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Systematical Studies on the Family Cleridae (Coleoptera) in Inner Western Anatolian Region of Türkiye

Türkiye'nin İç Batı Anadolu Bölgesi'nde Cleridae (Coleoptera) Familyası Üzerine Sistematik Çalışmalar

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ABSTRACT

It was aimed to examine the morphological characteristics of the male reproductive organs in the sampled Clerid species, to discuss them with the existing literature and to contribute to the taxonomy of Cleridae by carrying out a total of 166 days of fieldwork in Inner Western Anatolia covering Afyonkarahisar, northeast of Denizli, Kütahya and Uşak provinces between May-October 2019, March-October 2021 and March-October 2022. In systematic evaluations; 16 species belonging to five genera from two subfamilies were identified by examining 992 specimens collected. The general morphologies of these species were examined, and detailed morphological descriptions were provided. Stereo microscope and Scanning Electron Microscope photographs were taken for the male reproductive organs of 15 and 14 species, respectively. Their drawings and descriptions were compared and discussed in relation to the identified species and literature data.

Key Words
Cleridae, Türkiye, inner Western Anatolia, systematic evaluations.

ÖZ

Mayıs-Ekim 2019, Mart-Ekim 2021 ve Mart-Ekim 2022 tarihleri arasında Afyonkarahisar, Denizli'nin kuzeydoğusu, Kütahya ve Uşak illerini kapsayan İç Batı Anadolu'da toplam 166 gün arazi çalışması yapılarak örneklenen Clerid türlerinde erkek üreme organlarının morfolojik özelliklerinin incelenmesi, mevcut literatür ile tartışılması ve Cleridae taksonomisine katkı sağlanması amaçlanmıştır. Sistematik değerlendirmelerde; toplanan 992 örnek incelenerek iki alt familyadan beş cinse ait 16 tür tespit edilmiştir. Bu türlerin genel morfolojileri incelenmiş ve ayrıntılı morfolojik tanımları yapılmıştır. Stereo mikroskop ve Taramalı Elektron Mikroskobu ile sırasıyla 15 ve 14 türün erkek üreme organlarının fotoğrafları çekilmiştir. Çizimleri ve tanımları, tanımlanan türler ve literatür verileri ile karşılaştırıldı ve tartışıldı.

Anahtar Kelimeler
Cleridae, Türkiye, İç Batı Anadolu, sistematik değerlendirmeler.

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INTRODUCTION

The family Cleridae, also known as checkered beetles, comprises a cosmopolitan group of predatory species [1]. Despite their worldwide distribution, clerids are predominantly found in tropical and subtropical regions [2]. Clerids encompass approximately 4000 described species divided into 300 genera [2-6]. Lastly, Hernández (2021) also stated that the family Cleridae is represented by approximately 4000 species in 334 genera [28].

The male reproductive organ of clerids, characterized by a single-layered ventral phallobase and a double-layered dorsal tegminal plate of the cucujoid type, is typically tubular and inverted [7-9]. This study aims to contribute to Cleridae taxonomy by providing descriptions, drawings, stereo and SEM microscope images of male reproductive organs of Cleridae species collected from the Inner Western Anatolia region.

MATERIALS and METHODS

A total of 166 days of fieldwork were conducted in the Inner Western Anatolia Region, covering Afyonkarahisar, the northeast of Denizli, Kütahya, and Uşak provinces, during May-October 2019, March-October 2021, and March-October 2022. Sampling points, totaling 1,420 localities, were selected randomly during field surveys by predicting potential habitats of Cleridae species. These habitats included forests, meadows, open areas, road and field edges, forest clearings, and river and stream banks. Dissection of the 992 collected specimens involved cutting from the dorsal terminal 3rd or 4th abdominal ventrites after soaking them in distilled water for 18-36 hours to soften. Isolated male reproductive organs from torn abdominal segments were immersed in 10-15% potassium hydroxide (KOH) solution for approximately 24 hours and then rinsed with distilled water on a concave slide to remove non-sclerotized tissues using soft-tipped forceps under the Euromex-Stereoblue microscope. Photographs of male reproductive organs were captured using the Euromex-Stereoblue stereomicroscope. SEM images were taken on a Tescan GAIA 3 Scanning Electron Microscope (SEM). Species identification was conducted using keys for subfamily, genus, and species available in the works of Gerstmeier, Winkler, and Zimmermann[10-15]. Morphological characters of aedeagus images captured with stereo and scanning electron microscopes were examined. A dataset was created and categorized using the examined morphological characters, and dendrograms were obtained by including categorized characters in the clustering analysis using the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) clustering method.

RESULTS and DISCUSSION

In this study, 16 species belonging to two subfamilies and five genera were identified from the Inner Western Anatolia Region of Türkiye. The general morphologies of these species were examined, detailed morphological descriptions were provided, and stereo microscope images of the male individuals of 15 species where available and scanning electron microscope photographs of 14 species were taken, drawn, and described. Detailed descriptions and especially imaging of male reproductive organ morphology is quite scarce in the existing literature. Of the 14 species with scanning electron microscope images of male reproductive organs, 13 were presented for the first time in this study, and of the 15 species with stereo microscope images of male reproductive organs, 10 were presented for the first time in this study.

Key to the Subfamilies

1. Anterior coxal cavities closed internally and externally; eyes, including pronotum, never wider; first tarsomere visible from above (almost equal in size to second. Tarsomere) ..... Tillinae

1'. Anterior coxal cavities never closed internally and almost always open externally; eyes, including head sometimes wider than pronotum; I. tarsomere not visible from above (hidden below second tarsomere) ..... Clerinae

Key to the Genus of Subfamily Clerinae

1. Terminal palpomeres of maxillary and labial palps triangular like an axe 2

1'. Terminal palpomeres securiform of all not triangular like an axe; terminal palpomer of maxillary palp cylindrical 3

2. Eyes with large facets ..... *Opilo*

2'. Eyes with small facets .....*Trichodes*

3. No basal denticle on claws ..... *Allonyx*

3'. Basal tooth present on claws 4

4. Eyes small, lateral on head and distant from each other ..... *Thanasimus*

4'. Eyes large, dorsal on head and close to each other..... *Clerus*

Key to the species of *Genus Thanasimus*

1. All thoracic sternite dark or light black; basal elytra with regular or irregular small rows of dots ..... *femoralis*
1'. All thoracic sternite red; basal elytra with regular or irregular large rows of dots ..... *formicarius*

Key to the species of *Genus Trichodes*

1. Isolated and dark spot present at the humeral corner of each elytron ..... *ganglbaueri*
1'. No isolated and dark spot present at the humeral corners of each elytron 2
2. Terminal 3 antennomeres forming the antennal club yellow..... 8
2'. Terminal 3 antennomeres forming the antennal club black 3
2. Pronotum slightly punctate 4
3'. Pronotum distinctly dotted 6
4. Male metasternum with two prominent bulges; spurs of hind tibiae hooked ..... *crabroniformis*
4'. Male metasternum without two prominent bulges; posterior tibial spurs slightly protruded like a spine..... 5
5. Hind femora strongly thickened; elytral suture not dark ..... *apiarius*
5'. Hind femora slightly thickened; elytral suture dark ..... *longissimus*
6. Apical band surrounds the scutellum and extends towards the humeral underside of the elytron in a branch-like manner..... *suspectus*
6'. Apical band surrounds the scutellum and does not extend towards the humeral underside of the elytron in a branch-like manner..... 7
7. Dark elytral bands do not reach the lateral edge; apical band only reaches the apex of elytra; hind tibia slightly curved .....*punctatus*
7'. Posterior band reaches the lateral edge of elytra; apical band does not reach the apex of elytra; hind tibia slightly curved .....*punctatus* ab. viridifasciata
8. Elytral apex emarginated with tooth, elytral suture toothed at the apex .....*nobilis*
8'. Elytral apex not emarginated with tooth, suture apex variable between blunt and rounded..... 9
9. The hind tibia ends with a broad lamella ..... *laminatus*
9'. The hind tibiae ending with a spine 10
10. Isolated spots present mediolaterally and posteriolaterally on each elytron..... *quadriguttatus*
10'. No isolated spots present mediolaterally and posteriolaterally on each elytron..... *alberi*

Subfamily: Clerinae Latreille, 1802

Genus: *Allonyx* Jacquelin du Val, 1860

Distribution of the genus is limited to *Pinus* genus coniferous forests in the Palearctic region. The morphological structure of the male reproductive organ, being dorsoventrally flattened in general appearance, is considered a specific character for the genus compared to other genera within the family.

***Allonyx quadrimaculatus* (Schaller, 1783) (Figure 1A-B)**

Male Reproductive Organ Morphology (Figure 1C-F): Lateral edges of tegmen parallel, connected ventrally with phallobasic apodeme, more intensely sclerotized towards the apex after the basal 1/3; parameroid lobes shorter than median lobe, rounded distally, triangular; tegminal arms rolled in a bow shape along the lateral edges, connected ventrally with phallobasic apodeme; phallobasic apodeme shorter than 1/3 of tegmen length, long and slender; median lobe rounded towards the apex, longer than parameroid lobes; dorsal sinus extending up to 1/5 of the length of parameroid lobes; ventral sinus above the dorsal sinus.

Male Reproductive Organ Scanning Electron Microscope Morphology (Figure 1G-J): Apex of median lobe densely concave in a disk shape, slightly concave inward from lateral at the apex; parameroid lobes slightly concave inward from lateral at the distal end, with a punctate structure at the apex.

Remarks: No literature descriptions, photographs, or illustrations of the male reproductive organ of this species were found, and this study provides the first detailed description, photographs, and illustrations of the male reproductive organ.

Genus: *Clerus* Geoffroy, 1762

Represented by 11 species in the Palearctic region [5], and four species in Türkiye [1, 19, 20]. From the study area, the species *Clerus mutillaroides* was identified within this genus. Due to the lack of drawings, descriptions, and photographs of the male reproductive organ of this species in the existing literature, it could not be discussed. When compared with other species within the family, no morphological characteristics specific to the genus were observed.

