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CHROMOSOME ANALYSIS IN FULGORIDS (FULGOROIDEA : HOMOPTERA)

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ABSTRACT

Nine fulgorid species are for the first time chromosomally known. Meiotic and mitotic chromosomes from gonial tissues were analysed and their behaviour during meiosis was studied. 14 is tentatively suggested to be the modal number of the superfamily. Evolution of chromosome number in the superfamily is also discussed.

INTRODUCTION

The group Auchenorrhyncha of Homoptera is broadly divided into four superfamilies : Fulgoroidea, Cicadoidea, Cercopoidea and Cicadelloidea. The Auchenorrhynchan species have been in the lime light of cytogenetics since Wilcox (1895) published a study dealing with the chromosomes of *Cicada tibicens* (Cicadoidea). Later on Stevens (1906) investigated chromosomes of a leafhopper, *Aphrophora quandrangularis* (Cercopoidea). Kornhauser (1914, 1919) in his two papers dealt with the chromosomes of three membracids. However, Hirai (1948) first described the chromosomes of an Araeopid (Fulgoroidea), belonging to the genus *Calligypona*. Out of 9000 species (Wade, 1960) belonging to 20 families (Richards and Davies 1977), only 80 species covering 13 families of fulgorids have been cytologically investigated. Cytotaxonomical studies on fulgorids have been attempted by various workers (Halkka, 1959, 1962, Halkka and Heinonen, 1964, Kurokawa, 1953, Leston, 1961 and Whitten, 1965). These species were mainly from the European, American and Australian fauna. As far as we are aware, no other species of fulgorids from India excepting a few reports (Rao, 1955*a*, *b*; Bhattacharya, 1971; Bhattacharya and Manna 1973; Parida and Dalua, 1979) have been reported. The present paper deals with the cytological findings on two species of Meenoplidae, 4 species of Delphacidae, one species of Dictyopharidae, one of Issidae and one species of Flatidae which are new to the field of fulgorid cytotaxonomy and these are followed by a discussion on the evolution of chromosome number.

MATERIAL AND METHODS

Thirteen species were collected from various parts of the country (table 1) and the gonads were dissected out for routine chromosome study. In most of the cases the species were represented by at least 5 individuals of both the sexes. Nymphs were taken for study when adult individuals did not yield good results. The study is mainly confined to spermatogenesis, but oogenesis has been studied in a few species from temporary aceto-carmine squash preparations. The slides were made permanent following Smith's (1943) technique.

Karyomorphometrical study from metaphase I chromosomes was conducted. The mean values for all the chromosomes of the haploid set in a species were finally expressed in relative percentage (table 2).

TABLE 1

List of fulgorid species with their families and source of collection.

	Species	Family	Source of collection	Place
1.	*Meenoplus* sp.	Meenoplidae	Grass, Light	Cuttack
2.	*Nisia atrovenosa*	,,	Paddy field Light	Bhubaneswar
3.	*Nilaparvata lugens*	Delphacidae	,,	,,
4.	*Perkinsiella saccharicida*	,	*Saccharum officinarum*	Cuttack
5.	*Sardia rostrata*	,,	Light	Bhubaneswar
6.	*Sogatella furcifera*	,,	Light, Paddy field	,,
7.	*Dictyophara* sp.	Dictyopharidae	Light	,,
8.	*Brahmaloka* sp.	Issidae	*Zizyphus jujuba*	Dehradun (U.P.)
9.	*Paraketumala* sp.	Flatidae	*Sorghum vulgare*	Bhubaneswar
10.	near *Melicharia* sp.	,,	*Shorea robusta*	Solan (H.P.)
11.	*Pyrilla perpusilla*	Lophopidae	*Saccharum officinarum*	Cuttack
12.	*P. pusana*	,,	Paddy field	Bhubaneswar
13.	*Eurybrachys tomentosa*	Eurybrachidae	*Strychnos nux-vomica*	,,

OBSERVATIONS

The general course of meiosis in all the species is of a uniform pattern and of orthodox nature. The diploid number varies from 25 to 29. The spermatogonial and oogonial metaphase complements occupy almost the entire equatorial region. The staining behaviour of the autosomes does not differ from that of the sex chromosome for which the sex chromosome is not identifiable. All the species excepting No. 10 and No. 13 (table 1) exhibit XO sex mechanism in males, whereas the two above mentioned species show XY sex mechanism in males.

