The Korean Journal of Systematic Zoology
Vol. 2, No. 1: 1—10 (1986)

Systematic Studies of Korean Rodents: II. A Chromosome Analysis in Korean Field Mice, *Apodemus peninsulae peninsulae* Thomas (Muridae, Rodentia), from Mungyong, with the Comparison of Morphometric Characters of these Korean Field Mice to Sympatric Striped Field Mice, *A. agrarius coreae* Thomas.

Koh, Hung Sun
(Chungbuk National University, Dept. of Biology, Chungju 310, Republic of Korea)

한국산 설치류의 계통분류학적 연구 : II. 문경산 흰 넓적다리 붉은쥐, *Apodemus peninsulae peninsulae* Thomas, 의 염색체 분석 및 문경산 등줄쥐, *Apodemus agrarius coreae*, 와의 형태적 형질의 비교분석

고 홍 선
(충북대학교 자연과학대학 생물학과)

적 요

문경산 흰 넓적다리 붉은 쥐, *Apodemus peninsulae peninsulae*, 의 염색체 핵형 분석과 단변량및 다변량분석방법들을 사용한 등줄쥐, *Apodemus agrarius coreae*, 와의 형태적 형질의 비교를 하였다.

흰 넓적다리 붉은 쥐의 염색체 수는 2n=50－54까지 수적 변이를 보였다. 차단부 염색체의 수는 48개로 개체간에 일정하였으나, 중부 염색체의 수는 2∼6개의 변이가 나타났다.

형태적 형질의 분석결과는 등줄쥐보다 흰 넓적다리 붉은 쥐가 크다고 판정되었으며, 가장 구별이 잘 되는 형질은 경구개의 길이였다.

Key words: Rodentia, Systematics, Chromosome, Morphometrics.

INTRODUCTION

Korean field mice, *Apodemus peninsulae* Thomas, distribute from Altai to Ussuri through Korea and Manchuria (Jones, 1956): the type locality of this species is Mungyong, 110 miles S.E. of Seoul, Korea (Corbet, 1978).

The Korean field mouse was originally proposed as a subspecies of the insular Japanese species, *A. speciosus* by Thomas (1906), but Allen (1940) reported that the Korean field mouse was not

1. 본 연구를 위한 연구비의 일부는 1985년도 문교부 학술조성연구비에서 충당되었음.
2. *Appendixes A and B* 는 요청에따라 한국동물분류학회의 *the Depository of Unpublished Data* 에서 실비로 복사, 제공될 것임.

conspecific with the Japanese *speciosus*. However, Woon (1967) stated that the Korean field mice from Korea with white patches on the ventor and the lower flanks were comparable to Japanese *A. speciosus speciosus* and that they were *A. speciosus peninsulae*.

In chromosomal studies of the Korean field mice from unknown locality, Kang and Kim (1965) stated that the diploid number of two specimens was 50. Recently, Vorontsov *et al.* (1977) described on the basis of karyological and morphometric data *A. peninsulae* as field mice of middle size with diploid number of 48 to 61 due to the presence of supernumerary chromosomes (distribution: Siberia, Sakhalin, and Hokkaido). They also designated *A. speciosus* as large field mice with diploid number of 48 (distribution: Japan, Kunashir-Island), although they did not mention the karyotype of Korean field mice from Korea.

The object of this paper is to analyze the karyotype of Korean field mice from Mungyong (type locality of *peninsulae*) in order to decide whether these mice are *A. peninsulae* or *A. speciosus*. For this purpose morphometric characters of these Korean field mice were also compared with those of sympatric striped field mice, *A. agrarius coreae*.

MATERIALS AND METHODS

Materials

Five samples of Korean field mice [♀1 (K-183); ♂4 (K-178, K-179, K-182, K-184)], *Apodemus peninsulae peninsulae* Thomas, from Mungyong were used for chromosomal and phenetic analyses. Nineteen specimens of striped field mice (K-0241 to K-0259), *A. agrarius coreae* Thomas, from Mungyong were also analyzed in order to compare phenetic characters to those of the Korean field mice.

