A Karyogram Study on Eighteen Species of Japanese Acrididae (Orthoptera)[1]

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(*With 36 Figures*)

During these forty years the cytological investigations of the Acridian grasshoppers have been extensively carried out by a number of investigators, and considerable contributions have been devoted to the advance of animal cytology. The orthopteran insects, especially those of the Acrididae, have proved very favourable as material for the study of chromosomes, on account of the fact that their chromosomes are large in size having clear morphological features and are relatively low in number. Over one hundred of species have been cytologically investigated since the pioneer work of McClung ('00) in this field, demonstrating many valuable and important facts and their bearing on problems of general cytology.

One of the important matters confronting the students of Acridian chromosomes is to determine the interrelationships of the chromosome complexes in the different species. The extensive studies by McClung and his colleagues have established a great uniformity and constancy of the chromosome numbers in the Acrididae. Efforts made by these investigators greatly served to homologize individual chromosomes in closely related genera and species. Recently Ramachandra Rao ('37) has made a comparative study of the chromosomes in eight genera of Pyrgomorphinae (Acrididae), in view of finding the chromosomal relationship existing among the members of this subfamily. In view of the similar object the present investigation has been undertaken with eighteen species of the Acrididae which cover four subfamilies.

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Material and Methods

The material on which the present study was carried out consists of the testes derived from eighteen species of the Acrididae listed below, which were collected by the author in Sapporo, Taiwan[1)] and Okinawa[2)] during the years 1940 and 1941, with the kind offices of Dr. S. Makino.

Immediately after collecting in the field, the insects were dissected alive and the testes were dropped into the fixative. For the fixative, Allen-Bouin's solution was exclusively employed in this study. Following the usual paraffin method, sections were prepared and subjected to the Heidenhain's iron-haematoxylin method of staining with light-green.

The dissected specimens were preserved in alcohol and identified by the specialists. The identification of the Taiwan and Okinawa specimens were made by Mr. J. Sonan of the Entomological Institute of Taihoku University and those from Sapporo and Yamanaka by Dr. H. Furukawa of the Tokyo Imperial University. At this opportunity the author wishes to express his cordial thanks to these gentlemen. The full names of the studied species and their localities may be referred to Table 1. They cover the following four subfamilies, Acridinae, Catantopinae, Oedipodinae and Pyrgomorphinae.

Observations

I. The chromosome number

The chromosome numbers established in this study for eighteen species of the Acrididae are listed in Table 1. With a few exceptions, as seen in *Chorthippus bicolor, Miramella dairisama, M. mikado* and

1), 2) For collection of the material the author is greatly indebted to Dr. S. Tateishi and Mr. R. Tanaka in Taiwan and Mr. H. Yashiro in Okinawa. The author wishes to express here his hearty thanks to these gentlemen.

TABLE 1. Species under investigation and their chromosome numbers

Species	Chrom. number 2n	Chrom. number n	Locality	Figure
Subfam. Acridinae				
1. *Acrida turrita*	23	12(I); 11, 11+X(II)	Taiwan	1, 19
2. *Aiolopus tamulus*	23	12(I); 11, 11+X(II)	Okinawa	2, 20
3. *Parapleurus alliaceus fastigiatus*	23	12(I); 11, 11+X(II)	Sapporo	3, 21
4. *Phlaeoba formosana*	23	12(I); 11, 11+X(II)	Taiwan	4, 22
5. *Phlaeoba infumata*	23	12(I); 11, 11+X(II)	Taiwan	5, 23
6. *Chorthippus bicolor*	17	9(I); 8, 8+X(II)	Okinawa	6, 24
Subfam. Catantopinae				
7. *Coptacra foedata*	23	12(I); 11, 11+X(II)	Taiwan	7, 25
8. *Eirenephilus longipennis*	23	12(I); 11, 11+X(II)	Sapporo	8, 26
9. *Gesonia punctifrons*	23	12(I); 11, 11+X(II)	Taiwan	9, 27
10. *Miramella dairisama*	21	11(I); 10, 10+X(II)	Yamanaka	10, 28
11. *Miramella mikado*	21	11(I); 10, 10+X(II)	Sapporo	11, 29
12. *Podisma sapporoensis*	23	12(I); 11, 11+X(II)	Sapporo	12, 30
13. *Oxya intricata*	23	12(I); 11, 11+X(II)	Okinawa	13, 31
14. *Oxya jezoensis*	23	12(I); 11, 11+X(II)	Sapporo	14, 32
15. *Oxya universalis*	23	12(I); 11, 11+X(II)	Okinawa	15, 33
16. *Traulia ornata*	23	12(I); 11, 11+X(II)	Okinawa	16, 34
Subfam. Oedipodinae				
17. *Gastrimarus transversus*	23	12(I); 11, 11+X(II)	Okinawa	17, 35
Subfam. Pyrgomorphinae				
18. *Atractomorpha ambigua*	19	10(I); 9, 9+X(II)	Okinawa	18, 36