The leptotene and zygotene stages show the usual long slender threads in the form of a relatively understained entangled mass, with one deeply stained region in XO males and with two deeply stained regions in XY males. These deep stained masses represent the sex chromatin (Chromosome) and they lie generally towards the nuclear membrane. The contraction phase is followed by the growth phase which continues upto the mid prophase where the stainability of the chromosomes is very poor. The diplotene nuclei contain 13 bivalents in all the species excepting *Nilaparvata lugens* and *Dictyophara* sp. The XY males have 12 faintly stained bivalents and a deep stained bivalent showing the sex chromosomes X and Y. The nuclei of other species exhibit a deep stained sex chromatin in the form of a univalent. *N. lugens* and *Dictyophara* sp. exhibit 14 bivalents and a univalent in their diplotene nuclei. The chiasma frequency is generally low in these species, at least one in each bivalent excepting two in longer bivalents of *Perkinsiella saccharicida*

and *Pyrella* species. By the time metaphase I is reached, the chiasmata in all the bivalents are terminalized. In metaphase I stage, the bivalents generally appear to be some what dumb-bell shaped structures, arranging themselves in a ring on the equator of the spindle, while the univalent X forms an accessory plate. But in the XY male, the X and Y form a parachute-like structure. The first division anaphase is invariably reductional as a result of which two types of second division metaphase complements are observed. In species with XY males two types of second metaphase plates containing the same number of chromosomes are observed, but they differ from one another by the presence of either X or Y. Second spermatocyte division is equational for all the chromosomes.

The relative percentage values of the haploid set of metaphase I chromosomes in all the 13 species have been determined (table 2). Table 2 shows that in *Perkinsiella saccharicida* and in genus *Pyrilla* the autosome No. 1 is much larger than autosome No. 2 and autosome 13 is much less in volume as compared to other autosomes. In all XO males the sex chromosomes are smaller than the first 4 autosomes, But in XY males the sex chromosomes are larger than the autosomes. In near *Melicharia* sp., the X chromosome is smaller than the autosome No. 1 only. But in *E. tomentosa*, the X chromosome is much larger than all the autosomes, while the Y is smaller than autosome No. 1.

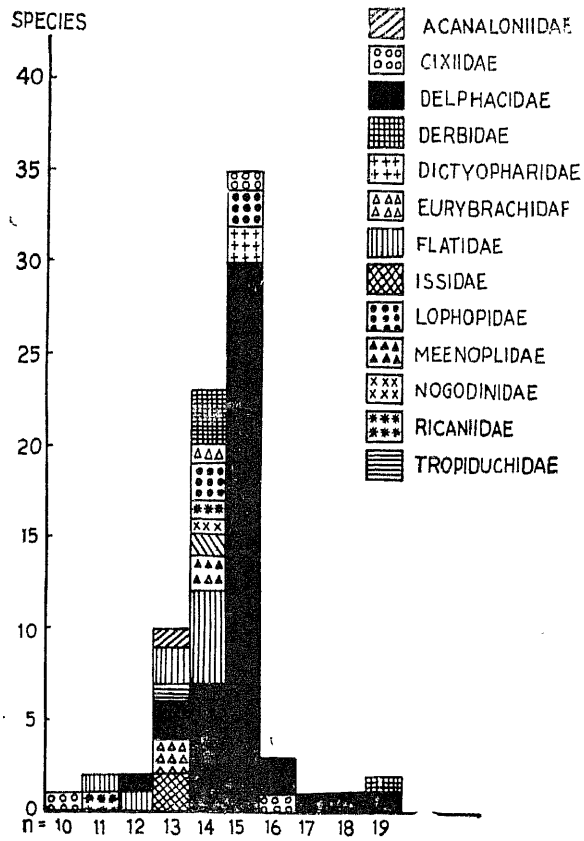

Fig. 1

TABLE 2

The relative percentage values of the haploid set of chromosome determined from metaphase I complements in thirteen species of Fulgorids