Samples of the two species were collected with live traps and five Korean field mice were kept alive for a few days in cages before chromosomal analyses were conducted. Skins and skulls of all specimens are in the collection of the author, Dept. of Biology, College of Natural Sciences, Chungbuk University, Chongju, Korea.

Chromosomal analyses

The bone-marrow *in vivo* method by Ford and Hamerton (1956) was used with modification. Before bone-marrow cells from femora were washed with 7 ml of isotonic NaCl solution, 0.03 ml of 0.03 % colchicine solution was injected and kept for 1 hour. The cell suspension was centrifuged at 700 rpm for 8 minutes and resuspended in 7 ml of hypotonic solution (0.075 M KCl) for 22 minutes. Five ml of fixative (3 methanol: 1 acetic acid) were added and cells were spun down at 1,000 rpm for 10 minutes. The fixation-centrifuge sequences were repeated at least twice. The air-drying method by Rothfels and Siminovitch (1957) was used for chromosomal preparation.

For conventionally stained chromosomes, slides were stained with 4 % Giemsa solution (GIBCO) for 7 minutes, and rinsed with distilled water and air-dried.

Good metaphases were photographed and printed so that the largest chromosomes were similar in size (about 1 ㎝). All acrocentric chromosomes were idiogrammed in order of decreasing length, and then metacentric chromosomes were done [chromosome nomenclature by Levan *et al.* (1964) was utilized].

Phenetic analyses

Analyses were based on four external and 27 cranial characters as follows (for details see Koh, 1983): 1, greatest length of the skull; 2, condylobasal length; 3, length between incisor and incisive foramen; 4, length of the nasal bone; 5, zygomatic width; 6, mastoid width; 7, width of brain case; 8, height of brain case; 9, width between infraorbital canals; 10, length of rostrum; 11, length of hard palate; 12, interorbital constriction; 13, width across upper third molars; 14, incisor-upper-first-molar length; 15, width across upper first molars; 16, length of incisive foramen; 17, width of the interparietal bone; 18, length of the interparietal bone; 19, postpalatine length; 20, height of rostrum; 21, bullae-brain case height; 22, greatest length of mandible; 23, length of mandibular tooth row; 24, height of mandible; 25, length of ramus; 26, length of upper third molars; 27, length of upper first molar; 28, length of tail vertebrae; 29, length of hind foot; 30, body length; 31, length of ear.

Sexual variation in striped field mice was not significant, whereas age variation was significant (Koh, *op. cit.*). Therefore, each specimen was assigned to one of five age classes (juvenile, subadult, young adult, middle-aged adult, and old adult) based on the eruption of upper third molar, degree of tooth-wear, and pelage colour (for details see Koh, *op. cit.*). Five Korean field mice were classified into two young adults and three middle-aged adults and 19 striped field mice into seven young adults and 12 middle-aged adults.

All computations were made using the Chungbuk University HP-3000 computer. In each species, sample statistics such as mean, standard deviation, skewness, and kurtosis were carried out by ELESTAT program of ISP, Interactive Statistical Programs, with 31 morphometric characters of samples in each age class (the results are shown in Appendix A-1 to A-4). Analysis of variance, ANOVA, between two species was performed with the measurements of 31 characters by ANOVA program of ISP.

Principal component analyses (Seal, 1964), PCA, was carried out with the measurements of 31 characters of two species by PCAS program of ISP. However, in one analysis with nine young adults the data was singular, and in the other analysis with 15 middle-aged adults the first component scores were calculated (the first component represented only 19.9 % of the variance). Therefore, the 14 characters (1, 3, 5, 11, 12, 14, 16, 18, 20, 22, 24, 26, 29, and 31), showing significant differences either in the result by ANOVA with young adults or in the result by ANOVA with middle-aged adults (see Table 2), were selected and used for PCA.

RESULTS

Chromosomal analyses

Diploid chromosome number and chromosome frequency of Korean field mice from Mungyong are shown in Table 1. The diploid number of K-178 was 54 and that of K-183 was 51, whereas diploid number of other three samples (K-179, K-182, K-184) was 50.