Atractomorpha ambigua, the number of chromosomes shows a remarkable uniformity, as far as the diploid complement consists of 23 chromosomes all of which are provided with a telomitic rod-shape. In *Miramella dairisama* and *M. mikado* (Figs. 10–11) the number of chromosomes was found to be 21 (as $2n$), and the reduction of the number depends upon the absence of one pair of the smallest autosomes. In *Chorthippus bicolor* (Fig. 6) the diploid number was given as 17 of which three pairs are represented by remarkable V-shaped elements and the remaining ones are rod-shape. *Atractomorpha ambigua* shows 19 chromosomes in diploid which number is characteristic to the members of Pyrgomorphinae as reported by Ramachandra Rao ('37). Throughout the species under study there is always present an unpaired X chromosome which is of telomitic nature.

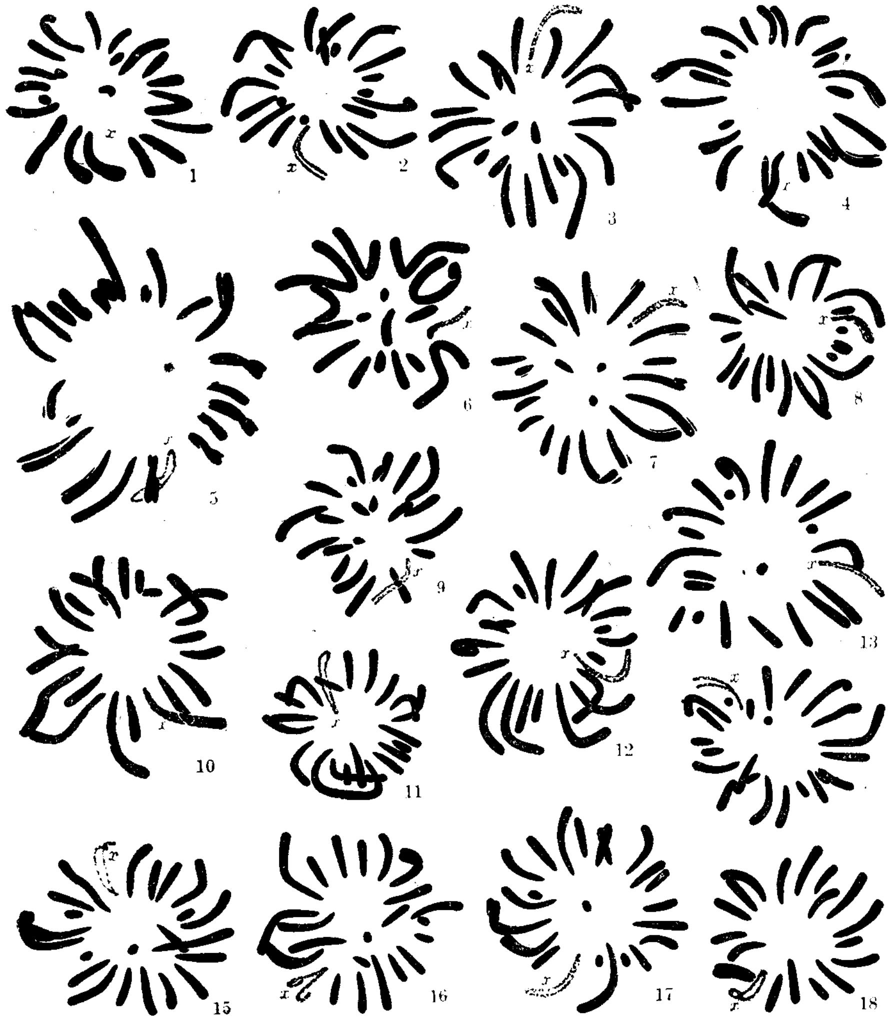
II. Comparative morphology of chromosomes