Species	Metrical value in percentage													Sex chr.	
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	X	Y
Meenoplus sp.	11.72	10.34	8.27	8.27	7.58	6.89	6.89	6.20	6.20	6.20	5.51	5.51	4.82	–	5.51	–
Nisia atrovenosa	12.96	11.39	10.85	9.84	7.77	7.25	6.73	6.21	5.69	5.18	4.66	3.62	3.10	–	4.66	–
Nilaparvata lugens	9.62	8.55	8.55	7.48	7.48	7.48	6.95	6.41	6.41	5.81	5.34	4.81	4.81	2.67	7.48	–
Perkinsiella saccharicida	25.63	9.24	8.82	8.82	6.30	5.88	5.88	4.62	4.62	4.62	3.36	2.94	2.10	–	7.14	–
Sardia rostrata	11.92	11.15	10.38	9.23	8.46	8.07	5.76	5.00	4.61	3.84	3.46	3.46	3.46	–	7.34	–
Soratella furcifera	13.02	11.62	9.30	7.90	7.90	7.44	6.97	6.04	5.58	5.11	4.65	4.65	4.18	–	5.58	–
Dictyophara sp.	15.72	11.27	8.01	7.41	7.12	6.82	6.82	5.63	5.04	4.45	4.45	3.85	3.26	2.37	7.71	–
Brahmaloka sp.	17.29	11.35	8.10	7.56	7.02	6.48	5.04	4.86	4.86	4.32	3.78	3.78	–	–	11.35	–
Paraketumala sp.	15.52	9.31	8.69	8.07	7.45	6.21	6.21	5.54	4.96	4.96	4.34	4.34	3.72	–	10.55	–
near *Melicharia* sp.	17.98	10.08	8.77	7.01	6.14	5.70	5.26	5.26	4.82	4.82	4.38	4.38	–	–	10.52	4.82
Pyrilla perpusilla	16.61	8.62	8.30	7.34	7.34	7.02	6.70	6.70	6.38	5.11	4.79	3.51	2.81	–	8.62	–
P. pusana	17.39	8.69	8.55	8.26	7.24	7.24	6.08	5.79	5.21	4.92	4.05	3 76	3.76	–	8.98	–
Eurybrachys tomentosa	10.79	9.15	7.51	6.57	5.86	5.39	4.92	4.92	4.69	4.46	4.46	3.52	–	–	18.07	9.62

A = Autosome

Discussion

Cytologically all the families of the superfamily Fulgoroidea have not been investigated. Only 80 species belonging to 13 families are cytologically known (Table 3) and 45 species of 20 genera (Halkka, 1959, 1962, Halkka and Heinonen, 1964; Bhattacharya and Manna, 1973; Parida and Dalua, 1979) come under the family Delphacidae (Araeopidae). The diploid number ranges from 24 to 37 with a peak at 29 (Fig. 1) chromosomes in this family.

The difference in the diploid number in different species could be largely due to the fusion/fission mechanism. These changes are probably due to the diffused centromeric activity. Similar mechanism has been envisaged by Manna (1956) in Heteroptera and by Whitten and Taylor (1969) in leaf hoppers. It is pertinent to mention here that the chromosome number is very high in fulgorids as compared to the other Auchenorrhynchan superfamilies (Dalua and Parida, unpublished). During spermatogenesis, no bouquet arrangement is found as is commonly met with in species of cercopids and to some extent in membracids and cicadellids.

Table 3 shows the distribution of chromosome number within the superfamily, studied so far. Excepting the families Delphacidae, Flatidae and Derbidae, the other 10 families are poorly represented. So it is difficult at this stage to give a modal (type) number for these families. In Delphacidae, 30 species possess 15 haploid chromosomes and 15 may, therefore, be treated as the modal number. In Flatidae, out of 9 species so far studied, 5 species possess 14 as the haploid number and 14 is speculated to be the modal number. In the family Derbidae, though poorly represented, 14 can be termed as the modal number as three species out of 4 studied have this number.

