Turkish Journal of Zoology

Volume 30 | Number 2 Article 13

1-1-2006

# Karyological and Some Morphological Characteristics of Spalax leucodon Nordmann, 1840 (Mammalia: Rodentia) Superspecies around Kastamonu Province, Turkey

MUSTAFA SÖZEN

MURAT SEVİNDİK

FERHAT MATUR

Turk J Zool
30 (2006) 205-219


# Karyological and Some Morphological Characteristics of *Spalax leucodon* Nordmann, 1840 (Mammalia: Rodentia) Superspecies around Kastamonu Province, Turkey*

Mustafa SÖZEN, Murat SEVİNDİK, Ferhat MATUR

Department of Biology, Zonguldak Karaelmas University, Zonguldak - TURKEY

Received: 05.08.2005

**Abstract:** The karyotypes and morphology of 98 specimens of the subterranean mole rat *Spalax leucodon* Nordmann, 1840 across 18 localities in and around Kastamonu province were analysed. It was determined that *S. leucodon* has 2n = 54, NF = 72; 2n = 56, NF = 74; 2n = 58, NF = 74; 2n =60, NF = 74 in the populations from the Kastamonu region.

According to these karyological findings based on chromosome morphology the diploid chromosome numbers of 2n = 56, 2n =58, and 2n = 60 determined here are new for *Spalax leucodon* in Turkey. Because diploid numbers of these populations were formerly found from geographically distant localities in Turkey, they were given as 2n = 56N, 58N, and 60N, to differentiate them from the other forms having the same diploid chromosome numbers but different chromosome morphology.

As a result of t-test analysis, separation of all chromosomal forms from each other beside 2n values by many character measurements supported the opinion that each of the chromosomal forms of *Spalax* should be evaluated as good biological species.

**Key Words:** *Spalax leucodon*, karyology, morphology, Kastamonu, Turkey

## Kastamonu İli Çevresindeki *Spalax leucodon* Nordmann, 1840 (Mammalia: Rodentia) Üsttürünün Karyolojik ve Bazı Morfolojik Özellikleri

**Özet:** Körfare *Spalax leucodon* Nordmann, 1840 üzerinde yapılan bu araştırmada Kastamonu çevresindeki 18 lokaliteden 98 örneğin karyolojisi ve morfolojisi incelendi. Kastamonu çevresinden incelenen körfare populasyonlarının 2n = 54, NF = 72; 2n = 56, NF = 74; 2n = 58, NF = 74; 2n =60, NF = 74 değerlerine sahip oldukları belirlendi.

Bu karyolojik sonuçlara göre kromozom morfolojileri bakımından Kastamonu çevresinden belirlenen 2n = 56, 2n = 58 ve 2n = 60 kromozom sayıları Türkiye'deki *Spalax leucodon* için yeni değerlerdir. Bu populasyonların diploid kromozom sayıları Türkiye'den coğrafik olarak uzak bazı bölgelerde daha önce belirlendiği için bu çalışmada belirlenen değerleri aynı kromozom sayısına ancak farklı kromozom morfolojilerine sahip diğer formlardan ayırmak için 2n = 56N, 58N ve 60N olarak isimlendirildiler.

t-testi analizleri sonucunda bütün kromozomal formların diploid kromozom sayıları yanında çok sayıda karakter ölçüsü bakımından da birbirlerinden ayrılabilmesi Spalax kromozomal formlarının ayrı biyolojik türler olarak değerlendirilmesi gerektiği şeklindeki yaklaşımı desteklemektedir.

**Anahtar Sözcükler:** *Spalax leucodon*, karyoloji, morfoloji, Kastamonu, Türkiye

## Introduction

The subterranean mole rats of the family Spalacidae are distributed throughout south-eastern Europe, Asia Minor, the Caucasus, Transcaucasia, Syria, Iraq, Israel, Jordan and north-eastern Africa (Corbet, 1978; Savic and Nevo, 1990; Harrison and Bates, 1991). To date, more than 50 chromosomal forms of *Spalax* have been reported in the literature from these areas. Of these areas, karyologically the most diverse area is Turkey, containing approximately 30 chromosomal forms alone (Nevo et al., 1994; Sözen et al., 1999, 2000a, 2000b; Coşkun, 2003; Sözen, 2004).

* This paper is a part of Murat Sevindik's MSc thesis

On a morphological basis, 2 species (*S. leucodon* and *S. ehrenbergi*) of blind mole rat are distributed in Turkey (Mursaloğlu, 1979; Kıvanç, 1988). On the other hand, Coşkun (2004) recently described a new species (*Nannospalax munzuri*) and also accepted *N. nehringi tuncelicus* determined by him (Coşkun, 1996) as a valid species (as *Nannospalax tuncelicus*), depending primarily on karyological and some morphological pecularities. A taxonomic evaluation of Spalacidae in Turkey based only on morphology is unrealistic (Nevo et al., 1994), because, to date, 20 karyological forms (2n = 36, 38, 40, 48, 50E, 50W, 50N; 52S, 52N; 54N, 54W, 56S, 56W; 56N; 58S, 58N; 60E, 60C, 60W and 62) or good biological species of *S. leucodon* in Turkey have been determined (Soldatovic and Savic, 1978; Savic and Soldatovic, 1979; Giagia et al., 1982; Yüksel, 1984; Gülkaç and Yüksel, 1989; Nevo et al., 1994, 1995; Sözen and Kıvanç, 1998a, 1998b; Sözen et al., 1999; Sözen et al., 2000a, 2000b; Tez et al., 2001, 2002; Yüksel and Gülkaç, 2001; Coşkun, 2003, 2004; Sözen, 2004). Despite this high variation in chromosome numbers, none of the exact distribution areas of any chromosomal form (or species) in Turkey are known.

Species and subspecies of *Spalax* have been determined by Kıvanç (1988) in Turkey by using only morphological data. However, to date, no study has been carried out to differentiate chromosomal forms of *Spalax* in Turkey via morphological characteristics.

The purpose of the study was to describe karyotypic and some morphologic characteristics of *Spalax leucodon* populations from Kastamonu in northern Turkey to fill at least partially some gaps in our knowledge about karyological forms, their morphological characteristics, distributional areas and evolutionary trends in Turkey.

## Materials and Methods

Blind mole rats (n = 98) were collected from 20 localities in and around Kastamonu province in northern Turkey, and 88 of them were karyotyped (Figure 1, Table 1). To catch the animals alive, one of the gallery of the burrow system was opened, and when an animal came to close the opened gallery the gallery was cut about 40-50 cm behind the opening with a hoe, and then the animal was captured between the gallery opening and the hoe.

The sampled localities, the number of individuals analysed and karyological results are presented in Table 1 and Figure 1.

Karyotypes were prepared from bone marrow according to Ford and Hamerton (1956), and about 25-30 metaphase cells, which were well stained, and whose chromosomes were separate and distinct, were examined from each animal. The diploid number of chromosomes (2n), the number of autosomal arms (NFa), and the total number of chromosomal arms (NF) were determined. Additionally, metacentric (m), acrocentric (a), subtelocentric (st), and submetacentric (sm) autosomal chromosomes, and sex chromosomes were determined.

Each mature specimen was weighed and 39 measurements from external and internal characteristics, listed in this section, were taken (Figure 2) with callipers to the nearest 0.1 mm, and by micrometer on a stereomicroscope (Nikon SMZ 1000) as in Kıvanç (1988) and Nevo et al. (1988). Because of the sexual dimorphism in *Spalax*, males and females were evaluated separately. A biometric comparison of measurements was performed by t-test (Microsoft Excel Student's t-test Two-Sample Assuming Unequal Variance) and $P < 0.05$ was regarded as significantly different.

The following characters were taken from each adult specimen (see also Figure 2 for skull variables): 1. Head and body length, 2. Hind foot length, 3. Weight (g), 4. Condylonasal length, 5. Condylobasal length, 6. Occipitonasal length, 7. Basal length, 8. Nasal length, 9. Nasal width, 10. Skull height, 11. Auditory meatus diameter, 12. Upper molar crown length, 13. Upper molar alveolar length, 14. Diastema length, 15. Facial region length, 16. Supraoccipital length, 17. Zygomatic breath, 18. Tympanic bullae length, 19. Tympanic bullae width, 20. Foramina incisiva length, 21. Interorbital constriction, 22. Rostrum width, 23. Hind palatal length, 24. Palatal length, 25. Sagital crest length, 26. Parietal length, 27. Parietal width on lambdoid crest, 28. Infraorbital foramen width, 29. Infraorbital foramen height, 30. Upper incisor alveolar width, 31. Upper incisor width, 32. $M^2$ crown width, 33. Lower incisor width, 34. Lower molar crown length, 35. Lower molar alveolar length, 36. Mandible height, 37. Coronoid process height, 38. Angular length, 39. Articular length, 40. Alveolar length.