With the exception of *Chorthippus bicolor,* the chromosomes of the studied species are all characterized by being a simple rod-type with terminal attachment, tapering at their inner ends of fibre attachment (Figs. 1–18). The individual chromosomes bear no characteristic feature beyond that of length. The mating up of the homologous chromosomes was made by means of the procedure according to Makino ('41), and the chromosomes were placed in pairs and arranged serially according to the descending order of length. Examples are given in Figs. 19 to 36. As pointed out in the studies of Makino ('41, '42), the chromosomes are comparable on the basis of their relative lengths.

The extensive studies carried out by McClung ('14), Carothers ('13, '17), Robertson ('16) and others have shown that the diploid chromosomes of the Acrididae in general can be divided into two sets, a larger set of longer chromosomes and a smaller set of short rod-shaped ones. The same evidence was also pointed out by Asana, Makino & Niiyama ('39) in the work with some Indian species. This is again true with the species herein concerned, as mentioned below.

1. Subfamily Acridinae

Six species belonging to this subfamily come under observation. As already mentioned, the chromosomes of the diploid complements, except the X, are sorted, in every species into two distinct sets, a larger set of longer chromosomes and a smaller set of short rod-shaped ones. *Acrida turrita* is characterized by the fact that the



Figs. 1–18. Spermatogonial complements. *ca.* ×2000. 1, *Acrida turrita.* 2, *Aiolopus tamulus.* 3, *Parapleurus alliaceus fastigiatus.* 4, *Phlaeoba formosana.* 5, *Phlaeoba infumata.* 6, *Chorthippus bicolor.* 7, *Coptacra foedata.* 8, *Eirenephilus longipennis.* 9, *Gesonia punctifrons.* 10, *Miramella dairisama.* 11, *Miramella mikado.* 12, *Podisma sapporoensis.* 13, *Oxya intricata.* 14, *Oxya jezoensis.* 15, *Oxya universalis.* 16, *Traulia ornata.* 17, *Gastrimarus transversus.* 18, *Atractomorpha ambigua.*

larger set of chromosomes is represented by nine pairs ranging from *a* to *i*, which form a closely graded series, and the smaller set consists of two pairs of short rods (*j* to *k*), slightly different in size (Fig. 19). In *Aiolopus tamulus*[1] and *Parapleurus alliaceus fastigiatus*, there are observable three pairs of short rods in their complements (Figs. 20–21). *Phlaeoba formosana* and *Ph. infumata*[2], on the other hand, possess only one pair of such short rods in their complements (Figs. 22–23). The X elements of these species generally assume at metaphase a slender and diffused contour with the exception of *Phlaeoba formosana* which is characterized by the evidence that the X always displays a compact appearance at metaphase.

In striking contrast to the above cases, *Chorthippus bicolor* shows the diploid number of 17, which consists of three pairs of large V-shaped chromosomes, five pairs of rod-shaped ones and an X element (Fig. 24). The V-shaped chromosomes of this species, according to Robertson ('16) and others, are regarded as multiples resulted from the association of non-homologous chromosomes, two by two, at their inner ends. If one assumes that a V is made up of two component rods, the number, 17, of *Chorthippus* may increase to 23, the number characteristic to the other members.

2. Subfamily Catantopinae

Ten species of this subfamily have been subjected to the present investigation. The names of the studied species are referable to Table 1.

