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New Species of Five-Toed Jerboa (Rodentia: Dipodidae, Allactaginae) from North-East Iran

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Abstract

The five-toed jerboas of genus *Allactaga* Cuvier, 1837 have been distributed in arid and semi-desert regions throughout northern Africa, Iranian Plateau and Central Asia to Mongolia. This genus has 12 species of which five have been so far reported from Iran including, Small Five-toed Jerboa (*A. elater*), William's Jerboa (*A. williamsi*), Euphrate's Jerboa (*A. euphratica*); Hotson's Jerboa (*A. hotsoni*) and Firouz Jerboa (*A. firouzi*). The Toussi Jerboa (*Allactaga toussi* sp. Nov.) is reported for the first time from the steppe regions of north east Iran. This new species is different in external, cranial and molars morphological and morphometric characteristics from its parapatric species i.e. *Allactaga elater*, and other Iranian five-toed jerboas. Multivariate analyses also confirm that *Allactaga toussi* sp. nov. is significantly distinct from other species.

Keywords: Toussi Jerboa; *Allactaga toussi* sp. nov.; New species; Iran

Introduction

The Five toaed jerboa of genus *Allactaga* including 12 morphospecies distributed in the arid and semiarid habitates of north Africa, Iranian plateau, to central Asia and Mongolia, five of which have been so far reported from different regions of Iran [1-3]: *Allactaga elater indica* Gray, 1824 (Small Five-toed Jerboa); *Allactaga williamsi* Thomas 1907 (Williams jerboa); *Allactaga euphratica* Thomas, 1881 (Euphrates Jerboa); *Allactaga hotsoni* Thomas, 1920 (Hotson's Jerboa); *Allactaga firouzi* Womochel, 1978 (Firouz Jerboa). The latter was discovered in south of Shahreza in Esfahan province as an endemic species [4,5] in a flat plain with a gravel substrate and sparse mountainous steppe vegetation [6]. *A. hotsoni* inhabits in the north, center and south east of Iranian central desert to Kalmand and Bahadoran in the south of Yazd province [1] and its habitat is a gravelly or stony pen plains in which practically no other rodents are found [1]. *Allactaga firouzi* is geographically separated from *A. hotsoni* by a chain of Boanat Mountains in south east of Esfahan province. *Allactaga elater* is distributed in the most parts of desert and semi-desert regions of Iran. *A. hotsoni* and *A. firouzi* are both in a stasipatric situation with the latter species. *A. williamsi* has been reported from west and north west of Iran. This species is close to *A. euphratica* [5]. A. *euphratica* has been reported from the west of Iran. Harrison and Atallah (1968) identified different subspecies for this species including *A. e. williamsi* distributed from west Iran to central Elburz areas; *A. e. euphratica* distributed in steppe and semi-desert areas from Turkey, Iraq, Syria to Jordan, north of Saudi Arabia and Kuwait [5,7,8].

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Eetemad (1975) reported *A. euphratica* from Ghuchan which brings some taxonomic problems due to geographic distribution of this species. Therefore, we studied the population of North West of Mashhad plain area as the first phase of determination of taxonomic status of this genus in the north east of Iran.

Materials and Methods

Forty specimens from 4 species of five-toed jerboa genus *Allactaga* were analyzed. *Allactaga toussi* sp.nov. (4 adult males and 4 adult females collected from Cheshme Gilas in northwest of Mashhad; 36°38′N and 59°19′E). *Allactaga elater* (25 specimens from Sabzevar, Jajarm, Tous, Shoorak Maleki, Kashmar and Bejestan all in Khorasan Province), *Allactaga hotsoni* (4 specimens from Bejestan and Yazd) and *Allactaga williamsi* (3 specimens from Zanjan) (Fig. 1). External, cranial and molars characters measured in this study are: body weight (W), head and body length (BL), tail length (TL), hind foot length (FL), ear length (EL), condylobasal length (CBL), zygomatic width (ZW), interorbital width (IW), cranial width (CW), diastema length (DL), anterior palate fissure length (APFL), tympanic bulla length (TBL), tympanic bulla width (TBW), upper cheekteeth length (UChL), lower cheekteeth length (LChL), skull height (SH), Mandible length (ML), upper M1 length (M1/L), upper M1 width (M1/W), upper M2 length (M2/L), upper M2 width (M2/W), upper M3 length (M3/L), upper M3 width (M3/W), lower M1 length (M1/L), lower M1 width (m1/W), lower M2 length (M2/L), lower M2 width (M2/W), lower M3 length (M3/L) and lower M3 width (M3/W).