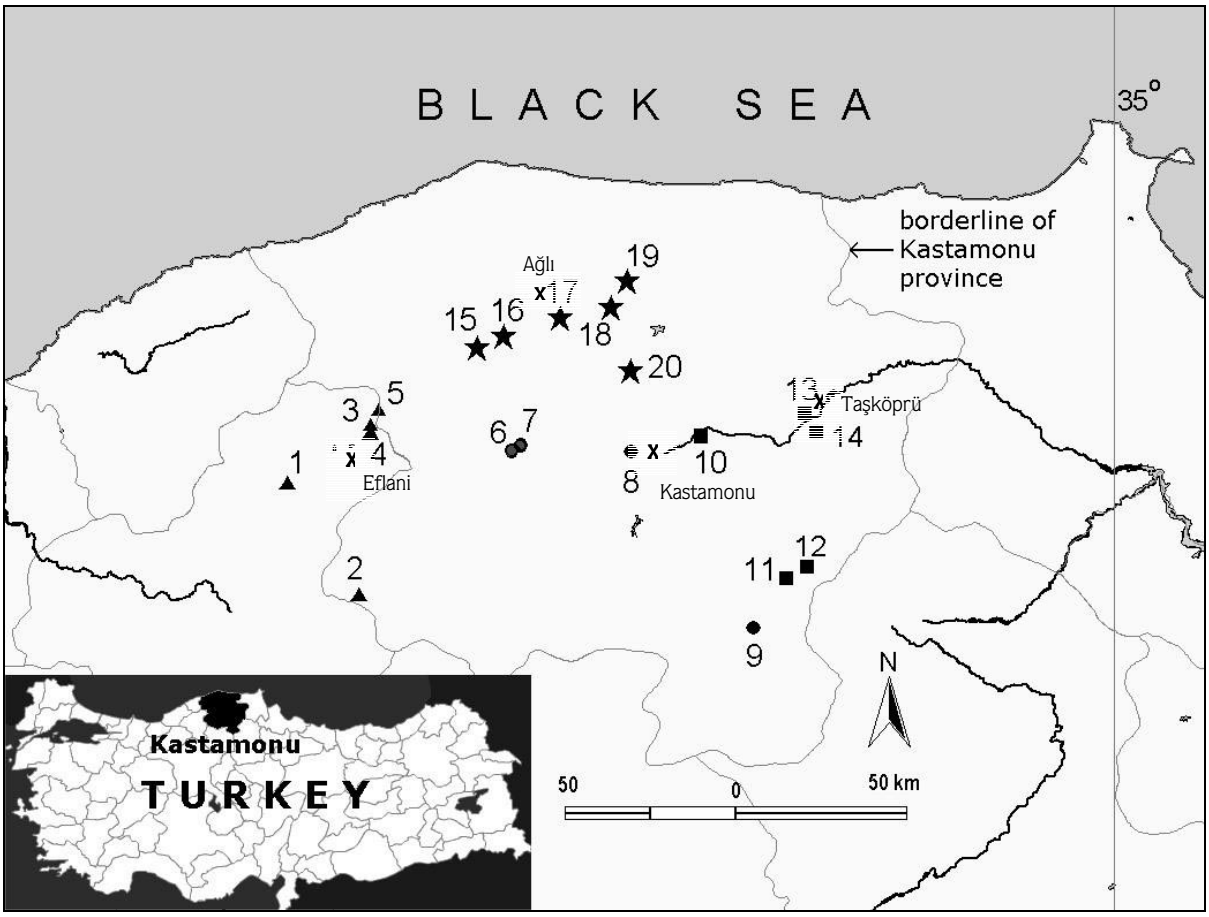



Figure 1. Distribution of chromosomal forms of *Spalax leucodon* around Kastamonu province, Turkey. ▲: 2n = 54, ●: 2n = 56, ■: 2n = 58, ★: 2n = 60. ✕: town and city centre. 1. Eflani 15 km W, 2. Taşpınar-Araç, 3. Pınarbaşı 17 km S, 4. Pınarbaşı 15 km S, 5. Pınarbaşı 12 km S, 6. Daday 6 km W, 7. Daday 4 km W, 8. Kastamonu 10 km W, 9. Tosya 12 km N, 10. Taşköprü 30 km W, 11. Taşköprü 40 km S, 12. Taşköprü 45 km S, 13. Taşköprü 2 km W, 14. Taşköprü 3 km S, 15. Azdavay 5 km E, 16. Azdavay 10 km E, 17. Ağlı, 18. Küre 5 km S, 19. Küre 10 km S, 20. Seydiler 2 km S.

The karyotype preparations and museum specimens are deposited in the Department of Biology, the Faculty of Arts and Science, Zonguldak Karaelmas University.

## Results

Four chromosomal forms (2n = 54, 56, 58, and 60) of *Spalax leucodon* were determined around Kastamonu (Figure 1).

### Karyology

**Eflani population:** The karyotype of this populations was 2n = 54, NF = 72 and NFa = 68. The X chromosome was medium-sized submetacentric, and the Y chromosome was small-sized acrocentric. The autosomal set contained 2 pairs of metacentric, 6 pairs of subtelocentric and 18 pairs of acrocentric chromosomes (Figure 3a). This population was sampled from Eflani 15 km W, Taşpınar, Pınarbaşı 12 km, 15 km and 17 km S.

**Kastamonu population:** This population had a karyotype of 2n = 56, NF = 74 and NFa = 70. The X chromosome was medium-sized submetacentric, and the Y chromosome was small-sized acrocentric. The autosomal set had 2 pairs of metacentric, 6 pairs of subtelocentric and 19 pairs of acrocentric chromosomes (Figure 3b). The samples of this population were collected from Daday 4 k and 6 km W, Kastamonu 10 km W and Tosya 12 km N.

Table 1. Localities, sample size (n), diploid chromosome numbers (2n) and fundamental numbers (NF) of chromosomes of the animals examined.

| Pop. No. | Localities | n ♂♂ | n ♀♀ | 2n | NF | X | Y |
|---|---|---|---|---|---|---|---|
| Eflani population | | | | | | | |
| 1 | Eflani 15 km W | 1 | - | 54 | 72 | sm | a |
| 2 | Taşpınar-Araç | 3 | 3 | 54 | 72 | sm | a |
| 3 | Pınarbaşı 15 km S | 1 | 2 | 54 | 72 | sm | a |
| 4 | Pınarbaşı 17 km S | 1 | - | 54 | 72 | sm | a |
| 5 | Pınarbaşı 12 km S | 1 | 1 | 54 | 72 | sm | a |
| Kastamonu population | | | | | | | |
| 6 | Daday 6 km W | 1 | 1 | 56 | 74 | sm | a |
| 7 | Daday 4 km W | 3 | 1 | 56 | 74 | sm | a |
| 8 | Kastamonu 10 km W | 4 | 4 | 56 | 74 | sm | a |
| 9 | Tosya 12 km N | 3 | 3 | 56 | 74 | sm | a |
| Taşköprü population | | | | | | | |
| 10 | Taşköprü 30 km W | 3 | 1 | 58 | 74 | sm | a |
| 11 | Taşköprü 40 km S | 3 | 2 | 58 | 74 | sm | a |
| 12 | Taşköprü 45 km S | 3 | 2 | 58 | 74 | sm | a |
| 13 | Taşköprü 2 km W | 0 | 3 | 58 | 74 | sm | a |
| 14 | Taşköprü 3 km S | 2 | 2 | 58 | 74 | sm | a |
| Ağlı population | | | | | | | |
| 15 | Azdavay 5 km E | 2 | 6 | 60 | 74 | sm | a |
| 16 | Azdavay 10 km E | 2 | 6 | 60 | 74 | sm | a |
| 17 | Ağlı | 1 | 3 | 60 | 74 | sm | a |
| 18 | Küre 5 km S | 5 | 4 | 60 | 74 | sm | a |
| 19 | Küre 10 km S | 4 | 4 | 60 | 74 | sm | a |
| 20 | Seydiler 2 km S | 1 | 1 | 60 | 74 | sm | a |
| | Total | 44 | 44 | | | | |

**Taşköprü population:** The karyotype of the Taşköprü population was 2n = 58, NF = 74 and NFa = 70. The X chromosome was medium-sized submetacentric; the Y chromosome was small-sized acrocentric. The autosomal set contained 7 pairs of bi-armed and 21 pairs of acrocentric chromosomes (Figure 4a). This population was sampled from Taşköprü 2 km and 30 km W, 3 km, 42 km and 45 km S.

**Ağlı population:** Twenty-seven animals from this population revealed a karyotype of 2n = 60, NF = 74 and NFa = 70. The X chromosome was medium-sized submetacentric, and the Y chromosome was small-sized acrocentric. The autosomal set contained 6 pairs of bi-armed, and 23 pairs of acrocentric chromosomes (Figure 4b). The samples of this population were collected from Azdavay 5 km and 10 km E, Ağlı, Küre 5 km and 10 km S, and Seydiler 2 km S.

### Morphology

External (body length, hind foot length and weight) and 37 cranial characters of mature specimens of each of the chromosomal forms were taken and evaluated separately. Tables 2 and 3 show the measurements. Some non-metric features of the animals were also determined and are listed in Tables 4-6 for each chromosomal form.