The species under observation show an agreement in having 23 chromosomes in the diploid complement, except two species, *Miramella dairisama* and *M. mikado*[3] in which the diploid number was found to be 21. In all cases investigated the diploid complement can be divided into two sets of larger and smaller elements as in the former species. In *Coptacra foedata* the larger set of chromosomes consists of nine pairs of long elements (*a* to *i*) forming a

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1) The same species from India was cytologically investigated by Asana, Makino and Niiyama ('39), establishing a similar result.

2) In a testis of this species two cysts were found in which a certain number of tetraploid and hexaploid primary spermatocytes were contained (for details, see Momma '42a).

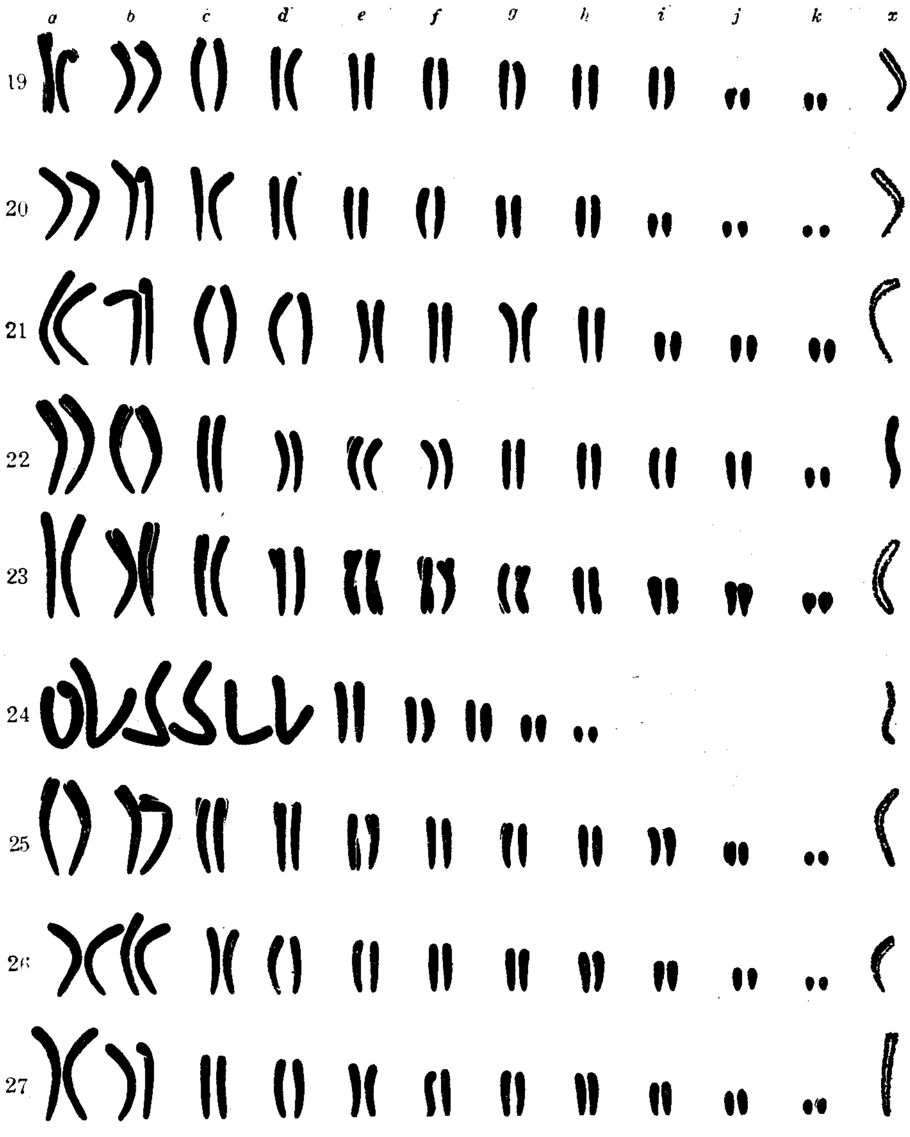
3) The chromosome number of this species has already been given by Makino ('36).

graded series, and the smaller set contains two pairs of short rods (*j* to *k*) which are considerably dissimilar in size (Fig. 25). The similar relationship of chromosomes was found to occur in *Oxya universalis* (Fig. 23) and *Traulia ornata* (Fig. 34). *Podisma sapporoensis* can be said to belong to the same category in the size-relation of the chromosomes (Fig. 30), but in this species the size-difference between the two pairs of small chromosomes is not so large as in the above mentioned species. The chromosomal condition found in *P. sapporoensis* is very closely related to that occurring in *Acrida turrita* (Fig. 19) of the Acridinae.

