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Two new cytotypes and additional karyological records for blind mole rats, *Nannospalax xanthodon* and *N. ehrenbergi* (Mammalia, Rodentia) in Turkey

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Abstract. Blind mole rats are model organisms for studies of chromosomal evolution, and have a variety of chromosomal forms in Turkey. This study was performed on subterranean mole rats of *Nannospalax xanthodon* (Satunin, 1898) and *N. ehrenbergi* (Nehring, 1898) in Turkey. Karyotypes of 63 specimens originating from 30 localities were analysed. Two new cytotypes with 2n = 54 from Adana and 2n = 56 from Karaman, two different populations of the cytotypes 2n = 54C and 2n = 58S, and four different chromosomal arm numbers of the 2n = 60 cytotype (NF = 74, 76, 78 and 80) were determined in *N. xanthodon*. The cytotypes characterized by 2n = 54, NF = 74 from Tufanbeyli and Saimbeyli in the Adana province (54S), and by 2n = 56, NF = 70 from Karaman (56K) are new for *N. xanthodon* in Turkey. A population of *N. ehrenbergi* from the Osmaniye province in southern Anatolia had a complement with 2n = 56, NF = 70. Additional karyological records for other cytotypes have extended their known distribution areas, and filled most karyological gaps in Turkey.

Key words: rodents, karyotype, Anatolia

Introduction

According to recent taxonomic checklists, three mole rat species, *Nannospalax xanthodon*, *N. leucodon* and *N. ehrenbergi*, are distributed in Turkey (Wilson & Reeder 2005, Yiğit et al. 2006, Kryštufek & Vohralík 2009). Within these three recognized species, more than 30 cytotypes have currently been recognized in blind mole rats in Turkey (Sözen & Kıvanç 1998a, b, Sözen et al. 1999, 2006a, b, 2013, Coşkun 2003, Matur & Sözen 2005, Kankılıç et al. 2007a, b, 2013, 2015, Ivanitskaya et al. 2008, Arslan & Bölükbaş 2010, Arslan & Zima 2013, 2014, 2015, Matur et al. 2013, Arslan et al. 2014a). The diploid number of chromosomes varies between 2n = 36 and 60 in Turkish blind mole rats, while the fundamental number of chromosomal arms ranges between NF = 66 and 92 (e.g. Sözen et al. 2006b, 2011, 2013, Ivanitskaya et al. 2008, Kankılıç et al. 2009, 2010, 2013, Arslan & Zima 2014, Arslan et al. 2014a). The cytotype with 62 chromosomes was eliminated from the list of Turkish *N. xanthodon* cytotypes (Ivanitskaya et al. 2008).

Nevo et al. (1994) indicated a correlation between 2n value and aridity stress. They showed that trends in chromosomal evolution revealed in Israeli blind mole rats by comparison of 2n and heterozygosity, were positively correlated with aridity stress and climatic unpredictability. Later Sözen et al. (2000a) proposed that NF values were also correlated with aridity stress and climatic unpredictability. However, Matur et al. (2011) rejected this hypothesis in a study of G- and C- banded chromosomes of four different 2n = 50 population, and concluded that such a correlation is useless in Turkish mole rats. Geographic structures act as an isolation mechanism and they separate the cytotypes (Matur & Sözen 2005). However, most cytotypes seem to be differentiated despite the lack of a barrier. The ranges of individual cytotypes are geographically close to each other but almost no hybrids have been found in Turkey (Sözen et al. 2006b, 2013, Ivanitskaya et al. 2008, Kankılıç et al. 2009, 2013, Matur et al. 2013).

Though extensive karyological studies have been made since 1978 in Turkey and new cytotypes have

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been recently discovered (Arslan et al. 2014a), some karyological gaps still exist in some areas that should be filled. Determination of all cytotypes and their distribution areas will open new ways for general evaluation and reaching of significant results about their real taxonomic status. The purpose of this study is to describe the karyotypic characteristics of several populations in Anatolia to fill the gaps in our information.

Material and Methods

In this study, 63 specimens (25 males, 38 females) of blind mole rats belonging to *Nannospalax xanthodon* and *N. ehrenbergi* were studied from 30 localities in Anatolia. The sampled localities, the number of individuals analysed and karyological results are presented in Table 1, and the distribution of cytotypes and collection localities in Fig. 1.