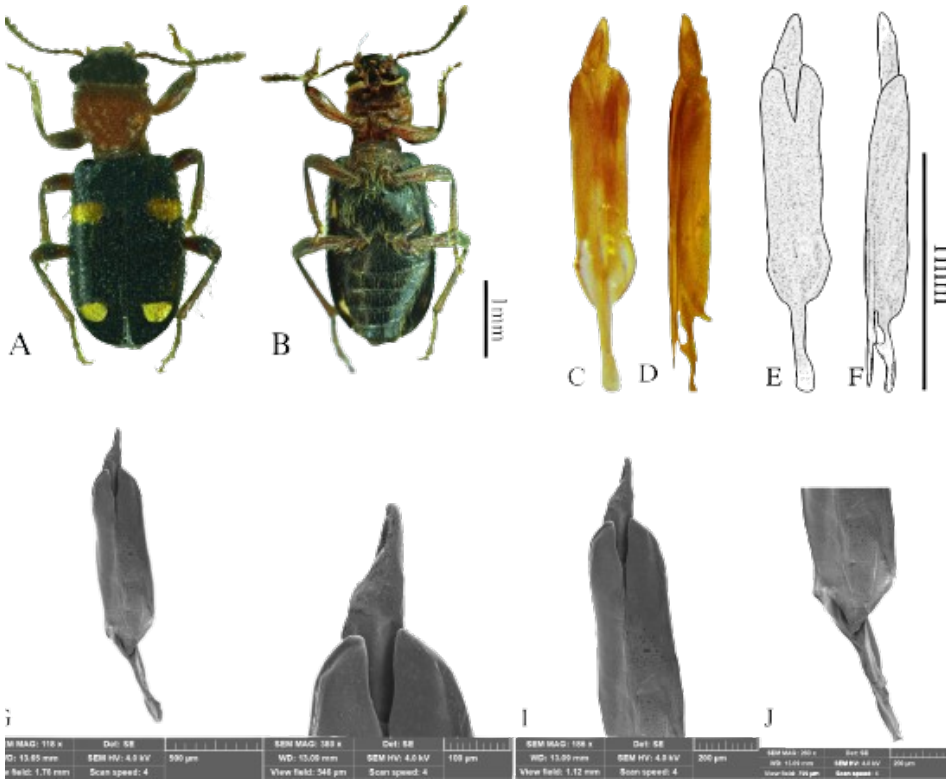

Figure 1. *Allonyx quadrimaculatus*, A. Habitus dorsal, B. Habitus ventral, C-F. Aedeagus photos and drawings, C-E. Aedeagus dorsal, D-F. Aedeagus lateral, G-J. Aedeagus ventral SEM photos.

Clerus mutillaroides **Reitter, 1894 (Figure 2A-B)**

Male Reproductive Organ Morphology (Figure 2C-F): The tegmen is longitudinally slender, fairly lightly sclerotized; parameroid lobes are shorter than the median lobe, rolled distally; tegminal arms are rolled apically, lateral margins are slightly inwardly angled, forming a curved shape, not attached to the fallobasic apodeme; fallobasic apodeme is almost half the length of the tegmen, long and slender; median lobe is rolled distally, longer than the parameroid lobes; dorsal sinus is up to 1/6 the length of the parameroid lobes; ventral sinus is in line with the dorsal sinus.

Male Reproductive Organ Scanning Electron Microscopy (Figure 2G-J): The median lobe is quite lightly and sparsely depressed at the apex; Parameroid lobes are slightly depressed at the apex in a dot-like shape.

Genus: *Opilo* Latreille, 1802

Represented by 25 species in the Palearctic region, and five species in *Türkiye* [5, 18]. Only one species, *Opilo taeniatus*, was identified from the study area.

Opilo taeniatus **(Klug, 1842) (Figure 3A-B)**

Male Reproductive Organ Morphology (Figure 3C-F): The tegmen narrows from the base to the apex, triangular, narrowing more rapidly after the median region; parameroid lobes are shorter than the median lobe, with dorsally sharply curved apices, pointed, hook-like, intensely sclerotized; tegminal arms are wider than the parameroid lobes, more intensely sclerotized at the base, curved in a bow shape, inwardly indented in the median region; fallobasic apodeme is shorter than half the length of the tegmen, ending in lobes distally; median lobe narrows distally, longer than the parameroid lobes, conical-shaped; dorsal sinus is almost half the length of the parameroid lobes; ventral sinus is below the dorsal sinus.

Male Reproductive Organ Scanning Electron Microscopy (Figure 3G-J): The median lobe is quite sparsely depressed at the apex, almost completely covering the endophallus; parameroid lobes are slightly indented laterally in the distal region.

Remarks: The male reproductive organ of *O. taeniatus* species is described and illustrated from the lateral and ventral aspects in Demir's [19] thesis work. When com-

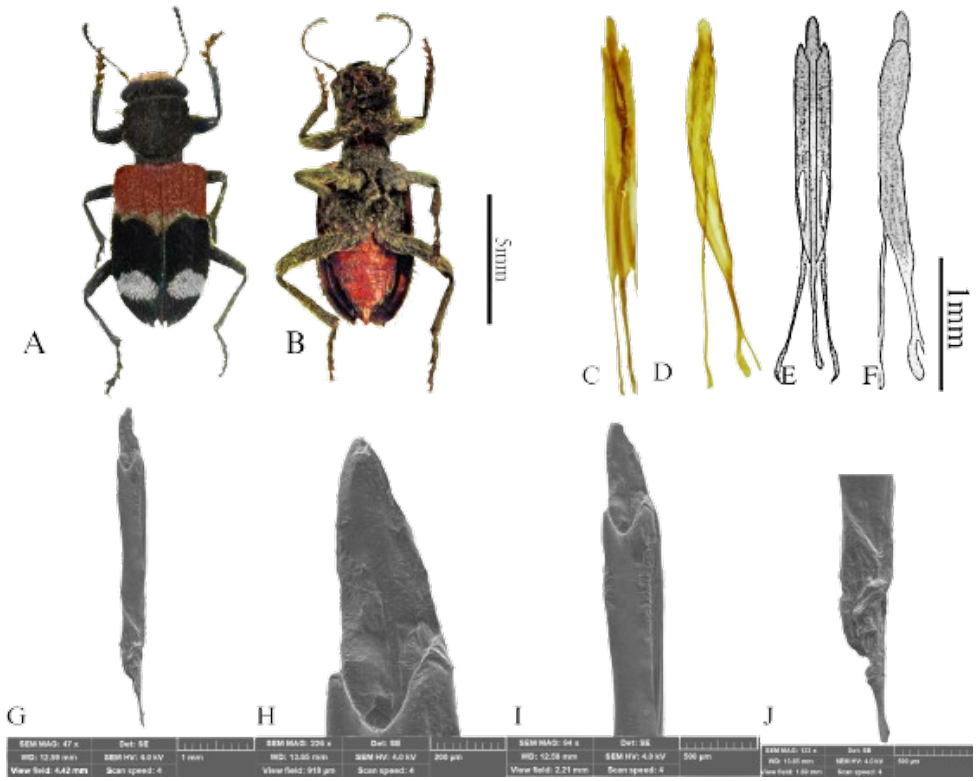

Figure 2. *Clerus mutillaroides* Reitter, 1894, A. Habitus dorsal, B. Habitus ventral, C-F. Photographs and drawings of Aedeagus, C-E. Aedeagus dorsal, D-F. Aedeagus lateral, G-J. Aedeagus dorsal SEM photos.

pared, only the appearance of the parameroid lobes as sickle-shaped from the lateral aspect shows similarity. Differences are observed in the absence of the median lobe drawing, the closer approximation of the parameroid lobes towards the apex, and the wider angle providing the sickle appearance.

Genus: *Thanasimus* Latreille, 1806

Another genus examined in the Clerinae subfamily, *Thanasimus*, is represented by a total of 39 species worldwide [7], including 12 species in the Palearctic region. From the study area, two species belonging to this genus, *Thanasimus femoralis* and *Thanasimus formicarius*, were identified.

***Thanasimus femoralis* (Zetterstedt, 1828) (Figure 4A-B)**

Male Reproductive Organ Morphology (Figure 4C-F): The lateral margins of the tegmen are almost parallel to each other, slightly widened towards the base, "U" shaped sclerotized area at the apex, more intensely sclerotized compared to the ventral side; parameroid lobes are shorter than the median lobe, rolled distally; tegminal arms are wider than the parameroid lobes, bow-shaped, not attached to the fallobasic apodeme; fallobasic apodeme is almost half the length of the tegmen, long and slender; median lobe narrows distally, longer than the parameroid lobes; dorsal sinus is almost 1/4 the length of the parameroid lobes; ventral sinus is above the dorsal sinus.

Male Reproductive Organ Scanning Electron Microscopy (Figure 4G-J): The median lobe is disk-shaped depressed at the apex; parameroid lobes are slightly indented laterally in the distal region and setal towards the median lobe, slightly depressed at the apex.

Remarks: Examination of the male reproductive organ of *Thanasimus femoralis* in the literature reveals the stereo microscope photographs by Gerstmeier [140], the description and dorsal drawing by Kolibáč [139], and the scanning electron microscope photographs and description by Öztürk [127]. When compared, the male reproductive organs show quite similarity with all the literature.

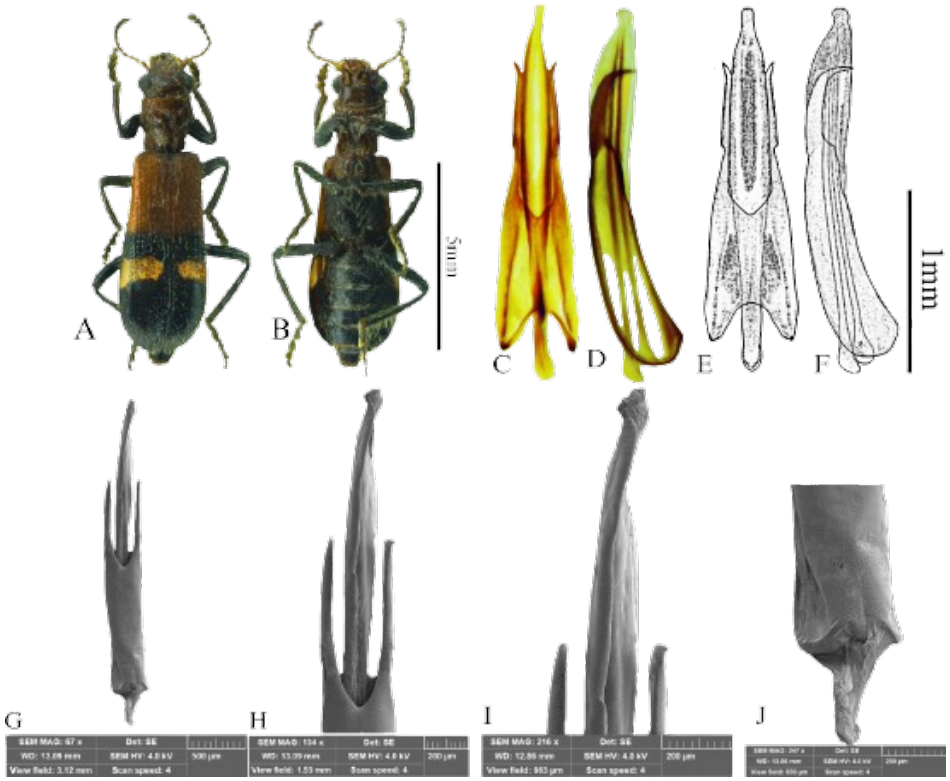

Figure 3. *Opilo taeniatus,* A. Habitus dorsal, B. Habitus ventral, C-F. Photographs and drawings of Aedeagus, C-E. Aedeagus dorsal, D-F. Aedeagus lateral, G-J. Aedeagus dorsal SEM photos.

Thanasimus formicarius **(Linnaeus, 1758) (Figure 5A-B)**

Male Reproductive Organ Morphology (Figure 5C-F): The lateral margins of the tegmen are almost parallel to each other, slightly widened towards the base, apex with "W" shaped sclerotized plates, more densely sclerotized dorsally than ventrally; parameroid lobes are shorter than the median lobe, rolled distally; tegminal arms are wider than the parameroid lobes, bow-shaped, not attached to the fallobasic apodeme; fallobasic apodeme is almost half the length of the tegmen, long and slender; median lobe narrows distally, longer than the parameroid lobes; dorsal sinus is up to 1/7 the length of the parameroid lobes; ventral sinus is above the dorsal sinus.

