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RESEARCH ARTICLE

Antennal morphology in the family Dolichopodidae (Diptera)

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Abstract: Nine hundred eighty species belonging to 182 genera of 15 subfamilies of the family Dolichopodidae were investigated to study antennal morphology. Length measurements of scape, pedicel, postpedicel and arista and height measurements of postpedicel bases were performed, and 4 ratios were selected. Use of morphometric characteristics of Dolichopodidae antennae allows meaningful distinctions between subfamilies to be made. Using these criteria, a cladistic tree of Dolichopodidae subfamilies was built.

Key words: Diptera, Dolichopodidae, antenna, morphology.

Introduction

Antennae of adult flies are important sense organs and play an important role in insect activity. Besides, considerable morphological variability of antennal structures makes them a major diagnostic characteristic in insect taxonomy. Characteristics of antennal morphology have been extensively studied (Mc–Alpine 2010), widely used in generic tables and accepted as a perspective for taxonomy and understanding of evolutionary processes (Stuckenberg 1999).

Dolichopodidae antennae comprise four segments. Distinctions between segment form and size, existence (or lack) of hairs and processes, and also location of arista are important characteristics for genera identification. Their color can have both specific and generic diagnostic characteristics.

The first antennal segment (scape) of various genera can be bare or covered with hairs (species *Argyra* Macquart, 1834, subfamily Dolichopodinae − with the scape bearing some dorsal bristles; species *Melanderia* Aldrich, 1922 with the scape bearing ventral bristles). Sometimes the scape is extended and thickened (some species of *Rhaphium* Meigen, 1803).

Its length can vary, but frequently the scape is short, several times shorter than the postpedicel.

The second antennal segment (pedicel) is usually slightly wider than the scape, rounded at the end, bearing a ring of noticeable bristles and can have a finger-shaped process which project to the congruous fossa in the medial part of the postpedicel (species *Syntormon* Loew, 1857).

The third antennal segment (postpedicel) can be triangular (species *Diaphorus* Macquart, 1824), or leaf-shaped, roundish (males of *Chrysotus* Meigen, 1824), reniform (males of *Trigonocera* Becker, 1902) or conic (species *Argyra* Macq., *Falbouria* Dyte, 1980). The postpedicel can have some bristles (species *Conchopus* Takagi, 1965) or not. Postpedicel length is an important diagnostic characteristic within subfamilies and genera: its length can exceed its width by several times (some species of *Rhaphium* Meig.), or it can be short and not exceed (or slightly exceed) its width (species *Chrysotus* Meig.).

The postpedicel is usually much longer than the pedicel, and can be compressed laterally (species of genus *Nematoproctus* Loew, 1857). Species of genus *Machaerium* Haliday, 1832 have an incision underneath on the main part of the postpedicel. Varations in postpedicel morphology are common in the family: for example, the male postpedicel has two long processes in genus *Eucoryphus* Mik, 1869, the female postpedicel has a noticeable incision, and species *Hydrophorus* Fallen, 1823 has an apicoventral notch.

Sexual dimorphism often occurs in the shape of the postpedicel. For example, the postpedicel of males of *Argyra* Macq., *Syntormon* Lw., *Rhaphium* Meig. and *Systenus* Loew, 1857 is much longer than high, while the postpedicel of females of the same genera is much shorter. The ratio of postpedicel length to its width at the base is often used as a diagnostic characteristic of genus *Dolichopus* Latreille, 1796.

The postpedicel bears an arista which has two segments in the majority of Dolichopodidae. However, the arista has only one segment in species *Ludovicius* Rondani, 1843. The arista is usually long and thin, but is especially extended in species of Sciapodinae, such as *Chrysosoma* Guerin-Meneville, 1831 and *Plagiozopelma* Enderlien, 1912. The arista can be located on the apical part of the postpedicel like in the majority of species *Rhaphium* Meig. and *Syntormon* Lw., or on the dorsal part as is the case with genera *Neurigona* Rondani, 1856 and *Dolichopus* Lart.

However, its position can be both a generic and specific feature. In different species (*Argyra* Macq., *Diaphorus* Meigen, 1824, *Hydrophorus* Fall., *Thinophilus* Wahlberg, 1844, *Chrysotimus* Loew, 1857, etc.), the arista can be located apically or subdorsally. The arista can be very pilose (species *Poecilobothrus* Mik, 1878) or bear short hairs (some species of *Dolichopus* Lart. and *Hercostomus* Loew, 1857), or be mostly bare (species *Tachytrechus* Haliday, 1851). Sometimes the apical part of the arista has enlargements. For example, males of *Sybistroma* Meig. have one or two enlargements on their arista.

