyen, 2017). This way, independent variables that are similar and dissimilar in terms of the features considered can be seen.

This study aimed to classify the local pigeon breeds raised in Turkey based on their characteristic descriptions. Qualitative and quantitative traits used in breed descriptions were considered binary as present or absent, and similarities between breeds were identified using multiple correspondence and hierarchical clustering analyses.

## Material and Method

This study utilised phenotypic and genetic traits of 22 pigeon breeds originating from Turkey. Descriptive information about the pigeon breeds that showed Table 1 is provided in the supplementary document. In determining these traits and the choice of the breeds, their recognition by the authors, scientific studies, registration documents of those registered by the Ministry of Agriculture and Forestry, and breeder information were used. As can be seen in Table 2, each main trait and sub-phenotype is coded as 1 (present) and 0 (absent) depending on whether the breed has it or not. Thus, 76 variables consisting of binary values were created.

Table 1. Turkish pigeon breeds in the study

*Tablo 1. Çalışmadaki Türk güvercin ırkları*

Breed	References	Breed	References
Adana	Özbaşer et al., 2018	Kafa-Kuyruk Kelebek	Savaş and Erdem, 2021
Akbaş Baska	Özbaşer et al., 2022	Kemalpaşa Kelebek	Savaş and Erdem, 2021
Alabadem	Erdem et al., 2021	Malatya	Yılmaz et al., 2013
Baska	Özbaşer et al., 2022	Manisa Azman	Savaş et al., 2023
Bayburt	Yılmaz et al., 2013	Mısıri	Özbaşer et al., 2022; Erdem and Savaş, 2025
Bursa	Balcı et al., 2018; Şimşek et al., 2024	Muğla	Official gazette, 2013
Denizli Azman	Savaş et al., 2023	Mülakat	Yılmaz et al., 2013
Dolapçı	Yılmaz et al., 2013	Takla	Atasoy et al., 2013; Üçtepe et al., 2023
Dönek	Yılmaz et al., 2013; Özbaşer et al., 2021	Tokur	Yılmaz et al., 2013
Edremit Kelebek	Erdem et al., 2018	Trabzon	Savaş and Erdem, 2021
Hünkâri	Savaş et al., 2023; Türkeş and Gündüz, 2024	Trakya	Soysal et al., 2011

### Statistical Analysis

Multiple correspondence analysis is a multivariate statistical method used to analyze relationships between more than two data categories. This analysis aims to identify and visualize patterns and relationships between different data categories in a two-way table. The components obtained from multiple correspondence analysis can be used to visually represent the relationships between variables. The proximity of points in the resulting space indicates that the corresponding combinations of variable values occur together more frequently. In fact, multiple correspondence analysis is a generalization of principal component analysis for analyzing a large number of categorical variables and revealing the “hidden” relationships between categorical variables. The method works by performing a series of mathematical transformations to calculate the principal coordinates of variable categories and observations in an optimal representation space based on the “inertia” criterion. Inertia corresponds to the

eigenvalue in principal component analysis, which measures how much categorical information each principal dimension explains. The higher the inertia, the higher the total variance explained among the categorical variables associated with the relevant principal dimension (El-Araby et al., 2023; Olugbara et al., 2021). Similarity between breeds was measured using Euclidean distance ( $d$ ). The three principal components obtained from the multiple correspondence analysis were used to create a three-dimensional graph. Furthermore, the Euclidean distance between the points where the breeds were located on the three-dimensional graph was calculated using the obtained coordinates (Equation 1). To simplify interpretation, Euclidean distance values have been converted to relative values (between 0 and 1) using equation 2.

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2} \quad (1)$$

$$d_R = 1 - \left[ \frac{1}{1+d} \right] \quad (2)$$

The Ward method based on Euclidean distance was used in hierarchical clustering analysis (Tamasauskas et al., 2012). The clustering solution was evaluated using Entropy, Dunn index, silhouette coefficient, and Pearson  $\gamma$  criteria. Entropy is a measure of uncertainty. The smaller this value, the better the clustering performance. The Dunn index is the ratio of the smallest distance between observations not in the same cluster to the largest intra-cluster distance, and takes values between zero and infinity. The Dunn index must be maximized. The silhouette coefficient measures the degree of confidence in the clustering assignment of a given object. A silhouette coefficient approaching 1 indicates that the clustering is well done, while approaching -1 indicates that the clustering is weak (Cibulková et al., 2020). In addition, a high Pearson  $\gamma$  coefficient indicates good clustering (Nerurkar et al., 2018).

