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Karyotypes of parasitic wasps of the family Eulophidae (Hymenoptera): new data and review

Кариотипы наездников семейства Eulophidae (Hymenoptera): новые данные и обзор

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КЛЮЧЕВЫЕ СЛОВА: хромосомы, кариотипы, Hymenoptera, Eulophidae.

ABSTRACT: A review of karyotypes of the family Eulophidae is given, including new chromosomal data for 10 species. Almost all newly studied species (*Entedon* sp., *Aprostocetus (Aprostocetus)* sp. (group *lycidas*), *Aprostocetus (Aprostocetus)* sp. 2, *Baryscapus evonymellae*, *Baryscapus* sp. 1 (group *evonymellae*), *Baryscapus* sp. 2 (group *evonymellae*), *Tetrastichus (Tetrastichus)* sp. 2, *Tetrastichus (Musciformia) atratulus* and *Euplectrus flavipes*) have 2n = 12 and/or n = 6, but *Aprostocetus (Aprostocetus)* sp. (group *epicharmus*) has 2n = 10. Chromosome numbers in the Eulophidae range from n = 5 to n = 8. The haploid karyotype with five long metacentric chromosomes and a short acrocentric is considered to be initial for the family.

РЕЗЮМЕ: Дан обзор кариотипов наездников семейства Eulophidae, включая новые данные о хромосомах 10 видов. Почти все вновь изученные виды (*Entedon* sp., *Aprostocetus (Aprostocetus)* sp. (группа *lycidas*), *Aprostocetus (Aprostocetus)* sp. 2, *Baryscapus evonymellae*, *Baryscapus* sp. 1 (группа *evonymellae*), *Baryscapus* sp. 2 (группа *evonymellae*), *Tetrastichus (Tetrastichus)* sp. 2, *Tetrastichus (Musciformia) atratulus* и *Euplectrus flavipes*) имеют 2n = 12 или (и) n = 6, но *Aprostocetus (Aprostocetus)* sp. (группа *epicharmus*) имеет 2n = 10. Количество хромосом эвлофид может варьировать от n = 5 до n = 8. Гаплоидный кариотип с пятью длинными метацентрическими хромосомами и одним коротким акроцентриком считается исходным для семейства.

Eulophidae is one of the largest and most diverse families of the superfamily Chalcidoidea. It contains about 300 genera and 3400 species [Grissell & Schauff, 1997]. A review of karyology of parasitic wasps of the family Eulophidae was published a few years ago ([Gokhman, 2002]; see also [Gokhman, 2003]). However, this review did not include chromosome numbers reported by Silva-Junior et al. [2000]. Moreover, new data on karyotypes of the Eulophidae were obtained during the last years. These results are given and discussed below.

Materials and methods

Adult females of Eulophidae were collected in the Moscow (Botanical Garden, Moscow State University, Moscow, and Ozhigovo, 60 km SW Moscow) and Volgograd regions (the Pichouga River, 30 km NE Volgograd) in 2001–2003. All species were collected by beating except for *Baryscapus evonymellae* [Bouché, 1834], which was reared from *Yponomeuta malinellus* [Zeller, 1838] (Lepidoptera, Yponomeutidae). Chromosome preparations were obtained from ovaries according to the standard technique for studying chromosomes in adult females of parasitic wasps [Gokhman & Quicke, 1995]. Cell divisions were studied and photographed using the optic microscope Zeiss Axioskop 40 FL fitted with the digital camera AxioCam MRc. To obtain karyograms, the resulting images were processed with the image analysis program AxioVision version 3.1 and Adobe Photoshop version 6.0. Mitotic chromosomes were classified in four groups (metacentric — M, submetacentric — SM, subtelocentric — ST and acrocentric — A) according to the works by Levan et al. [1964] and Imai et al. [1977], meiotic ones — according to the monograph by Darlington [1965]. Arm numbers (NF) were also calculated. Parasitic wasps were identified by the author, identifications were confirmed by V.V. Kostjukov (All-Russian Institute for Biological Plant Protection, Krasnodar). Voucher specimens are deposited in the Zoological Museum, Moscow State University, Moscow.

Results

Subfamily Entedoninae

Entedon sp. (Fig. 1). 2n = 12 (10M + 2A); NF = 22. Acrocentric chromosomes of the last pair are much smaller than the others. Homologous chromosomes of the third and fourth pairs are unequal in their size and shape.