The following characteristics have been used for generic diagnoses in Dolichopodidae (Becker 1917-1918; Stakelberg 1933; Parent 1938; Robinson 1975; Bickel 1994; Brooks 2005; Grichanov *et al.* 2011):

1) Position of arista; 2) Pubescence of arista; 3) Existence of enlargements on arista; 4) Existence of hairs on scape; 5) Form and size of scape; 6) Form and size of postpedicel and 7) Existence of process on pedicel.

Material and methods

The aim of this research is to identify new taxonomic characters in antennal morphometry and morphology in Dolichopodidae flies, and to use those characters for

identification of subfamilies and for phylogenetic study. Our focus was on the quantitative antennal characteristics of the representatives of various genera of Dolichopodidae.

Nine hundred eighty species belonging to 182 genera of 15 subfamilies of family Dolichopodidae were investigated. Measurements of the lengths of scape, pedicel, postpedicel, arista and the height of postpedicel at its base were performed, and 4 ratios were selected. Measurements were taken according to lateral microphotos and drawings in the Adobe Illustrator program, and also by means of an eyepiece micrometer.

For studying the variability of morphometric antennal characteristics of Dolichopodidae, dispersion analysis was applied. This revealed significant deviations of distinctions of Dolichopodidae subfamilies from each other. Thus, it was shown that features of antennae morphometry play a role in dispersions of subfamilies, while the analysis of intra group distinctions revealed considerable deviations only for subfamily Medeterinae.

Further inspection of the reliability of distinctions was carried out by the nonparametric Kruskal-Wallis test. The obtained data were presented graphically. Using morphometric characteristics of Dolichopodidae antennae allowed us to determine the degree of distinction between the various subfamilies.

Results

The ratio "length of arista / length of postpedicel" is the most representative (Fig. 1). This indicator possesses maximal uniformity within subfamilies with trebled root-mean-square deviation values within limits. Sciapodinae significantly differs from all other subfamilies by this factor, because the extended arista is typical for most representatives of Sciapodinae.