Cranial characters were measured using a vernier caliper to the nearest 0.05 mm and dental traits using measurescope to the nearest 0.001 mm. Test of normality of the was performed by the Kruskal-Wallis test and revealed that they all have normal distributions. Comparison of means was carried out using multiple and single analysis of variance. A canonical variate analysis (CVA) was performed to reveal the distinction of different populations. All the statistical analyses were done using SPSS 11.50. Skull and dental traits were drawn using a drawing tube and morphologically compared with skull and dental traits of other five-toed jerboa species in northeast Iran. The standard voucher specimens (skins and skulls) were prepared and stored in Zoology Museum of Ferdowsi University of Mashhad, Iran (ZMFUM).

Karyotype of Cheshme Gilas specimens was prepared using bone marrow cells and compared with reported karyologal characters of other species.

Systematics

Allactaga toussi sp. nov.

Acronyms: ZMFUM: Zoological Museum of Ferdowsi University of Mashhad.

Tousi: refers to the Tous region, a well known historical area close to the Mashhad in the NE of Iran near which the new taxon was found.

Holotype: ZMFUM-1398, adult male, Mashhad (Cheshme Gilas, 36°38′N and 59°19′E), Khorasan Razavi Province, Iran, 2006, collector: T. Hajjar.

Paratypes: ZMFUM-1410, adult male,. ZMFUM-1414, adult male, ZMFUM-1415, adult female, ZMFUM-1416, adult female, ZMFUM-1418, adult female, ZMFUM-1425, adult female and ZMFUM-1449, adult male. Mashhad (Cheshme Gilas 36°38′N and 59°19′E), collector: T. Hajjar.

Measurements (in mm) of holotype: TL: 182; BL: 92; FL: 55; EL: 33; CBL: 27.29; TBL: 7.31; ML: 5.37.

Description

External traits: dorsal coat brown; ventral coloration white; ear with dark inner surface and white hairs; outer surface of ear dark with lighter margins and black hairs; sole and sole margins are completely naked; nails with darker bases compared to other species; subterminal portion of tail brush (SPTB) light brown; mean length of vibrissa 71 mm (Fig. 2).

Cranial traits: nasal bones short, anterior portions does not reach upper incisor sockets; lachrymal bones flat; fissure in posterior portion of palate with blunt angles. Table 1 shows the comparison of means of external, cranial and molars traits for different five-toed jerboas including *A. toussi* sp. nov.

Dental traits: upper incisors are proodont; the first two upper and lower molars are considerably larger than the third ones; the crown of molar teeth is flat with low or medium tubercles and inward distinct rugosity; margins of tubercles and enamels are round; enamel thick all around teeth but it is thin in tips of inward angles (Fig. 3).

Male genitalia: Baculum does not exist; glans of penis with a pointed tip; longitudinal furrow bifurcate toward tip of glans.

Results of Species Comparison

Morphological studies: comparing of *A. toussi* sp. nov. with *A. williamsi* shows that they are different in color. In other word, in the new species hairs at bases are dark gray and brown at apexes, whereas in *A. williamsi* hairs at bases are dark gray and cream at