Table 3

The distribution of chromosome number within the superfamily Fulgoroidea

Taxonomic group Family	Species examined	Type No.	Number of species with haploid complement (N)									
			10	11	12	13	14	15	16	17	18	19
Cixiidae	3	-	1	-	-	-	-	1	1	-	-	-
Derbidae	4	14	-	-	-	-	3	-	-	-	-	1
Meenoplidae	2	14	-	-	-	-	2	-	-	-	-	-
Delphacidae (Areopidae)	45	15	-	-	1	2	7	30	2	1	1	1
Dictyopharidae	2	15	-	-	-	-	-	2	-	-	-	-
Issidae	3	13	-	-	-	2	1	-	-	-	-	-
Tropiduchidae	1	-	-	-	-	-	1	-	-	-	-	-
Nogodidnidae	1	-	-	-	-	-	-	1	-	-	-	-
Flatidae	9	14	-	1	1	2	5	-	-	-	-	-
Acanalonidae	1	-	-	-	-	-	1	-	-	-	-	-
Ricanidae	2	-	-	1	-	-	1	-	-	-	-	-
Lophopidae	4	-	-	-	-	-	2	2	-	-	-	-
Eurybrachidae	3	13	-	-	-	2	1	-	-	-	-	-
Total	80	14	1	2	2	10	23	35	3	1	1	2

It appears from Table 3 that out of 80 species 35 possess 15 chromosomes in their haploid set of which 30 belong to the family Delphacidae and the other 5 belong to the families Cixiidae, Dictyopharidae and Lophopidae. On the other hand, 23 species out of a total of 80 possess 14 chromosomes in their haploid set, but they are distributed over 9 families. From this analysis a tentative conclusion may be drawn that the modal number of the superfamily is 14. Further work is, however, necessary to know the correct modal number of the superfamily Fulgoroidea.

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ROLE OF TRACE ELEMENTS IN BRACKISHWATER AQUACULTURE*

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ABSTRACT

Role of trace elements like zinc, molybdenum, cobalt, boron, manganese, etc., in brackishwater aquaculture has been determined. The trace elements were used at the concentration of 0.5 ppm and 0.25 ppm. The experiment was conducted in three series. In the first series plankton production and in the second and third series primary production and fish yield respectively were used as indices. Among the trace elements tried molybdenum, boron and zinc appear to be effective in brackishwater.

INTRODUCTION

In an aquatic ecosystem phytoplankton constitutes the basic trophic rung of the natural food ladder responsible for primary productivity, leading to zooplankton production and in turn to better fish crop. For the production of phytoplankton the nutrient status of the environment is of prime importance. In spite of having sufficient supplies of nutrients such as nitrogen, phosphorus, potassium and calcium the productivity may be impaired by the lack of sufficient supply of some of the trace elements. Role of the major nutrient elements in imroving the productivity of a water body has been well documented in the works of several authors (Mortimer, 1954 ; Holden, 1957 ; Swingle and Smith, 1938). The part played by trace elements such as manganese, cobalt, boron, zinc, molybdenum etc, has been elucidated by many workers (Sommer and Lipman, 1926 ; Branchley and Warrington, 1927 ; Arnon and Stout, 1939 ; Thompson, 1957 ; Davies, 1970 ; Lewin and Chen, 1973 ; Murphy and Lean, 1975 ; Stumm and Morgan, 1970 ; Garrels and Christ, 1965 ; Burns and Nriagu, 1976). In India much of the studies on this aspect has been carried out for freshwater (Banerjea and Banerji, 1966 ; Sreenivasan *et al.*, 1975 ; Saha *et. al.*, 1979). For brackishwater such studies are very scanty. Hence it was considered worthwhile studying the influence of trace elements in enhancing production in brackishwater medium.

MATERIALS AND METHODS

The experiment was conducted in cylindrical glass jars of 12 l capacity with 10 l of brackishwater. A bottom of 3 cm of soil collected from lake Pulicat was provided. Three series of experiments were carried out. In each series five sets of experiments were done applying trace elements zinc, cobalt, boron, molybdenum and manganese separately. These trace elements were added at 0.5 ppm and 0.25 ppm based on water volume. The whole set was replicated once.