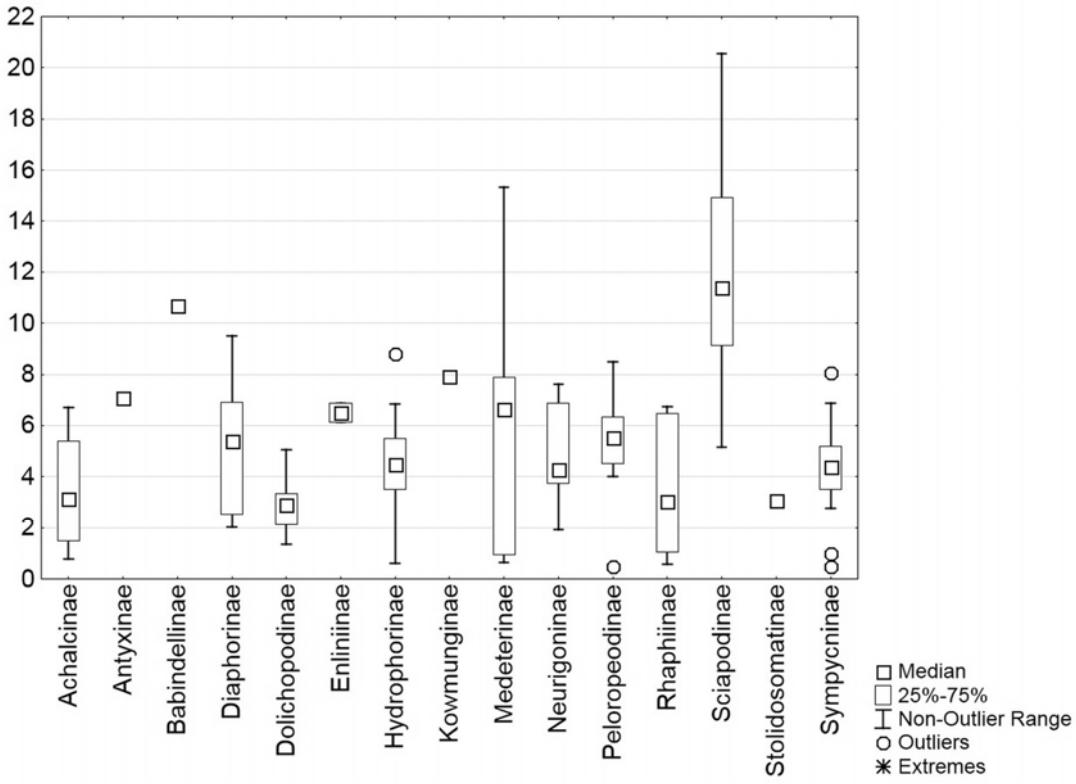

Figure 1. The diagram of median test results for ratio "length of arista / length of postpedicel" for Dolichopodidae subfamilies (Statistica 10).

The confidence range for the subfamily Medeterinae is increased because of the obvious differentiation of the subfamily into two groups by the criterion of relative postpedicel length: tribe Systenini representatives have significantly elongated postpedicel while tribe Medeterini representatives have relatively short postpedicel.

Statistically reliable distinctions by this criterion can be used for taxonomical differentiation of subfamilies Dolichopodinae, Hydrophorinae and Peloropeodinae (Table 1). Confidence ranges of other subfamilies overlap with each other, and reliable distinctions can not be made.

Table 1. Diagnostically significant morphometric ratios for Dolichopodidae subfamilies.

Subfamily	Length of arista / length of postpedicel	Length of postpedicel / height of postpedicel	Length of postpedicel / Length of pedicel
Dolichopodinae	3,13±0,32	1,53±0,25	4,12±0,60
Hydrophorinae	4,09±0,17	1,81±0,11	3,35±0,19
Neurigoninae	4,94±0,65	1,48±0,38	3,88±0,52
Peloropeodinae	6,07±0,89	1,11±0,35	1,75±0,41
Sciapodinae	12,84±0,83	1,38±0,42	2,22±0,56

The ratio "length of postpedicel / height of postpedicel" is not reliable, and there are extreme outliers for the subfamilies Sympycninae (species *Nothorhaphium* Bickel, 1999, *Chaetogonopteron* De Meijer, 1913 and *Anepsiomyia* Bezzi, 1902), Sciapodinae (species *Gigantosciapus* Grichanov, 1997) and Hydrophorinae (species *Machaerium* Hal. and *Aphrosylus* Haladay, 1851) (Fig. 2). Accordingly, this criterion can not be used as diagnostic for these subfamilies.