Table 2. Traits that were subject to the study

Tablo 2 Çalışmaya konu olan özellikler

<b>A. Weight</b>	<b>E. G. uropygialis</b>	<b>L. Chest frill</b>	<b>R. Rolling-tumbling</b>
1. Large (>350g)	1. Presence	1. Presence	1. Presence
2. Medium (300-350g)	2. Absence	2. Absence	2. Absence
3. Small (250-300g)	<b>F. Major color locus</b>	<b>M. Leg feather</b>	3. Rolling
4. Very small (<250)	1. Ash-red	1. Presence	4. Short rolling
	2. Blue	2. Absence	5. Tumbling
	3. Brown	3. Feather on tarsus	
<b>B. Beak</b>		4. Slipped	<b>S. Spin</b>
1. Long (> 18 mm)	<b>G. Pattern locus</b>	5. Grouseed	1. Presence
2. Normal (16-18 mm)	1. Barless	6. Muffed	2. Absence
3. Short (13 mm-16 mm)	2. Bar		3. One spin each
4. Extra short (<13 mm)	3. Check	<b>N. Crest</b>	4. Successively single spins
	4. T-Checker	1. Presence	5. Slow spins
<b>C. Tail feathers</b>	<b>H. Recessive red locus</b>	2. Absence	6. Fast spins
1. 12 feathers	1. Presence	3. Peak crest	7. Horizontal spins
2. 14 feathers	2. Absence	4. Normal crest	8. Vertical spins
3. 16 feathers	<b>I. Dilute locus</b>	5. Shell crest	<b>T. Diving</b>
<b>D. Piedness</b>	1. Presence	<b>O. Beak crest</b>	1. Presence
1. Presence	2. Absence	1. Point	2. Absence
2. Absence	<b>J. White locus</b>	2. Middle	<b>V. Ring beating</b>
3. White head	1. Presence	3. Large	1. Presence
4. Colored head	2. Absence	<b>P. Flight ability</b>	2. Absence
5. White flight feather	<b>K. Spread locus</b>	1. Presence	<b>W. Vocalization</b>
6. White tail	1. Presence	2. Absence	1. Presence
7. Colored neck	2. Absence	3. Low	2. Absence
8. Colored tail feather		4. Medium	
9. Colored whole tail		5. High	
10. Colored flight feathers			
11. Spot tail			
12. Mottled			

## Results

Table 3 shows that the first three dimensions of the Multiple Correspondence Analysis explain 40.92% of the variation in total. The three-dimensional distribution of breeds created with the coordinates obtained from multiple correspondence analysis is shown in Figure 1. In terms of the traits considered, the Takla breed differs markedly from other breeds. It has been observed that the Kelebek breeds, Dolapçı and Dönek, form one group by being located close to each other; while the Akbaş Baska, Baska, Denizli Azman, Hünkari, Manisa Azman, Mısırı, and Tokur breeds form another group. The Malatya and Muğla breeds, however, despite their position close to these groups, have relatively high Euclidean distances from the nearest group members ( $d_R=0.31, 0.27$ , respectively).

Table 3. Evaluation criteria for multiple correspondence analysis results for the first three dimensions

Tablo 3. İlk üç boyut için çoklu uyum analizi sonuçlarının değerlendirme kriterleri

Dimension	Inertia	$\chi^2$	$\chi^2\%$	Cumulative %
1	0.305	156.53	16.25	16.25
2	0.256	131.26	13.63	29.87
3	0.207	106.37	11.04	40.92

To better understand the distances between the breeds forming the groups in Figure 1, the relative Euclidean distances between the points belonging to the breeds are presented in Table 4. Although a three-dimensional plane is created, the presentation of this three-dimensional graph is still two-dimensional, so the distance that occurs in depth can be misleading in this sense. Therefore, considering Figure 1 and Table 4 together will provide a clearer understanding of the relationships between the points (breeds).

