

The male reproductive organs and karyotype of *Oeclidius* pr. *nanus* Van Duzee: first record for the family Kinnaridae (Homoptera: Fulgoroidea)

Репродуктивные органы самца и кариотип *Oeclidius* pr. *nanus* Van Duzee: первое сообщение для семейства Kinnaridae (Homoptera: Fulgoroidea)

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KEY WORDS: Fulgoroidea, Kinnaridae, *Oeclidius* pr. *nanus*, karyotype, male reproductive organs, testicular follicles, accessory glands, evolution.

КЛЮЧЕВЫЕ СЛОВА: Fulgoroidea, Kinnaridae, *Oeclidius* pr. *nanus*, кариотип, репродуктивные органы самца, семенные фолликулы, придаточные железы, эволюция.

ABSTRACT. The data on the reproductive organs and karyotype of a male of *Oeclidius* pr. *nanus* Van Duzee (the Kinnaridae, the Fulgoroidea) are presented. This is the first record for the family Kinnaridae. The male studied displays testes consisting each of 6 follicles, and a pair of short accessory glands undivided into chambers. The karyotype includes $2n = 25 (24 + X)$. The data obtained are compared with those available for the closely-related to the Kinnaridae families Meenoplidae, Derbidae, Achilidae, and Cixiidae.

РЕЗЮМЕ. Приводится описание кариотипа и репродуктивных органов самца *Oeclidius* pr. *nanus* Van Duzee из ранее не изученного семейства Kinnaridae (Homoptera, Fulgoroidea). Показано, что у самца *O.* pr. *nanus* семенники состоят из 6 семенных фолликулов; имеется пара коротких и не разделённых на части придаточных желёз. Кариотип включает $2n = 25 (24 + X)$. Полученные данные обсуждаются в сравнении с таковыми для близкородственных с Kinnaridae семейств Meenoplidae, Derbidae, Achilidae и Cixiidae.

Introduction

The planthopper family Kinnaridae has been established and described by Muir, who separated the Kinnaridae from the Cixiidae [Muir, 1925, 1930]. The Kinnaridae is one of the small families of the Fulgoroidea, with its higher diversity in the Oriental region of the Old World and in the Neotropic region of the New World. The family is classified into two subfamilies, the Kinnarinae and the Prosotropinae [Fennah, 1945], with a total of about 80 described species referred to 17 genera

[Metcalf, 1945; Emeljanov, 1984]. The family-level systematics of the Kinnaridae is however exclusively poorly advanced; in many cases descriptions of the taxa within the family are not sufficient and highly dissimilar, and the comprehensive generic characters are few in number [Emeljanov, 1984 and a personal communication]. The Kinnaridae are phylogenetically grouped with the families Meenoplidae, Derbidae, and Achilidae, the Kinnaridae being considered as a sister family to the Meenoplidae, and the Cixiidae as a nearest ancestor of the group as a whole [Emeljanov, 1984, 1990, 1991]. Bourgoïn [1993] however treats the Meenoplidae as the daughter family to the Kinnaridae, then, the latter, based on the cladistic terminology, is a paraphyletic group. There is no general consensus among taxonomists as to relationships within the Fulgoroidea if only morphological criteria are used [Ashe, 1988; Emeljanov, 1991; Bourgoïn, 1993; Chen, Yang, 1995], and it becomes apparent that new characters other than morphological ones are required to gain better insight into the phylogeny of the group. Several reports using molecular approaches have recently attempted to address the phylogeny of the Fulgoroidea [Campbell et al., 1995; Bourgoïn et al., 1997; Yeh et al., 1998, 2005] however molecular-based phylogenies using different genes come, on occasion, into conflict not only with morphology-based phylogenies but also to one another.

The data on karyotypes and reproductive organs, primarily because of their evident scarcity for all the families, remain underutilized in phylogenetic investigations of the Fulgoroidea. The sole exception is the family Dictyopharidae, in which changes in the above characters seem to follow significantly the phylogenetic and the taxonomic schemes [Kuznetsova, 1985; Eme-