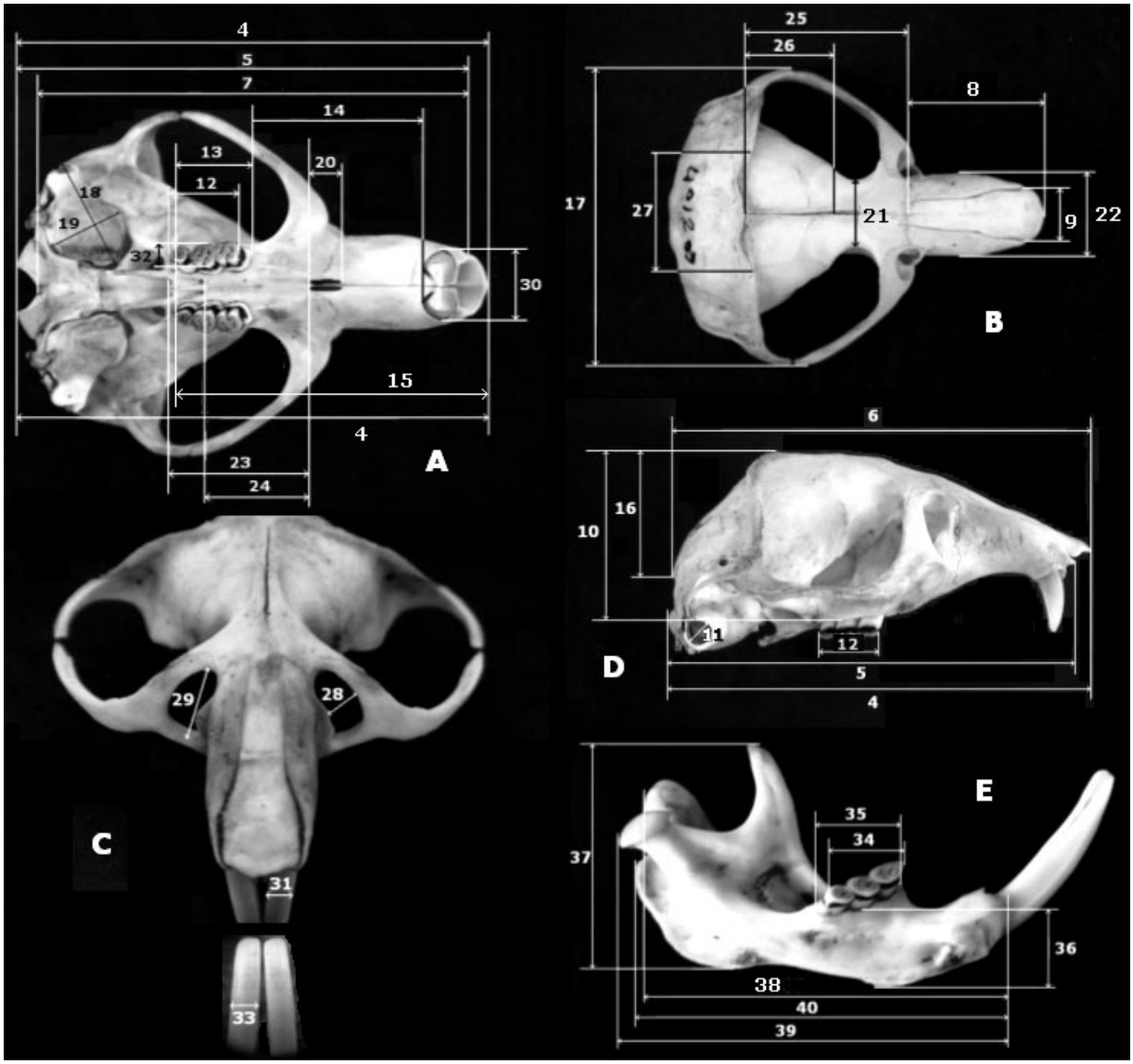



Figure 2. Measurements of cranial and mandibular variables of *Spalax leucodon* as used in text and in Tables 2 and 3: 4. Condylonasal length, 5. Condylobasal length, 6. Occipitonasal length, 7. Basal length, 8. Nasal length, 9. Nasal width, 10. Skull height, 11. Auditory meatus diameter, 12. Upper molar crown length, 13. Upper molar alveolar length, 14. Diastema length, 15. Facial region length, 16. Supraoccipital length, 17. Zygomatic breath, 18. Tympanic bullae length, 19. Tympanic bullae width, 20. Foramen incisiva length, 21. Interorbital constriction, 22. Rostrum width, 23. Hind palatal length, 24. Palatal length, 25. Sagital crest length, 26. Parietal length, 27. Parietal width on lambdoid crest, 28. Foramen infraorbital width, 29. Foramen infraorbital height, 30. Upper incisor alveoles width, 31. Upper incisor width, 32. $M^2$ crown width, 33. Lower incisor width, 34. Lower molar crown length, 35. Lower molar alveolar length, 36. Mandible height, 37. Coronoid height, 38. Angular length, 39. Articular length, 40. Alveolar length. A. Ventral view of cranium, B. Dorsal view of cranium, C. Antero-dorsal view of cranium, D. Lateral view of cranium, D. Lingual view of mandible.

Most of the specimens (96.94%) have supracondyloid foramina on both sides of the occipital condyle. This foramen was only present on one side (2.04%), or was absent (1.02%). Parietals are similar in all forms and wider than long (Tables 2 and 3). Despite "leucodon" meaning white-tooted, a great portion (86.45%) of animals have orange upper incisors, and about a quarter (26.73%) have orange lower incisors (Table 4). The rare

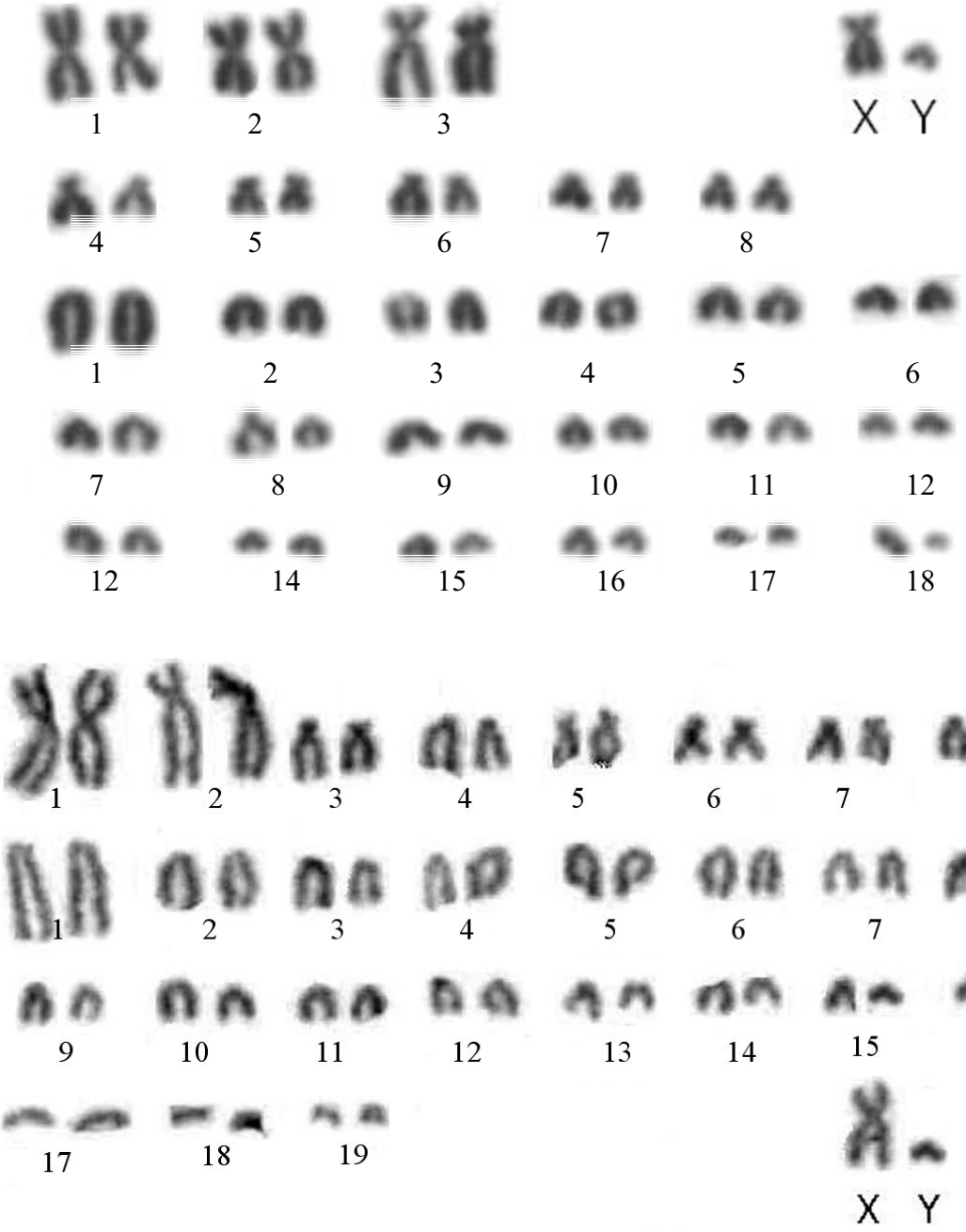
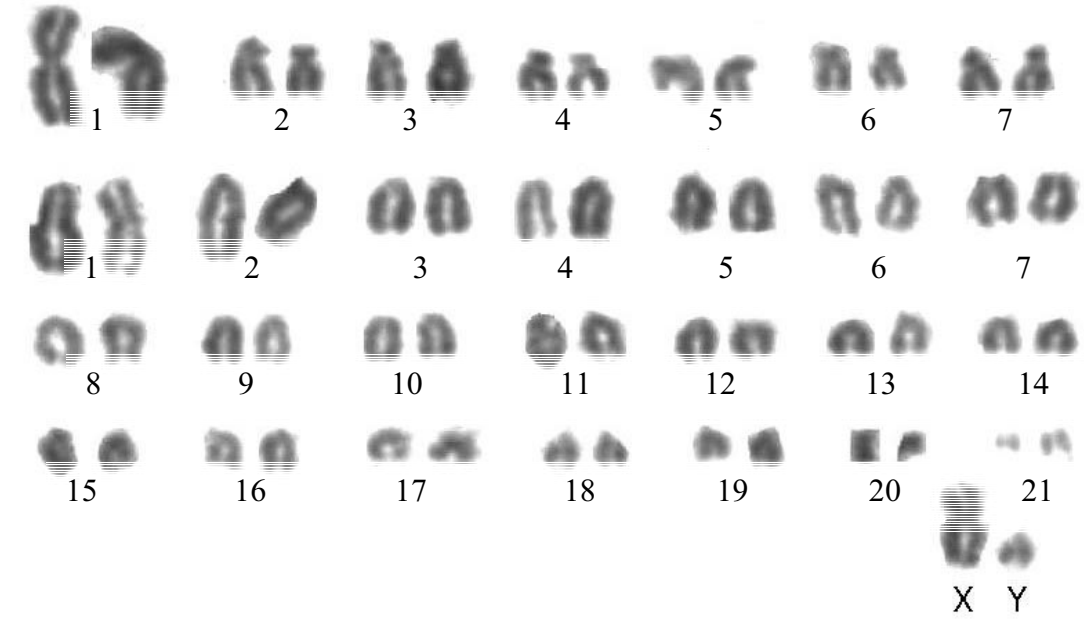


