

## The Cytogenetical Comparisons of *Spalax (Rodentia: Spalacidae)* Populations From Middle Kızılırmak Basin, Turkey<sup>1</sup>

Eşref YÜKSEL

İnönü University, Art and Science Faculty, Department of Biology, 44069 Campus, Malatya-TURKEY

Mehmet Doğan GÜLKAÇ

Kocaeli University, Faculty of Medicine, Department of Medical Biology,  
41900 Derince, Kocaeli-TURKEY

Received: 13.03.1997

**Abstract:** Chromosomal polymorphism and speciation problem in genus *Spalax* has been investigated.

All the specimens were identified as *Spalax leucodon cilicicus* Mehely, 1909. In according to karyotype analysis, two different populations were described from the field. The diploid number of Population A from south ant northwest of the field were found to be 60 and number of fundamental numbers were 80. The corresponding numbers in the Population B from northeast of the field were 54 and 74 respectively.

In the result, the possibility of inversions in the Population B was discussed from evolutionary point of view and also the evolutionary background of *Spalax* brought into attention.

**Key Words:** *Spalax*, chromosomal polymorphism, speciation.

### Introduction

Chromosomes which lead to evolution have been used for taxonomy and speciation in a lot of animal groups. The studies on mammalian chromosomes have been constituted an effective investigation area to explain their relationship. Approximately 40 karyotype of *Spalax* had been reported up to date from North Africa (1), Israel (2, 3) Turkey (4, 5, 6, 7, 8, 9, 10, 11), Greece (5, 12, 6, 8), Yugoslavia (5, 6, 8, 13, 14, 15, 16), Bulgaria (4, 5, 6, 17, 18, 19), Rumania (20, 21, 22) and Caucasia (23, 24). It is of interest to state that the diploid number of chromosomes ranges of *Spalax* from 38 to 60, while the NF values vary from 74 to 98 (6, 7, 9, 10, 16).

Karyotypic studies of mole rats in Turkey were initiated by Savic and Soldatovic (5, 6, 7) and Soldatovic and Savic (4). Other karyotypes were reported from Turkey by Giagia *et al.* (8), Yüksel (9), Gülkaç and Yüksel (10).

<sup>1</sup> This study was supported by Turkish Scientific and Technical Research Council-TÜBİTAK (Project Number: TBAG-904).

## Materials and Methods

Analysis of karyotype were conducted in the populations of mole rats from middle region of River Kızılırmak (Fig. 1). In this study, a total of 25 mole rat specimens (15 ♂, 10 ♀) were examined.

A direct method of development from the bone marrow according to Patton's (25) "Colchicine-hypotonic-citrate" technique was applied for the preparation of chromosomes.

An average of 20 to 30 metaphase cells were counted in order to determine the diploid number of each animal investigated.

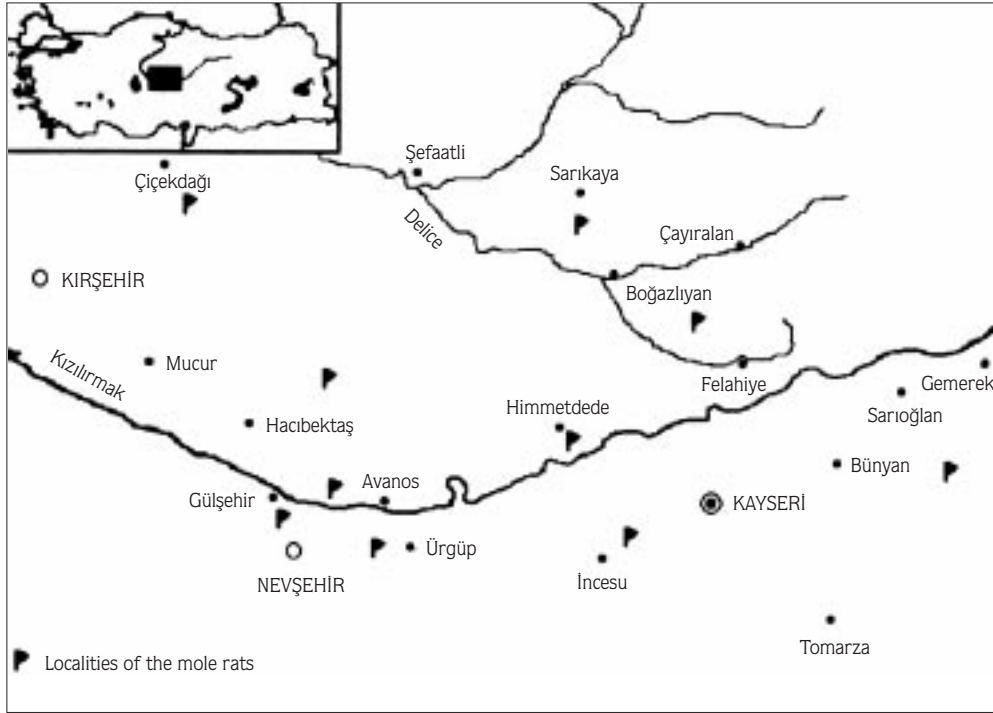


Fig. 1. The map showing the area under study.