Karyotypes were prepared from bone marrow according to Ford & Hamerton (1956), and about 25-30 metaphase cells were examined in each animal. The diploid number of chromosomes (2n), the number of autosomal arms (NFa), the total number of chromosomal arms (NF) and the sex chromosomes were determined from photos of metaphase plates. The cytotypes were named according to their chromosome diploid number, the geographic position of their occurrence, or species pertinence (e.g. S – southern, C – central, K – Karaman, *eh* – *N. ehrenbergi*).

The karyotype preparations and animals examined were deposited in the Department of Biology, the

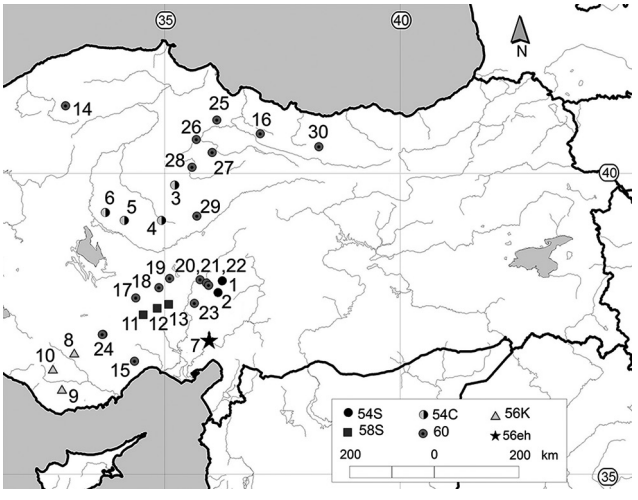

Fig. 1. Map of study area in Turkey, and distribution of cytotypes determined. The numbers of localities are the same as in Table 1.

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Results

Two new cytotypes of *Nannospalax xanthodon* with

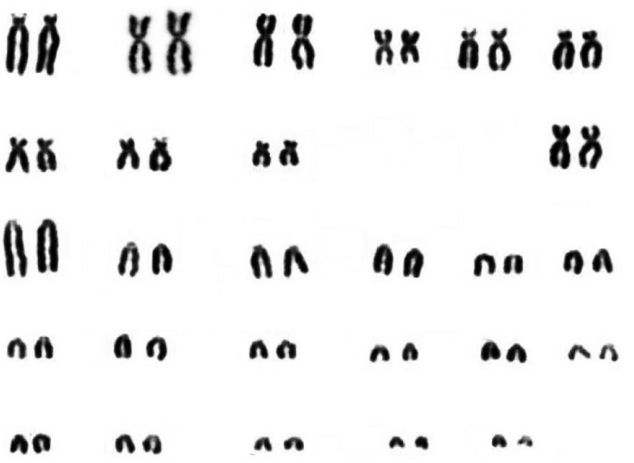

Fig. 2. Karyotype of a female of 2n = 54S cytotype from Saimbeyli.

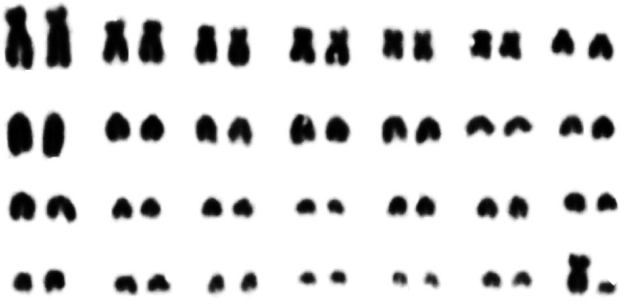

Fig. 3. Karyotype of a male of 2n = 56K cytotype from Çandır Plateau.

2n = 54S from Adana and 56K from Karaman, two different populations for *Nannospalax xanthodon* possessing 2n = 54C and 2n = 58S, NF = 72, four different chromosomal arm numbers of 2n = 60 cytotype (NF = 74, 76, 78 and 80), and one cytotype of *N. ehrenbergi* (2n = 56*eh*) were revealed.

2n = 54S: This cytotype was found in Tufanbeyli and Saimbeyli in the Adana province. The X chromosome is medium-sized metacentric, and the Y could not be determined since all animals of this cytotype were females. Autosomal set consists of nine pairs of bi-armed and 17 pairs of acrocentric chromosomes (2n = 54, NF = 74; Fig. 2).