ljanov et al., 2005; unpublished data]. Knowledge of the cytogenetics of the Fulgoroidea has considerably expanded over the past few decades. The summaries of the available information have been repeatedly presented both for the superfamily as a whole [Halkka, 1959; Kirillova, 1991; Emeljanov & Kirillova, 1991] or for groups of the families [Kuznetsova et al., 1998; Maryacska-Nadachowska et al., 2006]. The majority of data however concern the families Dictyopharidae, Delphacidae and somewhat the Issidae, whereas other families remain extremely poorly studied or unstudied at all, as the Kinnaridae and the Achilixiidae. The data on reproductive organs are also highly fragmentary for all families except for the male Delphacidae [Ivanov, 1928; Lindberg, 1939; Kirillova, 1989; Kuznetsova & Kirillova, 1990]. For other families the information is either completely absent, as for the Kinnaridae, or is confined to number of seminal follicles in males (very rarely to that of ovarioles in females). The variability of this character within the families was shown to tell something about the systematics and family-level relationships within the Fulgoroidea [Emeljanov & Kuznetsova, 1983; Kuznetsova, 1985; Kirillova, 1989; Emeljanov et al., 2005; D'Urso et al., 2005]. The phylogenetic value of this character and some other characters of the internal male and female reproductive apparatuses has been recently discussed by D'Urso et al. [2005].

The objective of this study was to provide first information about chromosomes and male reproductive organs for the family Kinnaridae, in which we have studied a single male of *Oeclidius* pr. *nanus* Van Duzee. The genus *Oeclidius* Van Duzee, 1914, with 22 species described to date, belongs to the subfamily Kinnarinae [Metcalf, 1945]. The data obtained are discussed as compared to the available data on the Fulgoroidea primarily on the closely-related to the Kinnaridae families Meenoplidae, Derbidae, Achilidae, and Cixiidae (the Cixiidae group).

Materials and methods

A single mature male of *O.* pr. *nanus* was collected by A.F. Emeljanov in California (Tulare Co, Lake Success) on 26.VIII.2005. The freshly picked specimen was fixed in 3:1 ethanol-glacial acetic acid solution. For examining the internal reproductive organs, the abdomen of the male was open on a slide in a drop of 45% acetic acid. The gonads were carefully removed dorsally with fine-tipped needles through an incision between the fourth and ninth abdominal segments and spread on the slide to allow tracing all the parts and calculating number of testicular follicles in every testis. Preparations for cytogenetic studies were made up from the follicles, taken in pairs, by a squash method. Cover glasses were removed by a dry-ice technique; slides were air-dried and analyzed under phase contrast at 400 \times . The best preparations were stained using a standard Feulgen-Giemsa procedure [Grozeva & Nokkala, 1996] as follows. They were subjected to hydrolysis in 1 N HCl at

60°C for 7 min and stained in Schiff's reagent for 20 min. After rinsing thoroughly in distilled water, the slides were additionally stained in 4% Giemsa in Sørensen's buffer pH 6.8 for 20 min. The slides were rinsed briefly with distilled water, air-dried and mounted with Entellan. The preparations were analysed with the aid of microscope Leica MM 4000 at 1000 \times , and the photomicrographs were taken using Camera Nikon DS-U1.

Voucher genitalia and other remains of the male are deposited in the Zoological Institute of the Russian Academy of Sciences, St. Petersburg, accompanied by the unique number.