Subfamily Tetrastichinae

Aprostocetus (*Aprostocetus*) sp. [group *lycidas* (Walker)] (Fig. 2). 2n = 12 (10M + 2A); NF = 22. The overall structure of the karyotype as in the previous species. Homologous metacentrics of certain pairs are unequal in their size and shape.

Aprostocetus (*Aprostocetus*) sp. [group *epicharmus* (Walker)] (Fig. 3). 2n = 10 (10M); NF = 20. Metacentric chromosomes of the first three pairs are moderately longer than the others.

Aprostocetus (Aprostocetus) sp. 2 (Fig. 4). 2n = 12 (10M + 2A); NF = 22. The overall karyotype structure as in the majority of the Eulophidae, but homologous chromosomes of certain pairs differ in their size and shape.

Baryscapus evonymellae (Bouché, 1834) (Fig. 5). 2n = 12 (10M + 2A); NF = 22. Karyotype structure as in many other members of the family.

Baryscapus sp. 1 (group *evonymellae*) (Fig. 6). 2n = 12 (10M + 2A); NF = 22. Karyotype as in the previous species.

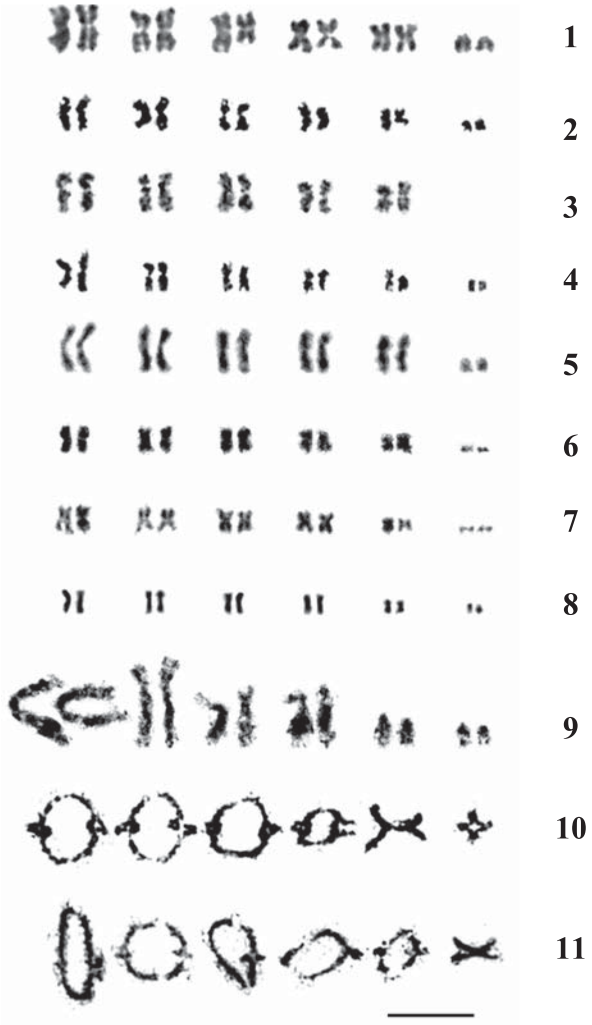
Baryscapus sp. 2 (group *evonymellae*) (Fig. 10). n = 6. The meiotic karyotype contains four larger bivalents (each of them bears two chiasmata) and two smaller ones (each of them has the only chiasma). The sixth bivalent is much smaller than the fifth one.

Tetrastichus (Tetrastichus) sp. 2 (Figs 7, 11). n = 6, 2n = 12 (10M + 2A); NF = 22. Metacentric chromosomes of the fifth pair are substantially smaller than those of the fourth one and comparable in size with acrocentrics of the last pair. Each of the five larger bivalents has two chiasmata, but the last bivalent bears the single chiasma. Two smallest bivalents are comparable in size.

Tetrastichus (Musciformia) atratulus (Nees, 1834) (Fig. 9). 2n = 12 (10M + 2A); NF = 22. Karyotype structure as in *Tetrastichus (Tetrastichus)* sp. 2.

Subfamily Eulophinae

Euplectrus flavipes (Fonscolombe, 1832) (Fig. 9). 2n = 12 (2M + 6SM + 4A); NF = 20. Chromosomes of the first two pairs are substantially larger than the others. Acrocentrics of the fifth and sixth pairs are much shorter than the other chromosomes.