The representative karyotypes of K-178 (2n=54) and K-179 (2n=50) are shown in Figs. 1 and 2, respectively. The karyotype of K-183 is shown in Appendix B-1 and metaphase chromosomes of K-182 and K-184 were shown in Appendix B-2.

In five specimens of Korean field mice from Mungyong the number of acrocentric chromosomes was constant, 48, while the number of metacentric chromosomes varied from two in K-179, K-182, and K-184 to six in K-178 through three in K-183.

Phenetic analyses

The results based on ANOVA in both young and middle-aged adults with 31 characters between samples of Korean field mice and those of striped field mice are shown in Table 2. F-ratios are shown in 31 characters and the characters showing significant difference are indicated by asterisks. In the analysis with young adults significant differences were revealed in six characters (11, 14, 18, 22, 26, and 29) in Table 2: in the analysis with middle-aged adults 13 characters differed significantly (1, 3, 5, 11, 12, 14, 16, 18, 20, 22, 24, 29, and 31) in Table 2.

Korean field mice appeared to be significantly different from striped field mice at least in five characters (11, length of hard palate; 14, incisor-upper-first molar length; 18, length of interparietal bone; 22, greatest length of mandible; 29, length of hind foot), as shown in Table 2.

Two dimensional configurations from PCA with nine young adults (two Korean field mice and seven striped field mice) are shown in Fig. 3. The correlations between original 14 characters and the principal components are given in Table 3-A (factors I, II, and III represented 63, 14, and 8 per cent of the variance, respectively).

Two dimensional configurations from PCA with 15 middle-aged adults (three Korean field mice and 12 striped field mice) are shown in Fig. 4. The correlations between original 14 characters and the principal components are given in Table 3-B (factors I, II, and III represented 55, 11, and 10 per cent of the variance, respectively).

Korean field mice appeared to be larger than striped field mice in size. And the character 11 (length of hard palate) seemed to be the most distinguishing character among 14 characters (the correlation coefficient between character 11 and the first principal component was 0.92 in young adults and −0.95 in middle-aged adults), as shown in Table 3.

Based on the results shown in Tables 2 and 3 and Figs. 3 and 4, Korean field mice seemed to be larger than striped field mice: the most distinguishing character among 31 characters is the length of hard palate (character 11): and the distinguishing external character is the length of hind foot (character 29).

In summary, chromosome polymorphism due to the presence of supernumerary, metacentric chromosomes was revealed (see Table 1 and Figs. 1 and 2) in Korean field mouse: it seemed to be larger in morphometric characters than striped field mouse (see Tables 2 and 3 and Figs. 3 and 4).

DISCUSSION

The genus *Apodemus* of 12 species confined to the Palaeoarctic and northern part of the Oriental regions: one subspecies of Korean field mice, *A. peninsulae peninsulae*, and four subspecies of striped field mice, *A. agrarius manchuricus*, *A. agrarius coreae*, *A. agrarius chejuensis*, *A. agrarius pallescens*, inhabit in Korea (Jones, *op. cit.*), based on external size differences.

In chromosomal analyses of the genus *Apodemus*, Bekasova *et al.* (1980) reported that in the karyotype of *A. peninsulae* there are 48 acrocentric chromosomes decreasing gradually in size and 1-13 metacentric, supernumerary chromosomes. They also noted that karyotype of *A. speciosus* consisted of eight meta- and submetacentric chromosomes and 40 acrocentric chromosomes.

In this paper (see Table 1; Figs. 1 and 2; Appendix B-1, B-2), five samples of Korean field mice from Mungyong (type locality of *A. peninsulae*) showed the diploid number of 50 to 54: 48 acrocentric chromosomes were gradually decreased in size and number of metacentric chromosomes varied from two to six. And these samples seemed to be *A. peninsulae peninsulae*, as noted by Jones (*op. cit.*), rather than *A. speciosus peninsulae*, as suggested by Woon (*op. cit.*).

Jones and Johnson (1965) also reported that the forty five field mice, *A. peninsulae peninsulae*, in the U.S. National Museum from central Korea had areas of white mottling which is usually confined to the ventor and the lower flanks and that the white patches were clearly evident in Korean field mice in the British Museum, including the holotype of *peninsulae*. Corbet *(op. cit.)* noted that *A. speciosus* had yellow pectoral spots, whereas *A. peninsulae* had no such pectoral spots. The samples of Korean field mice used in this paper had white patches and no yellow pectoral spots: they are *A. peninsulae*, not *A. speciosus*.