## Results

Live trapped specimens of mole rats were identified according to Kıvanç (26) as *Spalax leucodon cilicicus* Mehely 1909.

By the analysis of the karyotypes of this subspecies it was established that two karyotypical forms are present in the area. The first karyotypical form is distributed at the south and northwest of the field which we called it "Population A". This karyological form is distributed on each sides of river Kızılırmak but is not distributed on northeast side of Delice stream. By the analysis of this form it was found that the diploid number of chromosomes is 60 and NF values are 80. According to position of the centromere the chromosomes could be placed in two groups. The first group consist of 9 pairs of submetacentric autosomes and the second group which were acrocentric found to be 20 pairs of autosomes. The X-chromosome is submetacentric, while Y-chromosome is submetacentric (Fig. 2).

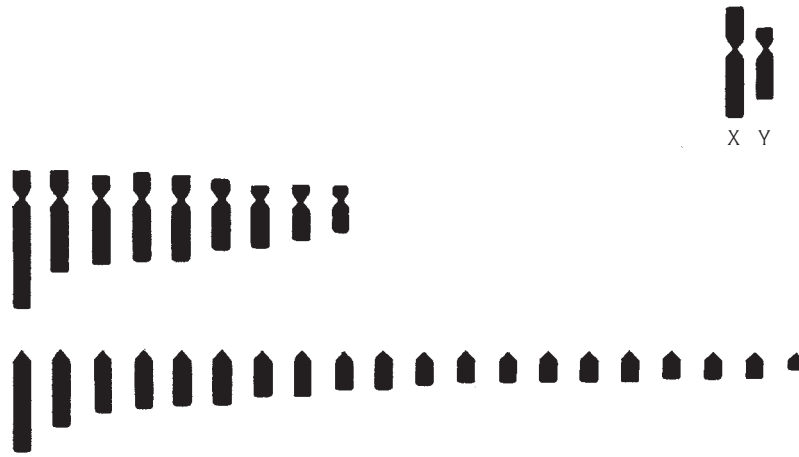


Fig. 2. Idiogram of the Population A of *Spalax leucon cilicicus*.

The other karyological form of this subspecies is distributed at the northeast of the field which we called it "Population B". This form is seperated from Population A by Delice stream and Akdağ mountains. By the karyotype analysis, it was established that the diploid number of chromosomes in this population is 54. This form includes 3 pairs of submetacentric, 6 pairs of submetacentric and 17 pairs of acrocentric autosomes. The X-chromosome is submetacentric, while Y-chromosome is submetacentric. According to described morphology of chromosomes NF amount are 74 (Fig. 3).

The number of individuals, sex composition, chromosome numbers and the types of chromosomes in both population are given in Table 1.

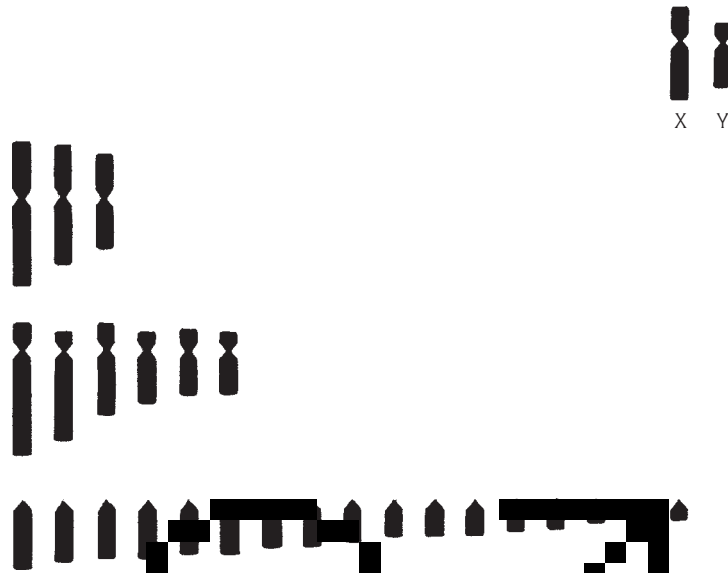


Fig. 3. Idiogram of the Population B of *Spalax leucodon cilicicus*.