Figs 1–11. Mitotic (1–9) and meiotic diplotene (10–11) karyograms of Eulophidae: 1 — *Entedon* sp., 2 — *Aprostocetus (Aprostocetus)* sp. (group *lycidas*), 3 — *Aprostocetus (Aprostocetus)* sp. (group *epicharmus*), 4 — *Aprostocetus (Aprostocetus)* sp. 2, 5 — *Baryscapus evonymellae*, 6 — *Baryscapus* sp. 1 (group *evonymellae*), 7, 11 — *Tetrastichus (Tetrastichus)* sp. 2, 8 — *Tetrastichus (Musciformia) atratulus*, 9 — *Euplectrus flavipes*, 10 — *Baryscapus* sp. 2 (group *evonymellae*). Scale bar indicates 10 μm.

Рис. 1–11. Кариограммы хромосом семейства Eulophidae в митозе (1–9) и диплотене мейозе (10–11): 1 — *Entedon* sp., 2 — *Aprostocetus (Aprostocetus)* sp. (группа *lycidas*), 3 — *Aprostocetus (Aprostocetus)* sp. (группа *epicharmus*), 4 — *Aprostocetus (Aprostocetus)* sp. 2, 5 — *Baryscapus evonymellae*, 6 — *Baryscapus* sp. 1 (группа *evonymellae*), 7, 11 — *Tetrastichus (Tetrastichus)* sp. 2, 8 — *Tetrastichus (Musciformia) atratulus*, 9 — *Euplectrus flavipes*, 10 — *Baryscapus* sp. 2 (группа *evonymellae*). Масштаб 10 μm.

Discussion

The haploid chromosome number in the Eulophidae ranges from 5 to 8 (Table). The new data confirm previous conclusions that n = 6 is the modal value for the whole family [Silva-Junior et al., 2000; Gokhman 2002, 2003]. This is also true for all its larger taxa, i.e. the subfamilies Entedoninae, Tetrastichinae and Eulophinae. The haploid set of five long bi-armed chromosomes and a short acro- or subtelocentric one is suggested to be initial for the Eulophidae [Gokhman 2002, 2003], although a few exceptions have been found up to now, namely: *Aprostocetus (Aprostocetus)* sp. 1 and *Aprostocetus (Aprostocetus)* sp. (group *epicharmus*), *Melittobia chalybii* and *Euplectrus bicolor* with n = 5, *Euplectus* sp. and *Euplectrus flavipes* (both have n = 6, but their karyotypes contain two pairs of small acrocentrics), *Aprostocetus (Hyperteles) elongatus* and *Trichospilus diatraeae* with n = 7 as well as *Elachertus* sp. with n = 8.

Chromosomal rearrangements involved in the karyotype evolution of the Eulophidae possibly include chromosomal fusions in a few species having n = 5. Interestingly, the smallest chromosome fused to one of

Table
Chromosome numbers in the family Eulophidae. Numbers given in brackets are extrapolated from the known ones
Таблица
Хромосомные числа наездников семейства Eulophidae. Числа в скобках экстраполированы по известным данным