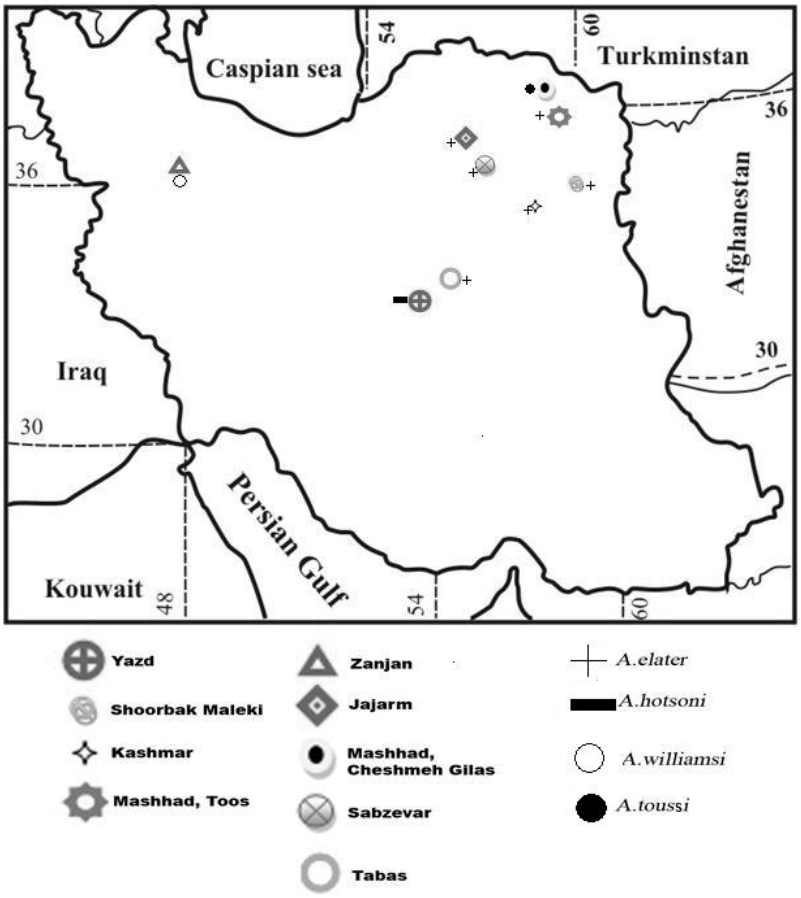


Figure 1. Map of localities of sampling.

apexes. *A. williamsi* is longer than the new species; the mean of total body length is 334 mm in *A. williamsi* and 278 mm in *A. toussi* sp nov. Vibrissae length is about 63 mm in *A. williamsi* and 75 mm in the new species. Subterminal portion of tail brush is dark brown-black in *A. williamsi* and light brown in *A. toussi*. The tip of the penis is mostly truncated in *A. williamsi*, but glans of penis with a pointed tip in *A. toussi* sp. nov.

Comparing *A. toussi* sp. nov with *A. elater* shows that inner surface of ear is dark with white hairs in *A. toussi* sp. nov. and grey in *A. elater*. Outer surface of ear is yellow in *A. elater* and dark with lighter margins and black hairs in *A. toussi* sp. nov. Subterminal portion of tail brush is black in *A. elater* and brown in *A. toussi* sp. nov. Soles and their margins are naked in the new species but in *A. elater* with black dense setae in the sole margins. The total size of skull in *A. toussi* sp. nov. is larger than *A. elater*. Posterior palate fissure is longer and narrower in *A. toussi* sp. nov. (Table 1).

The new species compared to *A. hotsoni* shows soles and sole margins and toes naked while they are with dark hairs in *A. hotsoni*. Subterminal portion of tail brush is light brown in *A. toussi* sp. nov. and dark brown in *A. hotsoni*. In *A. hotsoni* first and fifth toes are more distant than the others compared to *A. toussi* sp. nov. In comparison with *A. hotsoni*, *A. toussi* sp. nov. has wider tail, larger white portion of terminal brush, longer and considerably wider ears. Tympanic bulla in *A. toussi* sp. nov. is significantly smaller than in *A. hotsoni.* The morphological differences among species are shown in Table 2.

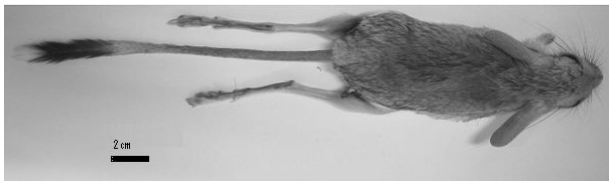


Figure 2. *Allactaga toussi* sp. nov.

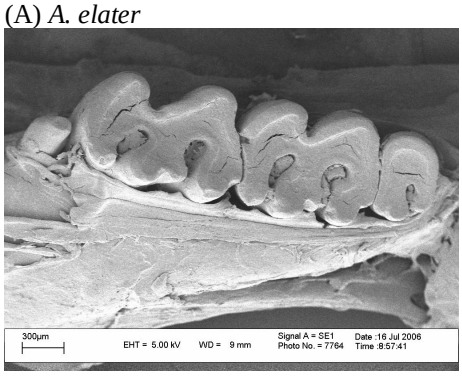
Table 1. Comparison of external, cranial, and Molars traits of different five-toed Jerboas (Mean ± SD)