Male Reproductive Organ Scanning Electron Microscopy (Figure 5G-I): The median lobe is densely depressed at the apex in a disk shape; parameroid lobes are not indented laterally in the distal region and setal towards the median lobe, slightly depressed at the apex in a dot-like shape.

Genus: *Trichodes* Herbst, 1792

The genus *Trichodes* is represented by 49 species and three subspecies in the Palearctic region, with 23 species and one subspecies specific to Türkiye [1, 5, 13, 14]. It is distinguished from other genera within the family by the terminal palpomeres of the maxillary and labial palpi shaped like an axe, and finely-faceted eyes [1]. Within the scope of this study, 10 species were identified from the study area.

Trichodes alberi **Escherich, 1894**

Only female individuals of this species could be collected from the study area, and the morphology of the male reproductive organ could not be examined and discussed in the literature.

Trichodes apiarius **(Linnaeus, 1758) (Figure 6A-B)**

Male Reproductive Organ Morphology (Figure 6C-F): The tegmen narrows from the base to the apex, with more dense chitin in the anterolateral regions; parameroid lobes are shorter than the median lobe, with apical tips pointed and curved dorsally, more blunt and densely sclerotized than the ventral region at the apex, resembling a hook-anchor when viewed laterally; tegminal arms are almost the same width as the parameroid lobes, bow-shaped; fallobasic apodeme extends to half the length of the tegmen, ending in lobes distally;

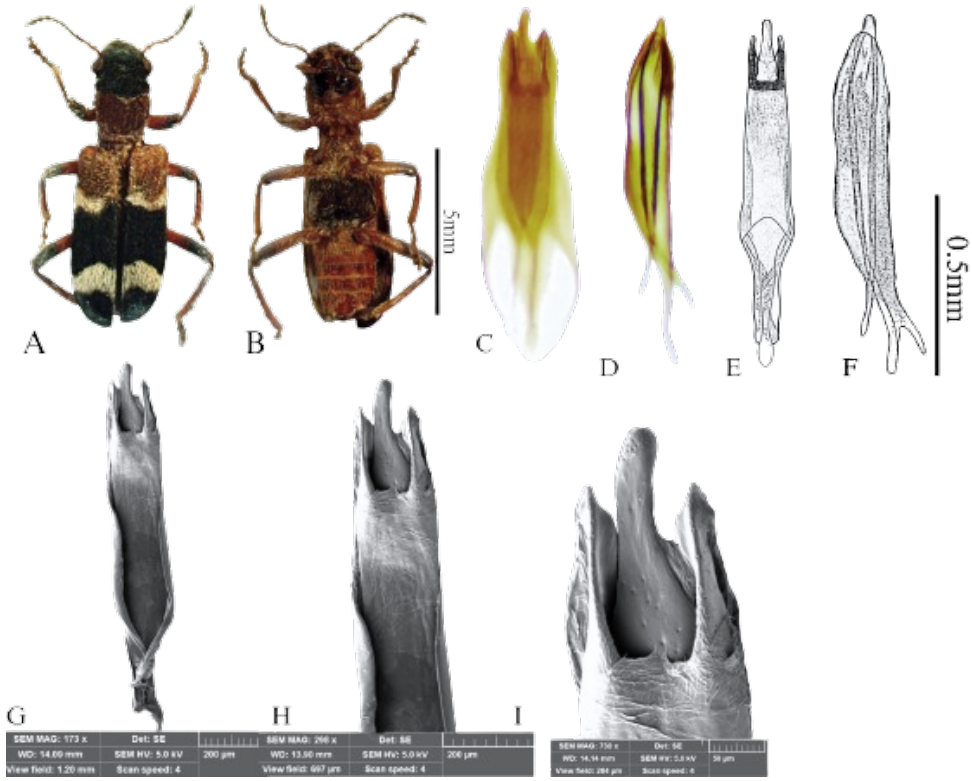

Figure 4. *Thanasimus femoralis* (Zetterstedt, 1828), A. Habitus dorsal, B. Habitus ventral, C-F. Photographs and drawings of Aedeagus, C-E. Aedeagus dorsal, D-F. Aedeagus lateral, G-I. Aedeagus dorsal SEM photos.

median lobe narrows distally, longer than the parameroid lobes, with a spherical lobular shape; dorsal sinus is almost 1/10 the length of the parameroid lobes; ventral sinus is below the dorsal sinus.

Male Reproductive Organ Scanning Electron Microscopy (Figure 6G-I): The median lobe is densely depressed in a disk shape at the apex; parameroid lobes are not indented laterally in the distal region and setal towards the median lobe, slightly depressed at the apex in a dot-like shape; the median lobe in the anterior region folds inwardly like a collar, covering the endophallus.

Remarks: When compared with descriptions and drawings in the literature [13, 19, 24], particularly the apices of the parameroid lobes and the drawings of the median lobes were found to be consistent.

***Trichodes crabroniformis* (Fabricius, 1787) (Figure 7A-B)**

Male Reproductive Organ Morphology (Figure 7C-F): The tegmen narrows from the base to the apex, with the lateral margins almost parallel, more densely chitinized in the anterolateral regions, slightly notched medially towards the apex; parameroid lobes are longer than the median lobe, with apical tips narrowing and rolling, lightly sclerotized, slightly curved dorsally; tegminal arms are almost the same width as the parameroid lobes, extending to the fallobasic apodeme, not attached to the fallobasic apodeme, bow-shaped; fallobasic apodeme is almost half the length of the tegmen, long and slender; median lobe narrows distally, shorter than the parameroid lobes; dorsal sinus is almost 1/4 the length of the parameroid lobes; ventral sinus is below the dorsal sinus.

Male Reproductive Organ Scanning Electron Microscopy (Figure 7G-I): The median lobe is sparsely depressed in a dot-like shape at the apex; parameroid lobes are not indented laterally in the distal region and setal towards the median lobe, slightly depressed at the apex in a dot-like shape; the median lobe in the anterior region folds inwardly like a collar, covering the endophallus.

Remarks: The drawings and descriptions in the current male reproductive organ literature show considerable similarity for both species [13, 14, 24].

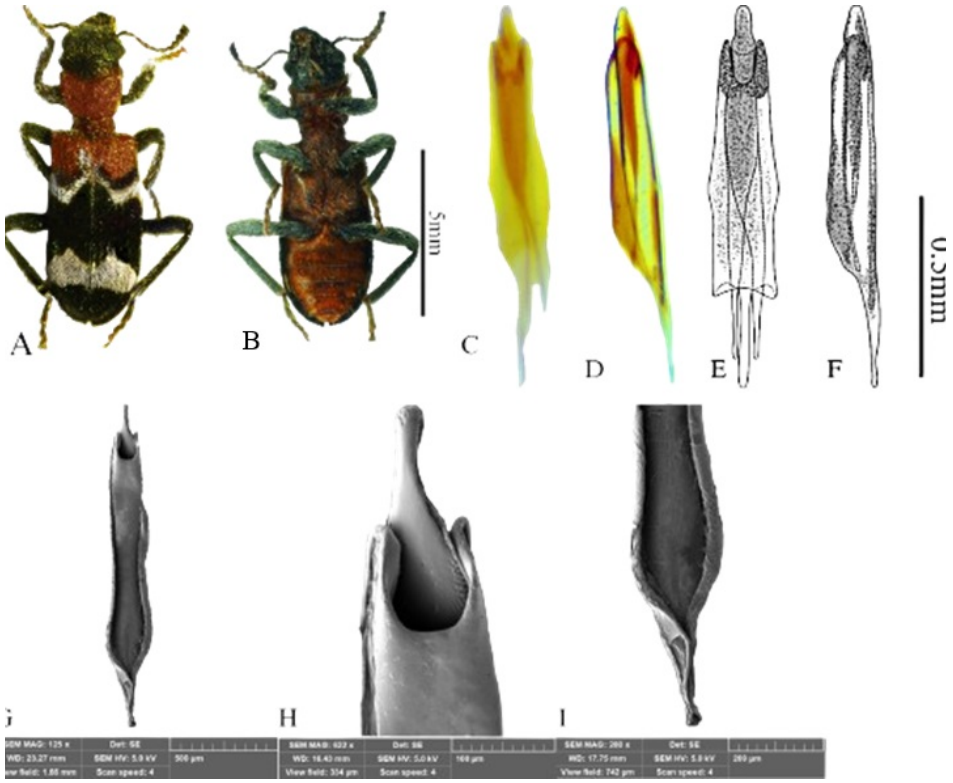

Figure 5. *Thanasimus formicarius* (Linnaeus, 1758), A. Habitus dorsal, B. Habitus ventral, C-F. Photographs and drawings of Aedeagus, C-E. Aedeagus dorsal, D-F. Aedeagus lateral, G-I. Aedeagus dorsal SEM photos.

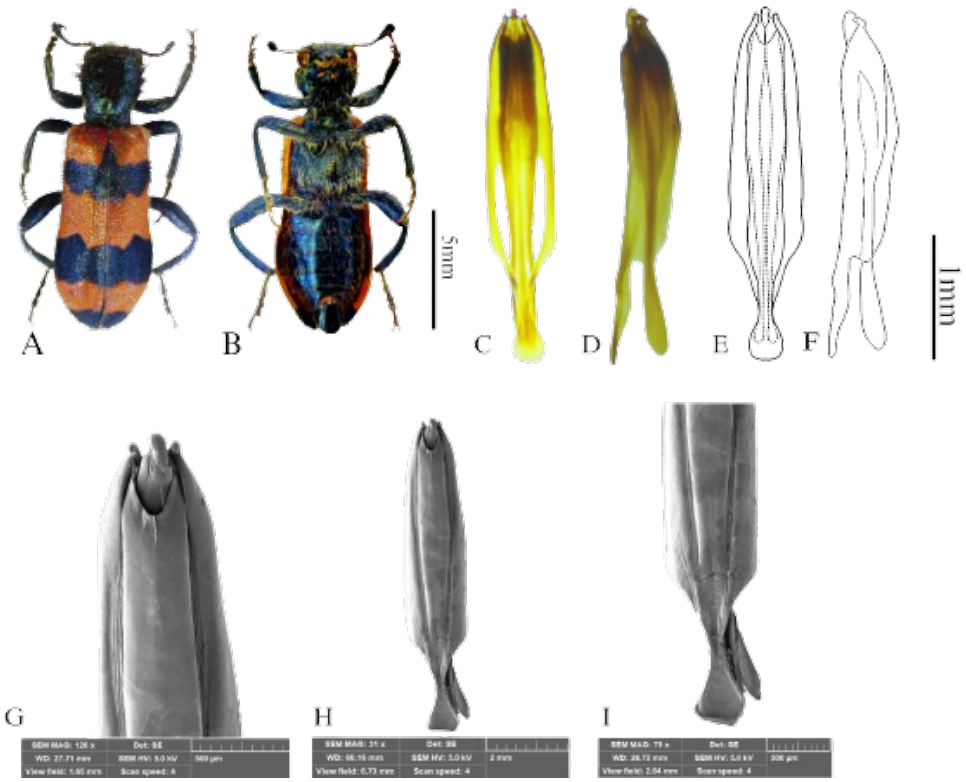

Figure 6. *Trichodes apiarius* (Linnaeus, 1758), A. Habitus dorsal, B. Habitus ventral, C-F. Photographs and drawings of Aedeagus, C-E. Aedeagus dorsal, D-F. Aedeagus lateral, G-I. Aedeagus dorsal SEM photos.