Woon *(op. cit.)* reported that Korean field mice, *A. speciosus peninsulae* (= *A. peninsulae peninsulae*), are larger in external sizes including the length of hind foot than striped field mice in Korea. In this paper Korean field mice were significantly different from striped field mice at least in five characters including the length of hind foot (see Table 2) and the former were larger in size than the latter (see Table 3; Figs. 3 and 4). Moreover, the most distinguishing character between them were character 11, length of hard palate (see Table 2 and 3).

Bekasova *et al. (op. cit.)* reported that supernumerary, metacentric chromosomes in *A. peninsulae* were heterochromatic: the analyses of C-banded chromosomes will be necessary in order to clarify the presence of heterochromatic, supernumerary chromosomes. The Standard G-banded karyotype of this subspecies is also needed to study. Furthermore, more samples of *A. peninsulae peninsulae* have to be collected for phenetic analyses with other species such as *A. speciosus* in Japan.

SUMMARY

Five Korean field mice from Mungyong were used for chromosomal analyses. Morphometric measurements of these Korean field mice were compared by univariate and multivariate analyses to those of 19 striped field mice, *Apodemus agrarius coreae*, from .Mungyong.

In chromosomal analyses with Korean field mice, the diploid number varied from 50 to 54 (48 acrocentric chromosomes and two to six metacentric, supernumerary chromosomes).

In morphometric analyses Korean field mice with areas of white mottling confined to the ventor and the lower flanks were larger than striped field mice. The most distinguishing character between them was length of hard palate.

It is concluded that Korean field mouse was not *A. speciosus peninsulae*, but *A. peninsulae peninsulae* Thomas. More samples of Korean field mice are needed for phenetic and chromosomal comparisons to other species such as *A. speciosus* in Japan.

REFERENCES

Allen, G. M., 1940. The mammals of China and Mongolia. Amer. Mus. Nat. Hist., New York, **2**:621-1350.

Bekasova, T. S., N. N. Vorontsov, K. V. Korobitsyna, and V. P. Korablev, 1980. B-chromosomes and comparative karyology of the mice of the genus *Apodemus*. Genetica, **52**:33-43.

Corbet, G. B., 1978. The mammals of the Palaearctic region: a taxonomic review. British Museum (Natural History), Cornell University Press, London.

Ford, C. E. and J. L. Hamerton, 1966. A colchicine, hypotonic citrate, squash sequence for mammalian chromosomes. Stain Techn., **31**:247-251.

Jones, J. K., 1956. Comments on the taxonomic status of *Apodemus peninsulae*, with description of a new subspecies from north China. Univ. Kansas Publ. Mus. Nat. Hist., **9**:337-346.

Jones, J. K. and D. H. Johnson, 1965. Synopsis of the lagomorphs and rodents of Korea. Univ. Kansas Publ. Mus Nat. Hist., **16**:357-407.

Kang, Y. S. and Y. J. Kim, 1965. Studies on chromosomes of Korean mammals. Zoologica (Kor), **2**:1-8.

Koh, H. S., 1983. A study on age variation and secondary sexual dimorphism in morphometric characters of Korean rodents: I. An analysis on striped field mice, *Apodemus agrarius coreae*, from Chongju. Kor. J. Zool., **26**:125-134.

Levan, A., K. Fredga, and A. A. Sandberg, 1964. Nomenclature for centromeric position on chromosomes. Hereditas, **52**:201-220.

Rothfels, K. H. and L. Siminovitch, 1957. An air-drying technique for flattening chromosomes in mammalian cells grown *in vitro*. Stain Techn., **33**:73-77.

Seal, H. L., 1964. Multivariate statistical analysis for biologists. J. Wiley, New York.

Thomas, O., 1906. The Duke of Bedford's zoological exploration in eastern Asia: II. List of small mammals from Korea and Quelpart. Proc. Zool. Soc. London, pp. 858-865.