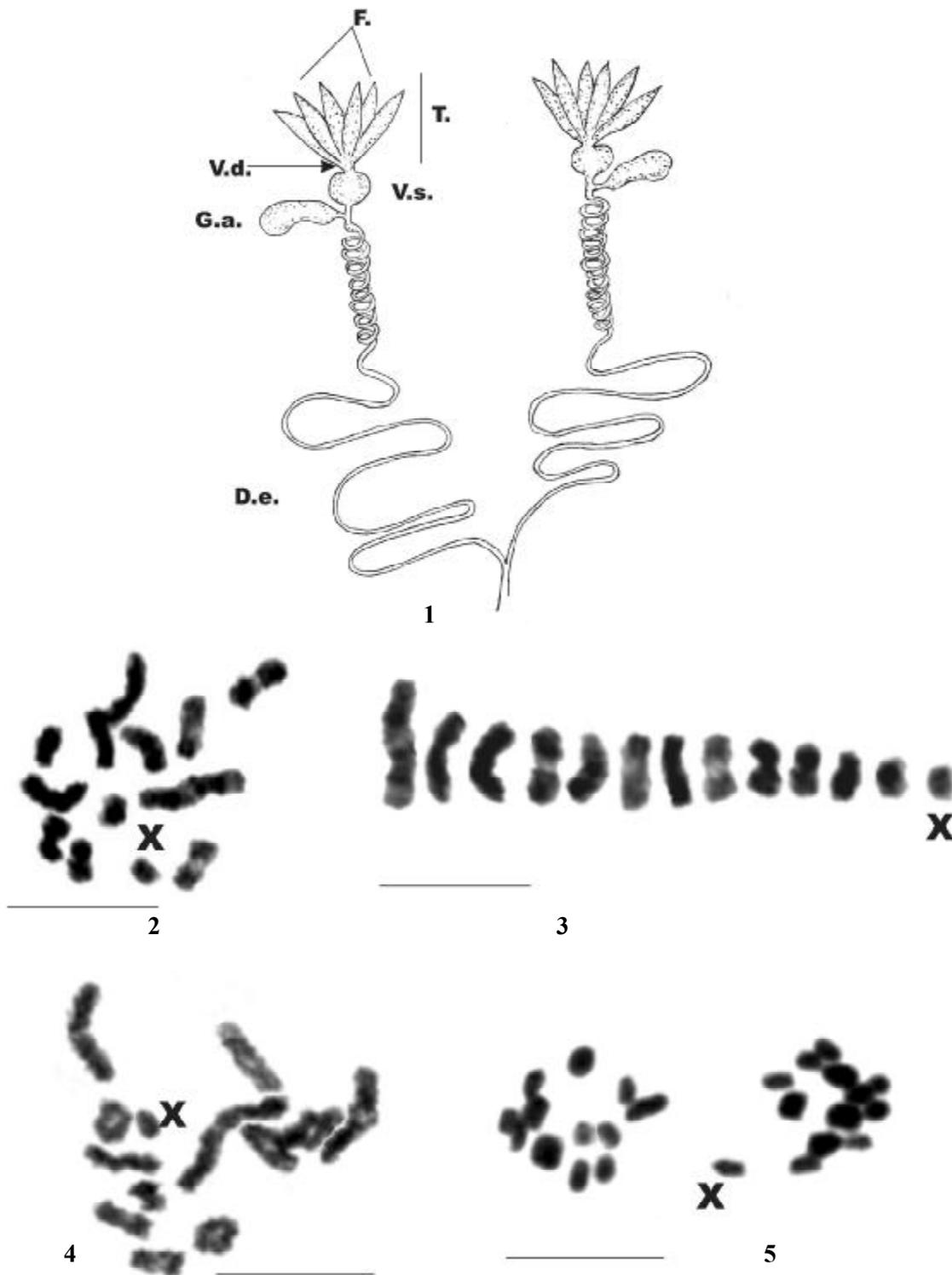
Results

Reproductive organs. The internal reproductive organs of the mature male are located dorsally between the fourth and ninth abdominal segments. Each testis consists of 6 tubular testicular follicles (testis tubes), pointed apically and enclosed by a pale yellow sheath. The follicles display no special stems (vasa efferentia). Each very long and tubular seminal duct (vas deferens) has a well developed, rounded in shape, seminal vesicle situated very close to the testis, and a fairly short, pear-shaped and undivided into chambers accessory gland. The seminal ducts are colorless except in their upper parts, which are red-colored and strongly twisted. The sister lateral ducts go in parallel along the abdomen and then combine to give a common ejaculatory duct, which opens into the aedeagus (Fig. 1).

Karyotype. No spermatogonial divisions have been discovered in the mature male, so they could have occurred in a larval stage. In spermatocyte first metaphases (MI) 12 autosomal bivalents and univalent X chromosome are observed (Figs 2–4). The male chromosome formula of the species is therefore determined as $2n = 25 (24 + X)$. The chromosomes lack a primary constriction, that is, centromere, therefore, they are holokinetic as this is the case in the Homoptera as a whole. The bivalents form a series decreasing in size, three of the bivalents standing out because of their larger sizes. The X is very small and similar in size to one of the smallest half-bivalents (Fig. 3). Each bivalent displays a single terminal or subterminal chiasma (Figs. 2–4). The course of meiosis conforms to the general auchenorhynchan pattern as has been described by Halkka [1959]. Second metaphases (MII) show 13 (12 autosomes + X) or 12 chromosomes, and the X is often seen as a laggard between the two sister MII (Fig. 5).

Discussion

In this paper we have presented results of study of the male reproductive organs and karyotype of *O.* pr. *nanus*. This is the first representative of the fulgoroid family Kinnaridae studied in the above-mentioned respects. We have found *O.* pr. *nanus* to display testes each with 6 tubular follicles, a pair of short accessory glands, undivided into chambers, and the karyotype $2n$



Figs. 1-5. *Oecleidius pr. nanus*: 1 — Schematic representation of the male reproductive organs, dorsal view (T — testis with 6 follicles, F; V.d. — vas deferens; V.s. — vesicula seminalis; G.a. — glandula accessorius; D.e. — ductus ejaculatorius); 2-5 — photomicrographs of several stages of spermatocyte meiosis (2 — MI, $n = 12 + X$; 3 — karyogram, $n = 12 + X$; 4 — early MI, $n = 12 + X$, several bivalents display subterminal chiasmata; 5 — two daughter MII, with $n = 12$ and $n = 13$ ($12 + X$) respectively. The X is seen as a laggard). Scale bars — 10 μm .