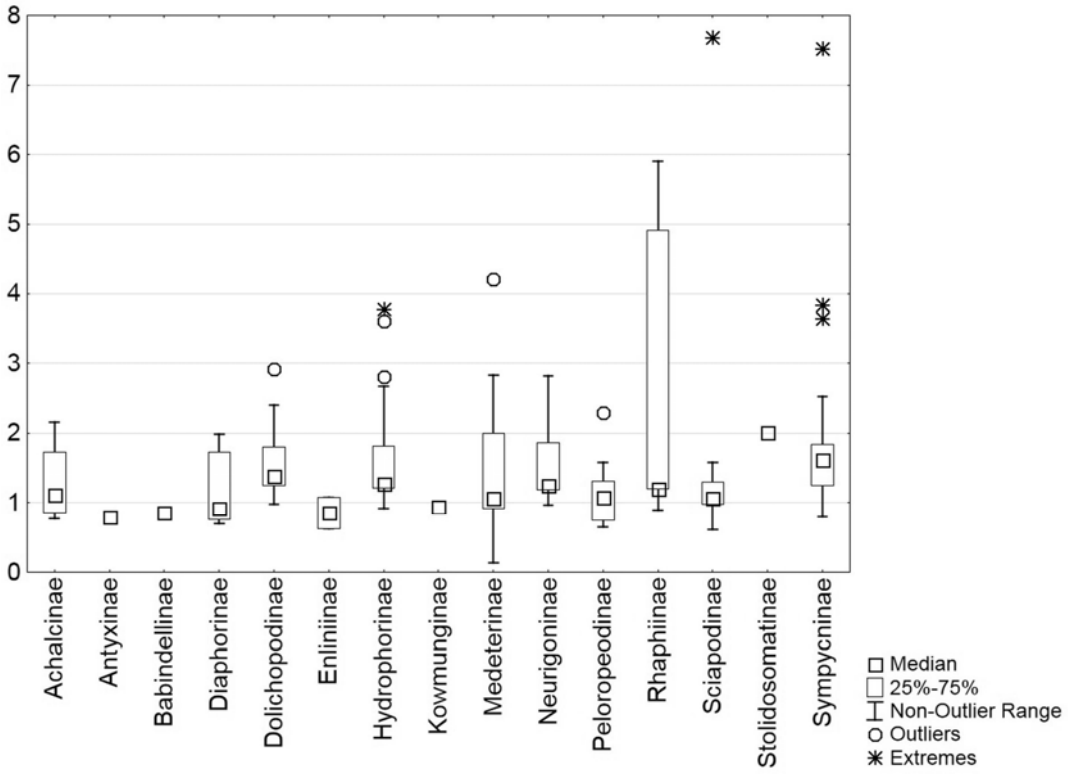

Figure 2. The diagram of median test results for ratio "length of postpedicel / height of postpedicel" for Dolichopodidae subfamilies (Statistica 10).

Although typical for *Rhaphium* Meig., a considerably extended postpedicel is not a feature at the subfamily level for subfamily Rhaphiinae, inasmuch as a shorter postpedicel is characteristic for the species of *Haplopharyngomyia* Meuffels & Grootaert, 1999, *Mischopyga* Grootaert & Meuffels, 1990 and *Urodolichus* Lamb, 1922, resulting in considerable underestimation by statistics.

However, this criterion can be applied to taxonomical differentiation of subfamilies Dolichopodinae and Peloropeodinae, and with less probability to the subfamilies Neurigoninae and Peloropeodinae (Table 1). In other cases, the graphics show mutual overlapping.

The criterion "length of postpedicel / length of pedicel" (Fig. 3) shows narrower limits of confidence ranges than the two previous ratios. However, it can be used as a diagnostic feature in the pairs of Sciapodinae with Neurigoninae or Dolichopodinae (see Table 1).

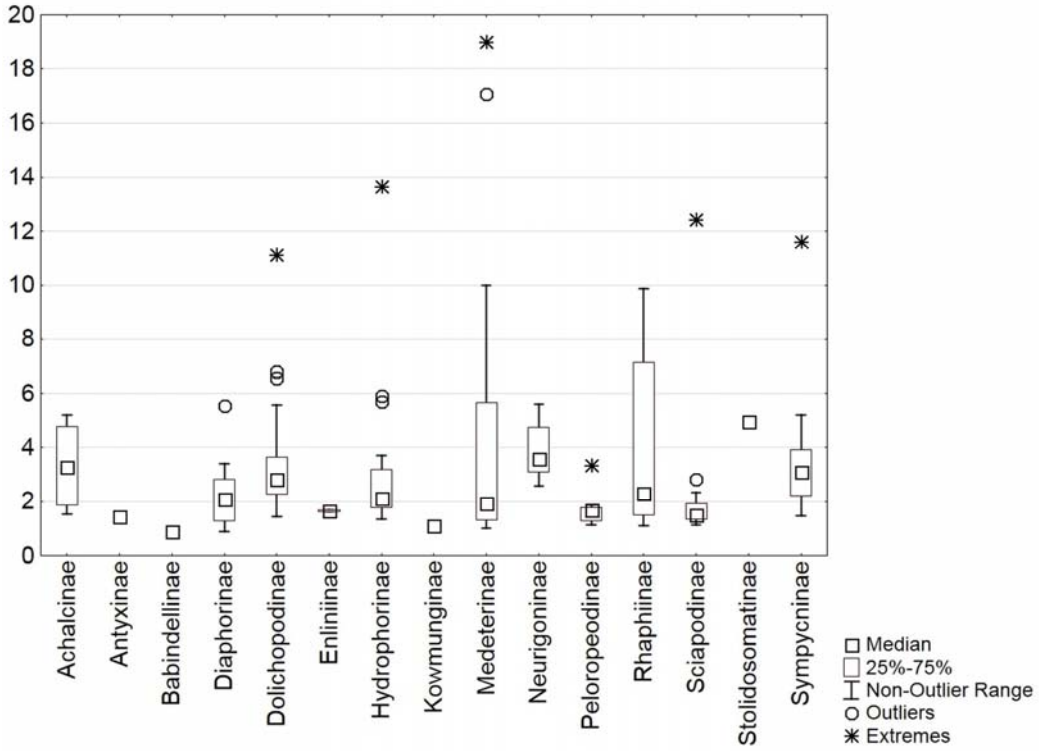

Figure 3. The diagram of median test results for ratio "length of postpedicel / length of pedicel" for Dolichopodidae subfamilies (Statistica 10).