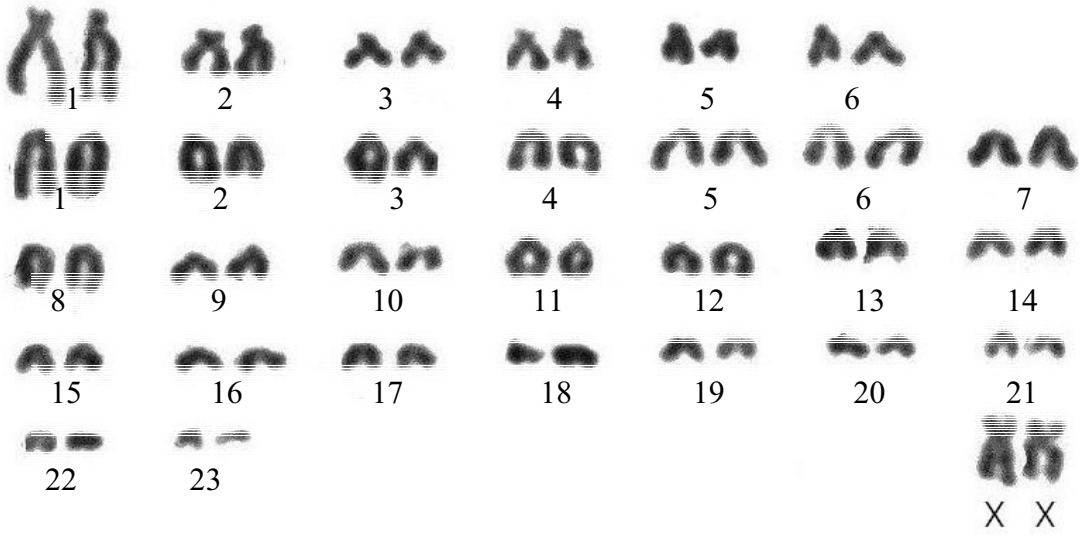

Figure 3. The karyotype of (a) a male from Eflani population (2n = 54, NF = 72), (b) a male from Kastamonu population (2n = 56, NF = 74).

end of the palatinum does not possess a styloid process. Most animals have upper molars with one root. All animals have 2-rooted first lower molars ($M_1$), while most of $M_2$s and $M_3$s are one-rooted (Tables 5 and 6).

In the majority of animals, the posterior margin of the nasals reached the line connecting the upper margins of the infraorbital foramen, with the nasal length shorter than sagital crest length. Foramen postpalatins are




(a)




(b)

Figure 4. The karyotype of (a) a male *Spalax leucodon* from Taşköprü population (2n = 58, NF = 74), (b) a female from Ağlı population (2n = 60, NF = 74).

located in front of the line passing between $M^2$ and $M^3$, and lacrimals are visible from above (Table 7).

Based on t-test analysis of 40 internal and external measurements, males of 2n = 54 and 56 forms were significantly different ($P < 0.05$) in 13 characters; 2n = 54 and 58 in 3 characters; 2n = 54 and 60 in 35 characters; 2n = 56 and 58 in 5 characters; 2n = 56 and 60 in 37 characters; and 2n = 58 and 60 in 25 characters. Additionally, in females, 2n = 54 and 56 were different in 19 characters; 2n = 54 and 58 in 12 characters; 2n = 54 and 60 in 34 characters; 2n = 56 and 58 in 1 character; 2n = 56 and 60 in 5 characters; and 2n = 58 and 60 in 6 characters (Table 8).

Table 2. Measurements (mm) and weight (g) of the adult female specimens of chromosomal forms of *Spalax leucodon* in Kastamonu. n: sample size, SD: standard deviation, CH: characteristics that indicated in the same order in materials and methods section.