Character	*A. toussi* (n=8) Mashhad	*A. elater* (n=25) Khorasan	*A. hotsoni* (n=4) Yazd	*A. williamsi* (n=3) Zanjan
Weigth	63.38±10.88	41.10 ± 3.34	64.88 ± 9.82	83.95 (n=2)
Body length	109.38 ± 7.87	99.84 ± 3.25	117.50 ± 8.67	124 (n=2)
Tail length	177.50 ± 6.60	156.28 ± 13.52	184.50 ± 20.97	218 ± 30.22
Hind foot	53.25 ± 1.60	49.52 ± 0.85	58.00 ± 2.25	68.67 ± 3.79
Ear length	37.00 ± 2.23	33.48 ± 1.54	41.00 ± 3.44	44.67 ± 3.79
Condylobasal Length	27.68 ± 0.31	25.40 ± 0.40	28.64 ± 1.17	32.86 ± 1.85
Zygomatic width	21.39 ± 0.38	19.24 ± 0.33	21.10 ± 1.19	23.62 ± 2.34
Least interorbital width	9.61 ± 0.25	8.88 ± 0.13	9.03 ± 1.20	9.31 ± 0.80
Cranial width	15.90 ± 0.19	15.05 ± 0.14	16.17 ± 0.78	17.86 ± 1.42
Length of Diastema	8.41 ± 0.16	7.80 ± 0.17	9.01 ± 0.71	10.26 ± 0.62
Length of Anterior Palatine Foramina	5.61 ± 0.20	5.07 ± 0.13	5.61 ± 0.45	6.92 ± 0.54
ngth of Tympanic BullaeLe	6.79 ± 0.32	6.36 ± 0.11	8.60 ± 1.12	7.72 ± 1.88
Length of Mandible	16.81 ± 0.43	15.36 ± 0.31	16.40 ± 0.32	18.18 ± 2.39
Upper Cheekteeth	5.57 ± 0.14	4.99 ± 0.10	5.36 ± 0.39	6.91 ± 0.11
Lower Cheekteeth	5.68 ± 0.20	5.01 ± 0.11	5.59 ± 0.43	6.97 ± 0.62
M1_length	2.03 ± 0.089	1.87 ± 0.089	2.02 ± 0.079	2.06 ± 0.120
M1_width	1.43 ± 0.067	1.21 ± 0.179	1.43 ± 0.089	1.38 ± 0.176
M2_length	1.79 ± 0.056	1.58 ± 0.078	1.74 ± 0.065	1.70 ± 0.175
M2_width	1.26 ± 0.135	1.07 ± 0.192	1.27 ± 0.054	1.20 ± 0.189
M3_length	0.90 ± 0.041	0.70 ± 0.103	0.84 ± 0.021	0.73 ± 0.076
M3_width	0.90 ± 0.072	0.75 ± 0.141	0.90 ± 0.036	0.79 ± 0.097
m1_length	1.97 ± 0.079	1.82 ± 0.132	2.10 ± 0.091	2.12 ± 0.031
m1_width	1.40 ± 0.089	1.25 ± 0.161	1.50 ± 0.090	1.34 ± 0.072
m2_lenth	1.95 ± 0.069	1.76 ± 0.134	2.07 ± 0.100	2.01 ± 0.292
m2_width	1.48 ± 0.104	1.23 ± 0.181	1.50 ± 0.051	1.28 ± 0.087
m3_length	1.25 ± 0.070	1.09 ± 0.151	1.33 ± 0.083	1.17 ± 0.060
m3_width	1.12 ± 0.085	0.86 ± 0.199	1.07 ± 0.106	0.97 ± 0.066

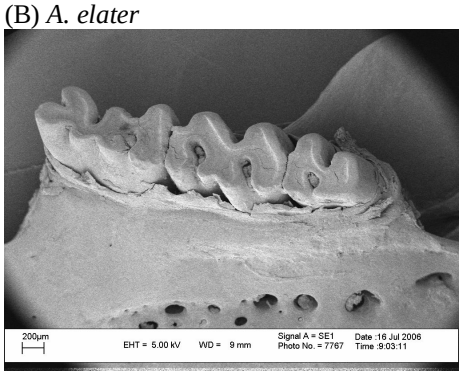
Table 2. Comparison of morphological characters in different species of five-toed jerboas