Рис. 1-5. *Oecleidius pr. nanus*: 1 — схематическое изображение мужских репродуктивных органов, сверху (Т — семенники с 6 семенными фолликулами, F; V.d. — семяпровод; V.S. — семенной пузырь; G.a. — придаточная железа; D.e. — семяизвергательный канал); 2-5 — микрофотографии нескольких стадий мейоза в сперматогенезе (2 — MI, $n = 12 + X$; 3 — кариограмма, $n = 12 + X$; 4 — ранняя MII, $n = 12 + X$, несколько бивалентов имеют субтерминальные хиазмы; 5 — две дочерние MII с $n = 12$ и с $n = 13$ ($12 + X$) соответственно. X-хромосома отстаёт от аутосом на веретене деления). Масштаб — 10 μm .

= 25 (24 + X). The testes consisting of 6 follicles are accepted as the plesiomorphic condition in the Fulgoroidea [Emeljanov & Kuznetsova, 1983]. Since in insects generally, the primitive number of seminal follicles in males (and also of ovarioles in females) is seven, which correlates with number of pre-genital segments in females [Sharow, 1966], six follicles represent autapomorphy of the Fulgoroidea. In different fulgoroid families, primarily in the most comprehensively studied Delphacidae and Dictyopharidae, 6 follicles per testis are characteristic of the basal taxa, essentially of the tribal or the subfamily levels. Specifically, in the Delphacidae this pattern is unique to the subfamily Asiracinae, while in the Dictyopharidae, to the tribe Ranissini (the Orgeriinae), whereas the more advanced groups within these families show respectively 3 and 4 follicles per testis in males [Kirillova, 1989; Kuznetsova, 1985]. These data suggest a very early and strong stabilization of the testis structure within the groups. In the Fulgoroidea, one clear exception to this pattern is the family Issidae, which shows an intrageneric and even intraspecific variation in follicle number; and no general tendencies are presently discernible, which probably indicates that the evolution of the family is still in progress [Maryńska-Nadachowska et al., 2006]. It is interesting to note that within the Issidae number 6 is not found, whereas more frequent number is 10, probably testifying to an initial stage of stabilization of the character with however a higher modal value as compared to other fulgoroid families, primarily the Delphacidae and the Dictyopharidae [Maryńska-Nadachowska et al., 2006].

As mentioned in Introduction, the Kinnaridae are phylogenetically grouped with the families Meenoplidae, Derbidae, and Achilidae, whereas the Cixiidae are considered as a nearest ancestor of the group [Emeljanov, 1984, 1990, 1991]. The Kinnaridae are treated as either a sister [Emeljanov, 1984, 1990, 1991] or a daughter [Bourgoin, 1993] family to the Meenoplidae. Of these families, the data on follicle number are exclusively fragmentary [summarized by Kuznetsova et al., 1998; see also D'Urso et al., 2005] and presently available for a single species of the Meenoplidae (*N. carolinensis*), 8 species (7 genera) of the Derbidae, 20 species (10 genera) of the Achilidae, and 10 species (7 genera) of the Cixiidae. In every family there are species or sometimes groups of species showing the primitive condition of the testes, i.e. those consisting of 6 follicles. This testis structure is observed in *N. carolinensis* Fennah, belonging to a more primitive subfamily Kermesiinae of the Meenoplidae, and in *Vekunta* sp.n., belonging to the Derbidae (the Cenchreini). In the Achilidae, testes with 3 follicles predominate, and the value 6 could be ancestral one, at least in the subfamily Achilinae [Kuznetsova et al., 1998; D'Urso et al., 2005]. In the Cixiidae, testes with 6 follicles are characteristic of the tribe Pentastirini only, and, based on this character, the tribe appears to be a primitive group, at least within the subfamily Cixiinae. The tendency toward oligomerization of the follicle number, with the lowest value 2 in the genera *Bothriocera* (the Cixiidae) and *Formalevu* (the

Derbidae), is clearly characteristic of the families under discussion, and *Synecdoche helenae* Van Duzee (the Achilidae) is the sole species displaying 7 follicles per testis.