Vorontsov, N. N., T. S. Bekasova, B. Kral, K. V. Korobitsina and E. Yu. Ivanitskaya. 1977. On specific status of Asian wood mice of the genus *Apodemus* (Rodentia, Muridae) from Siberia and Far East. Zool. Zh., **56**:437-449.

Woon, P. H., 1967. Illustrated encyclopedia of fauna and flora of Korean mammals. Samhwa, Seoul.

RECEIVED: 5 FEBRUARY, 1986
ACCEPTED: 30 APRIL, 1986

Table 1. Summary of chromosomes counted in five samples of *Apodemus peninsulae peninsulae* from Mungyong.

Specimen number	Frequency of chromosome counted								2n
	48	49	50	51	52	53	54	55	
K178					2		19	1	54
K179		1	18	1					50
K182		1	12						50
K183			1	6					51
K184	1	1	15	1					50

Table 2. Results of analysis of variance between samples of *Apodemus peninsulae peninsulae* and *A. agrarius coreae* in 31 morphometric characters. In the analysis with young adults (YA) two *A. peninsulae* and seven *A. agrarius* were used and in the analysis with middle-aged aults (MA) three *A. peninsulae* and 12 *A. agrarius* were used.

*$P<0.05$

Character	F-ratio		Character	F-ratio	
	YA	MA		YA	MA
1	3.71	6.35*	17	1.48	1.96
2	3.15	2.88	18	9.87*	9.00*
3	0.17	5.80*	19	0.66	3.86
4	0.88	0.56	20	2.83	7.95*
5	4.12	12.58*	21	0.65	0.63
6	0.13	0.53	22	14.10*	20.74*
7	4.67	3.77	23	0.89	0.59
8	0.51	0.20	24	0.11	9.12*
9	0.16	3.58	25	1.87	3.37
10	1.01	3.89	26	20.39*	2.63
11	26.48*	20.80*	27	0.94	0.14
12	0.85	7.67*	28	1.39	3.18
13	1.92	0.24	29	31.45*	20.00*
14	10.40*	9.65*	30	0.32	0.85
15	3.80	0.10	31	5.76	10.77*
16	0.2	9.33*			

Table 3. Principal components I, II and III expressed as correlations between characters and individual components from samples of *Apodemus peninsulae peninsulae* and *A. agrarius coreae* from Mungyong. Individual measurements of 14 selected characters were used. A. correlations in young adults. B. correlations in middle aged adults.

A

Character	Factors I	Factors II	Factors III
1	0.91	0.29	0.03
3	0.62	-0.64	0.37
5	0.93	-0.01	-0.05
11	0.92	-0.32	0.01
12	0.67	0.47	0.30
14	0.91	0.22	0.05
16	0.44	0.79	-0.31
18	0.81	0.06	0.08
20	0.58	-0.23	-0.74
22	0.88	0.01	0.29
24	0.40	0.57	0.23
26	0.92	-0.16	0.17
29	0.97	-0.12	-0.20
31	0.83	-0.27	0.25
% Trace	63	14	8

B

Character	Factors I	Factors II	Factors III
1	-0.82	-0.22	0.45
3	-0.62	0.55	0.23
5	-0.80	0.16	0.18
11	-0.95	0.11	-0.06
12	-0.65	0.49	0.11
14	-0.82	0.25	0.29
16	-0.48	0.65	0.36
18	-0.65	-0.01	-0.67
20	-0.83	-0.13	-0.36
22	0.86	0.10	0.71
24	-0.64	0.19	0.58
26	-0.43	0.35	0.14
29	-0.78	-0.41	0.17
31	-0.43	0.35	0.14
% Trace	55	11	10