Extreme outliers (species *Nepalomyia* Hollis, 1964) for subfamily Peloropeodinae were found. Confidence ranges for Peloropeodinae and Neurigoninae overlap; therefore, these subfamilies can not be reliably distinguished using this criterion.

The dispersion of values of this indicator in subfamilies Medeterinae and Rhaphiinae is high for the same reasons, as in previous cases.

Comparison of confidence ranges of all subfamilies does not support the use of the ratio "length of postpedicel / length of scape" as diagnostic (Fig. 4).

It is necessary to point out the characters common to a number of the subfamilies, regardless of the systematic position of species, sometimes in rather exceptional cases. For example, an apical enlargement of the arista is observed in both the progressive subfamily Dolichopodinae (species *Hercostomus* Lw., *Paraclius* Lw., *Sybistroma* Meig.) and in the subfamily Sciapodinae, which is the most evolutionarily primitive (according to Wang *et al*.

2007, Negrobov *et al*. 2014) (species *Chrysosoma* Guer.-Men., *Krakatauia* Enderlein, 1912, *Heteropsilopus* Bigot, 1859), in subfamily Sympycninae (*Nothorhaphium* Bick., *Pinacocerus* Van Duze, 1930 and *Yumbera* Bickel, 1922). Enlargement of the arista is a rare character in Hydrophorinae (some species of *Diostracus* Loew, 1861) and Medeterinae (species *Systenus* Lw. and *Papallacta* Bickel, 2006).

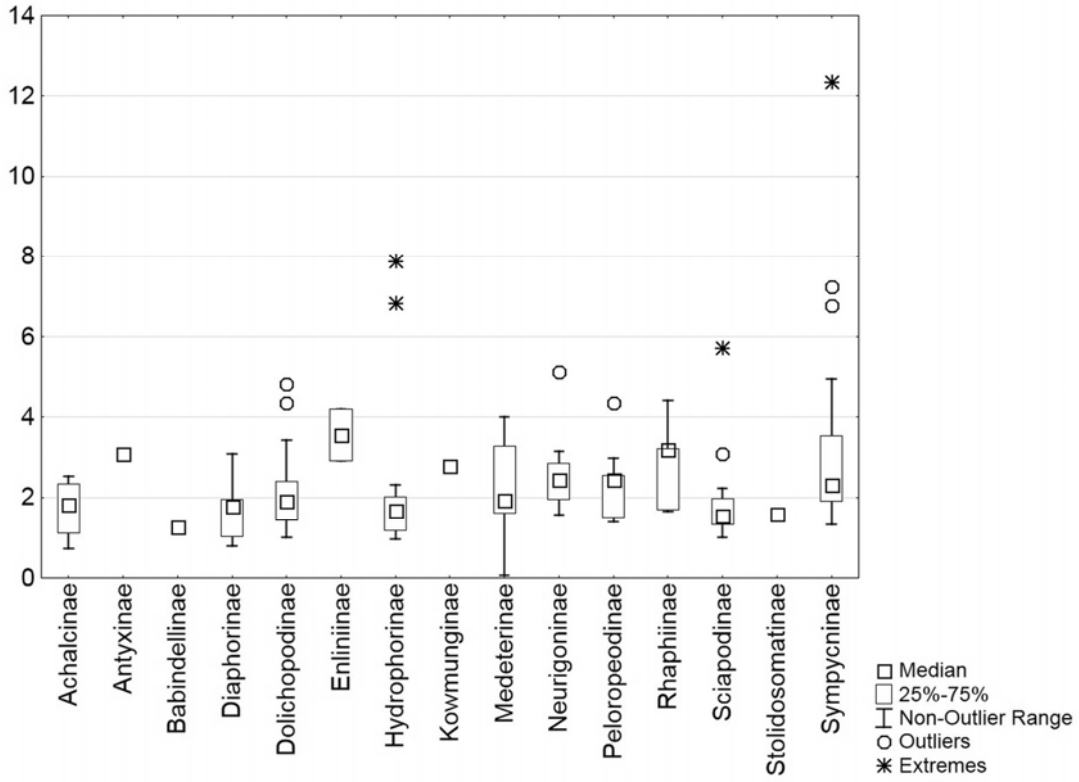

Figure 4. The diagram of median test results for ratio "length of postpedicel / length of scape" for Dolichopodidae subfamilies (Statistica 10).