| | Chromosomal forms (Females) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2n = 54 ♀♀ | | 2n = 56 ♀♀ | | 2n = 58 ♀♀ | | 2n = 60 ♀♀ | |
| CH | n | mean ± SD | n | mean ± SD | n | mean ± SD | n | Mean ± SD |
| 1 | 18 | 199.44 ± 16.1 | 5 | 203.6 ± 16.7 | 7 | 206.71 ± 8.83 | 13 | 206.23 ± 15 |
| 2 | 20 | 26.15 ± 1.68 | 6 | 26.17 ± 1.95 | 7 | 26.43 ± 0.49 | 14 | 27.43 ± 1.35 |
| 3 | 18 | 198.28 ± 29.5 | 5 | 206.2 ± 27.4 | 7 | 188.14 ± 23.4 | 14 | 224.71 ± 46.6 |
| 4 | 22 | 46.6 ± 1.65 | 6 | 48.63 ± 1.48 | 7 | 47.13 ± 1.59 | 15 | 48.57 ± 2.16 |
| 5 | 22 | 44.95 ± 1.55 | 6 | 46.65 ± 1.4 | 7 | 45.33 ± 1.58 | 15 | 46.71 ± 2.26 |
| 6 | 22 | 44.4 ± 1.71 | 6 | 46.35 ± 1.39 | 7 | 45.11 ± 1.69 | 15 | 44.39 ± 2.27 |
| 7 | 22 | 42.67 ± 1.51 | 5 | 44.56 ± 1.44 | 7 | 43.24 ± 1.59 | 15 | 43.39 ± 2.42 |
| 8 | 22 | 17.3 ± 1.11 | 6 | 17.62 ± 1.47 | 7 | 18.39 ± 0.96 | 15 | 18.36 ± 1.15 |
| 9 | 22 | 6.41 ± 0.69 | 6 | 6.28 ± 0.26 | 7 | 6.31 ± 0.4 | 16 | 6.39 ± 0.42 |
| 10 | 22 | 18.9 ± 0.8 | 6 | 20.12 ± 0.2 | 7 | 19.76 ± 1.02 | 16 | 20.01 ± 1.22 |
| 11 | 22 | 2.52 ± 0.37 | 6 | 2.68 ± 0.26 | 7 | 2.83 ± 0.13 | 16 | 2.74 ± 0.28 |
| 12 | 22 | 6.63 ± 0.61 | 6 | 7.2 ± 0.6 | 7 | 6.96 ± 0.47 | 16 | 7.41 ± 0.61 |
| 13 | 22 | 7.56 ± 0.5 | 6 | 8.12 ± 0.36 | 7 | 7.91 ± 0.15 | 16 | 8.64 ± 0.48 |
| 14 | 22 | 15.7 ± 1.08 | 6 | 16.9 ± 0.77 | 7 | 16.4 ± 0.63 | 15 | 16.59 ± 0.99 |
| 15 | 22 | 30.8 ± 1.37 | 6 | 32.25 ± 0.98 | 7 | 31.03 ± 0.96 | 15 | 32.05 ± 1.42 |
| 16 | 22 | 15.17 ± 0.94 | 6 | 14.13 ± 0.64 | 7 | 14.43 ± 0.8 | 16 | 14.98 ± 0.94 |
| 17 | 22 | 33.79 ± 1.95 | 6 | 36.17 ± 1.57 | 7 | 34.83 ± 1.73 | 16 | 35.68 ± 1.92 |
| 18 | 22 | 10.57 ± 0.88 | 6 | 10.67 ± 0.41 | 7 | 11.33 ± 0.27 | 16 | 11.3 ± 0.61 |
| 19 | 22 | 7.9 ± 0.85 | 6 | 8.25 ± 0.4 | 7 | 8.16 ± 0.39 | 16 | 8.69 ± 0.46 |
| 20 | 22 | 2.75 ± 0.44 | 6 | 2.57 ± 0.42 | 7 | 3.03 ± 0.55 | 15 | 3.11 ± 0.23 |
| 21 | 22 | 7.1 ± 0.29 | 6 | 7.45 ± 0.36 | 7 | 7.36 ± 0.29 | 16 | 7.41 ± 0.24 |
| 22 | 22 | 8.95 ± 0.46 | 6 | 10.1 ± 0.75 | 7 | 9.57 ± 0.44 | 15 | 9.36 ± 0.43 |
| 23 | 22 | 13.16 ± 1.07 | 6 | 14.62 ± 1.06 | 7 | 13.97 ± 0.56 | 15 | 13.93 ± 0.97 |
| 24 | 22 | 9.15 ± 0.92 | 6 | 10.02 ± 0.43 | 7 | 9.47 ± 0.52 | 15 | 9.55 ± 0.92 |
| 25 | 22 | 18.97 ± 0.91 | 6 | 20.25 ± 0.81 | 7 | 20.34 ± 0.63 | 15 | 20.31 ± 1.16 |
| 26 | 22 | 8.7 ± 1.74 | 6 | 9.3 ± 0.34 | 7 | 9.64 ± 0.71 | 16 | 9.8 ± 0.85 |
| 27 | 22 | 13.06 ± 1.34 | 6 | 11.47 ± 0.94 | 7 | 10.9 ± 1.96 | 16 | 11.13 ± 0.97 |
| 28 | 22 | 3.51 ± 0.49 | 5 | 3.16 ± 0.43 | 7 | 3.06 ± 0.44 | 16 | 3.13 ± 0.48 |
| 29 | 22 | 6.71 ± 0.81 | 6 | 6.87 ± 0.65 | 7 | 7.2 ± 0.69 | 16 | 6.75 ± 0.44 |
| 30 | 22 | 6.34 ± 0.33 | 6 | 7.1 ± 0.63 | 7 | 6.73 ± 0.49 | 15 | 6.89 ± 0.28 |
| 31 | 22 | 2.25 ± 0.2 | 6 | 2.37 ± 0.12 | 7 | 2.36 ± 0.12 | 16 | 2.46 ± 0.3 |
| 32 | 22 | 2.17 ± 0.2 | 6 | 2.33 ± 0.2 | 7 | 2.37 ± 0.13 | 16 | 2.41 ± 0.18 |
| 33 | 22 | 2.33 ± 0.18 | 6 | 2.62 ± 0.19 | 7 | 2.39 ± 0.26 | 16 | 2.74 ± 0.26 |
| 34 | 22 | 6.29 ± 0.5 | 6 | 7.05 ± 0.66 | 7 | 6.74 ± 0.23 | 16 | 7.06 ± 0.53 |
| 35 | 22 | 7.03 ± 0.53 | 6 | 7.65 ± 0.47 | 7 | 7.39 ± 0.29 | 16 | 7.94 ± 0.65 |
| 36 | 22 | 7.52 ± 0.35 | 6 | 7.98 ± 0.51 | 7 | 8.07 ± 0.54 | 16 | 8.33 ± 0.65 |
| 37 | 22 | 15.26 ± 0.84 | 6 | 16.53 ± 0.32 | 7 | 15.96 ± 0.95 | 16 | 16.68 ± 0.96 |
| 38 | 22 | 26.46 ± 1.71 | 6 | 27.73 ± 1.68 | 7 | 26.8 ± 2.23 | 16 | 27.61 ± 1.28 |
| 39 | 22 | 27.49 ± 1.23 | 6 | 28.75 ± 1.3 | 7 | 27.84 ± 1.43 | 15 | 28.48 ± 1.33 |
| 40 | 22 | 28.04 ± 1.52 | 6 | 29.92 ± 2.06 | 7 | 29.21 ± 1.59 | 15 | 29.18 ± 1.8 |

Table 3. Measurements (mm) and weight (g) of the adult male specimens of chromosomal forms of *Spalax leucodon* in Kastamonu. n: sample size, SD: standard deviation, CH: characteristics that indicated in the same order in materials and methods section.

| | Chromosomal forms (Males) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2n = 54 ♂♂ | | 2n = 56 ♂♂ | | 2n = 58 ♂♂ | | 2n = 60 ♂♂ | |
| CH | n | mean ± SD | n | mean ± SD | n | mean ± SD | n | Mean ± SD |
| 1 | 11 | 216.91 ± 13.49 | 7 | 215.43 ± 12.35 | 4 | 216.25 ± 17.46 | 11 | 247.18 ± 12.22 |
| 2 | 11 | 28.55 ± 2.06 | 8 | 27.63 ± 1.41 | 5 | 27 ± 1.67 | 11 | 30.18 ± 1.59 |
| 3 | 11 | 258.36 ± 33.15 | 7 | 234.71 ± 50.34 | 5 | 244.6 ± 33.37 | 11 | 360.82 ± 36.94 |
| 4 | 11 | 51.44 ± 1.81 | 10 | 48.88 ± 2.91 | 5 | 51.34 ± 2.67 | 11 | 55.72 ± 2.19 |
| 5 | 11 | 49.39 ± 1.89 | 10 | 46.65 ± 3.01 | 5 | 49.38 ± 2.36 | 11 | 53.64 ± 2.11 |
| 6 | 11 | 49.25 ± 1.77 | 10 | 46.24 ± 3.11 | 5 | 49.5 ± 2.41 | 11 | 53.68 ± 2.22 |
| 7 | 11 | 47.37 ± 1.96 | 11 | 44.49 ± 2.91 | 5 | 47.66 ± 2.38 | 11 | 51.74 ± 2.1 |
| 8 | 11 | 18.87 ± 1.25 | 11 | 18.45 ± 1.17 | 5 | 18.12 ± 1.44 | 11 | 21.53 ± 1.24 |
| 9 | 11 | 6.31 ± 0.26 | 11 | 6.14 ± 0.42 | 5 | 6.78 ± 0.36 | 11 | 7.1 ± 0.35 |
| 10 | 11 | 21.3 ± 1.53 | 10 | 19.92 ± 1.67 | 5 | 21.1 ± 1.13 | 11 | 23.76 ± 1.62 |
| 11 | 11 | 2.75 ± 0.27 | 11 | 2.77 ± 0.26 | 5 | 2.86 ± 0.22 | 11 | 3.3 ± 0.27 |
| 12 | 11 | 7.01 ± 0.44 | 11 | 6.89 ± 0.55 | 5 | 7.48 ± 0.74 | 11 | 8.07 ± 0.77 |
| 13 | 11 | 7.76 ± 0.47 | 11 | 7.61 ± 0.58 | 5 | 8.22 ± 0.42 | 11 | 9.24 ± 0.59 |
| 14 | 11 | 18.48 ± 1.65 | 11 | 16.92 ± 1.58 | 5 | 18.5 ± 1.48 | 11 | 20.53 ± 1.23 |
| 15 | 11 | 33.66 ± 1.26 | 10 | 31.93 ± 2.31 | 5 | 34.04 ± 1.87 | 11 | 37.16 ± 1.49 |
| 16 | 11 | 15.68 ± 1.31 | 11 | 14.61 ± 1.35 | 5 | 15.36 ± 0.84 | 11 | 17.1 ± 0.91 |
| 17 | 11 | 38.21 ± 1.79 | 10 | 35.83 ± 2.81 | 5 | 38.44 ± 1.88 | 11 | 41.88 ± 2.24 |
| 18 | 11 | 11.41 ± 0.69 | 11 | 11.43 ± 0.84 | 5 | 12.12 ± 0.59 | 11 | 12.61 ± 0.61 |
| 19 | 11 | 8.04 ± 0.81 | 11 | 8.11 ± 0.56 | 5 | 8.36 ± 0.54 | 11 | 8.89 ± 0.65 |
| 20 | 11 | 2.89 ± 0.39 | 11 | 2.84 ± 0.72 | 5 | 3.64 ± 0.66 | 11 | 3.56 ± 0.28 |
| 21 | 11 | 7.14 ± 0.36 | 10 | 7.58 ± 0.37 | 5 | 7.56 ± 0.3 | 11 | 7.27 ± 0.36 |
| 22 | 11 | 9.94 ± 0.65 | 11 | 9.62 ± 0.58 | 5 | 10.44 ± 0.61 | 11 | 11.07 ± 0.67 |
| 23 | 11 | 14.39 ± 1.57 | 11 | 13.75 ± 1.03 | 5 | 15.46 ± 0.98 | 11 | 16.14 ± 1.08 |
| 24 | 11 | 9.76 ± 1.11 | 11 | 9.2 ± 0.83 | 5 | 10.22 ± 0.94 | 11 | 11.01 ± 0.89 |
| 25 | 11 | 21.6 ± 1.48 | 10 | 19.93 ± 1.07 | 5 | 21.96 ± 1.35 | 11 | 23.74 ± 2.09 |
| 26 | 11 | 8.22 ± 1.1 | 11 | 9.28 ± 0.85 | 5 | 9.76 ± 0.87 | 11 | 10.49 ± 0.97 |
| 27 | 11 | 13.93 ± 1.61 | 11 | 12.01 ± 1.13 | 5 | 12.26 ± 1.24 | 11 | 12.17 ± 1.57 |
| 28 | 11 | 3.56 ± 0.81 | 10 | 3.12 ± 0.54 | 5 | 2.96 ± 0.15 | 11 | 3.55 ± 0.37 |
| 29 | 11 | 7.63 ± 1.05 | 10 | 6.6 ± 0.85 | 5 | 7.22 ± 0.46 | 11 | 8.3 ± 0.85 |
| 30 | 11 | 6.95 ± 0.47 | 11 | 6.66 ± 0.57 | 5 | 7.32 ± 0.57 | 11 | 8.13 ± 0.51 |
| 31 | 11 | 2.52 ± 0.21 | 11 | 2.29 ± 0.19 | 5 | 2.68 ± 0.21 | 11 | 2.79 ± 0.19 |
| 32 | 11 | 2.3 ± 0.21 | 11 | 2.32 ± 0.28 | 5 | 2.54 ± 0.16 | 11 | 2.8 ± 0.21 |
| 33 | 11 | 2.38 ± 0.19 | 11 | 2.39 ± 0.18 | 5 | 2.4 ± 0.19 | 11 | 2.87 ± 0.15 |
| 34 | 11 | 6.46 ± 0.35 | 11 | 6.57 ± 0.58 | 5 | 6.96 ± 0.51 | 11 | 7.22 ± 0.42 |
| 35 | 11 | 7.09 ± 0.41 | 11 | 7.17 ± 0.57 | 5 | 7.72 ± 0.48 | 11 | 8.26 ± 0.51 |
| 36 | 11 | 8.65 ± 0.6 | 11 | 7.84 ± 0.62 | 5 | 8.56 ± 0.35 | 11 | 9.86 ± 0.62 |
| 37 | 11 | 17.31 ± 1.51 | 11 | 16.58 ± 1.15 | 5 | 17.54 ± 1.02 | 11 | 19.93 ± 1.48 |
| 38 | 11 | 30.08 ± 2.02 | 11 | 29.41 ± 1.93 | 5 | 28.76 ± 1.52 | 11 | 32.75 ± 1.54 |
| 39 | 11 | 30.43 ± 1.65 | 11 | 30.09 ± 1.89 | 5 | 30.06 ± 1.88 | 11 | 33.11 ± 1.39 |
| 40 | 11 | 30.58 ± 2.12 | 11 | 30.92 ± 2.01 | 5 | 30.7 ± 1.37 | 11 | 33.67 ± 1.33 |