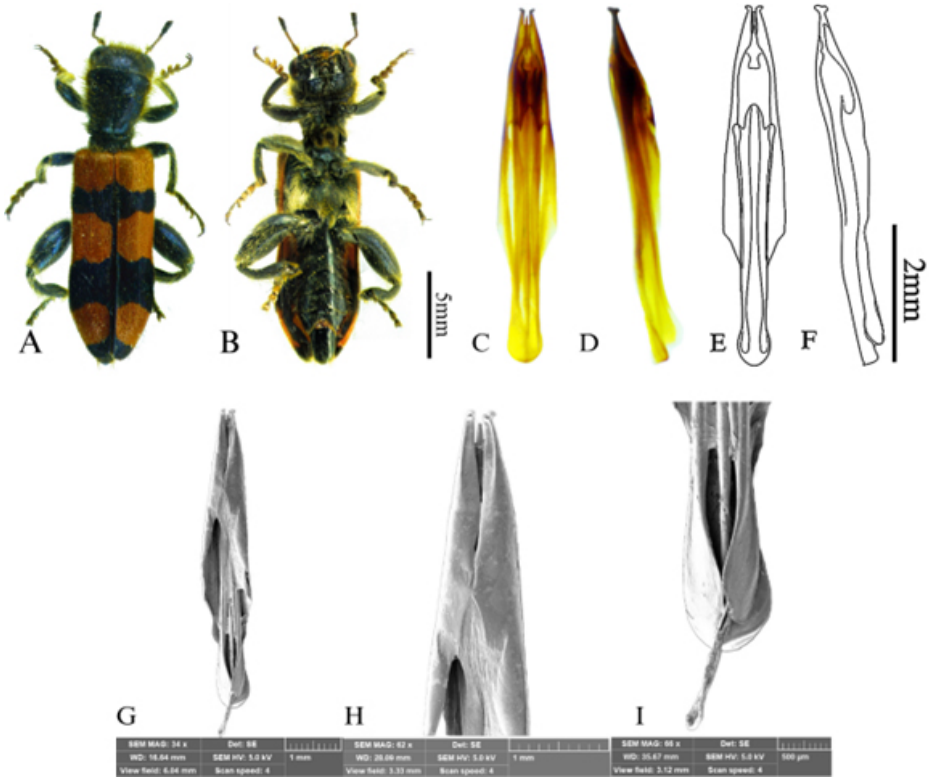

Figure 7. *Trichodes crabroniformis* (Fabricius, 1787), A. Habitus dorsal, B. Habitus ventral, C-F. Photographs and drawings of Aedeagus, C-E. Aedeagus dorsal, D-F. Aedeagus lateral, G-I. Aedeagus ventral SEM photos.

***Trichodes ganglbaueri* Escherich, 1893 (Figure 8A-B)**

Male Reproductive Organ Morphology (Figure 8C-F): The tegmen narrows from the base to the apex, with almost parallel lateral margins, more densely chitinized in the anterolateral regions and median region; parameroid lobes are longer than the median lobe, with apical tips narrowing and rolling, lightly sclerotized, slightly curved dorsally; tegminal arms are almost the same width as the parameroid lobes, extending to the fallobasic apodeme, not attached to the fallobasic apodeme, bow-shaped; fallobasic apodeme is shorter than half the length of the tegmen, ending in lobes distally; median lobe narrows distally, shorter than the parameroid lobes, triangular lobed with slightly flattened lateral edges; dorsal sinus is up to 1/8 the length of the parameroid lobes; ventral sinus is below the dorsal sinus.

Male Reproductive Organ Scanning Electron Microscopy (Figure 8G-I): The median lobe is sparsely depressed in a dot-like shape at the apex; parameroid lobes are not indented laterally in the distal region and setal towards the median lobe, slightly depressed at the apex in a dot-like shape.

Remarks: When compared with Zimmermann's [13] drawings, the obtained data show considerable similarity, but differ in the longer median lobe.

***Trichodes laminatus* Chevrolat, 1843 (Figure 9A-B)**

Male Reproductive Organ Morphology (Figure 9C-F): The tegmen has almost parallel lateral margins, slightly widened towards the base, curved, with more densely sclerotized anterolateral regions and median region; parameroid lobes are longer than the median lobe, with apical tips dorsally curved and pointed, lightly sclerotized; tegminal arms are slightly wider than the parameroid lobes laterally, extending to the fallobasic apodeme; fallobasic apodeme is shorter than half the length of the tegmen, ending in lobes distally; the median lobe in the anterior region folds inwardly like a collar, covering the endophallus, with a triangular-globular shape and button-like appearance, shorter than the parameroid lobes; dorsal sinus is up to 1/5 the length of the parameroid lobes; ventral sinus is below the dorsal sinus.

Male Reproductive Organ Scanning Electron Microscopy (Figure 9G-I): The median lobe is densely punctate at the apex; parameroid lobes are not indented laterally in the distal region and setal towards the median lobe, slightly depressed at the apex in a dot-like shape;

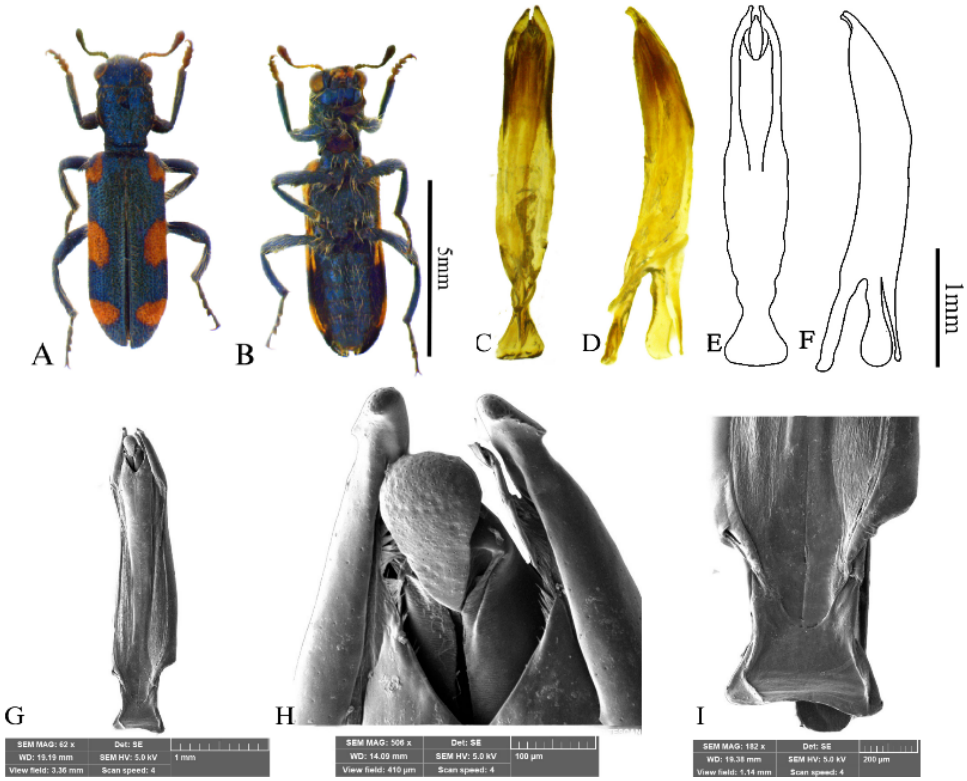

Figure 8. *Trichodes ganglbaueri* Escherich, 1893, A. Habitus dorsal, B. Habitus ventral, C-F. Photographs and drawings of Aedeagus, C-E. Aedeagus dorsal, D-F. Aedeagus lateral, G-I. Aedeagus dorsal SEM photos.

the median lobe in the anterior region folds inwardly like a collar, covering the endophallus.

Remarks: The obtained data show considerable similarity with Zimmermann's [13] drawings but differ in the longer median lobe.

Trichodes longissimus (Abeille, 1881) (Figure 10A-B)

Male Reproductive Organ Morphology (Figure 10C-F): The tegmen narrows from the base to the apex, with more densely sclerotized anterolateral regions and median region; parameroid lobes are shorter than the median lobe, with apical tips dorsally curved and pointed, lightly sclerotized; tegminal arms are almost the same width as the parameroid lobes laterally, extending to the fallobasic apodeme; fallobasic apodeme is shorter than half the length of the tegmen, ending in lobes distally; the median lobe in the anterior region does not cover the endophallus, shorter than the parameroid lobes, with a triangular-globular shape; dorsal sinus is up to 1/5 the length of the parameroid lobes; ventral sinus is below the dorsal sinus.

Male Reproductive Organ Scanning Electron Microscopy (Figure 10G-I): The median lobe is sparsely punctate at the apex; parameroid lobes are not indented laterally in the distal region and setal towards the median lobe, slightly depressed at the apex in a dot-like shape.

Remarks: The drawings and descriptions in the current male reproductive organ literature show considerable similarity for *T. crabroniformis* and *T. longissimus* [13, 14, 24].

***Trichodes nobilis* Klug, 1842 (Figure 11A-B)**

Male Reproductive Organ Morphology (Figure 11C-F): The tegmen narrows from the base to the apex, with more densely sclerotized anterolateral regions and median region; parameroid lobes are longer than the median lobe, with apical tips dorsally curved and pointed, lightly sclerotized; tegminal arms on the dorsal side are almost the same width as the parameroid lobes, narrowing towards the base laterally, bow-like; fallobasic apodeme extends to half the length of the tegmen, thin and rounded at the end; the median lobe in the anterior region folds inwardly like a collar, covering the endophallus, with a slightly nodular, spherical shape, shorter than the parameroid lobes; dorsal sinus is up to 1/5 the length of the parameroid lobes; ventral sinus is below the dorsal sinus.