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In the first series five sets of experiments were conducted to study the primary productivity at the end of 15 and 30 days using light and dark bottle method. In the second series total plankton was estimated by filtering the entire volume of water through a plankton net made of No. 25 bolting silk at the end of 30 days after treatment. In the third series of experiments equal number of mullet fry were introduced in all jars at the end of 15 days after the addition of trace elements and the growth was recorded at the end of 15 days.

Samples of water and soil were collected once in a week and analysed according to Standard Methods (A. P. H. A., 1955), soil by Piper (1950) and plankton by Sedgwick Rafter counting chamber method.

OBSERVATIONS

The results of experiments are presented in table 1. In the first series of experiments trace elements zinc, cobalt, molybdenum, boron and manganese were tried at 0.25 and 0.5 ppm. Primary productivity was studied at the end of 15 days and 30 days after the application. In all the cases the production was higher at the end of 15 days than at the end of 30 days and was higher in the higher dose of element. Among these trace elements tried molybdenum gave highest primary production of 5.4 gC/m^3 / day at 0.5 ppm concentration (Table 1) and was followed both by zinc and boron with 4.2 gC/m^3/ day. Next in rank were manganese with 3.9 gC/m^3/day and cobalt 3.6 gC/m^3/day. In the control jars it was 1.2 gC/m^3/day. When the primary productivity was estimated at the end of 30 days it was observed that better sustained production was given by molybdenum in both the doses followed by manganese and boron.

TABLE 1

Effect of different trace elements on plankton production, primary productivity and fish growth

Trace elements	Dose (ppm)	Primary production (gC/m^3/day)		Plankton (ml/10 l) At the end of 30 days	Average increase in weight of mullet fry (mg) At the end of 15 days.
		15 days	30 days		
Molybdenum	0.25	4.8	3.9	50.0	88.0
	0.5	5.4	4.2	82.5	97.0
Boron	0.25	2.3	0.9	41.0	90.0
	0.5	4.2	1.8	70.0	97.0
Zinc	0.25	3.6	1.2	44.0	96.0
	0.5	4.2	1.8	45.0	95.0
Manganese	0.25	2.2	1.2	34.0	40.0
	0.5	3.9	3.4	34.5	43.0
Cobalt	0.25	2.1	1.8	22.0	29.0
	0.5	3.6	3.3	30.5	36.0
Cowdung+Urea (Control)		1.2	0.6	14.7	25.0

In the second series of experiments the plankton production at the end of 30 days was also highest with molybdenum (825 ml/10 l at 0.5 ppm) when compared to other elements used. Next to this was boron (70.0 ml/10 l at 0.5 ppm) followed by zinc (45.0 ml/10 l at 0.5 ppm). The plankton volume was higher in the higher dose of molybdenum, boron, manganese and cobalt as compared to the lower dose and control of cowdung and urea only. In the case of zinc both the doses gave almost equal volumes of plankton (44.0 ml/10 l and 45.0 ml/10 l at lower and higher doses respectively).

In the third series of experiments the growth of fish (mullet fry) was used as an index of efficiency. The fish yield in 15 days was highest with molybdenum and boron, the average increase in weight being 97.0 mg at 0.5 ppm. This was followed by zinc with almost equal average increment at 0.5 ppm and 0.25 ppm (95.0 mg and 96.0 mg respectively). The fish growth was higher in the higher dose of molybdenum, boron, manganese and cobalt and in the case of zinc both the doses gave almost equal growth increments.

Chemical changes :

The relevant data on the physical and chemical characteristics of the soil used are given below

Sand	65.5%
Silt	24.0%
Clay	10.5%
Chloride	2.75%
Free $CaCO_3$	3.40%
Organic carbon	0.48%
Available phosphate	2.4mg/100 g
pH	7.45

The soil was found to be alkaline in reaction low in available phosphate and organic carbon.