Table 4. Upper and lower incisors' colours and proportion (%). n: sample size.

| | Upper incisors | | | | Lower incisors | | | |
|---|---|---|---|---|---|---|---|---|
| | White | | Orange | | Orange | | White | |
| Chromosomal forms | n | % | n | % | n | % | n | % |
| 2n = 54 | 3 | 8.82 | 31 | 91.18 | 18 | 52.94 | 16 | 47.06 |
| 2n = 56 | 1 | 5.5 | 17 | 94.5 | - | - | 18 | 100 |
| 2n = 58 | 1 | 6.6 | 14 | 93.4 | 2 | 13.3 | 13 | 86.7 |
| 2n = 60 | 9 | 33.3 | 18 | 66.7 | 11 | 40.7 | 16 | 59.3 |

Table 5. Upper molar root size and proportion (%). n: sample size.

| | | UPPER MOLARS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Chromosomal forms | | $M^1$ Root size | | | $M^2$ Root size | | | $M^3$ Root size | | |
| | | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 2n = 54 | n | 18 | 12 | 2 | 22 | 10 | 0 | 21 | 4 | 7 |
| | % | 56.3 | 37.5 | 6.2 | 68.8 | 31.2 | | 65.6 | 12.5 | 21.9 |
| 2n = 56 | n | 13 | 5 | 0 | 13 | 5 | 0 | 14 | 4 | 0 |
| | % | 72.2 | 27.8 | | 72.2 | 27.8 | | 77.8 | 22.2 | |
| 2n = 58 | n | 13 | 2 | 0 | 14 | 1 | 0 | 12 | 1 | 2 |
| | % | 86.6 | 13.4 | | 93.3 | 6.7 | | 80 | 6.7 | 13.3 |
| 2n = 60 | n | 20 | 6 | 1 | 24 | 3 | 0 | 24 | 3 | 0 |
| | % | 74.1 | 22.2 | 3.7 | 88.9 | 11.1 | | 88.9 | 11.1 | |

Table 6. Lower molar root size and proportion (%). n: sample size.

| | | LOWER MOLARS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Chromosomal forms | | $M_1$ Root size | | | $M_2$ Root size | | | $M_3$ Root size | | |
| | | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 2n = 54 | n | 0 | 32 | 0 | 23 | 9 | 0 | 22 | 5 | 5 |
| | % | | 100 | | 71.9 | 28.1 | | 68.8 | 15.6 | 15.6 |
| 2n = 56 | n | 0 | 18 | 0 | 17 | 1 | 0 | 17 | 1 | 0 |
| | % | | 100 | | 94.4 | 5.6 | | 94.4 | 5.6 | |
| 2n = 58 | n | 0 | 15 | 0 | 14 | 1 | 0 | 14 | 1 | 0 |
| | % | | 100 | | 93.3 | 6.7 | | 93.3 | 6.7 | |
| 2n = 60 | n | 0 | 27 | 0 | 23 | 4 | 0 | 19 | 8 | 0 |
| | % | | 100 | | 85.2 | 14.8 | | 70.3 | 29.7 | |

Table 7. Comparison of some morphological characteristics of chromosomal forms. n: sample size.

| Chromosomal forms | | Posretior margins of the nasals reach or do not reach the line passing the upper margins of foramen infraorbitals | | Nasal length longer, the same length or shorter than sagital crest length | | | The place of foramen postpalatins is located in front of the line passing between $M^2$s and $M^3$s or on the line | | Posterior margin of palatinum is at the same level as the line passing the posterior margin of the alveolus of $M^3$ or extends behind the line | | Lacrimals, viewed from above | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Reach | Do not reach | Longer | Same | Shorter | In front of | On the line | At the same level | Behind | Visible | Invisible |
| 2n = 54 | n | 29 | 3 | 4 | - | 28 | 26 | 6 | 3 | 29 | 32 | - |
| | % | 90.6 | 9.4 | 12.5 | - | 87.5 | 81.3 | - | 9.4 | 90.6 | 100 | - |
| 2n = 56 | n | 18 | - | - | - | 18 | 16 | 2 | 2 | 16 | 18 | - |
| | % | 100 | - | - | - | 100 | 88.9 | 11.1 | 11.1 | 88.9 | 100 | - |
| 2n = 58 | n | 15 | - | - | - | 15 | 15 | - | - | 15 | 15 | - |
| | % | 100 | - | - | - | 100 | 100 | - | - | 100 | 100 | - |
| 2n = 60 | n | 24 | 3 | 1 | - | 26 | 27 | - | 9 | 18 | 25 | 2 |
| | % | 88.9 | 11.1 | 3.7 | - | 96.3 | 100 | - | 33.3 | 66.7 | 92.6 | 7.4 |

## Discussion

The 2n = 54 karyotypes were formerly given from Yozgat (Yüksel and Gülkaç, 2001), Bolu and Bingöl (Nevo et al., 1994, 1995), and Eflani, Aplagut, Yukarıaktaş, and 38 km W of Daday (Sözen, 2004). The chromosome morphology of the Bingöl population determined by Nevo et al. (1994, 1995) is unknown since the figure given for 2n = 54 karyotype is for the Bolu population. On the other hand, the karyotype of the Yozgat population (2n = 54, NF = 74 and NFa = 68) given by Yüksel and Gülkaç (2001) is similar on the basis of the 2n value but different in NF value from that of ours (Table 9). The chromosome morphology of 2n = 54 form given by Sözen (2004) is the same.

The 2n = 56 form was determined around Daday, Kastamonu and Tosya. These areas were surrounded by the 2n = 54 form to the west, by the 2n = 60 form to the north, and by the 2n = 58 form to the east. There were distributional gaps among these forms, and there were no contact zones. Two different 2n = 56 forms of *S. leucodon* were formerly determined from Thrace by Soldatovic and Savic (1978), and by Sözen and Kıvanç (2000b) from southern Turkey (Table 9). These localities are very distant geographically and the chromosome morphologies are different. On the other hand, the karyotypes of the Aşağıçiftlik and Safranbolu populations (2n = 56, NF = 74) given by Sözen (2004) are identical on the basis of chromosome morphology (Table 9).