Character	***A. toussi***	***A. elater***	***A. hotsoni***	***A. williamsi***
Dorsal color	Brown	Brown	Brown	Cream-Brown
Inner surface of ear	Dark	Light	Dark	Dark
Subterminal portion of tail brush	Light brown	Dark brown-black	Dark brown-black	Dark brown-black
Hind sole	Without hair	Without hair	With hair	Without hair
Hind sole margin	Without hair	With hair	With hair	Without hair
Tympanic bulla	Small	Small	Large	Small
Glans of penis	pointed tip	pointed tip		no pointed tip

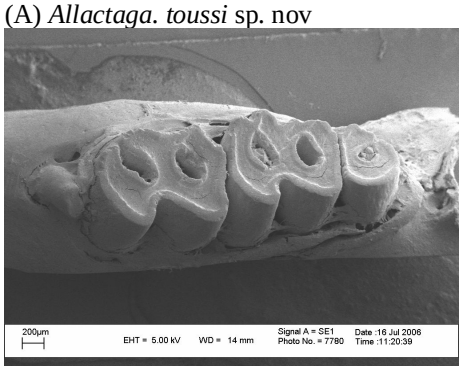
(A) *A. elater*



(B) *A. elater*



(A) *Allactaga. toussi* sp. nov



(B) *Allactaga. toussi* sp. nov

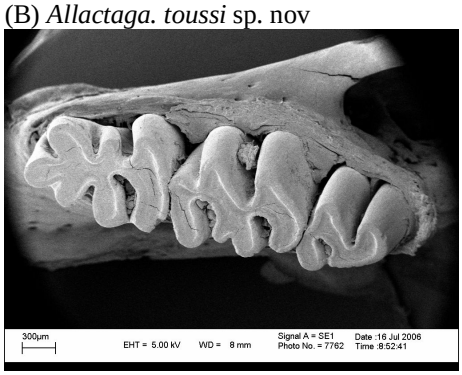


Figure 3. Scanning micrograph of the upper (A) and lower (B) molar in *Allactaga. toussi* sp. nov. and *Allactaga elater*.

Morphometric Studies

Multivariate analysis of variance (MANOVA) confirms the significant differences of the studied taxa (P<0.0001). The following results were obtained using single Analysis of variance (ANOVA) at %5 level: *A. toussi* sp. nov. and *A. elater* are significantly different in all traits except in tail length (TL) and tympanic bulla width (TBW). *A. toussi* sp. nov. and *A. hotsoni* are significantly different in foot length (FL), ear length (EL), condylobasal length (CBL), tympanic bulla length (TBL), tympanic bulla width (TBW), diastema length (DL), upper M3 length (M3/L), upper M1 length (M1/L), upper M2 width (M2/W) and upper M2 length (M2/L). *A. toussi* sp. nov. and *A. williamsi* are significantly different in all traits except in interorbital width (IW) and lower M3 width (M3/W). From canonical discriminate analysis extracted three functions of which the first two functions involves %95 of variance (%69.9 and %25.1 respectively; Table 3). The morphometric traits of length of posterior foot (FL), length of upper molars row (UChL) and length of tympanic bulla (TBL) have the most effect on formation of function 1 and the width of tympanic bulla (TBW) has the most effect on formation of function 2 (Table 4). This analysis confirms the distinction of 4 studied taxa (Fig. 4). The multivariate analysis of upper and lower molar confirm that *Allactaga toussi* sp. nov. is more similar to *A. hotsoni* than *A. elater* and *A. williamsi* (Table 5 and Fig. 4).

Karyological Studies

Chromosomal number of *A. toussi* is similar to the

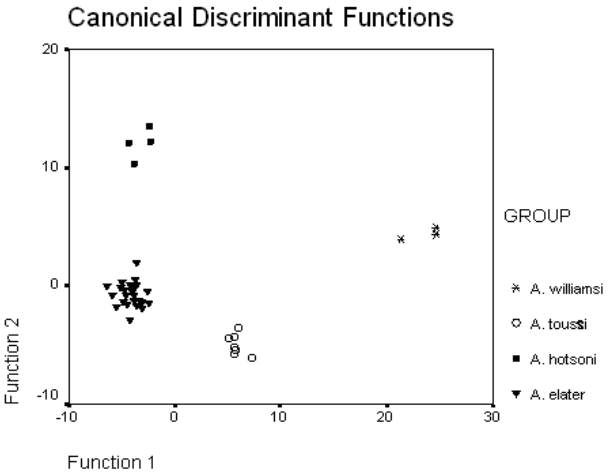


Figure 4. Distribution of studied populations using Canonical discriminant analysis of external, cranial and dental characters.