Species	Chromosome no. n	2n	Reference
Subfamily Entedoninae			
Emersonella sp.	(6)	12	Silva-Junior et al., 2000
Entedon sp.	(6)	12	Present paper
Mestocharis bimacularis Dalman	(6)	12	Gokhman, 2003
Pediobius cassidae Erdös	(6)	12	Gokhman, 2002
P. planiventris Walker	6	(12)	Gokhman, 2003
Subfamily Tetrastichinae			
Aprostocetus (s.str.) sp. [group *epicharmus* (Walker)]	(5)	10	Present paper
Aprostocetus (s.str.) sp. [group *lycidas* (Walker)]	(6)	12	Present paper
Aprostocetus (s.str.) sp. 1	5	(10)	Gokhman, 2002
Aprostocetus (s.str.) sp. 2	(6)	12	Present paper
A. (Hyperteles) elongatus (Foerster)	(7)	14	Gokhman, 2003
A. (Ootetrastichus) crino (Walker)	(6)	12	Gokhman, 2002
Baryscapus evonymellae (Bouché)	(6)	12	Present paper
B. gigas (Burks)	6	(12)	Goodpasture, 1974
B. megachilidis (Burks)	6	12	Goodpasture, 1974
B. orgyiae Kostjukov	(6)	12	Kostjukov & Gokhman, 2001
B. pallipes Graham	(6)	12	Gokhman, 2003
Baryscapus sp. 1 [group *evonymellae* (Bouché)]	(6)	12	Present paper
Baryscapus sp. 2 [group *evonymellae* (Bouché)]	6	(12)	Present paper
Oomyzus galerucivorus (Hedqvist)	(6)	12	Gokhman, 2002
Melittobia australica Girault	(6)	12	Silva-Junior et al., 2000; Maffei et al., 2001
M. chalybii Ashmead	5	10	Schmieder, 1938; MacDonald & Krunić, 1971
M. hawaiiensis Perkins	(6)	12	Silva-Junior et al., 2000
Palmistichus elaeisis Delvare et LaSalle	(6)	12	Silva-Junior et al., 2000
Tetrastichus (Musciformia) dasyops Graham	(6)	12	Gokhman, 2003
T. (M.) atratulus (Nees)	(6)	12	Present paper
Tetrastichus (s.str.) sp. 1	(6)	12	Gokhman, 2003
Tetrastichus (s.str.) sp. 2	6	12	Present paper
Subfamily Eulophinae			
Tribe Cirrospilini			
Cirrospilus diallus (Walker)	(6)	12	Gokhman & Quicke, 1995
Trichospilus diatraeae Cherian et Margabandhu	(7)	14	Silva-Junior et al., 2000
Tribe Eulophini			
Colpoclypeus florus (Walker)	6	(12)	Dijkstra, 1986
Euplectrus bicolor (Swederus)	(5)	10	Gokhman, 2002
Eu. flavipes (Fonscolombe)	(6)	12	Present paper
Euplectrus sp.	(6)	12	Gokhman, 2002
Elachertus sp.	(8)	16	Gokhman, 2002
Sympiesis acalle (Walker)	(6)	12	Gokhman, 2002
S. sandanis (Walker)	(6)	12	Gokhman, 2002

the larger elements to form a karyotype with n = 5 in all studied cases. On the other hand, an increase in chromosome number in *Aprostocetus* (*Hyperteles*) *elongatus* and *Elachertus* sp. could take place by aneuploidy and the subsequent restoration of even chromosome numbers [Gokhman, 2004]. Signs of reciprocal translocations are found in *A. (H.) elongatus* [Gokhman, 2003] as well as in *Entedon* sp. and some other species.

The characteristic karyotype structure found in many Eulophidae (i.e., the combination of five long metacentric chromosomes with a short acrocentric) may be considered as a possible synapomorphy for the family as a whole [Gokhman, 2003]. Nevertheless, many Torymidae also have similar karyotypes [see e.g. Goodpasture, Grissell, 1975], and therefore this feature can be either a synapomorphy of Eulophidae + Torymidae, or, more likely, it has been independently acquired by the two families [Gokhman, 2004].

Kostjukov [2004] considers *Hyperteles* Foerster, 1856 and *Ootetrastichus* Perkins, 1906 (subgenera of the genus *Aprostocetus* Westwood, 1833 s.l.) as separate genera together with *Aprostocetus* s.str. This is also supported by the fact that members of all these groups have different chromosome numbers, i.e. n = 7, 6 and 5 respectively [Gokhman, 2003]. However, the real pattern appears to be more complex. Specifically, some members of the subgenus *Aprostocetus* also have n = 6.

Karyotype structure of the genus *Tetrastichus* Haliday, 1844 and probably also of some members of the genus *Baryscapus* Foerster, 1856 differs from that basic for the family in having fifth chromosome substantially shorter than in many other Eulophidae (including all remaining Tetrastichinae).

Chromosomal research of the family Eulophidae has also revealed differences between karyotypes of related species (at least those belonging to the same genus (*Aprostocetus* s.l., *Melittobia* Westwood, 1847, *Euplectrus* Westwood, 1832) and even subgenus (*Aprostocetus* s.str.). Therefore chromosomal studies can potentially be used for searching and identifying sibling species in the Eulophidae, as in many other families of parasitic wasps (e.g. Ichneumonidae and Pteromalidae) [Gokhman, 2003 and in press].

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