The 2n = 58 karyotypic form was formerly determined from Madenköy and Ulukışla in southern Turkey by Sözen and Kıvanç (1998a) and Sözen et al. (2000b), and from Sarıkavak by Sözen (2004). However, the NF values of these 2 forms and those of the Taşköprü population are different (Table 9).

The karyotypes of the *Spalax* populations in central Anatolia have been found as 2n = 60 and 62, while the NF value is more diverse, varying between 72 and 84 (Table 9). The diploid karyotype of the Azdavay, Küre, Seydiler and Ağlı populations is similar on the basis of the 2n value to those reported from most parts of central Anatolia (Table 9), but different in the NF value from these karyotypes except for the karyotype of the Aksaray 12 km E population. The Kastamonu 2n = 60 population is surrounded by 2n = 54 to the west, 2n = 56 to the south and 2n = 58 to the east. Therefore, it is isolated from other 2n = 60 populations located in central Anatolia. That is why it is regarded as a new form and designated as 2n = 60N, to differentiate it from other 2n = 60 forms.

*Spalax leucodon* is widely distributed in Turkey except for south-eastern Anatolia (Kıvanç, 1988; Sözen, 2005). The populations in and around Kastamonu have been included in *Spalax leucodon cilicicus* without giving specimens from these areas by Kıvanç (1988). The study presented here has clearly shown that each of the chromosomal forms in Kastamonu was distinguished

Table 8. Characters that separated the chromosomal forms by t-test ($P < 0.05$).

| | Females | | | | | | Males | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Characteristics (mm) | 54-56 | 54-58 | 54-60 | 56-58 | 56-60 | 58-60 | 54-56 | 54-58 | 54-60 | 56-58 | 56-60 | 58-60 |
| Head and body length | | | | | | | | | * | | * | * |
| Hind foot length | | | * | | | * | | | | | * | * |
| Weight (g) | | | | | | * | | | * | | * | * |
| Condylonasal length | * | | * | | * | | | | * | | * | * |
| Condylobasal length | * | | * | | | | * | | * | | * | * |
| Occipitonasal length | * | | * | | | | * | | * | | * | * |
| Basal length | | | * | | | | * | | * | | * | * |
| Nasal length | | * | * | | | | * | | * | | * | * |
| Nasal width | | | * | | | | | | * | * | * | |
| Skull height | * | | * | | | | | | * | | * | * |
| Auditory meatus diameter | | * | * | | | | | | * | | * | * |
| Upper molar crown length | | | * | | | | | | * | | * | |
| Upper molar alveolar length | * | * | * | | * | * | | | * | | * | * |
| Diastema length | * | | * | | | | * | | * | | * | * |
| Facial region length | * | | * | | | | | | * | | * | * |
| Supraoccipital length | * | | | | * | | | | * | | * | * |
| Zygomatic breath, | * | | * | | | | * | | * | | * | * |
| Tympanic bullae length | | * | * | * | * | | | | * | | * | |
| Tympanic bullae width | | | * | | * | * | | | * | | * | |
| Foramen incisiva length | | | * | | | | | | * | | * | |
| Interorbital constriction | | | * | | | | * | | | | | |
| Rostrum width | * | * | * | | | | | | * | | * | |
| Hind palatal length | * | * | * | | | | | | * | * | * | |
| Palatal length | * | | | | | | | * | * | | * | |
| Sagital crest length | * | * | * | | | | * | | * | * | * | |
| Parietal length | | | * | | | | * | | * | | * | |
| Parietal width on lamb. crest | * | * | * | | | | * | | * | | | |
| Foramen infraorbital width | | | * | | | | | * | | | | |
| Foramen infraorbital height | | | | | | | * | | | | * | * |
| Upper incisor alveoles width | * | | * | | | | | | | | * | * |
| Upper incisor width | | | * | | | | * | | * | * | * | * |
| M2 crown width | | * | * | | | | | * | * | | * | * |
| Lower incisor width | * | | * | | | * | | | * | | * | * |
| Lower molar crown length | * | * | * | | | | | | * | | * | |
| Lower molar alveolar length | * | * | * | | | * | | | * | | * | |
| Mandible height | | * | * | | | | * | | * | * | * | * |
| Coronoid process height | * | | * | | | | | | * | | * | * |
| Angular length | | | * | | | | | | * | | * | * |
| Articular length | | | * | | | | | | * | | * | * |
| Alveolar length | | | | | | | | | * | | * | * |
| The number of characters that separate chromosomal forms | 19 | 12 | 34 | 1 | 5 | 6 | 13 | 3 | 35 | 5 | 37 | 25 |

Table 9. Chromosomal records of *Spalax leucodon* Nordmann, 1840 from Turkey. sm: submetacentric, st: subtelocentric, a: acrocentric, m: metacentric.

| Locality | 2n | NF | X | Y | References |
|---|---|---|---|---|---|
| Bayındır | 36 | 70 | – | – | Sözen et al., 1999 |
| Havran, Selçuk | 38 | 74 | st | a | Savic and Soldatovic, 1979 |
| Balıkesir, İzmir | 38 | 74 | st | a | Nevo et al., 1994, 1995 |
| Bigadiç 17 km S | 38 | 74 | sm | a | Sözen, 2004 |
| Dikili, Bigadiç | 38 | 74 | sm | a | Tez et al., 2002 |
| Beyşehir | 40 | 72 | sm | – | Nevo et al., 1994, 1995 |
| Ağrı and Van | 48 | 68 | sm | a | Coşkun, 2003 |
| Aydın | 50W | – | – | – | Nevo et al., 1994, 1995 |
| Keltepe | 50N | 70 | sm | a | Sözen, 2004 |
| Erzurum, Sarıkamış | 50E | 70 | sm | – | Nevo et al., 1994, 1995 |
| Erzurum, Susuz, Ardahan | 50E | 72 | sm | a | Sözen et al., 2000a |
| Erzurum and Kars | 50E | 70 | sm | a | Coşkun, 2003 |
| Sebil | 52S | 72 | sm | a | Sözen and Kıvanç, 1998b |
| Çamlıyayla | 52S | 72 | sm | a | Sözen et al., 2000b |
| Near Abant Lake, Mudurnu, Nallıhan, | 52N | 70 | sm | a | Sözen, 2004 |
| Seben, Kartalkaya ski centre, Yeniçağa, | 52N | 70 | sm | a | Sözen, 2004 |
| Mengen | 52N | 70 | sm | a | Sözen, 2004 |
| Eflani 12 km W, Yukarıaktaş, Alpagut, | 54N | 72 | sm | a | Sözen, 2004 |
| Daday 38 km W, Başçiftlik | 54N | 72 | sm | a | Sözen, 2004 |
| Eflani 15 km W, Pınarbaşı 12, 15 and 17 | 54N | 72 | sm | a | This study |
| km S, Taşpınar | 54N | 72 | sm | a | This study |
| Yozgat | 54C | 74 | sm | st | Yüksel and Gülkaç, 2001 |
| Bolu | 54W | – | sm | – | Nevo et al., 1994, 1995 |
| Bingöl | 54E | – | – | – | Nevo et al., 1994, 1995 |
| Gülek | 56S | 72 | m | a | Sözen and Kıvanç, 1998a |
| Tekir | 56S | 72 | m | a | Sözen et al., 2000b |
| Tosya 12 km N, Daday 4, 6 km W, | 56N | 74 | sm | a | This study |
| Kastamonu 10 km W | 56N | 74 | sm | a | This study |
| Aşağıçiftlik, Safranbolu | 56N | 74 | sm | a | Sözen, 2004 |
| Çorlu, Karaevli (in Thrace) | 56W | 78 | sm | a | Soldatovic and Savic, 1978 |
| Eceabat (in Thrace) | 56 | 76 | sm | a | Sözen, 2004 |
| Madenköy | 58S | 72 | sm | a | Sözen and Kıvanç, 1998a |
| Ulukışla (centre) | 58S | 72 | sm | a | Sözen et al., 2000b |
| Taşköprü | 58N | 74 | sm | a | This study |
| Sarıkavak | 58N | 78 | sm | a | Sözen, 2004 |
| Ulukışla 30 km W | 60 | 72 | sm | a | Sözen et al., 2000b |
| Aksaray 12 km E | 60 | 74 | sm | a | Sözen et al., 2000b |
| Azdavay, Küre, Ağlı, Seydiler | 60N | 74 | sm | a | This study |
| Aksaray 35 km W | 60 | 76 | sm | st | Sözen et al., 2000b |
| Akşehir | 60 | 76 | sm | st | Sözen et al., 1999 |
| Malatya, Pınarbaşı | 60E | 78 | sm | a | Nevo et al., 1994, 1995 |
| Kayseri, Gürün | 60 | 78 | sm | – | Tez et al., 2001 |
| Nallıhan, Beypazarı, Bakırlı, | 60 | 78 | sm | st | Sözen, 2004 |
| Kartalkaya 8 km W, | 60 | 78 | sm | st | Sözen, 2004 |
| Malatya | 60 | 80 | sm | st | Yüksel, 1984 |
| Kırşehir, Nevşehir, Kayseri | 60 | 80 | sm | st | Yüksel and Gülkaç, 2001 |
| Malatya, Yazıhan | 60 | 80 | sm | st | Gülkaç and Yüksel, 1989 |
| Batıkent, Sarayköy | 60 | 80 | sm | st | Sözen, 2004 |
| Arguvan | 60 | 82 | sm | – | Gülkaç and Yüksel, 1989 |
| Ankara, Afyon | 60 | 82 | sm | st | Sözen et al., 1999 |
| Burdur | 60 | 84 | sm | st | Sözen et al., 1999 |
| Denizli | 60W | – | – | – | Nevo et al., 1994, 1995 |
| Karaman | 60C | – | – | – | Nevo et al., 1994, 1995 |
| Kütahya, Afyon, Konya, Sivas, Ankara, | 62 | – | – | – | Nevo et al., 1994, 1995 |
| Kayseri, Havza, Suşehri | 62 | – | – | – | Nevo et al., 1994, 1995 |

from each other by chromosome morphology and some morphological peculiarities. These results clearly show that the taxonomy of *Spalax* in Turkey needs a modern revision based on karyological (especially chromosome banding), ethological, molecular, genetic, biometric, ecologic etc. studies.