2n = 54C: This cytotype was recorded from Sorgun (Yozgat province), Kozaklı (Nevşehir), Kırşehir centre, Kaman (Kırşehir). The X chromosome is medium-sized metacentric and the Y small acrocentric. Autosomal set contains nine pairs of bi-armed and 17 pairs of acrocentric chromosomes (2n = 54, NF = 74, NFa = 70).

2n = 56K: This karyotype was found in samples from the Barjin high-plateau (Karaman), and the Çandır high-plateau (Mersin) populations. The X chromosome is medium-sized metacentric, and the

Table 1. Synopsis of the specimens examined and basic results. See text for details.

	Locality	Province	no. ♂♂	no. ♀♀	2n	NF	X	Y
1	Tufanbeyli 1 km S	Adana	0	2	54S	74	sm	-
2	Saimbeyli 10 km N	Adana	0	2	54S	74	sm	-
3	Sorgun	Yozgat	2	0	54C	74	sm	a
4	Kozaklı 10km N	Nevşehir	0	3	54C	74	sm	a
5	Kırşehir 10 km N	Kırşehir	0	2	54C	74	sm	a
6	Kaman	Kırşehir	0	1	54C	74	sm	a
7	Çukurköprü 1 km E, Kadirli	Osmaniye	1	1	56*eh*	70	sm	a
8	Karaman 20 km S	Karaman	1	0	56K	70	sm	a
9	Ermenek 40 km S, Çandır plateau	Mersin	1	1	56K	70	sm	a
10	Barjin plateau	Karaman	1	2	56K	70	sm	a
11	Ulukışla 30 km N, Kolsuz village	Niğde	1	2	58S	72	sm	a
12	Çamardı 15 km W	Niğde	1	1	58S	72	sm	a
13	Demirkazık village, Çamardı	Niğde	0	1	58S	72	sm	a
14	Ovacık 2 km W	Karabük	1	1	60	78	sm	a
15	Fındıkpınarı plateau	Mersin	1	2	60	78	sm	a
16	Çamiçi plateau, Niksar	Tokat	2	1	60	78	sm	a
17	Altunhisar 2 km SE	Niğde	0	1	60	80	sm	a
18	Hüyük village 2 km SW	Niğde	0	1	60	80	sm	a
19	Yeşilhisar 9 km S	Kayseri	1	1	60	80	sm	a
20	Bakırdağ 6 km W	Kayseri	1	1	60	80	sm	a
21	Bakırdağ 10 km E	Kayseri	1	0	60	80	sm	a
22	Bakırdağ 15 km E	Kayseri	1	1	60	80	sm	a
23	Mansurlu village	Adana	1	3	60	74	sm	a
24	Ayrancı town	Karaman	1	0	60	76	sm	a
25	Ladik 20 km S	Samsun	2	2	60	78	sm	a
26	Gediksaray 10 km N	Amasya	0	2	60	78	sm	a
27	Turhal 10 km S	Tokat	0	1	60	76	sm	a
28	Çekerek 5 km E	Yozgat	1	1	60	76	sm	a
29	Çayıralan	Yozgat	1	2	60	76	sm	a
30	Karataş plateau, Koru graveyard, Şebinkarahisar	Giresun	3	0	60	78	sm	a
			25	38				

Y chromosome small acrocentric. The autosomal set consists of six pairs of bi-armed and 21 pairs of acrocentric chromosomes (2n = 56, NF = 70, NFa = 66; Fig. 3).

2n = 56*eh*: The karyotype was found in the sample from Kadirli (Osmaniye). The X chromosome is medium-sized submetacentric and the Y chromosome small acrocentric. The autosomal set contains six pairs of bi-armed and 21 pairs of acrocentric chromosomes (2n = 56 NF = 70, NFa = 66).

2n = 58S: The karyotype was found in samples from Kolsuz and Demirkazık villages, and from vicinity of Çamardı. The X chromosome is medium-sized submetacentric; Y chromosome small acrocentric. The autosomal set contains six pairs of bi-armed and 22 pairs of acrocentric chromosomes (2n = 58, NF = 72, NFa = 68).

2n = 60: The karyotype with 60 chromosomes was found in most localities studied. Four different NF values (NF = 74, 76, 78 and 80) were determined in the complement, and the differences in the NF value were due to varying number of bi-armed and acrocentric chromosomes. The X chromosome is medium-sized submetacentric, and Y chromosome small acrocentric.