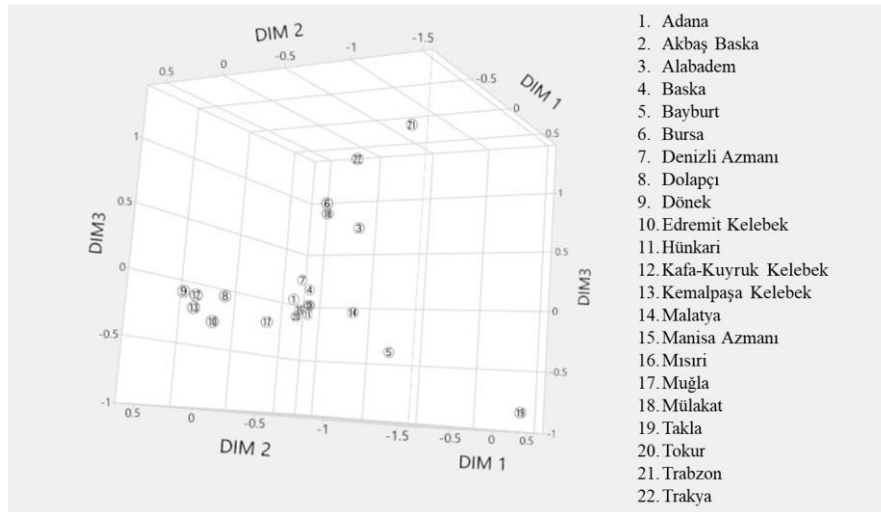


Figure 1. The three-dimensional distribution of breeds was created with the coordinates obtained from multiple correspondence analysis

Şekil 1. Çoklu uyum analizi ile elde edilen koordinatlar kullanılarak oluşturululan ırkların üç boyutlu dağılımı.

It is observed that the relative Euclidean distances between the Kelebek breeds and, the Dolapçı and Dönek breeds vary between 0.11 and 0.17. The relative Euclidean distances between the Akbaş Baska, Baska, Denizli Azman, Hünkari, Manisa Azman, Mısıri, and Tokur breeds, which appear as a group in Figure 1, vary between 0.09 and 0.22. Although the Adana breed appears similar to short-beaked breeds in Figure 1, it is actually clearly distinct from them (Table 4). In this sense, the breeds to which the Adana breed is closest are not breeds in the short-beaked group, but the Malatya and Muğla breeds ( $d_R=0.31$ ).

On the other hand, the relative Euclidean distance between the Bursa and Mülakat breeds is 0.10, and the nearest breed to these is Alabadem (Table 4). If we group breeds with a relative Euclidean distance value of below 0.30, the Kelebek breeds form one group with the Dolapçı and Dönek breeds, the short-beaked breeds form another group, and the Alabadem, Bursa, and Mülakat breeds form a third group. The lowest relative Euclidean value among the breeds within these groups is 0.07, and the highest value is 0.26.