A taxonomic revision of species and subspecies of *Spalax* in Turkey was performed by Kıvanç (1988) using only morphological data. According to Nevo et al. (1995), this attempt at a revised taxonomy was unrealistic in view of the karyotype and allozyme study performed by them. Some subspecies indicated by Kıvanç (1988) have more than one karyotype, for example *Spalax leucodon cilicicus* has at least 9 chromosomal forms (2n = 50N, 52N, 52S, 54, 56N, 58N, 58S, 60 and 62) (Nevo et al., 1995; Sözen and Kıvanç, 1998a, 1998b; Sözen et al., 1999, 2000b; Sözen, 2004) (see Table 9). Additionally, Nevo et al. (1995) considered the populations with different diploid chromosome numbers, 2n, as good biological species. Thus, splitting the populations based on karyotypes produces a more realistic taxonomy in *Spalax* (Nevo et al., 1995).

To date, despite more than 20 chromosomal forms of *Spalax leucodon* in Turkey having been determined, no study has been carried out to differentiate them using morphological characteristics. In the present study, measurements of the morphological characteristics of the karyological forms were compared with each other by t-test and it was shown that all forms have many significantly different characteristics. Additionally, some non-metric morphological characteristics listed in Tables 4-7 can separate the chromosomal forms. These findings supported the opinion that each of the chromosomal forms is a good biological species.

This study clearly showed that chromosomal forms of *Spalax* are very diverse in Turkey and many other new forms may be found by new studies. After all chromosomal forms are determined, numerous new studies will be necessary to clarify their evolutionary relationships. After that, as performed in Israel, each of the chromosomal forms may be determined as a biological species and named formally. Such a process would add at least about 30 new species to the Turkish mammalian fauna.

**Acknowledgements**

We would like to thank Kamuran Çataklı, Halil Özgür Harıp and Muhammet Ören for their help in collecting animals, and Dr. Ahmet Karataş in preparing the map in Figure 1. This study was supported by TÜBİTAK (TBAG – 2073).

**References**

Corbet, G.B. 1978. The mammals of the Palaearctic region: A taxonomic review. London: British Museum (Nat. Hist).

Coşkun, Y. 1996. A new subspecies of *Nannospalax nehringi* (Satunin, 1898) (Rodentia: Spalacidae) from Turkey. Saugetierkdl. Mitt. 37: 103-109.

Coşkun, Y. 2003. A study on the morphology and karyology of *Nannospalax nehringi* (Satunin, 1898) (Rodentia: Spalacidae) from Northeast Anatolia, Turkey. Turk. J. Zool. 27: 171-176.

Coşkun Y. 2004. A new species of mole rat, *Nannospalax munzuri* sp. n., and karyotype of *Nannospalax tuncelicus* (Coşkun, 1996) (Rodentia: Spalacidae) in eastern Anatolia. Zoology in the Middle East 33: 153-162.

Ford, C.E. and Hamerton, J.L. 1956. A colchicine hypotonic citrate, squash for mammalian chromosomes. Stain Technol. 31: 247-251.

Giagia, E., Savic, I. and Soldatovic, B. 1982. Chromosomal forms of the mole rat Micro*spalax* from Greece and Turkey. Sond. Z. Säugetierkunde 47: 231-236.

Gülkaç, M.D. and Yüksel, E. 1989. Malatya yöresi körfareleri (Rodentia; Spalacidae) üzerine sitogenetik bir inceleme. DOĞA TU. Biyol. D., 13: 63-71.

Harrison, D.L. and Bates, P.J.J. 1991. Mammals of Arabia. Second Edition. Harr. Zool. Mus.Pub, 1-353.

Kıvanç, E. 1988. Türkiye *Spalax*'larının Coğrafik Varyasyonları. Ankara 72, Teksir- Daktilo- Fotokopi s. 88

Mursaloğlu, B. 1979. Türkiye *Spalax*'larında (Mammalia: Rodentia) Sistematik Problemler. TÜBİTAK VI. Bilim Kongresi, Mat., Fiz. ve Biyo. Bil. Araş. Gr. Biyo. Sek. Teb., s. 83-92.

Nevo, E., Tchernov, E. and Beiles, A. 1988. Morphometrics of speciating mole rats; Adaptive differentiation in ecological speciation. Z. Zool. Syst. Evolut.-forsch. 26: 286-314.

Nevo, E., Filippucci, M.G., Redi, C., Korol, A. and Beiles, A. 1994. Chromosomal speciation and adaptive radiation of mole rats in Asia Minor correlated with increased ecological stress, Proc. Natl. Acad. Sci. USA, 91: 8160-8164.

Nevo, E., Filippucci, M.G., Redi, C., Simson, S., Heth, G. and Beiles, A. 1995. Karyotype and genetic evolution in speciation of subterranean mole rats of the genus *Spalax* in Turkey. Biological Journal of the Linnean Society 54: 203-229.

Savic, I. and Nevo, E. 1990. The Spalacidae; Evolutionary history, speciation and population biology, in; Evolution of Subterranean Mammals at the Organismal and Molecular Levels. (E. Nevo and A.O. Reig, eds.), 129-153, Alan R. Liss, New York.

Savic, I. and Soldatovic, B. 1979. Distribution range and evolution of chromosomal forms in the Spalacidae of the Balkan Peninsula and bordering regions. J. of Biogeography 6: 363-374.

Soldatovic, B. and Savic, I. 1978. Karyotypes in some populations of the genus *Spalax* (*Mesospalax*) in Bulgaria and Turkey. Sonderdruck aus Säugetierk. Mitt. 26, Jhg., Heft 4: 252-256.

Sözen, M., 2004. A karyological study on subterranean mole rats of the *Spalax leucodon* Nordmann, 1840 superspecies in Turkey, Z. Säugetierkunde 64: 420-429.

Sözen, M. and Kıvanç, E. 1998a. Two new karyotypic forms of *Spalax leucodon* Nordmann, 1840 (Mammalia: Rodentia) from Turkey. Z. Säugetierkunde 63: 307-310.

Sözen, M. and Kıvanç, E. 1998b. A new karyotype of *Spalax leucodon cilicicus* Mehely, 1909 (Mammalia: Rodentia) from type locality in Turkey. Isr. J. Zool, 44: 53-56.

Sözen, M., Çolak, E., Yiğit, N., Özkurt, Ş. and Verimli, R. 1999. Contributions to the karyology and taxonomy of the genus *Spalax* Güldenstaedt, 1770 (Mammalia: Rodentia) in Turkey. Z. Saugetierkunde 64: 210-219.

Sözen, M., Çolak, E. and Yiğit, N. 2000a. Contributions to the karyology and taxonomy of *Spalax leucodon* nehringi Satunin, 1898 and *Spalax leucodon armeniacus* Mehely, 1909 (Mammalia: Rodentia) in Turkey. Z. Säugetierkunde 65: 309-312.

Sözen, M., Çolak, E. and Yiğit, N. 2000b. A study on karyotypic evolution of the genus *Spalax* Güldenstaedt, 1770 (Mammalia: Rodentia) in Turkey. Isr. J. Zool. 46: 239-242.

Tez, C., Gündüz, İ. and Kefelioğlu, H. 2001. Karyological study of *Spalax leucodon* Nordmann, 1840 in central Anatolia, Pakistan Journal of Biological Sciences 4: 869-871.

Tez, C., Gündüz, İ. and Kefelioğlu, H. 2002. New data on the distribution of 2n = 38 *Spalax leucodon* Nordmann, 1840 cytotype in Turkey. Isr. J. Zool. 48: 155-159.

Yüksel, E. 1984: Cytogenetic study in *Spalax* (Rodentia; Spalacidae) from Turkey. Communications, C; Biologie 2: 1-12.

Yüksel, E. and Gülkaç, M.D. 2001: The cytogenetical comparison of *Spalax* (Rodentia: Spalacidae) populations from middle Kızılırmak basin, Turkey. Turk. J. Biol. 25: 17-24.