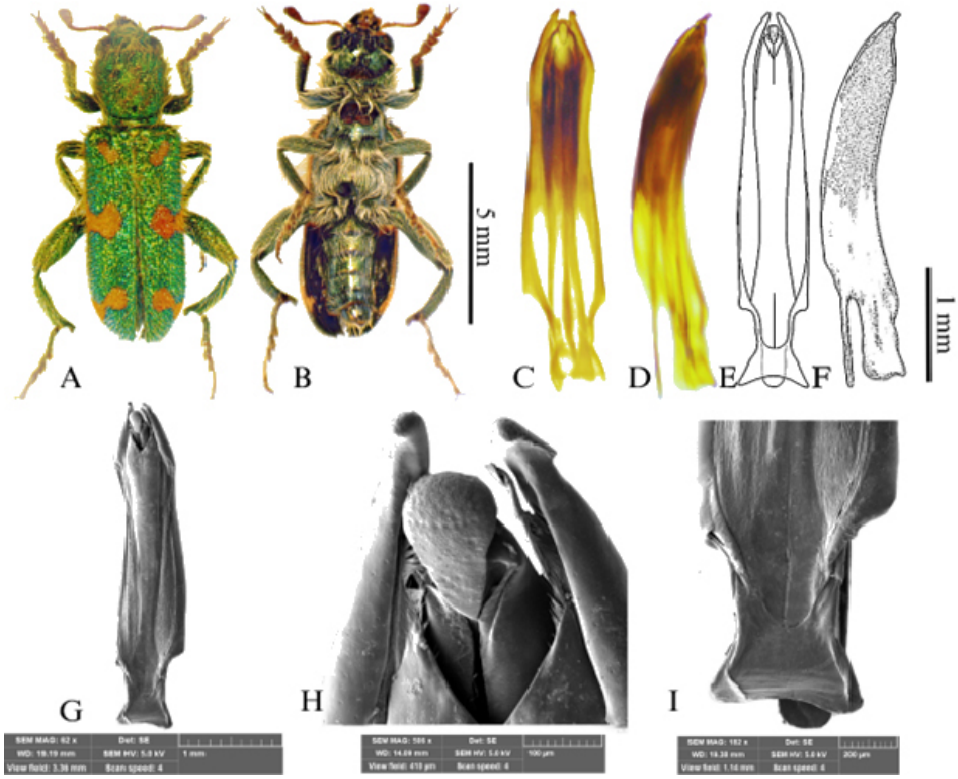

Figure 9. *Trichodes ganglbaueri* Escherich, 1893, A. Habitus dorsal, B. Habitus ventral, C-F. Photographs and drawings of Aedeagus, C-E. Aedeagus dorsal, D-F. Aedeagus lateral, G-I. Aedeagus dorsal SEM photos.

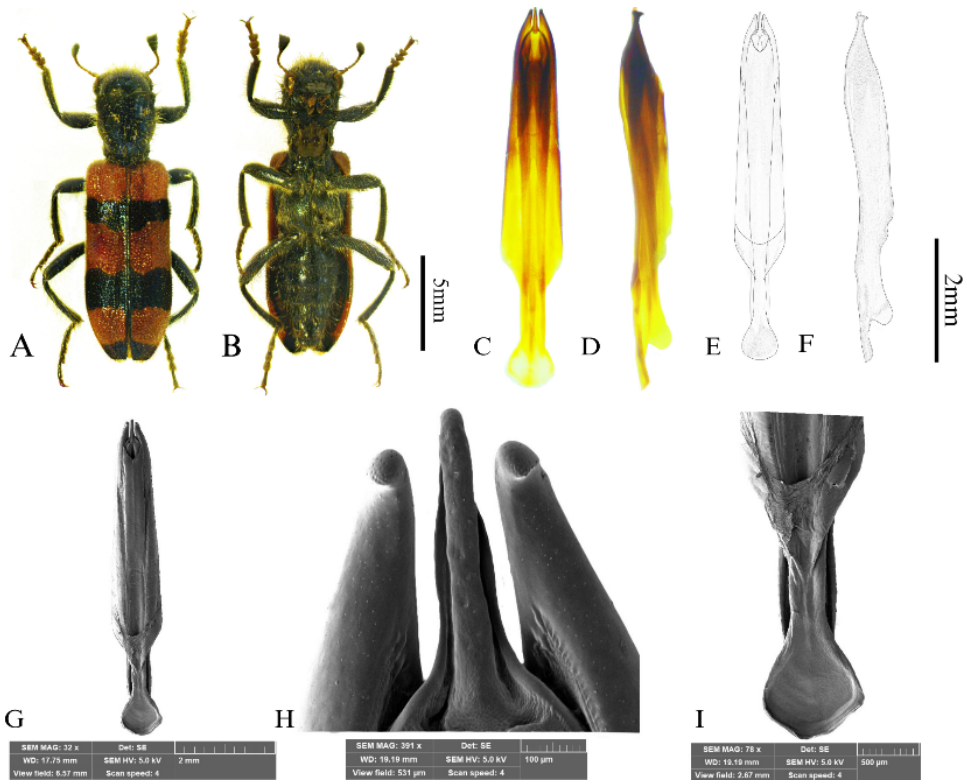

Figure 10. *Trichodes longissimus* (Abeille, 1881), A. Habitus dorsal, B. Habitus ventral, C-F. Photographs and drawings of Aedeagus, C,E. Aedeagus dorsal, D,F. Aedeagus lateral, G-I. Photographs of Aedeagus dorsal SEM.

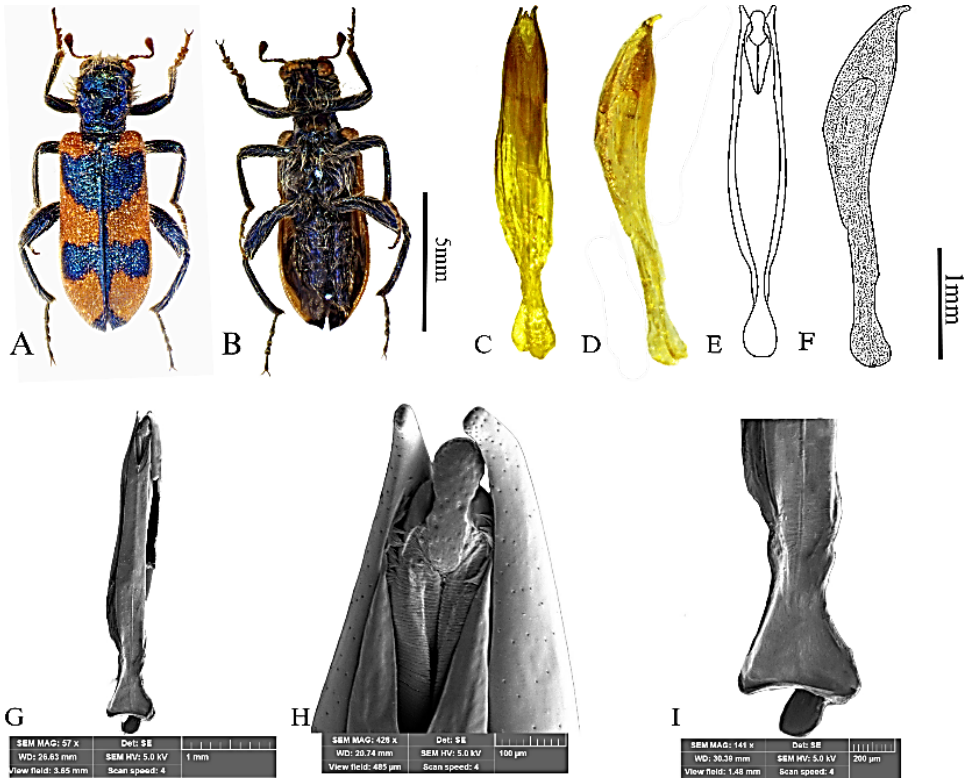

Figure 11. *TTrichodes nobilis* Klug, 1842, A. Habitus dorsal, B. Habitus ventral, C-F. Photographs and drawings of Aedeagus, C-E. Aedeagus dorsal, D-F. Aedeagus lateral, G-I. Photographs of Aedeagus dorsal SEM.

Male Reproductive Organ Scanning Electron Microscopy (Figure 11G-I): The median lobe is sparsely punctate at the apex and sparsely hexagonally raised; the median lobe in the anterior region folds inwardly like a collar, covering the endophallus; parameroid lobes are not indented laterally in the distal region and setal towards the median lobe, slightly depressed at the apex in a dot-like shape.

Remarks: The obtained data show considerable similarity with Zimmermann's [13] drawings but differ in the longer median lobe.

***Trichodes punctatus* Fischer von Waldheim, 1829 (Figure 12A-B)**

Male Reproductive Organ Morphology (Figure 12C-F): The tegmen has almost parallel lateral margins, narrowing anterodorsally, with denser sclerotization in the anterolateral and median regions; parameroid lobes are longer than the median lobe, with apical regions dorsally curved, pointed, and slightly sclerotized, the dorsal part of the apical region is more blunt-ended, appearing hammer-like from the lateral view, with dense sclerotization, the dorsal apex is above the ventral one; tegminal arms on the dorsal side are almost the same width as the parameroid lobes, narrowing basally laterally, bow-shaped, extending to the fallobasic apodeme and not attached to the ventral fallobasic apodeme; the fallobasic apodeme is almost half the length of the tegmen, thin, and rounded at the end; the median lobe is slightly nodular in the apicomedian region, with a terminal spherical shape, shorter than the parameroid lobes; the dorsal sinus is up to 1/4 the length of the parameroid lobes; the ventral sinus is below the dorsal sinus.

Male Reproductive Organ Scanning Electron Microscopy (Figure 12G-J): The median lobe is sparsely concave and sparsely hexagonally raised at the apex; the median lobe is folded inwardly like a collar in the anterior region, covering the endophallus; parameroid lobes are not laterally indented in the distal region and sparsely setal towards the median lobe, sparsely concave at the apex.

Remarks: The descriptions and drawings of the male reproductive organ of this species [13, 19, 24] are quite similar to the data obtained from the study, especially with the nodular structure of the apex of the median lobe and the hammer-like appearance of the tegmen's apex from the lateral view.

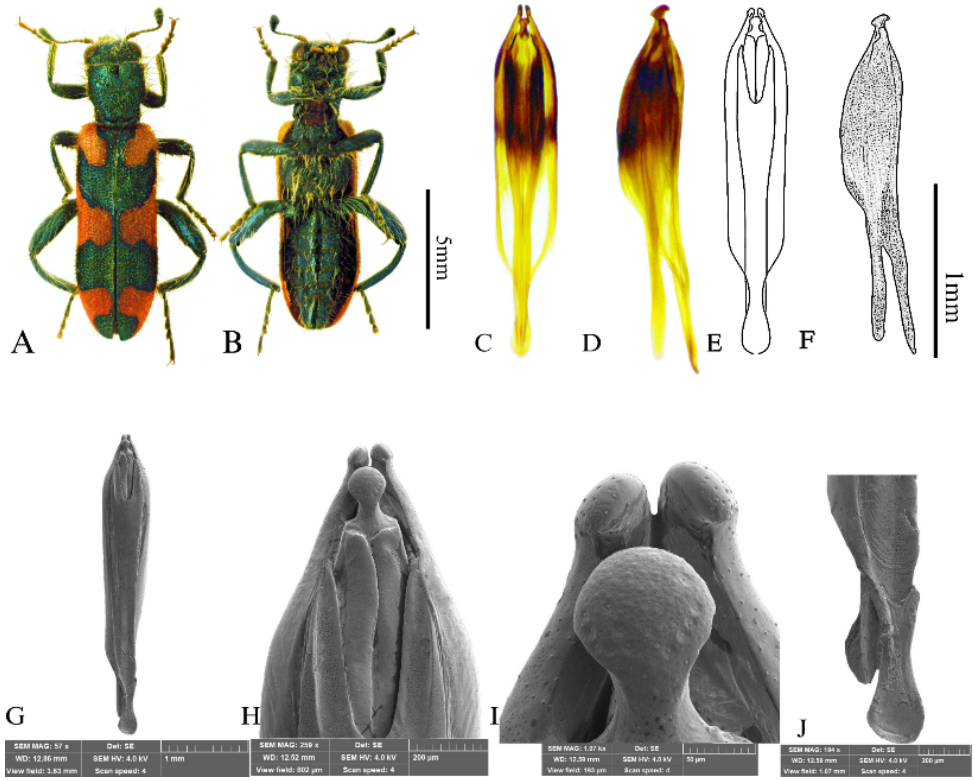

Figure 12. *Trichodes nobilis* Klug, 1842, A. Habitus dorsal, B. Habitus ventral, C-F. Photographs and drawings of Aedeagus, C-E. Aedeagus dorsal, D-F. Aedeagus lateral, G-I. Photographs of Aedeagus dorsal SEM.