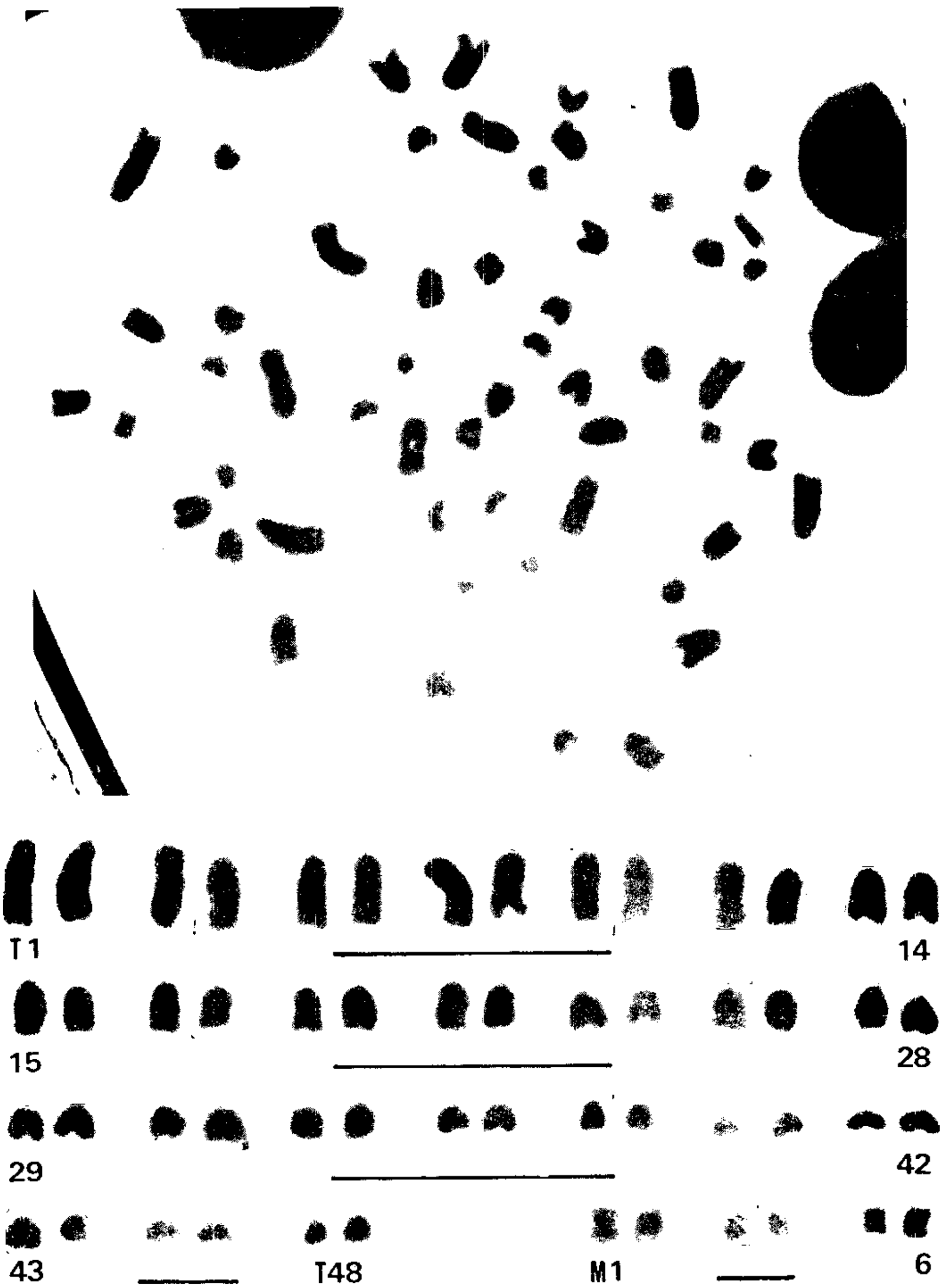

Fig. 1. Karyotype of a Korean field mouse (K-178, ♂), *Apodemus peninsulae peninsulae*, from Mungyong. T and M indicate acrocentric and metacentric chromosomes, respectively.