A process of the pedicel is characteristic of the tribe Thinophilini (subfamily Medeterinae), also of some species of *Tenuopus* Curran, 1924 (Neurigoninae), *Vetimicrotes* Dyte, 1980 (Peloropeodinae), *Australachalcus* Pollet, 2005 (Achalcinae), and of species of genera *Syntormon* Lw., *Ceratopos* Vaillant, 1952 and *Scotiomyia* Meuffels & Grootaert, 1997 (Sympycninae).

Another similar characteristic of the original form of the postpedicel is an apically incised postpedicel with arista placed in an incision. This modification occurs in some species of Diaphorinae (*Chrysotus* Meig.), Sympycninae (*Scotiomyia* Meuff.), Hydrophorinae (*Hypocharassus* Mik, 1879), Peloropeodinae (*Nepalomyia* Holl.) and Medeterinae (*Craterophorus* Lamb, 1921).

These examples suggest that the evolution of antennae took place in parallel for some groups of Dolichopodidae. The transformation of Dolichopodidae antennae possibly developed from an elongated and oval postpedicel with apical arista (Fig 5A) in three directions:

1) Shortening of the postpedicel (*Chrysotus* Meig., *Medetera* Fischer, 1819) (Fig. 5B) with further movement of arista on its dorsal side (*Diaphorus* Meig., *Asyndetus* Loew, 1869) (Fig. 5C).

2) Lengthening of the postpedicel (*Rhaphium* Meig., *Syntormon* Zell.) (Fig. 5D).

3) Displacement of the arista from the apical part of postpedicel to the basal part (*Hypocharassus* Mik) (Fig. 5E). Then shortening of the postpedicel and change of its shape from oval to triangular took place along with the transformation of an apical arista into dorsal arista (*Campsicnemus* Haliday, 1851 (Fig. 5F), *Neurigona* Rond. (Fig. 5G), *Dolichopus* Latr. (Fig. 5H), *Sciapus* Zeller, 1842, *Sympycnus* Loew, 1857 (Fig. 5E).