Table 1. Somatic chromosome numbers and morphological types of "Population A" and "Population B".

POPULATION	CHROMOSOMES										
	SEX		Autosomes					Gonosomes			
	2n	m	st	a	X	Y	NF	NFa			
Population A	9	3	60	-	-	9	20	sm	st	80	76

### Discussion

The problem of speciation processes and evolution of genus *Spalax* has been discussed in great detail by many workers (1-37). The present data is not adequate in full explanation of these problems due to lack of data concerning in biochemical and behavioral investigations.

According to the analysis of karyotypes presented, it seems that the river Kızılırmak has not been acted as a natural barrier between the two populations of *Spalax leucodon cilicicus*, because

the mole rat populations of both sides of the river have the same karyotype. But, Delice stream, which join to river Kızılırmak, has been acted as a geographical barrier and did not permit exchanging genetic material. The narrow passageway between river Kızılırmak and Delice stream has been closed by a chain of Akdağ Mountains. These mountains are approximately 2000 m from sea level.

Population A ( $2n=60$ ,  $NF=80$ ) show the same chromosomal characters both in number and morphology with that reported by Yüksel (9) and Gülkaç and Yüksel (10) from east Anatolia. It has been argued by Nevo and Cleve (38) and Nevo (34) that in *Spalax* complex, relatively very few allelic changes are needed for the dispersion of populations. That is to say, at least at the level of structural genes, the essence of speciation, i.e. the development of pre- and post-mating reproductive isolation per se may occur with little genomic changes, either genic and chromosomal.

It is believed (6, 9, 10, 11, 25, 40) that karyotypic changes may be brought about through Robertsonian variation, i.e. centric fusion, and pericentric inversions. Through Robertsonian variation two acrocentric chromosomes may fuse at the centromere to produce one bi-armed chromosome. Thus, this mechanism allows for the evolution of the karyotype in such a way that the diploid number is reduced but the fundamental number is kept constant. Fundamental numbers, on the other hand, may change by pericentric inversions through which some acrocentric chromosomes may be converted into a biarmed chromosome without changing chromosome number. In the present study, it seems that the both mechanism were in action. That is, by analysing the karyotypes of Population A ( $2n=60$ ,  $NF=80$ ) and Population B ( $2n=54$ ,  $NF=74$ ) one may realize that the latter can be evolved from the former by the pericentric inversions between three of acrocentric and three of subtelocentric chromosomes. Therefore, both diploid number and the fundamental numbers were changed.

Some peculiarities of *Spalax* must be taken into account; these are; i) They are largely confined to a subterranean existence with a limited motility. Thus the gene flow between populations is limited. ii) Interbreeding between overlapping karyotypes either not observed at all (11, 16 and in the present study) or very narrow and lower than expected proportions of hybrid were observed (37) which indicates strong selection against hybrids. iii) Generally, the ethologic isolation mechanism endowes a very complex genetical background. However, the major origin of isolation in *Spalax ehrenbergi* complex seems to be incidental by-product of adaptive differentiation (39).

Occasional chromosomal variations were encountered within cells of single individual. These included a centrically fused chromosome in one cell of an animal with i.e.  $2n=60$  chromosomes, and an inverted chromosome in one cell of an animal with i.e.  $2n=54$  chromosomes. The fixation of these changes is not so surprising as it has been pointed out by Nevo (34) that, those population separated by natural barriers may have different chromosome numbers. In the case of mole rats, natural barriers may have different chromosome numbers. In the case of mole

rats, natural barriers are not even necessary, in the classic sense, in as much as mole rats in peripheral situations live in small somewhat isolated populations and their motility, in generally is very restricted (2). Such populations expected to be highly inbred and gene exchange is restricted between them. The achievement of relatively rapid fixation of new karyotypes prevents hybridization, and also often results in the evolution of pre- and post-mating reproductive isolation. Ultimately, the gene pools became more or less separated and the species or subspecies level was practically reached (11).