The data on water and soil during the course of experiment are given in table 2. The salinity of water ranged from 25.0 to 30.0 ppt during the course of the experiments. The water pH was highest in molybdenum treated jars and it ranged from 7.40 to 9.05 and lowest in manganese (7.2 to 8.4). The higher pH values are an index of greater productivity. The phenolphthalein alkalinity was highest 46.0 to 68 0 ppm in molybdenum treated jars and 48.0 to 52.0 ppm both in boron and zinc. Lowest value of 32.0 to 42.0 ppm was noted in jars treated with manganese.

Plankton production

In all the jars the prominent groups of phytoplankton were diatoms and blue-green algae. Zooplankton was represented mainly by rotifers. In all cases both phyto and zooplankton forms were present except in cobalt where no zooplankton was noticed.

The phytoplankton encountered were mainly, *Pleurosigma* spp., *Amphora* spp., *Diploneis* sp., *Nitzschia* spp., *Navicula* spp , *Oscillatoria* spp., *Lyngbya* sp. and *Spirulina* sp. and zooplankters were *Brachionus* spp., *Paracalanus* sp., *Oithona* sp., *Pseudodiaptomus* sp., nauplii, *Vorticella* sp., other ciliates and nematodes.

TABLE 2

Details of water and soil analysis

Parameter	Molybdenum	Boron	Zinc	Manganese	Cobalt	Control
Water pH	7.4-9.05	7.6-8.9	7.4-8.75	7.2-8.4	7.7-8.6	7.4-8.25
Salinity ppt	26.0-30.0	25.0-30.0	26.0-30.0	25.0-30.0	26 5-30.0	25.0-30.0
P. alkalinity ppm	46.0-68.0	48.0-52.0	48.0-52.0	32.0-42.0	34.0-46.0	32.0-38.0
M. O. alkalinity ppm	76.00-184.00	64.0-184.0	66.0-176.0	64.0-88.0	64.0-176.0	64.0-88.0
Phosphate ppm	0.03-0.97	0.03-0.80	0.03-0.92	0.03-0.62	0.03-0.6	0.03-0.5
D. O. ppm	1.2-8.8	1.6-8.8	1.6-8.8	2.0-8.4	1.6-8.0	2.4-8.0
Soil pH	7.25-8.55	7.45-8.3	7.45-8.35	7.45-8.2	7.45-8.1	7.45-8.1
Organic carbon %	1.08-1.38	1.08-1.23	0.66-1.02	0.63-0.96	0.57-0.96	0.54-0.9
Ava. phosphate mg/100g	2.8-5.8	2.8-4.0	2.8-4.8	2.6-4.5	2.6-3.4	2.6-3.0

DISCUSSION

According to Hutchinson (1957) nature of the pond can be known from the dissolved oxygen values than from any other chemical parameter. The dissolved oxygen ranged from 1.2 to 8.8 ppm in molybdenum treated jars, 1.6 to 8.8 ppm both in boron and zinc and in manganese it was 2.0 to 8.4 ppm. All the samples were collected between 09.30 and 09.45 hrs. The molybdenum treated jars had lowest dissolved oxygen (1.2 ppm) and manganese had highest (2.0 ppm). Low oxygen in the early mornings and supersaturation values in the afternoons indicate high rate of production. The marked fluctuations observed in dissolved oxygen, pH and alkalinity in the treated jars as compared to those of the control jars may be due to the increased biological turn over in the treated jars.

In all the cases phosphate was detected throughout the period in spite of increased plankton production and an increase of available phosphate content in the soil phase. This may be due to the release of inorganic phosphate by the decomposing cowdung. In the treated jars the phosphate content was always higher when compared to control of cowdung and urea. This may brobably be due to the effect of trace elements on the mineralisation of organic matter.

While discussing the rate of organic production in the marine environment Prasad (1967) mentions "it is the rate of replenishment of the nutrients in the euphotic zone and not the concentration observed at a given time which determines the productivity". Thus as the phytoplankton population uses up the important nutrient items like nitrogen and phosphorus the system is to be replenished with fresh supplies of these elements in the available form. This can be done either by addition of fertilizer or by mineralisation within the system itself. In the latter process trace elements are probably playing a vital role thus preventing some of the major nutrient elements from acting as limiting factors.