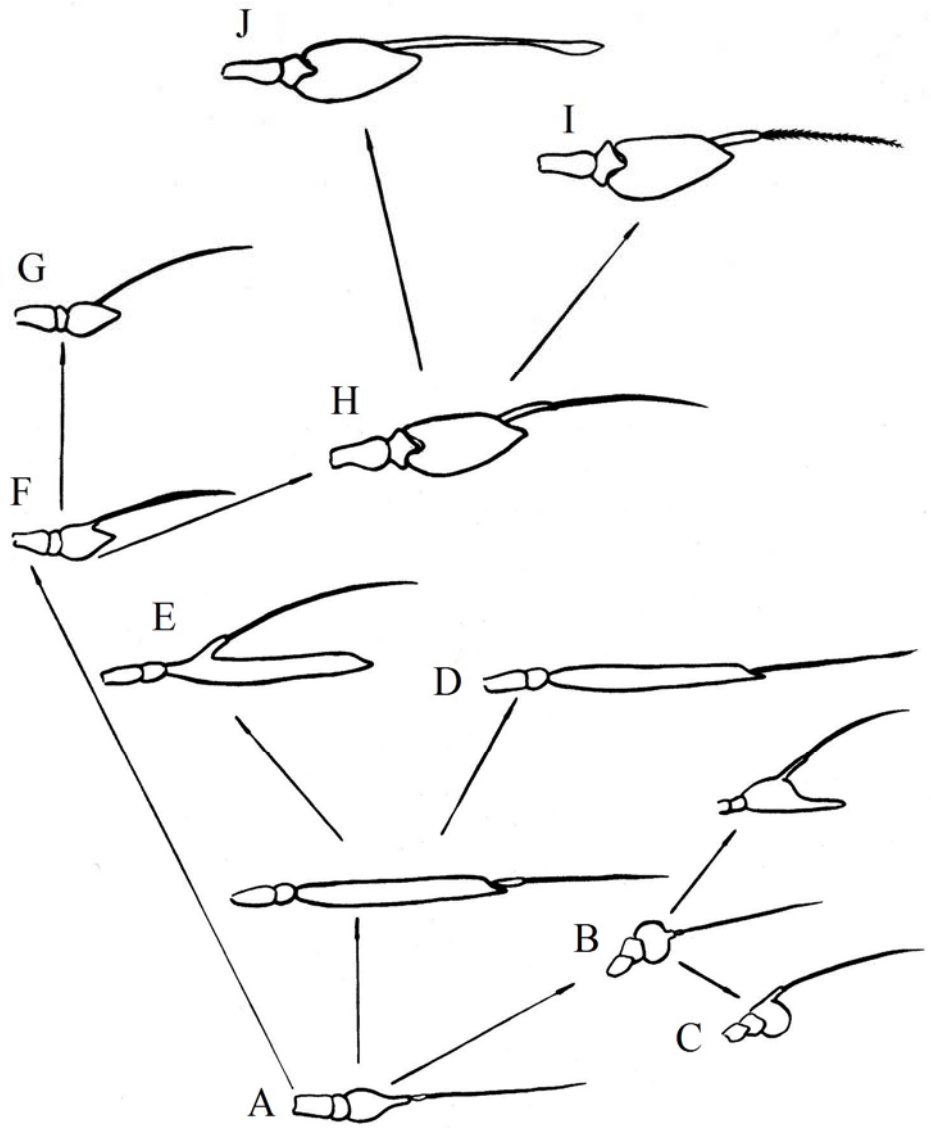

Figure 5. Diagram of possible ways of the antennal evolution in the family Dolichopodidae. **A,** *Achalcus* Loew; **B,** *Chrysotus* Meigen, *Medetera* Fischer; **C,** *Diaphorus* Meigen, *Asyndetus* Loew; **D,** *Rhaphium* Meigen, *Syntormon* Zeller; **E,** *Hypocharassus* Mik; **F,** *Campsicnemus* Haliday; **G,** *Neurigona* Rondani; **H,** *Dolichopus* Latreille; **I,** *Poecilobothrus* Mik; **J,** *Sybistroma* Meigen.

Later the arista of some species developed an apical enlargement and pubescence (Fig. 5I-J).

To build a cladistic tree of the subfamilies (Fig. 6), the following data of typical genera of subfamilies were considered:

1. Scape with hairs (1). Scape bare (0).
2. Scape developed normally (1). Scape extended or swollen (0).

3. Pedicel developed normally (1). Pedicel with process extended (projected?) to postpedicel (0).

4. Postpedicel 1.5 or more times longer than wide at its base (1). Length of postpedicel approximately equal to or less than its height at the base (0).

5. Arista placed on dorsal part of postpedicel (1). Arista placed on apical part of postpedicel (0).

6. Arista simple (1). Arista with enlargement (0).

7. Arista bare or poorly pubescent (1). Arista densely pubescent (0).

8. Arista normal (1). Arista extended (almost 5 times as long as postpedicel and longer), or truncated (not more than 1.5 times as long as postpedicel) (0).