Table 3. Eigenvalues of canonical variate functions

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	63.838[a]	69.9	69.9	.992
2	22.932[a]	25.1	95.0	.979
3	4.548[a]	5.0	100.0	.905

Table 4. Cross-validated classification derived from the CVA of four Iranian *Allactaga* species using molar variables (see the text for more information)

Actual groups	Percent of correct attribution
A. toussi 87.5%	(12.5% with A. hotsoni)
A. elater 73.6%	(5.3% with *A. toussi*; 10.5% with *A. hotsoni* and 10.5% with *A. williamsi*)
A. hotsoni 75%	(25% with *A. williamsi*)
A. williamsi 75%	(25% with *A. hotsoni*)

other species of *Allactaga* i.e. 2N=48 (NFa=96); each autosomal chromosome has 2 arms; X chromosome is medium and submetacentric (Fig. 5).

Discussion

Genus *Allactaga* is a homogenous taxon distributed in arid and semiarid regions as its adaptive zone which is clearly reflected in the taxonomic characteristics of this genus. In this genus molars are relatively complex; upper molars with three external fold, and lower molars with three internal folds which is an adoption for grain eating. Vertical branch of zygomatic arc is almost as broad as horizontal branch. Ear very large, forfoot with five digits, the pollex short, the claws well developed, hind foot perissodactyle with three functional digits, and with two subsequent outer digits placed higher on the foot, not reaching the ground which is the consequence of adaptation to jumping and bipedal movement. Hind limb is enormously elongated. The claws of the three central digits have large pad presenting under each claw. Tail is longer than head and body, with a black and white brush terminally, round and thin throughout most of its length. These characters have different states and can be used for determination of species of five-toed Jerboas. Most of species of this genus are Asiatic except for one in North east of Africa. Iranian Plateau must be one of the cradle of speciation for this genus, due to different adaptive zone separated by range of mountains as Zagross, Elburz, Kahar, Binaloud, Copet Dag and two extend deserts (Central and Lout), semi-arid and

Table 5. Correlation between variables with canonical variate functions

Character	Function		
	1	2	3
FL	.313*	.288	.051
UCHL	.313*	.088	.049
CBL	.295*	.206	.186
M2L	.281*	.091	.051
CW	.276*	.178	.149
LCHL	.263*	.104	.134
SH	.242*	.067	−.100
DL	.221*	.201	.110
APFL	.216*	.102	.062
M1L	.192*	.085	.063
M3L	.183*	.050	.005
m1L	.160*	.0143	.092
M1W	.156*	.077	.078
m2L	.152*	.124	.072
M3W	.151*	.068	−.030
M3L	.142*	.097	.021
M2W	.124*	.062	.056
TL	.078*	.053	.065
TBW	.127	.278*	−.057
m1W	.122	.135*	.109
TBL	.099	.328	.361*
ZW	.220	.086	.289*
IW	.070	−.055	.268*
ML	.154	.041	.199*
m2W	.103	.081	.191*
m3W	.097	.032	.137*
EL	.111	.125	.130*

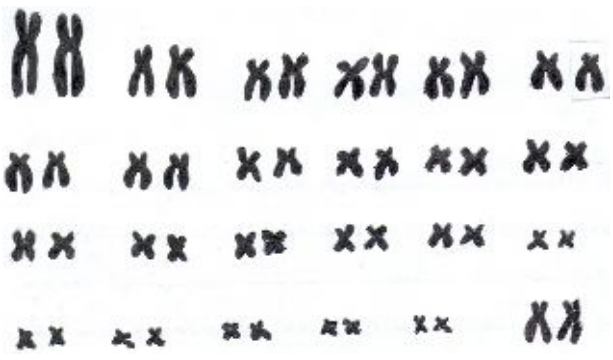


Figure 5. The karyotype of *A. toussi* sp. nov.

arid region. In our opinion, one of the hypotheses for the distribution of the different species of the genus may be geographic speciation. For example, *Allactaga firouzi* is limited to semi-arid desert of Esfahan. *Allactaga williamsi* is limited to Zagross and North West mountains of Elburz. The study of specimens of Cheshmeh Gilas, Mashhad confirms the presence of another species in this region and impose the necessity of taxonomic revision of five toed jerboa in north east of Iranian plateau including Hindu Kush populations to resolve the taxonomic problem of five-toed jerboas of Ghuchan and Shiber pass (in Afghanistan) attributed to *A. w. caprimulga*.

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