Table 4. Relative Euclidean distance between breeds

*Tablo 4. Irklar arasındaki oransal Öklid mesafeleri*

<b>İrk</b>	<b>ADA</b>	<b>ABAS</b>	<b>ALA</b>	<b>BAS</b>	<b>BAY</b>	<b>BUR</b>	<b>DAZ</b>	<b>DOL</b>	<b>DON</b>	<b>EKEL</b>	<b>HUN</b>	<b>KKKEL</b>	<b>KPKEL</b>	<b>MAL</b>	<b>MAZ</b>	<b>MIS</b>	<b>MUG</b>	<b>MUL</b>	<b>TAK</b>	<b>TOK</b>	<b>TRA</b>	
<b>Akbaş Baska</b>	0.40																					
<b>Alabadem</b>	0.44	0.53																				
<b>Baska</b>	0.34	0.17	0.48																			
<b>Bayburt</b>	0.44	0.51	0.51	0.50																		
<b>Bursa</b>	0.47	0.57	0.26	0.53	0.56																	
<b>Denizli Azmanı</b>	0.34	0.22	0.47	0.09	0.51	0.52																
<b>Dolapçı</b>	0.41	0.57	0.53	0.54	0.55	0.51	0.54															
<b>Dönek</b>	0.49	0.61	0.58	0.59	0.60	0.55	0.58	0.22														
<b>Edremit Kelebeği</b>	0.49	0.61	0.58	0.59	0.58	0.56	0.59	0.24	0.23													
<b>Hünkâri</b>	0.39	0.07	0.54	0.21	0.50	0.58	0.25	0.57	0.61	0.61												
<b>Kafa-Kuyruk Kelebek</b>	0.49	0.61	0.57	0.59	0.59	0.54	0.59	0.22	0.11	0.17	0.61											
<b>Kemalpaşa Kelebeği</b>	0.49	0.61	0.58	0.59	0.59	0.55	0.59	0.21	0.12	0.14	0.61	0.09										
<b>Malatya</b>	0.31	0.47	0.41	0.43	0.29	0.47	0.44	0.48	0.54	0.52	0.47	0.54	0.54									
<b>Manisa Azmanı</b>	0.32	0.16	0.49	0.12	0.47	0.54	0.18	0.53	0.58	0.58	0.17	0.59	0.58	0.41								
<b>Mısıri</b>	0.40	0.08	0.54	0.20	0.52	0.58	0.24	0.56	0.60	0.61	0.07	0.61	0.60	0.48	0.18							
<b>Muğla</b>	0.31	0.51	0.51	0.49	0.48	0.51	0.49	0.27	0.38	0.35	0.51	0.38	0.36	0.38	0.47	0.51						
<b>Mülakat</b>	0.44	0.55	0.21	0.50	0.55	0.10	0.49	0.50	0.54	0.55	0.56	0.54	0.55	0.45	0.52	0.56	0.49					
<b>Takla</b>	0.66	0.69	0.65	0.68	0.54	0.68	0.69	0.68	0.70	0.68	0.68	0.69	0.69	0.60	0.67	0.69	0.65	0.67				
<b>Tokur</b>	0.37	0.14	0.54	0.22	0.50	0.57	0.26	0.55	0.59	0.59	0.10	0.60	0.59	0.46	0.16	0.10	0.49	0.55	0.68			
<b>Trabzon</b>	0.63	0.67	0.49	0.65	0.65	0.47	0.64	0.65	0.67	0.67	0.68	0.66	0.67	0.62	0.66	0.68	0.65	0.49	0.70	0.68		
<b>Trakya Makaracısı</b>	0.57	0.63	0.39	0.60	0.62	0.30	0.60	0.58	0.61	0.61	0.64	0.60	0.61	0.56	0.61	0.64	0.59	0.35	0.69	0.64	0.32	

ADA: Adana, ABAS: Akbaş Baska, ALA: Alabadem, BAS: Baska, BAY: Bayburt, BUR: Bursa, DAZ: Denizli Azman, DOL: Dolapçı, DON: Dönek, EKEL: Edremit Kelebek, HUN: Hünkari, KKKEL: Kfa-Kuyruk Kelebek, KPKEL: Kemalpaşa Kelebek, MAL: Malatya, MAZ: Manisa Azman, MIS: Mısıri, MUG: Muğla, MUL: Mülakat, TAK: Takla, TOK: Tokur, TRA: Trakya

Evaluation criteria for the hierarchical cluster analysis results are presented in Table 5. As a result of the cluster analysis, pigeon breeds were grouped into four groups (Tables 5 and 6). The variation explained ( $R^2$ ) for the resulting clusters is seen to be 38%. The silhouette score indicates that the clusters are not very healthy. This low score indicates that the clusters are not sufficiently distinct from other clusters. The Pearson  $\gamma$  correlation, which expresses the relationship between the distance between two points and whether or not these two points belong to the same cluster, indicates a moderate level of relationship. As the distance between two points increases, it is expected that they will not be in the same cluster.

Table 5. Hierarchical cluster analysis evaluation criteria

Tablo 5. Hiyerarşik kümeleme analizi değerlendirme kriterleri

N	Clusters	$R^2$	Silhouette Score	Pearson's $\gamma$	Dunn index	Entropy
22	4	0.38	0.150	0.528	0.683	1.19

The Dunn index is a measure of the separation between clusters and the similarity within clusters. The Dunn index here was determined to be 0.683, indicating that clustering is not very strong. A high entropy value, expected to be closer to 0, indicates that the resulting clustering is poorly structured and that the clusters contain elements from different clusters. Considering all evaluation criteria, it is observed that the clustering was not performed in a healthy manner.