***Trichodes quadriguttatus* Adams, 1817 (Figure 13A-B)**

Male Reproductive Organ Morphology (Figure 13C-F): The tegmen narrows slightly from the base to the apex, with denser sclerotization in the anterolateral and median regions, curved dorsally after the median region; parameroid lobes are longer than the median lobe, with dorsally curved and pointed apices, lightly sclerotized, the dorsal part of the apical region is slightly concave and pointed, lightly sclerotized; tegminal arms on the dorsal side are almost the same width as the parameroid lobes, narrowing basally laterally, bow-shaped, extending to the fallobasic apodeme and not attached to the ventral fallobasic apodeme; the fallobasic apodeme is almost half the length of the tegmen, thin and rounded at the end; the median lobe is cylindrical-shaped at the terminal, shorter than the parameroid lobes; the dorsal sinus is up to 1/3 the length of the parameroid lobes; the ventral sinus is below the dorsal sinus.

Male Reproductive Organ Scanning Electron Microscopy (Figure 13G-J): The median lobe is sparsely concave and sparsely hexagonally raised at the apex; the median lobe is folded inwardly like a collar in the anterior region, covering the endophallus but not completely; parameroid lobes are not laterally indented in the distal region and sparsely setal towards the median lobe, densely concave at the apex.

Remarks: The male reproductive organ literature for *T. quadriguttatus* [17] is highly compatible with the data obtained in the study, except for minor differences resulting from drawing errors.

***Trichodes suspectus E*scherich, 1892 (Figure 14A-B)**

Male Reproductive Organ Morphology (Figure 14C-F): The tegmen has almost parallel lateral margins, narrowing anterodorsally, with denser sclerotization in the anterolateral and median regions; parameroid lobes are shorter than the median lobe, with apical regions dorsally curved, slightly concave and inwardly indented on the dorsal side, slightly dorsally curved, pointed, and hook-like in the distal, laterally and dorsally curved, projecting, hook-like, densely sclerotized; tegminal arms on the dorsal side are wider than the width of the parameroid lobes, narrowing basally laterally, bow-shaped, extending to the fallobasic apodeme and not attached to the ventral fallobasic apodeme; the fallobasic apodeme is almost half the length of the tegmen, thin and rounded at the end; the median lobe is slightly nodular in the apicomedian region, with a terminal spherical

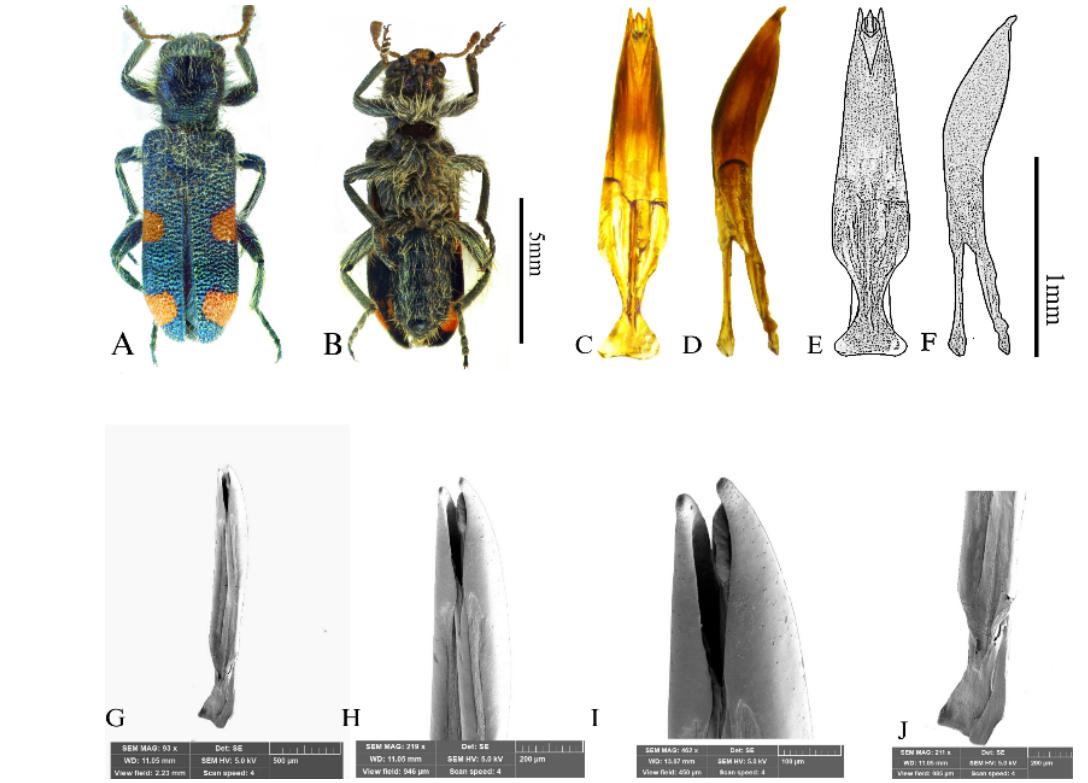

Figure 13. *Trichodes quadriguttatus* Adams, 1817, A. Habitus dorsal, B. Habitus ventral, C-F. Aedeagus fotoğrafları ve çizimleri, C-E. Aedeagus dorsal, D-F. Aedeagus lateral, G-J. Aedeagus dorsal SEM fotoğrafları.

shape, shorter than the parameroid lobes; the dorsal sinus is up to 1/3 the length of the parameroid lobes; the ventral sinus is below the dorsal sinus.

Male Reproductive Organ Scanning Electron Microscopy (Figure 14G-J): The median lobe is densely concave and sparsely hexagonally raised at the apex; the median lobe is folded inwardly like a collar in the anterior region, covering the endophallus, the folding continues up to the terminal bulge, the median region is connected to the terminal with a triangular-shaped membrane; parameroid lobes are not laterally indented in the distal region and sparsely setal towards the median lobe, densely concave at the apex.

Remarks: The male reproductive organ literature for this species [13, 19] is parallel to the descriptions and drawings obtained in the study.

Subfamily: Tillinae Leach, 1815
Genus: *Tilloidea* Laporte, 1832

In the Palearctic region, represented by 22 genera and 57 species, while in *Türkiye*, it is represented by three genera and five species. Only one species, *Tilloidea transversalis*, belonging to the Tillinae subfamily, was identified from the study area.

***Tilloidea transversalis* (Charpentier, 1825) (Figure 15A-B)**

Male Reproductive Organ Morphology (Figure 15C-F): The tegmen is wide in the median area and narrows towards the apex, with denser chitinization in the anterolateral region; parameroid lobes are shorter than the median lobe, rolled distally and slightly pointed; tegminal arms are slightly inwardly angled and sclerotized laterally, not attached to the fallobasic apodeme; the fallobasic apodeme is almost half the length of the tegmen, long and thin; the median lobe is rolled distally, longer than the parameroid lobes; the dorsal sinus is about 1/10 the length of the parameroid lobes; the ventral sinus is almost in line with the dorsal sinus, with the dorsal sinus positioned higher.

Remarks: When the literature regarding the male reproductive organ of this species is examined, it is noted that comparisons and discussions could not be made due to the lack of identification, drawings, or photog-

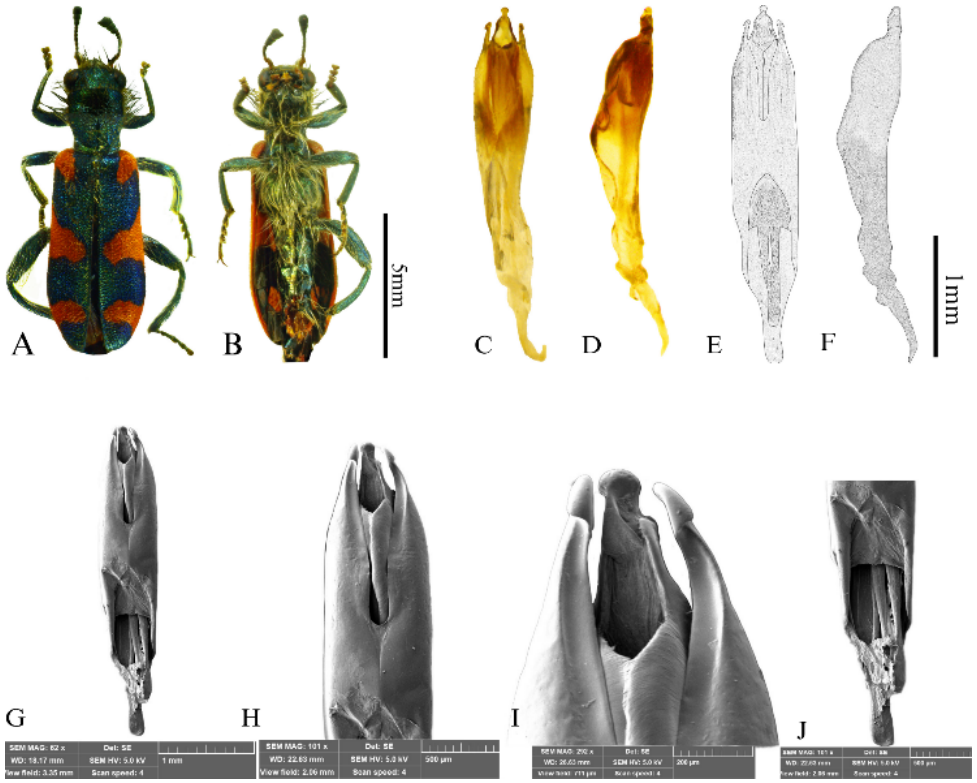

Figure 14. *Trichodes suspectus* Escherich, 1892, A. Habitus dorsal, B. Habitus ventral, C-F. Photographs and drawings of Aedeagus, C-E. Aedeagus dorsal, D-F. Aedeagus lateral, G-J. Photographs of Aedeagus dorsal SEM.

raphs found in the study.