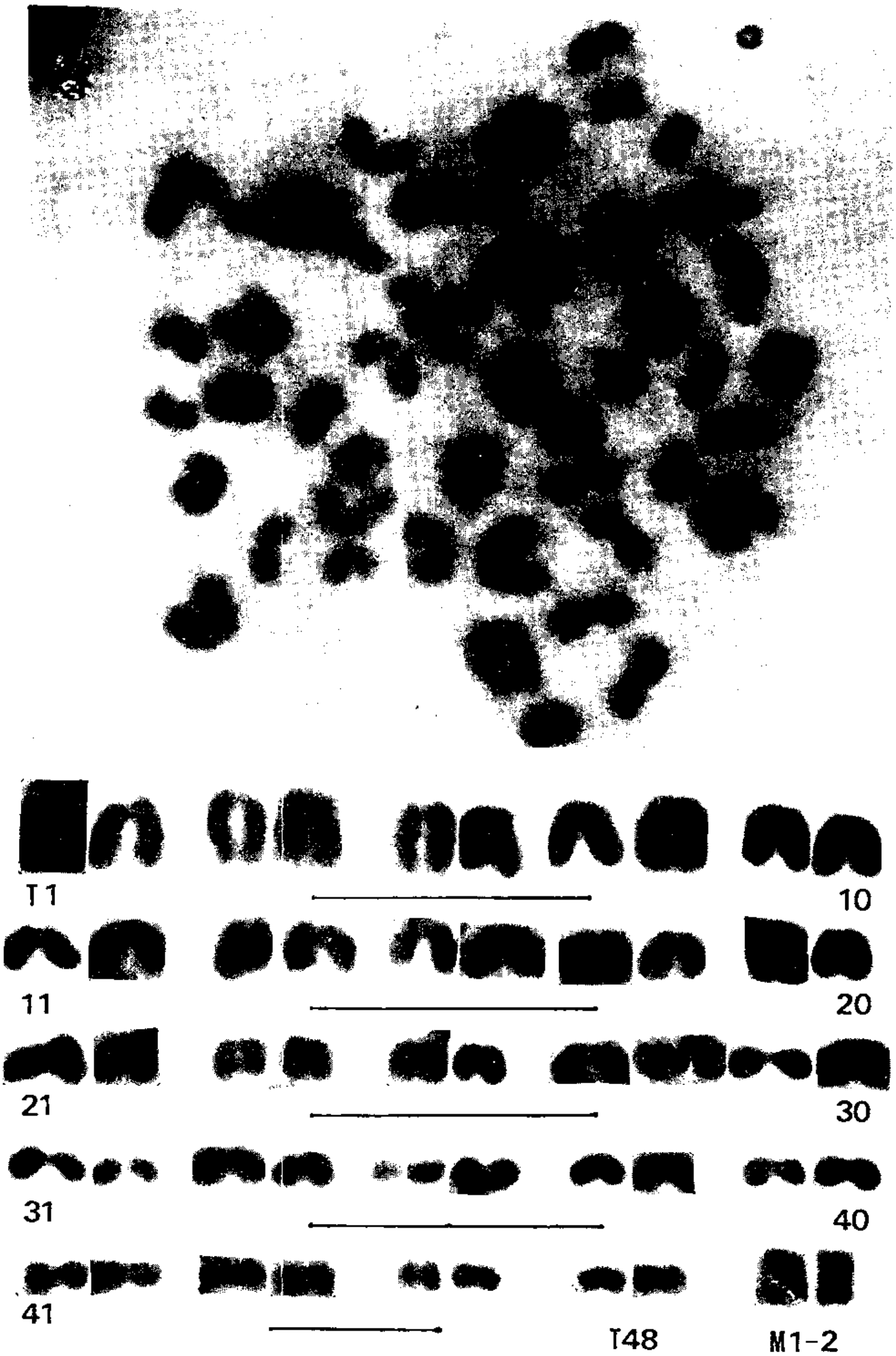

Fig. 2. Karyotype of a Korean field mouse (K-179, ♂), *Apodemus peninsulae peninsulae*, from Mungyong. T and M indicate acrocentric and metacentric chromosomes.