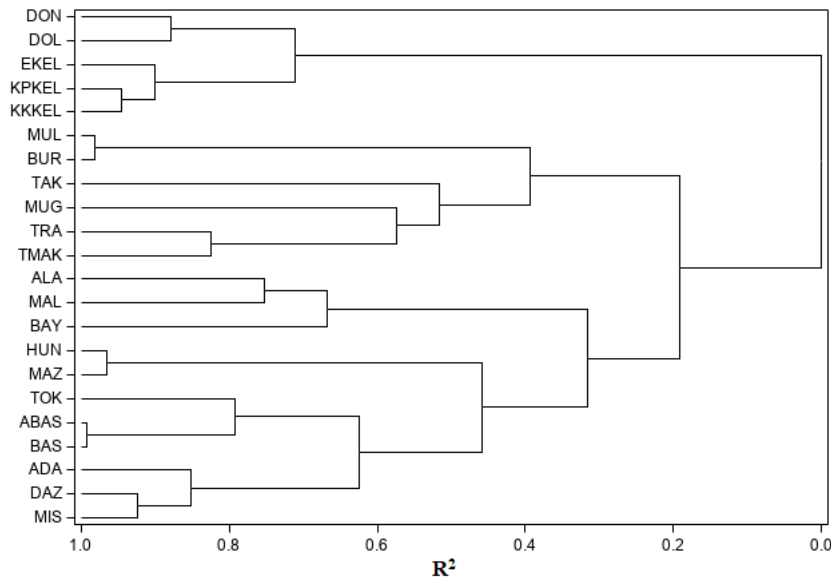


Figure 2. Dendrogram for breeds according to hierarchical clustering analysis (ADA: Adana, ABAS: Akbaş Basksa, ALA: Alabadem, BAS: Baska, BAY: Bayburt, BUR: Bursa, DAZ: Denizli Azmanı, DOL: Dolapç1, DON: Dönek, EKEL: Edremit Kelebek, HUN: Hünkari, KKKEL: Kafa-Kuyruk Kelebek, KP KEL: Kemalpaşa Kelebek, MAL: Malya, MAZ: Manisa Azmanı, MIS: Mısıri, MUG: Muğla, MUL: Mülakat, TAK: Takla, TOK: Tokur, TRA: Trakya)

Şekil 2. Hiyerarşik kümeleme analizine göre ırklara ait dendrogram

Table 6. Clusters and breeds obtained according to hierarchical clustering analysis results

*Tablo 6. Hiyerarşik kümeleme analizi sonuçlarına göre elde edilen kümeler ve ırklar*

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Cluster Size	10	5	6	1
Silhouette score	0.123	0.331	0.084	0.000
Breeds	Adana Akbaş Baska Baska Bayburt Denizli Azman Hünkari Malatya Manisa Azman Mısıri Tokur	Dolapçı Dönek Edremit Kelebek Kafa-Kuyruk Kelebek Kemalpaşa Kelebek	Alabadem Bursa Muğla Mülakat Trabzon Trakya	Takla

## Discussion and Conclusion

In this study, the multiple correspondence analysis and hierarchical clustering analysis were applied to 21 traits of 22 local pigeon breeds in Turkey. Although the three dimensions used to visualize the distance between breeds explain 40.92% of the variation, it can be concluded that the other evaluation criteria of the multiple correspondence analysis well reflect the similarity or difference between breeds.

Morphometric and morphological differences or similarities between breeds have been the subject of many studies with the help of multivariate analyses in different species. (Jordana et al., 1993; Jordana et al., 1999; Parés I Casanova, 2013; Savaş et al., 2023; Traoré et al., 2008). Hierarchical clustering analysis has also been used in many of these studies. However, under the current study conditions, the evaluation criteria of hierarchical clustering analysis indicate that this analysis may be problematic in the context of the breeds and characteristics in the study. Indeed, it is thought that the main problem is that breed-related traits/variables were considered in binary terms, as either present or absent. Although Cibulková et al. (2020) report that hierarchical clustering analysis with the Euclidean distance measure yields good results for binary variables, however, D'Enza and Palumbo (2013) report that Euclidean distance can only be used for binary variables with non-hierarchical clustering. From this perspective, there was no consensus that hierarchical clustering analysis could show good results for binary variables. Indeed, in this study, the evaluation criteria for the analysis in question indicated that the findings were not very reliable. On the other hand, the results of this analysis contain points that are difficult to explain in biological terms. Although hierarchical cluster analysis grouped mostly short-beaked breeds in cluster 1, it also included the Adana, Bayburt, and Malatya breeds in this group, despite their similarities being unexplainable. The grouping of diver-spinner breeds in cluster 2 is meaningful. However, the similarity between the Muğla, which is also in the third cluster, and the breeds in the same cluster is not reasonable. The dendrogram resulting from hierarchical clustering analysis is also difficult to explain for many breeds

(Figure 2). It is impossible to make sense of the closeness of the Muğla to the Takla, the closeness of Alabadem to Malatya, and the closeness of Adana to the Denizli Azman, and Mısırı.