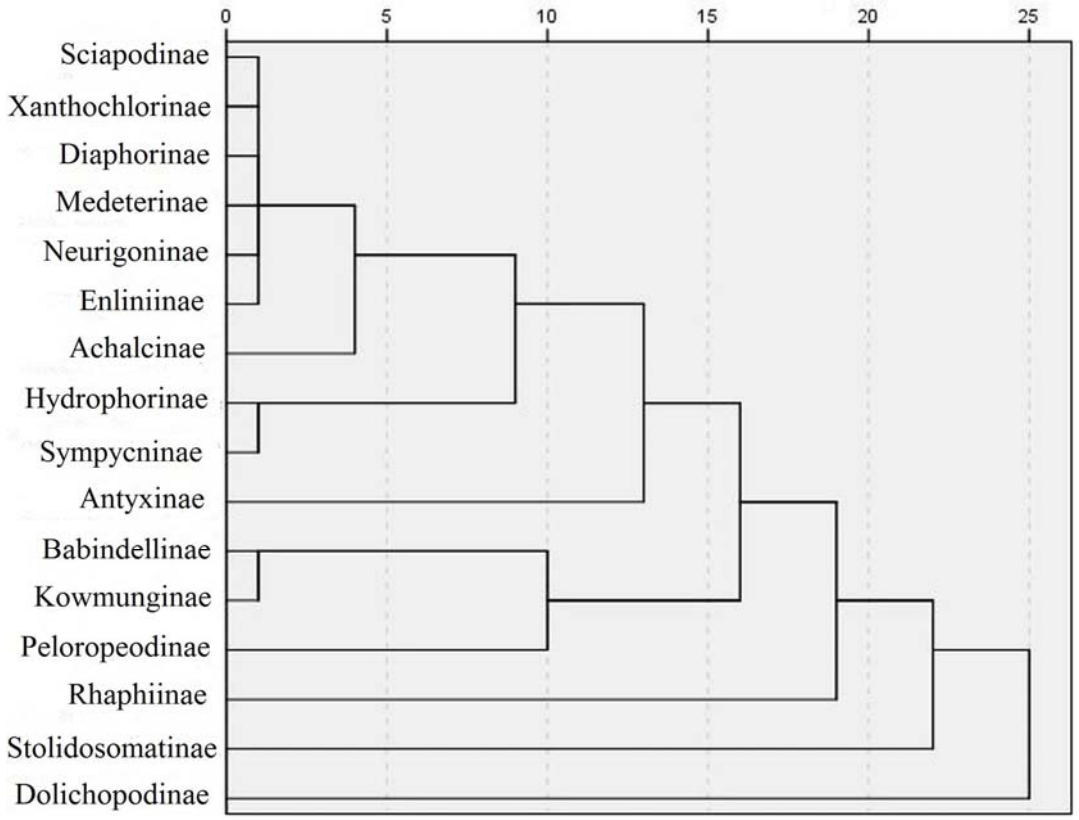

Figure 6. Cladistic tree for antennal morphology in Dolichopodidae subfamilies with using the method of intra-group relations.

Discussion

Representatives of subfamily Dolichopodinae are known as the most progressive of Dolichopodidae. A characteristic feature of this subfamily is a scape with dorsal hairs. Practically all species of Dolichopodinae have dorsal arista. In general this subfamily is characterized by the greatest uniformity of the studied parameters. Significant fluctuations of metric indicators are absent. More or less extended triangular or conic postpedicel with often pointed apex is typical for the majority of Dolichopodinae. However there are some species with shorter postpedicel.

More primitive subfamilies such as Hydrophorinae and Sympycninae are heterogeneous. The morphology of postpedicel is varied; it can be triangular, pear-shaped or

bulb-shaped, strongly extended or truncated. It bears dorsal or apical arista. Some species are remarkable in the truncated arista.

A short postpedicel with rounded apex is characteristic for most representatives of subfamily Diaphorinae. Position of the arista varies considerably in the subfamily and even within genera. Some genera are classified by existence of dorsal hairs on the scape.

Antennae of Neurigoninae are small. The scape is always without dorsal hairs, the postpedicel is usually small, triangular with more or less pointed apex, squeezed from sides, and sometimes considerably extended and rounded at the apex. For this subfamily in general, extended arista, usually bare, only rarely with weakly developed pubescence is characteristic.

Subfamily Sciapodinae is a plesiomorphic group, with highly variable features, reflected by significant fluctuations of the metric characteristics even within genera. Often, sexual dimorphism is found. The scape is bare, the postpedicel is usually small sized and modified – swollen, cup-shaped, seldom more than 1.5 times longer than high at its base. The postpedicel of females of some species is much shorter than that of males, rounded at the apex. The arista is often longer than the body, which is an attributive feature of some genera. The arista can be either dorsal or apical. It should be noted that in this case the arista of females and males can have various positions.

It is necessary to allocate separate branches for Dolichopodinae, Sciapodinae, Hydrophorinae and Neurigoninae. While the intrasubfamily characteristics, and in certain cases, a reduction of the pedicel, formation of the processes on the postpedicel, plumose arista and extended scape should be recognized as secondary modifications in these subfamilies, they appeared after the divergence of evolutionary branches and their manifestation in the investigated material has no systematic significance.

The branches of Medeterinae, Rhaphiinae and Diaphorinae have earlier origins, which is supported by the apical position of the arista and elongated and oval postpedicel (or roundish in Medeterinae that can also be a further modification).

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