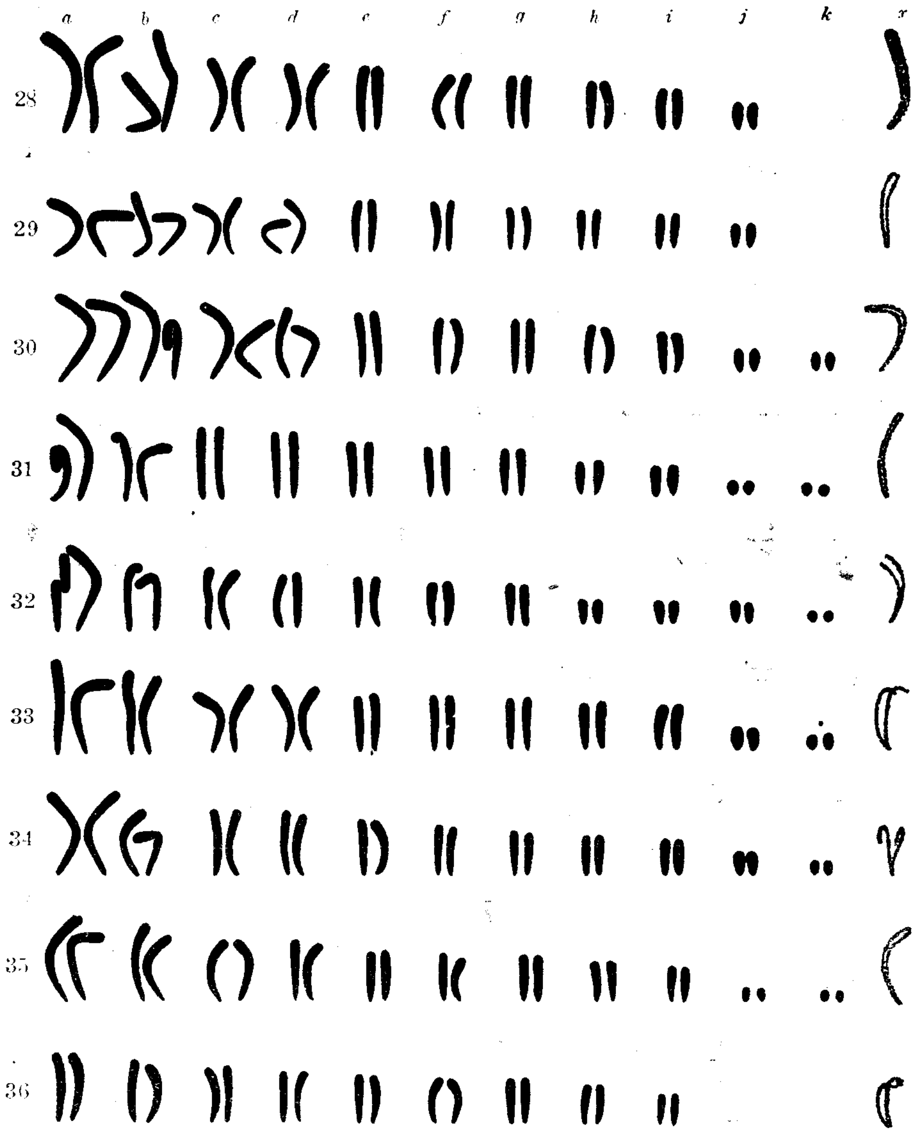
Eirenephilus longipennis (Fig. 26) and *Gesonia punctifrons* (Fig. 27) possess a larger set of chromosomes consisting of eight pairs of large elements (*a* to *h*) and a smaller set made up of three pairs of small elements, the members of both sets showing in each set a graded seriation of size. The similar condition was also found in *Aiolopus tamulus* (Fig. 20) and *Parapleurus alliaceus fastigiatus* (Fig. 21) belonging to the Acridinae.