In this study, it was concluded that the distance between breeds should be discussed according to the MCA analysis findings, due to the weakness of hierarchical cluster analysis, and because optimal quantitative distinctions can be made using categorical variables in clustering, according to the results of the MCA. Accordingly, the breeds representing the short-beaked group, namely Akbaş Baska, Baska, Denizli Azman, Hünkari, Manisa Azman, Mısırı, and Tokur, originate from geographically relatively close locations (Figure 3). However, despite the breeder's claim that Akbaş Baska originates from Baska, the distance between them is relatively high ( $d_R = 0.17$ ). Akbaş Baskas are likely to have been crossed with other breeds, particularly to introduce different feather colours not present in the original breed.

The diver-spinner breeds (Kelebek, Dolapçı, and Dönek breeds), which have been intensively bred in the same region for many years, are clearly clustered separately from other breeds. The Kelebek breeds (Kafa-Kuyruk, Kemalpaşa, Edremit), which probably began to diverge in the recent period, differ from each other almost exclusively in terms of color patterns. Their flight characteristics are quite similar. In terms of feather structures, all breeds have a similar feathered leg type, but the crest is only found in Edremit Kelebek. This is probably why the Kafa-Kuyruk and Kemalpaşa breeds are closer to each other in terms of relative Euclidean distance than the Edremit Kelebek breed. The distance between the Dönek breed and the Kemalpaşa and Kafa-Kuyruk Kelebek breeds ( $d_R=0.12$  and  $0.11$ ) is lower than that between Dönek and Edremit Kelebek ( $d_R=0.23$ ) and Dolapçı ( $d_R 0.22$ ). In fact, a subjective assessment would suggest that the Dönek and Dolapçı breeds should be closer to each other. However, likely, the differences between the Dolapçı and Dönek breeds in terms of their feather colours are responsible for the distance between them. The Dönek, Kemalpaşa Kelebek and Kafa-Kuyruk Kelebek breeds are similar in terms of feather colour and pattern genes. The Bursa and Mülakat breeds are also tumbler pigeons of the same origin. They differ only in color, which is reflected in the small relative distance between them ( $d_R=0.10$ ).

Local populations are considered to be distinct breeds that have 'evolved' as a result of the geographical isolation and cultural differentiation of communities that produce livestock (Rege, 2001; Gizaw et al., 2007). For example, Traoré et al. (2008) reported that goats bred in different geographical regions differed in terms of morphological characteristics. In addition, breeds with similar functional purposes (such as flight capability) are phenotypically more similar in terms of these characteristics (Parés I Casanova, 2013). When considering the geographical distances between the pigeon breeds in this study, breeds other than the Takla breed are associated with a specific geography. Furthermore, some of these breeds are named after the geography where they are bred. There is almost no region where the Takla breed is not raised.

Breeds produced in geographically distant regions may also be similar to each other. For example, the Trakya and Trabzon breeds of pigeons are positioned close to each other in both analyses. These pigeon breeds, produced in two geographically opposite corners of Turkey (north-west and north-east respectively), exhibit certain similar characteristics. Since Trabzon is an important port city, the pigeons from which these two breeds may have descended could probably have spread along both the Thracian and the eastern Black Sea coast. However,