Discussion

The 2n = 54 cytotype of *N. xanthodon* was previously recorded from central, northern and eastern Anatolia (Nevo et al. 1994, Yüksel & Gülkaç 2001, Coşkun 2004, Sözen 2004, Aşan & Yağcı 2008, Arslan et al.

2011b, Kankılıç et al. 2013, 2015). The additional distribution records for the 54C cytotype from central Anatolia (Yozgat, Nevşehir and Kırşehir) fill the gaps in the distribution in the Kızılırmak basin in Central Anatolia. The distribution records of the populations with 54 and 60 chromosomes show that the 54C cytotype is surrounded by populations with 2n = 60 in Central Anatolia (Sözen et al. 2006a, 2013, Arslan et al. 2011b, Kankılıç et al. 2013). This distribution pattern also suggests that the River Kızılırmak forms a barrier between the 2n = 60 and 2n = 54 cytotypes in the west, however, the river is not a barrier for the former cytotype in the southern part of the basin. The 54S cytotype from Saimbeyli and Tufanbeyli was recorded for the first time. The geographic distance between the assumed ranges of the 54C and 54S cytotypes is considerable, and the latter cytotype is accepted as a new one here. The River Kızılırmak separates the two 2n = 54 cytotypes and the area between their ranges is occupied by populations with 60 chromosomes (Fig. 1).

The 2n = 56 cytotype was previously recorded from Gülek, Pozantı and Aksu in southern Anatolia (Sözen & Kıvanç 1998, Sözen et al. 2006b, Kandemir et al. 2012, Arslan et al. 2014b, Kankılıç & Gürpınar 2014). Arslan et al. (2014b) compared four different cytotypes with 2n = 56 according to the C-banding pattern and the NOR distribution. The localities studied in this paper are new records for this cytotype in southern Anatolia. Considering the geographic distance between the Pozantı and Karaman regions as well as the specific chromosome morphologies found in karyotypes of the specimens from Karaman, we propose to recognize these populations as a new cytotype designated as 56K to indicate that this cytotype is distributed around Karaman region.

Records of populations with 2n = 56 belonging to *N. ehrenbergi* were previously reported from Tarsus (Nevo et al. 1994, 1995, Ivanitskaya et al. 1997), Kadirli (Osmaniye), Ceyhan and Kozan (Adana) (Coşkun et al. 2006), and Adana and Şeyfmurat (Sözen et al. 2006a). In all these localities, the number of chromosomal arms in the karyotype was NF = 70. We recorded the same cytotype near Kadirli, and extended the distribution area of this cytotype northward.

The 2n = 58S cytotype was recorded in *N. xanthodon* from Ereğli, Ulukışla and Pozantı in southern Anatolia by Sözen & Kıvanç (1998), Sözen et al. (2000b, 2006b), and Arslan et al. (2011a). We found the same karyotype in additional three localities and extended the distribution of the cytotype to the north by more than 50 km.

The karyotype with 2n = 60 was mostly recorded from central Anatolia (Yüksel 1984, Gülkaç & Yüksel 1989, Nevo et al. 1994, 1995, Sözen et al. 1999, 2000b, 2006a, b, 2011, 2013, Tez et al. 2001, Yüksel & Gülkaç 2001, Sözen 2004, Matur & Sözen 2005, Kankılıç et al. 2007a, b, 2009, 2010, Ivanitskaya et al. 2008, Arslan & Bölükbaş 2010, Arslan et al. 2011a, Kandemir et al. 2012, Aşan et al. 2013, Matur et al. 2013). In the karyotype with 60 chromosomes, several different NF values were determined in various parts of its occurrence (reviewed in Sözen et al. 2006a and Arslan & Zima 2014). This cytotype was recorded from 18 additional localities here and these new localities generally determine its northern and southern distribution borders, and fill most karyological gaps in central Anatolia.

Chromosome studies have provided rather comprehensive picture of karyotypic variation of blind mole rat populations in Anatolia. Cytogenetic investigations should be supplemented now by analyses of other phylogenetic markers. Molecular systematic studies on chromosomal forms of blind mole rats have been recently performed (e.g. Arslan et al. 2010, Kandemir et al. 2012, Kryštufek et al. 2012, Kankılıç et al. 2013, 2015, Kankılıç & Gürpınar 2014), and we can expect that new species will be described based on such data in the near future.

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