This argument let us to look for hybrids along the contacts between different karyotypical forms and no hybrids were found. This finding is in agreement with that reported by Savic and Soldatovic (16). Nevertheless, Wahrman *et al.* (2), Nevo (35) and Nevo and Bar-El (37) reported that narrow hybrid zones occur in *Spalax ehrenbergi* along the contact between different karyotypical forms. However, the authors also emphasized that the hybrids were inferior in fitness in these forms. In discussing the distribution range and evolution of Spalacidae by Savic and Soldatovic (6) concluded that subspecies *Spalax leucodon turcicus* from Turkish part of Balkans was the form with the most primitive karyotype and might be closets to initial one. *Spalax leucodon turcicus* has 2 pairs of metacentrics, 5 pairs of submetacentrics, 3 pairs of subtelocentrics and 17 pairs of acrocentrics. Diploid number and NF values of this subspecies are 54 and 78, respectively. The karyotypic forms of *Spalax leucodon cilicicus* from middle Kızılırmak basin (in the present study) and east Anatolia (9, 10) have  $2n=60$  and  $NF=80$  and 82 with no metacentric and submetacentric autosomes. Therefore, these forms seems to be more primitive and probably closer to the initial one than other described forms up to now. These data have been supported to the thesis of a common Asiatic origin of the European Spalacidae and the existence of a direct initial nucleus in Asia Minor.

### Acknowledgements

Our deep gratitude is extended to Turkish Scientific and Technical Research Council-TÜBİTAK (Project Number: TBAG-904) for financing this study. We are very grateful to all who assisted us in field work.

### References

1. Lay, D.M., Nadler C.F., Cytogenetics and Origin of North African Spalax (Rodentia: Spalacidae). *Cytogenetics*, 11: 279-285 (1972).
2. Wahrman, J., Gotein, R., Nevo, E., Geographic Variation of Chromosomal Forms in Spalax, a Subterranean Mammal of Restricted Mobility. In *Comparative Mammalian Cytogenetics*, Springer Verlag, New York, 30-48 (1969a).
3. Wahrman, J., Gotein, R., Nevo, E., Mole Rat Spalax: Evolutionary Significance of the Chromosome Variation. *Science*, 164: 82-84 (1969b).

4. Soldatovic, B., Savic, I., Karyotype in Some Populations of the genus *Spalax* (*Mesospalax*) in Bulgaria and Turkey. *Saugetierk. Mitt.*, 26: 252-256 (1978).
5. Savic, I., Soldatovic, B., Contribution to the Study of Ecogeographic Distribution and Evolution of Chromosomal Forms of the *Spalacidae* from the Balkan Peninsula. *Arh. Biol. Nauka*, 29: 141-156 (1977).
6. Savic, I., Soldatovic, B., Distribution Range and Evolution of the Chromosomal Forms in the *Spalacidae* of the Balkan Peninsula and Bordering Regions. *J. Biogeography*, 6: 363-374 (1979a).
7. Savic, I., Soldatovic, B., Contribution to Knowledge of the Genus *Spalax* (*Microspalax*) Karyotype from Asia Minor. *Arh. Biol. Nauka*, 31: 1-2 (1979b).
8. Giagia, E., Savic, I., Soldatovic, B. Chromosomal Forms of the Mole Rat *Microspalax* from Greece and Turkey. *Z. Saugetierkunde* 47: 231-236 (1982).
9. Yüksel, E., Cytogenetics Study in *Spalax* (Rodentia: *Spalacidae*) from Turkey. *Communications, Serie C: Biologie*, 2: 1-12 (1984).
10. Gülkaç M.D., Yüksel, E., Malatya Yöresi Kör Fareleri (Rodentia: *Spalacidae*) Üzerine Sitogenetik Bir İnceleme. *DOĞA Türk Biol. Derg.*, 13: 63-71 (1989).
11. Yüksel, E., Gülkaç, M.D., On the Karyotypes in Some Populations of the Subterranean Mole Rats in the Lower Euphrates-Basin, Turkey. *Caryologia*, 45: 175-190 (1992).
12. Savic, I., Soldatovic, B., Studies on the Karyotype and Distribution Range of the Mole Rat (*Spalax leucodon* Nordmann), in Greece. *Caryologia*, 31: 63-73 (1978).
13. Soldatovic, B., Zivkovic, S., Savic, I., Milosevic, M., Comparative Karyotype Analysis of Two Populations of *Spalax leucodon* Nordman 1840. *Arh. Biol. Nauka*, 18: 15-16 (1966).
14. Soldatovic, B., Zivkovic, S., Savic, I., Milosevic, M., Vergleichende Analyse der Morphologie und der Anzahl der Chromosomen zwischen verschiedenen Populationen von *Spalax leucodon* Nordmann 1840. *Saugetierkunde*, 32: 238-245 (1966).
15. Soldatovic, B., Savic, I., New Karyotype Form of the Mole Rat (*Spalax* Güld.). *Arh. Biol. Nauka*, 25: 13-14 (1973).
16. Savic, I., Soldatovic, B., Distribution of the Karyotype Forms of the Genus *Spalax* (*Mesospalax*) in Yugoslavia. *Arh. Biol. Nauka*, 26: 115-122 (1974).
17. Walknowska, J., Les Chromosomes chez *Spalax leucodon* Nordm. *Folia Biol.*, 11: 293-309 (1963).
18. Peshev, D., On the Karyotypes in Some Populations of the Mole Rat (*Spalax leucodon* Nordmann) in Bulgaria. *Zool. Anz.*, 206: 129-133 (1981).
19. Peshev, D., New Karyotype Forms of the Mole Rat *Nannospalax leucodon* Nordmann (*Spalacidae*, Rodentia) in Bulgaria. *Zool. Anz.*, 211: 65-72 (1983).
20. Raicu, P., Bratosin, S., Hamar, M., Study on the Karyotype of *Spalax leucodon* and *Spalax microphthalmus*. *Caryologia*, 21: 127-135 (1968).
21. Raicu, P., Duma, D., Cytogenetical Study in *Sp. leucodon* in Moldavia (Rumania). *Genet. Res.*, 13: 99-104 (1969).
22. Raicu, P., Torcea, S., Chromosomal Polymorphism in the Lesser Mole Rat *S. Leucodon*. *Chromosomes Today*, 4: 383-386 (1973).
23. Matthey, R., Formules Chromosomiques de Muridae et de *Spalacidae*. La Question du Polymorphisme Chromosomique chez les Mammaferes. *Rev. Suisse de Zool.*, 66: 175-209 (1959).