It seems worthwhile to use the follicle number, as a character in investigations of the systematics and evolution of the Fulgoroidea [Emeljanov & Kuznetsova, 1983; D'Urso et al., 2005], as it has been recently done in the family Dictyopharidae [Emeljanov et al., 2005]. In addition, form of accessory glands can be successfully used in taxonomic and phylogenetic investigations of the Fulgoroidea [Kirillova, 1989; D'Urso et al., 2005]. Kirillova [1989] has distinguished several types of accessory glands in the Delphacidae. In the above author's opinion, the primitive glands are long and tubular, and in the evolution of the family glands are shortening and dividing into chambers. If this is indeed the case, the fairly short and undivided glands of male *O. pr. nanus* should be considered as an intermediate evolutionary state of the character.

D'Urso et al. [2005] have discussed the phylogenetic value of different structures of male and female reproductive apparatuses within the Fulgoroidea. In males, such characters, as (1) number of seminal follicles, (2) shape (ampullar or partially twisted) and position (proximal or distal end of vas deferens) of seminal vesicles, (3) shape of accessory glands (long and tubular or short and divided into chambers), and (4) shape (tubular, pear-shaped, both tubular and pear-shaped) and structure of the "ejaculatory duct", might be of phylogenetic interest at the family level or/and at lower levels.

The karyotypes are presently known in 223 species from 137 genera and 17 families of the Fulgoroidea, and the chromosome numbers within this superfamily were found to range from 19 (X0) to 37 (X0) in males [Halkka, 1959; Kirillova, 1986; Emeljanov & Kirillova, 1991; Maryacska-Nadachowska et al., 2006]. The most common karyotypes are $2n = 27 (26 + X)$ and $29 (28 + X)$, however predominance of these conditions is greatly due to the families Dictyopharidae, Delphacidae, and Issidae, in which in aggregate over 140 species have been so far karyotyped [Kuznetsova, 1985; Kirillova, 1991; Kuznetsova, Kirillova, 1990; Tian et al., 2004; Maryacska-Nadachowska et al., 2006]. In the Dictyopharidae, the variability of karyotypes was shown to be of taxonomic and phylogenetic significance [Kuznetsova, 1985; Emeljanov & Kirillova, 1991; Emeljanov et al., 2005]. In the Delphacidae, however, the karyotypic changes demonstrate neither regular trends nor evident association with taxonomy and phylogeny [Kirillova, 1986; Emeljanov & Kirillova, 1991]. Within the Cixiidae-group the data are available for only 3 species of the Meenoplidae, 8 species of the Derbidae, 6 species of the Achilidae, and 6 species of the Cixiidae [reviewed by Kuznetsova et al., 1998; see also Tian et al., 2004]. The karyotypes are diversified between the families and also within the families, and only the Meenoplidae show a single condition $2n = 26 + X$ in *Nisia nervosa* Motsch. (the Kermesiinae), *Meenoplis albosig-*

natus Fieb., and *Meenoplis* sp. (the Meenoplinae). The same karyotype is also found within the Derbidae (in the Cedusinae and the Otiocerinae), except in *Proutista moesta* Westw. (the Otiocerinae) with $2n = 24 + X$, and within the Achilidae (in the tribes Plectoderini and Seviini), except in *Synecdoche helenae* Van Duzee (the Plectoderini) and *Sevia* sp.n. 2, showing respectively $2n = 24 + XY$ and $2n = 22 + XY$. These two last-mentioned karyotypes are indubitably secondary. It is generally accepted that the X0 sex chromosome system is evolutionarily primitive in the Auchenorrhyncha (the same is true for the Insecta as a whole), and that the XY system, with some exceptions (Nokkala et al., 2003) originates from the X0 system by a fusion between the X chromosome and an autosome [Kuznetsova, 1985; Blackman, 1995]. The karyotype $2n = 26 + X$ is not found within the Cixiidae, in which $2n = 18 + X$, $2n = 24 + X$, $2n = 28 + X$, and $2n = 30 + X$ have been so far described. The available data are indubitably inadequate to allow any conclusions. It is noteworthy, however, that the karyotype $2n = 26 + X$ is spread among fulgoroid families most widely (by now it is not found only in the Cixiidae and in the Tettigometridae), and, exclusively on the basis of its predominance, this condition has been taken as a probable ancestral one in the Fulgoroidea as a whole [Kuznetsova et al., 1998; Tian et al., 2004]. If this is correct, then the karyotype $2n = 24 + X$ of *O. pr. nanus*., as well as that of *P. moesta* (the Derbidae) could have independently originated from the ancestral karyotype $2n = 26 + X$ through one autosomal fusion. However the modal condition cannot be equalized *a priori* to the most primitive one, therefore, more research effort is needed to solve the question of ancestral karyotype and main trends of the karyotype evolution within the Fulgoroidea as well as within the Cixiidae-group.

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