Clustering Analyses

A summary of the morphological characteristics of the male reproductive organ, as observed under a stereo microscope and scanning electron microscope, is presented in Table 1 in the form of a character matrix. By clustering analysis (UPGMA), a pattern of similarity-difference among species was obtained. This pattern was compared with the evolutionary kinship status of known species in the existing literature. Since SEM photographs of the male reproductive organ of the species *Tilloidea transversalis*, belonging to the Tillinae subfamily and the only species identified, could not be taken, only morphological characters under a stereo microscope were used in the clustering analysis. When the literature regarding Cleridae phylogeny is examined, the studies of Gimmel et al. [16] and Yuan et al. [17] stand out. In the phylogenetic study of the superfamily Cleriodae (24 families) based on 395 taxa and using 4 gene regions (18S, 28S, cox1, cytb), Gimmel et al. [16] determined that the Clerinae subfamily was not monophyletic. Four of the genera identified in this study are included in the tree. When the phylogenetic tree is examined, it is observed that the genera *Trichodes* and *Opilo* are in close proximity, while the genera *Clerus* and *Thanasimus* are in another clade together. Yuan et al. [17] included the genera *Trichodes*, *Opilo*, and *Clerus* in the phylogenetic study based on the mitochondrial genome of 18 Clerid species. While *Clerus* and *Trichodes* genera are closer to each other in the phylogenetic tree, the genus *Opilo* is positioned outside these genera. Based on the clustering analysis of morphological characters under a stereo microscope, the pattern of *Trichodes*+(*Tilloidea*+(*Thanasimus*+(*Opilo*+*Clerus*))) was obtained (Figure 16). In the clustering analysis of morphological characters under a scanning electron microscope, a pattern of *Opilo*+(*Trichodes*+(*Clerus*+(*Allonyx*+*Thanasimus*))) was observed (Figure 17). In the clustering analysis output of morphological characters under a scanning electron microscope and stereo microscope, the pattern of *Trichodes*+(*Opilo*+(*Allonyx*+(*Clerus*+*Thanasimus*))) was obtained (Figure 18). When the patterns obtained from the study are compared with the literature findings, it is compatible with the phylogenetic tree in the study conducted by Yuan et al. [25], with the genera *Clerus* and *Trichodes* being closer to each other and *Opilo* genus positioned outside these genera. The clustering of

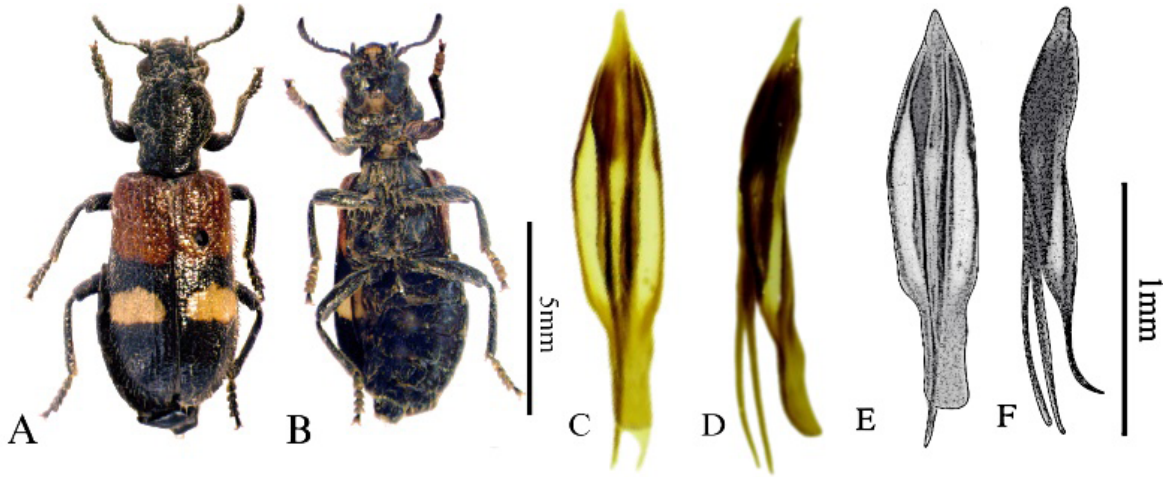

Figure 15. *Tilloidea transversalis* (Charpentier, 1825), A. Habitus dorsal, B. Habitus ventral, C-F. Photographs and drawings of Aedeagus, C-E. Aedeagus dorsal, D-F. Aedeagus lateral.

Table 1. Male reproductive organ morphological character matrix of the species identified from the study area. Scanning electron microscope and stereo microscope male reproductive organ morphological character matrix of the studied species. (For Scanning Electron Microscope Characters: Rare: 1, Intense: 2, None: 0).

	Stereo microscope Morphological Characters						Scanning Electron Microscopy Morphological Characters					
Species	Parameroid Lobes Compared to Median Lobe (Long:1, Short: 0)	Parameroid Lobes at Apex (Pointed: 1, Rounded: 0)	Ventral Sinus Compared to Dorsal Sinus (Upwards: 1, Equal or Downwards: 0)	Median Lobe at Apex (Conical: 0, Rolled: 1)	Parameroid Lobes Laterally (Hooked: 1, Pointed or Rounded: 0)	Phallobasic Apodeme Half the Length of Tegmen (Short: 0, Long: 1)	Median Lobe Apex with Disc-shaped Depressions	Median Lobe Apex with Disc-shaped Elevations	Median Lobe Anteriorly Covers Endophallus	Parameroid Lobes Distally Indented Laterally	Parameroid Lobes Apex with Dot-Shaped Depressions	Parameroid Lobes Distally Setose Inwardly
Allonyx quadrimaculatus	0	0	1	0	0	0	2	0	0	1	1	0
Clerus mutillariodes	0	0	0	1	0	1	1	0	0	0	1	0
Opilo taeniatus	0	1	0	1	0	1	0	0	1	1	0	0
Thanasimus femoralis	0	0	1	1	0	1	1	0	0	1	1	1
Thanasimus formicarius	0	0	1	1	0	1	2	0	0	1	1	1
Tilloidea transversalis	0	1	0	1	0	0	-	-	-	-	-	-
Trichodes apiarius	0	1	1	1	1	0	1	0	1	0	1	1
Trichodes crabroniformis	1	1	0	0	1	1	1	0	1	0	1	1
Trichodes ganglbaueri	1	0	0	0	0	0	1	0	0	0	2	2
Trichodes laminatus	1	0	0	1	1	0	2	1	1	0	1	2
Trichodes laminatus	0	1	0	0	1	1	1	0	1	0	1	1
Trichodes nobilis	1	1	0	1	0	1	1	1	1	0	1	2
Trichodes punctatus	1	0	0	1	1	1	1	1	1	0	1	1
Trichodes quadriguttatus	1	1	0	0	0	1	1	1	0	0	2	1
Trichodes suspectus	0	0	0	1	1	1	2	1	1	0	1	1

the genera *Thanasimus* and *Clerus* in the dendrogram based on morphological characters under a stereo microscope is consistent with the data in the study by Gimmel et al. [16]. The clustering of the genera *Thanasimus* and *Clerus* in the dendrogram based on morphological characters under a stereo microscope is consistent with the data in the study by Gimmel et al. [16]. In all three clustering analyses conducted, the clustering displayed by the species and the distances between the species varied depending on the characters. More precise interpretations can be made regarding whether the characters used in the clustering are taxonomic characters or not when the number of characters and species included in the analysis is increased. It is considered that this study serves as a pioneering study that can provide data for possible similar studies in the future with more taxa and more male reproductive organ characters.

The genus *Opilo* is distinguished by its open anterior coxal cavities, axe-shaped terminal labial and maxillary palpomeres, and by having the terminal flagellomere slightly longer than the subterminal flagellomere, which differentiates it from the nearest *Trichodes* [10]. In the Palearctic region, it is represented by 25 species, while in *Türkiye*, it is represented by five species [5, 18]. Only one species, *Opilo taeniatus*, has been identified from the study area. This species is distinguished from the closely related *Opilo mollis* by the striae not reaching the apex of the elytra [10]. The male reproductive organ of O. *taeniatus* has been described and illustrated laterally and ventrally in Demir's thesis [19]. When comparing the drawings and descriptions, only the lateral sickle shape of the parameroid lobes shows similarity. Differences are noted with the absence of a drawing of the median lobe, the parameroid lobes converging apically, and the wider angle creating the sickle appearance.

The monotypic genus *Allonyx* is distinguished from other genera in the family by its cylindrical terminal maxillary and labial palpomeres and the lack of teeth at the base of the tarsal claws [10]. It is limited to the spread of coniferous forests of the genus Pinus in the Palearctic region. In the existing literature, no descriptions, photos, or drawings of the male organ of *Allonyx quadrimaculatus*, the only species in the genus, could be found. The flattened dorsoventral morphology of the male reproductive organ compared to other genera in the family suggests it as a genus-specific character.

The genus *Clerus* is distinguished from other genera in the family and its closest genus by the head being almost as wide as the pronotum's peak and the eyes being close to each other at the top of the head [10]. It is represented by 11 species in the Palearctic region [5] and by four species in *Türkiye* [10, 19, 20]. The species *Clerus mutillaroides* from this genus has been identified in the study area. Due to the lack of drawings, descriptions, and photos related to the male reproductive organ in the existing literature, it could not be discussed. When compared to other species in the family, the male reproductive organ does not exhibit genus-specific morphological characteristics.

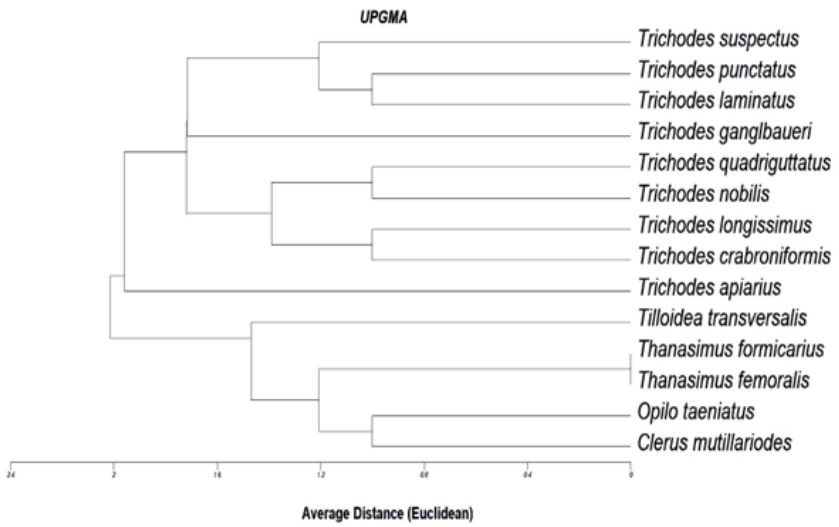

Figure 16. Cluster analysis of male reproductive organ stereo microscope morphological characters.