Oxya intricata (Fig. 31) and *Oxya jezoensis* (Fig. 32) show a condition somewhat different from the above cases. In these two species it is possible to distinguish seven pairs of longer chromosomes (*a* to *g*) as the larger set, and four pairs of shorter ones (*h* to *k*) as the smaller set. The longer elements are nearly equal in size-relation between the two species and form a graded series, but the four pairs of shorter elements are dissimilar in size in the two species. In *Oxya intricata* the four smaller pairs under consideration consist of two pairs of medium-sized elements with nearly equal length and two pairs of very short dot-like elements having approximate size (Fig. 31). In *Oxya jezoensis* the composition of the four smaller pairs shows three pairs of small elements giving a slight diminution in length and a pair of prominently minute elements (Fig. 32). It is noticeable that *Oxya universalis*, as already noted, shows a chromosomal condition considerably different from *O. intricata* and *O. jezoensis*, irrespective of the taxonomical kinship existing among them.

Miramella dairisama and *M. mikado* are very remarkable in this subfamily in having an exceptional chromosome number, that is, 21, instead of 23 which is the characteristic and common number through the allied forms. As reported in the short paper (Momma '42 b), the reduction of the number in these species results from



Figs. 19–27. Paired alignments of homologous mates from spermatogonial chromosomes in descending order. 19, *Acrida turrita*. 20, *Aiolopus tamulus*. 21, *Parapleurus alliaceus fastigiatus*. 22, *Phlaeoba formosana*. 23, *Phlaeoba infumata*. 24, *Chorthippus bicolor*. 25, *Coptacra foedata*. 26, *Eirenephilus longipennis*. 27, *Gesonia punctifrons*.



Figs. 28–36. Paired alignments of homologous mates from spermatogonial chromosomes in descending order. 28, *Miramella dairisama*. 29, *Miramella mikado*. 30, *Podisma sapporoensis*. 31, *Oxya intricata*. 32, *Oxya jezoensis*. 33, *Oxya universalis*. 34, *Traulia ornata*. 35, *Gastrimarus transversus*. 36, *Atractomorpha ambigua*.

the absence of one pair of the smallest chromosomes (Figs. 28–29). The comparison of the chromosome complex with the allied form, *Podisma sapporoensis* (Fig. 30) indicates that, excepting the smallest pair, the remaining pairs of chromosomes in the latter species seem not dissimilar from those of *Miramella dairisama* and *M. mikado,* at least in their relative size-relation. Such a reduction in the chromosome number based on the diminution of the smallest elements has been known to occur in several instances, a remarkable example of which was reported in *Lacerta vivipara* (Reptilia) by Oguma ('34).

3. Subfamily Oedipodinae

The chromosomes of only one species, *Gastrimarus transversus,* were investigated here.

The 23 chromosomes of this species can be divided into two distinct groups (Fig. 35), a larger set in which are contained nine pairs of longer chromosomes with a graded seriation in size (*a* to *i*), and a smaller set which consists of two pairs of prominently small elements with a slight size-difference (*j* to *k*). The chromosomal condition of this species nearly resembles that of *Podisma sapporoensis* (Catantopinae), so far as the relative length of the chromosomes is concerned. According to Carothers ('13), *Arphia simplex* (Oedipodinae) also possesses the small elements in two pairs.

4. Subfamily Pyrgomorphinae

The chromosomes of *Atractomorpha ambigua* were dealt with in this study.

As is the case with all the species of Pyrgomorphinae so far studied (Machida '17, Asana & Makino '34, Ramachandra Rao '37), the chromosome number of the present form under investigation was also observed to be 19 in diploid. The chromosomes show a graded seriation and there is present no pair outstanding in size. According to Machida ('17), a similar condition seems to occur in the allied species, *Atractomorpha bedeli.* On the other hand, Ramachandra Rao ('37) reported that in *Atractomorpha crenulata* the last pair is remarkably small, outstanding in size.

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