similarities may also have arisen due to breeders' preferences for similar characteristics. Although the Trakya is a roller breed and the other is a ring-beater, it is known that the Trabzon breed also performs somersaults. As breeds become geographically closer, the number of similar traits between them increases. This phenomenon can be attributed to the fact that the majority of these breeds are bred for analogous structural or functional characteristics, as Pares I Casanova (2013) noted. For example, the Dolapçı and Dönek breeds of pigeons have similar body structures and flight behaviours, and neither has feather structures. They are distinguished from each other by their colour-pattern and the 'severity' of their similar flight behaviour. These two breeds, which belong to the category of spinner pigeons, exhibit a flight behaviour characterised by rolling around the beak-tail axis, unlike tumbler or roller pigeons. Analogous to the Kelebek breeds, which are predominantly bred in the same geographical area (Marmara and Aegean regions), the Dönek, Dolapçı, and Kelebek breeds differ in terms of characteristics such as flight style, spinning style, and speed. On the other hand, all Kelebek breeds have feathered legs. These breeds differ in color, pattern, and whether their head is smooth or crested. The Adana pigeon, named after the province of Adana and its region where it is predominantly bred, is relatively close to the short-beaked breeds raised in the Aegean and Marmara regions. This similarity is clearly based on their 'diving' traits. However, it should also be noted that the Adana breed is more closely related to the Malatya breed than to short-beaked breeds.

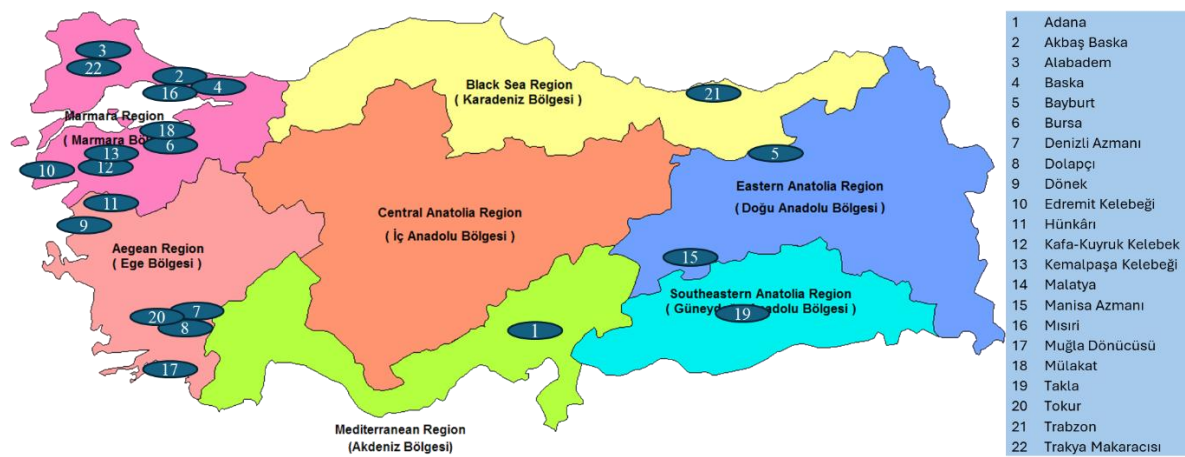


Figure 3. Regions in Turkey where the pigeon breeds used in the study originated or are intensively bred

Şekil 3. Çalışmada kullanılan güvercin ırklarının köken aldığı veya yoğun olarak yetiştirildiği bölgeler

Consequently, within the scope of this study, it was observed that hierarchical clustering analysis was unable to produce a sound clustering based on the data scales, whereas the findings of multiple correspondence analysis were usable. Turkish pigeon breeds have been observed to exhibit a propensity for aggregation based on their functional characteristics. This tendency is further influenced by their shared geographical origin. Consequently, as anticipated, it has become evident that breeds with short beaks originating from geographically proximate regions constitute one group, while breeds designated as diver-spinners comprise another group. Furthermore, the striking parallels that exist between the Bursa and Mülakat breeds are of particular interest. Conversely, the Bayburt and Malatya breeds have also been shown to be

closely related. It can be concluded that the tumbler breeds are relatively closely related to one another. Finally, the noteworthy point regarding the tumbler breed is its marked distinction from all other breeds, which is also reflected in its alternative appellation, Mardin, or Takla. Turkish pigeon breeds have been observed to exhibit a propensity for aggregation based on their functional characteristics. This tendency is probably also due to the fact that most of them have the same geographical origin. This study makes a significant contribution to the existing body of knowledge surrounding the behavioral, morphological, and genetic relationships observed among various native pigeon breeds of Turkey. Moreover, it provides a methodological framework that facilitates the characterization and conservation of these cultural assets. Integrating aspects such as management practices, nutritional requirements, and feed preferences into future research will be pivotal for the effective conservation of these breeds.

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