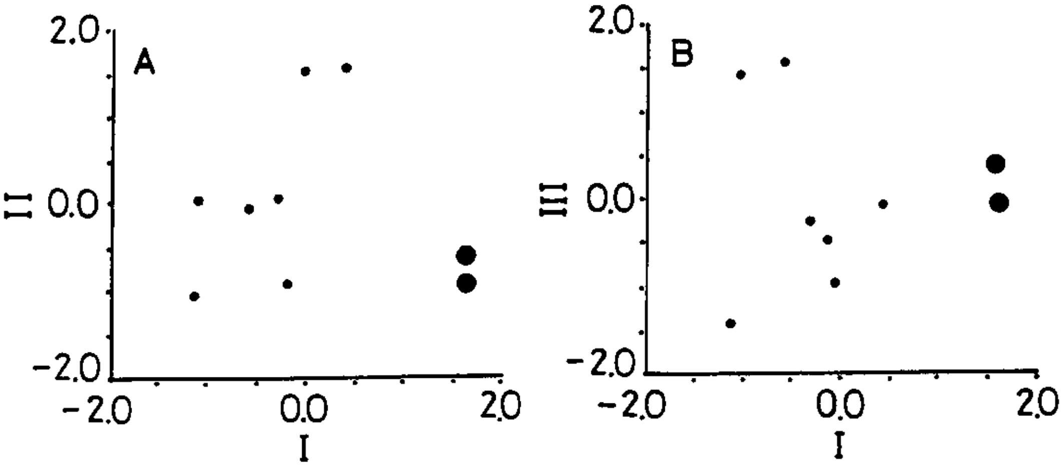

Fig. 3. Projections of nine young adults of *Apodemus peninsulae peninsulae* and *A. agrarius coreae* based on principal component analysis in three dimensions. Individual measurements of 14 selected characters were used. Factors I, II and III represented 63, 14 and 8 per cent of the variance, respectively (85 per cent in total). Symbols for samples are as follows: large shaded circle, *A. peninsulae peninsulae* (2); small shaded circle, *A. agrarius coreae* (7). A, samples ordinated with factor I vs. factor II. B, samples ordinated with factor I vs. factor III.

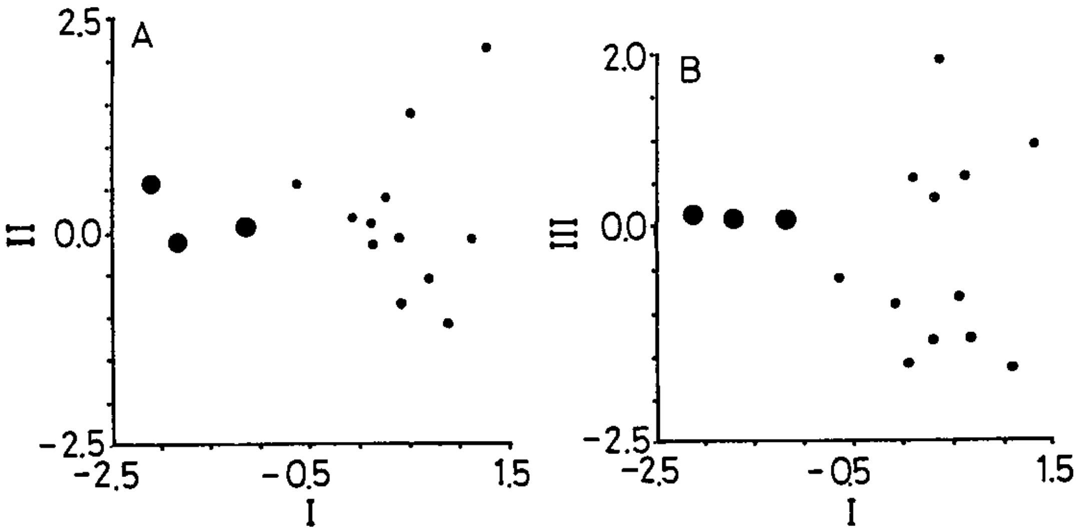

Fig. 4. Projections of 15 middle-aged adults of *Apodemus peninsulae peninsulae* and *A. agrarius coreae* based on principal component analysis in three dimensions. Individual measurements of 14 selected characters were used. Factors I, II and III represented 55, 11 and 10 per cent of the variance, respectively (76 per cent in total). Symbols for samples are as follows: large shaded circle, *A. peninsulae peninsulae* (3); small shaded circle, *A. agrarius coreae* (12). A, samples ordinated with factor I vs. factor II. B, samples ordinated with factor I vs. factor III.