The Cytogenetical Comparisons of *Spalax* (*Rodentia: Spalacidae*) Populations From Middle Kızılırmak Basin, Turkey

24. Lyapunova, E.A., Vorontsov, N.N., Martynova, L.Y., Cytogenetical Differentiation of Burrowing Mammals in the Palaearctic. Symp. Theriologicum II Proceeding, 203-215 (1974).
25. Patton, J.L., Chromosome Studies of Certain Pocket Mice Genus *Perognatus* (*Rodentia, Heteromyidae*). *J. Mammalogy*, 48: 27-37 (1967).
26. Kıvanç, E., Türkiye *Spalax*'larının Coğrafik Varyasyonları (*Mammalia: Rodentia*). 72 Teksir-Daktilo-Fotokopi, 88 pp. Ankara (1988).
27. Nevo, E., Observations of Israeli Populations of the Mole-Rat *Spalax ehrenbergi* Nehring 1988. *Mammalia*, 25: 127-144 (1961).
28. Nevo, E., Mole-Rat *Spalax*: A Model of Prolific Speciation. Proc. NATO Adv. Study Inst. Istanbul, Turkey, Conf. Vertebrate Evolution, August, 1969 (1969a).
29. Nevo, E., Mole-Rat *Spalax ehrenbergi*: Mating behavior and its Evolutionary Significance. *Science*, 163: 484-486 (1969b).
30. Nevo, E., Test of Selection and Neutrality in Natural Populations. *Nature*, 244: 573-575 (1973a).
31. Nevo, E., Variation and Evolution in Subterranean Mole Rat, *Spalax*. *Israel J. Zool.*, 22: 207-208 (1973b).
32. Nevo, E., Genetic Variation in the Natural Populations: Patterns and Theory. *Theor. Popul. Biol.*, 13: 121-177 (1978).
33. Nevo, E., Adaptive Convergence and Divergence of Subterranean Mammals. *Ann. Rev. Ecol. Syst.*, 10: 269-308 (1979).
34. Nevo, E., Speciation in Subterranean Mammals, in *Mechanism of Speciation*, Bariccozzi C. (ed). Alan R. Liss, Inc., 191-218, New York (1982).
35. Nevo, E., Speciation in Action and Adaptation in Subterranean Mole Rats: Pattern and Theory. *Boll. Zool.* 52: 65-95 (1985).
36. Nevo, E., Evolutionary Behaviour Genetics in Active Speciation and Adaptation of fossorial Mole Rats. Proc. of the Intern. Meet. "Variability and Behavioral Evolution", Rome, 23-26 Nov. 1983, *Acad. Nazionale Lincei* 259: 39-109, (1986).
37. Nevo, E., Bar-El, H., Hybridization and Speciation in Fossorial Mole Rats. *Evolution*, 30: 831-840 (1976).
38. Nevo, E., Cleve, H., Genetic Differentiation during Speciation. *Nature*, 275: 125-126 (1978).
39. Heth G., Nevo E., Origin and Evolution of Ethological Isolation in Subterranean Mole Rats. *Evolution*, 35: 254-274 (1981).
40. Swanson, C.P., *Cytology and Cytogenetics*. Macmillan and Co. Ltd., 596 pp. London (1965).