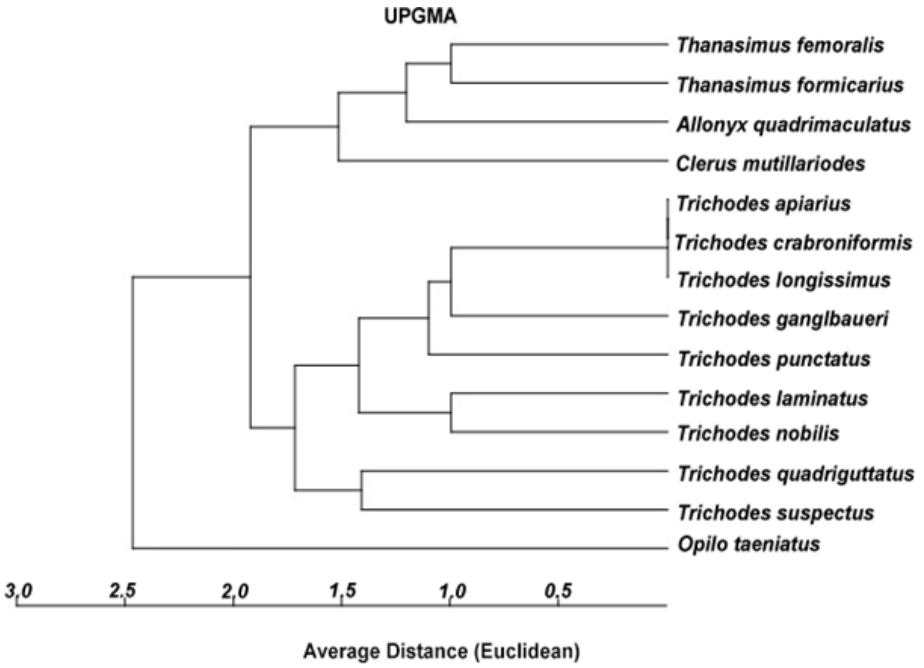

Figure 17. Cluster analysis of male reproductive organ scanning electron microscopy morphological characters

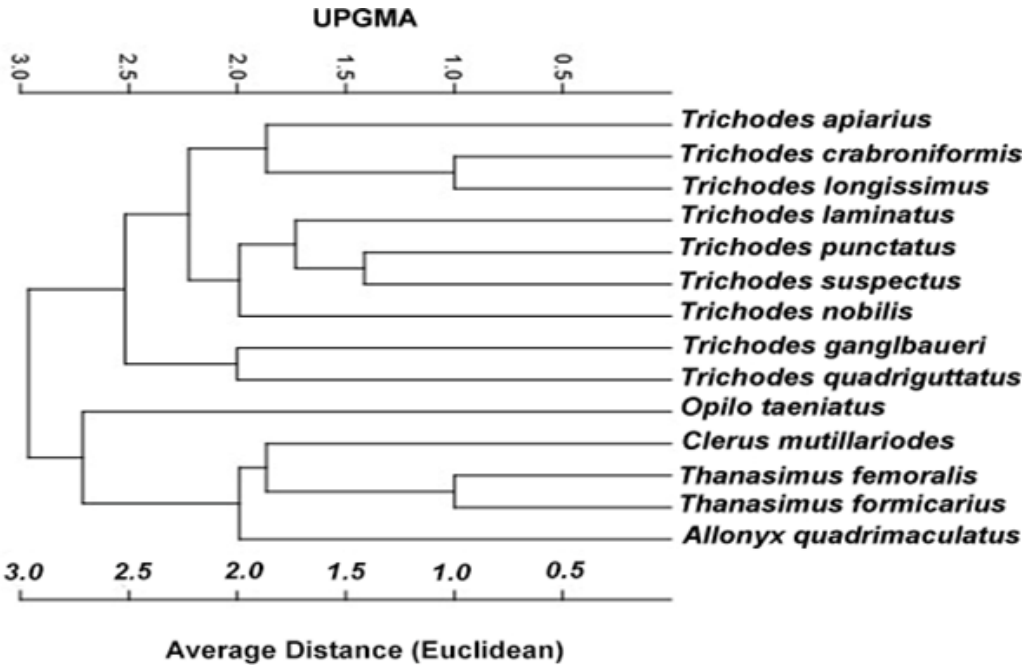

Figure 18. Cluster analysis of scanning electron microscopy characters and stereo microscope morphological characters of male reproductive organs.

Another genus examined in the subfamily Clerinae, *Thanasimus*, is represented by a total of 39 species worldwide [21] and 12 species in the Palearctic region. It is distinguished from other genera in the family by its typically black, red, and pale white colored elytra, eyes positioned on the side of the head and not approaching each other at the top, and the loosely formed club of the last three antennomeres [10]. Two species, *Thanasimus femoralis* and *Thanasimus formicarius*, from this genus have been identified in the study area. For T. *formicarius*, Gerstmeier [22] provided photographs, and Kolibáč [19] and Demir [55] described the male genitalia with separate drawings of the tegmen and median lobe. The structures of the male reproductive organs examined in this study correspond exactly with Gerstmeier's [20] drawings. Kolibáč's [19] findings describe the lateral edges of the parameroid lobes as nearly parallel and the apex of the tegmen as "W" shaped, which closely matches the findings of this study. Demir's [55] drawings of the male reproductive organ of this species do not match due to incomplete drawings of the parameroid lobes. For T. *femoralis*, Gerstmeier [20] provided stereomicroscope photographs, Kolibáč [19] provided descriptions and dorsal drawings, and Öztürk [23] provided scanning electron microscope photographs and descriptions. The male reproductive organs match the literature findings quite closely. No genus-specific morphological structures that would differentiate species among closely related genera like *Clerus* were observed.

The genus *Trichodes* in this subfamily is represented by 49 species and 3 subspecies in the Palearctic Region and by 23 species and one subspecies in *Türkiye* [5, 10, 13, 14]. It is distinguished from other genera in the family by its open anterior coxal cavities, axe-shaped terminal maxillary and labial palpomeres, and finely faceted eyes [10]. Within the scope of the thesis, 10 species from the study area have been identified: *Trichodes alberi* Escherich, 1894, *Trichodes apiarius* (Linnaeus, 1758), *Trichodes crabroniformis* (Fabricius, 1787), *Trichodes ganglbaueri* Escherich, 1893, *Trichodes laminatus* Chevrolat, 1843, *Trichodes laminatus* (Abeille, 1881), *Trichodes nobilis* Klug, 1842, *Trichodes punctatus* Fischer von Waldheim, 1829, *Trichodes quadriguttatus* Adams, 1817, and *Trichodes suspectus* Escherich, 1892.

Trichodes alberi is distinguished from other species in the genus by the lateral extension of the anterior transverse band along the lateral margin towards the humeral corners, sometimes completely surrounding the scutellum, and not reaching the lateral margin [10]. Only female individuals of *T. alberi* have been collected from the study area, so the male reproductive organ morphology could not be examined. The male reproductive organ morphology of *T. apiarius* matches the existing literature descriptions and drawings, particularly in the apices of the parameroid lobes and the drawings of the median lobes [13, 14, 24]. The male reproductive organ morphologies of *T. apiarius* and *T. suspectus* are very similar. *T. suspectus* is distinguished from T. *apiarius* by the distance of the parameroid lobes to the median lobe and the more indented terminal segment of the median lobe. *T. crabroniformis* and *T. longissimus*, often confused due to the band pattern on the elytra, are distinguished by the two large projections extending between the metacoxae at the posterior of the metasternum and the coloration of the elytral suture [10]. The drawings and descriptions of the male reproductive organs in the literature are very similar for both species [13, 14, 24]. *T. crabroniformis* is distinguished from *T. longissimus* by the sharper apical ends of the parameroid lobes and the shorter median lobe compared to the parameroid lobes [10]. *T. ganglbaueri* is distinguished from other species in the genus by an isolated dark spot on the humeral corners of each elytron [10]. For T. *ganglbaueri*, Demir [17] provided a ventral drawing of the aedeagus and descriptions of the apices of the parameroid lobes, and Zimmermann [13] provided a description of the aedeagus and a ventral drawing of the tegmen and median lobe. The findings of this study align with Demir's [17] descriptions and Zimmermann's [13] drawings and descriptions. The median lobe extending beyond the tegmen in Demir's [17] drawing differs from the study findings and may be due to the mobility of the median lobe during genital dissection. *T. nobilis* is distinguished from the closest species in the genus by the yellow color of the last three flagellomeres forming the antennal club and the dentate terminal elytral suture [13]. Although not morphologically very similar, the male reproductive organ morphologies are quite similar to *T. quadriguttatus*. The male reproductive organ literature for *T. quadriguttatus* [25] is highly compatible with the findings of this study, except for minor differences due to drawing errors. A similar comparison for *T. nobilis* could only be made from a single publication. The obtained data is very similar to Zimmermann's [13] drawing but differs in the longer median lobe. *T. laminatus* is distinguished from other species in the genus by its typical elytral pattern and the broadened lamellar shape of the posterior tibial spurs [1]. The male repro-

ductive organ descriptions and drawings in the literature [13, 17] are quite similar to the findings of this study. *T. punctatus* is distinguished from other species in the genus by the deeply punctured pronotum and the apical bands only reaching the apex of the elytra [1]. The descriptions and drawings of the male reproductive organ [13, 17, 22] match the findings of this study, particularly in the terminal knotted structure of the median lobe apex and the hammer-like appearance of the apical tegmen from the side. T. *suspectus*, another species from the study area and morphologically very similar to *T. punctatus*, is distinguished from T. *punctatus* by the apical band surrounding the scutellum and extending towards the humeral lower surface of the elytra in a long or short branch [10]. The male reproductive organ literature [13, 17] is parallel with the descriptions and drawings obtained in this thesis study. In the clustering analysis based on the morphological characters of the male reproductive organs, T. *suspectus*, *T. punctatus*, and *T. laminatus*, which show close clustering, are quite similar in having a button-like conical structure at the apex of the median lobe and hook-like parameroid lobes from the side. *T. suspectus* is distinguished from *T. laminatus* and *T. punctatus* by the shorter parameroid lobes compared to the median lobe. *T. laminatus* is distinguished from *T. punctatus* by the parameroid lobes extending behind the median lobe.

The Tillinae subfamily, the other subfamily identified in the study area, is distinguished from other subfamilies by its internally and externally closed anterior coxal cavities and the width of the head, including the eyes, not being wider than the pronotum [10]. It is represented by 22 genera and 57 species in the Palearctic region and by three genera and five species in *Türkiye* [5]. From the Tillinae subfamily, only the species *Tilloidea transversalis* from the genus *Tilloidea* has been identified in the study area.

Tilloidea transversalis is distinguished from the closest species in the genus by having serrate black antennae starting from the 5th antennomere in males and from the 6th antennomere in females [13]. When examining the literature related to the male reproductive organ of the species, no descriptions, drawings, or photos could be found, so it could not be compared and discussed with the data obtained in the study.

The morphological structures, drawings, stereomicroscope, and scanning electron microscope photos of the male reproductive organs of 15 out of the 16 species identified from the study area have been provided in this study and compared with the current literature [6, 10, 13, 14, 26, 27].

CONCLUSION

The morphological descriptions, drawings, stereo microscope, and scanning electron microscope photographs of the male reproductive organs of 15 out of 16 species identified in the study area have been provided and compared with the current literature. With the systematic examinations conducted in this study, the diagnosis keys of the identified genera and species have been arranged; detailed descriptions, drawings, stereo, and scanning electron microscope photographs of the male reproductive organs of the species *Allonyx quadrimaculatus*, *Clerus mutillariodes*, and *Opilo taeniatus* have been provided for the first time. Stereo microscope and scanning electron microscope photographs of the male reproductive organs of the species *T. apiarius*, *T. ganglbaueri*, *T. laminatus*, *T. nobilis, T. punctatus*, *T. quadriguttatus*, and *T. suspectus* have been provided for the first time. In all three clustering analyses conducted, the clustering displayed by the species and the distances between the species varied depending on the characters. More precise interpretations can be made regarding whether the characters used in the clustering are taxonomic characters or not when the number of characters and species included in the analysis is increased. It is considered that this study serves as a pioneering study that can provide data for possible similar studies in the future with more taxa and more male reproductive organ characters.

ACKNOWLEDGEMENTS

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