

Descriptions of the Male and Female Terminalia of Two Morphologically Similar Species of the Genus *Trachys* (Coleoptera, Buprestidae), with Notes on the Taxonomic Significance of the Structures

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Abstract Structures of the male and female terminalia of *Trachys griseofasciatus* SAUNDERS, 1873 and *T. yanoi* KUROSAWA, 1959, which are difficult to distinguish based on external features, are examined and described in detail with illustrations. Accordingly, terminology is defined for the external genitalia in the genus for the first time. The two species are distinguishable by differences in structures of the male sternite IX and tegmen, as well as in those of the female styli.

Introduction

Trachys griseofasciatus SAUNDERS, 1873 and *T. yanoi* KUROSAWA, 1959, are small buprestid beetles belonging to the tribe Tracheini, subfamily Agrilinae (Coleoptera, Buprestidae). One of them, *T. griseofasciatus*, is known to be distributed in Northeast to Southeast Asia and associated with Cannabaceae plants, while the other, *T. yanoi*, is limited in Northeast Asia and feeds exclusively on Ulmaceae plants (YANO, 1952; KUROSAWA, 1959; BELLAMY, 2008; KUBÁŇ, 2016).

The two species are very similar in general appearance, barely distinguishable based on external features. Generally, *Trachys griseofasciatus* is distinguished from *T. yanoi* by the following two morphological features: 1) the body and elytral hairs are darker than those of *T. yanoi* (KUROSAWA, 1959, 1976 a, b; OHMOMO & FUKUTOMI, 2013) (Figs. 7 & 8) and 2) the clypeus is wider than *T. yanoi*, about twice as wide as long (about 1.5 times as wide as long in *T. yanoi*) (Figs. 9 & 10). However, color of the body and elytral hairs and proportion of the clypeus, which is the most important distinguishing point between *T. griseofasciatus* and *T. yanoi*, are sometimes variable individually and thus unclear as diagnostic characters for the two species. Recently, ISHIGURO and NISHIDA (2018) investigated male genital structures of Japanese species of the two Tracheini genera, *Trachys* and *Habroloma*, to clarify the taxonomic significance of the structures. Consequently, they concluded that the structures are useful to distinguish the two genera, as well as to identify most species from Japan including *T. griseofasciatus* and *T. yanoi* which show slight interspecific differences in the structures. Additionally, distribution ranges of *T. griseofasciatus* and *T. yanoi* overlap partially in Northeast Asia (China, Korea, and Japan) (KUROSAWA, 1959; BELLAMY, 2008; KUBÁŇ, 2016). The two species sometimes occur sympatrically at least in Japan (KUROSAWA, 1976 a). With regard to feeding habit, *T. griseofasciatus* is associated with two Cannabaceae trees, *Aphananthe aspera* and *Celtis sinensis*, while *T. yanoi* with *Zelkova serrata* (Ulmaceae) (YANO, 1952; KUROSAWA, 1959; OHMOMO & FUKUTOMI, 2013). At the moment, therefore, the only certain way to distinguish the two species is to collect specimens with host plant information.

Generally, structures of the male terminalia, especially the male genitalia, are useful for species identification in the family Buprestidae. The observation of ISHIGURO and NISHIDA (2018) that identification based on male genital structures are difficult between *T. griseofasciatus* and *T. yanoi* should be verified, since it was based on rough and insufficient morphological observations of only a part of the male terminalia. Structures of the female terminalia have never been satisfactorily studied in this family, but a few buprestid beetles are known to show some important interspecific differences in the structures (KUBÁŇ, 1995; NELSON & WESTCOTT, 1995; NELSON & BELLAMY, 1996). In the genus *Trachys*, the structures have never been studied, with an exception of *Trachys minutus minutus* (LINNAEUS, 1758) whose female sternite VIII and tergite VIII, proctiger, and vagina were observed by KASAP and CROWSON (1975) and by KOLIBÁČ (2000), respectively.

This study is addressed to investigate interspecific differences of two morphologically similar *Trachys* species in structures of the male and female terminalia. Through detailed morphological observation, we describe the male and female terminalia of *T. griseofasciatus* and *T. yanoi* with illustrations, and then discuss the taxonomic significance of the structures.

Materials and Methods

Examined specimens in this study, which were collected from the Japan proper, are preserved in the private collection of the first author.

Habitus photographs were taken under a Keyence VHX-1000 digital microscope. Each final image was assembled from a series of photographs with different focal planes in the high resolution focus stacking mode of the digital microscope.

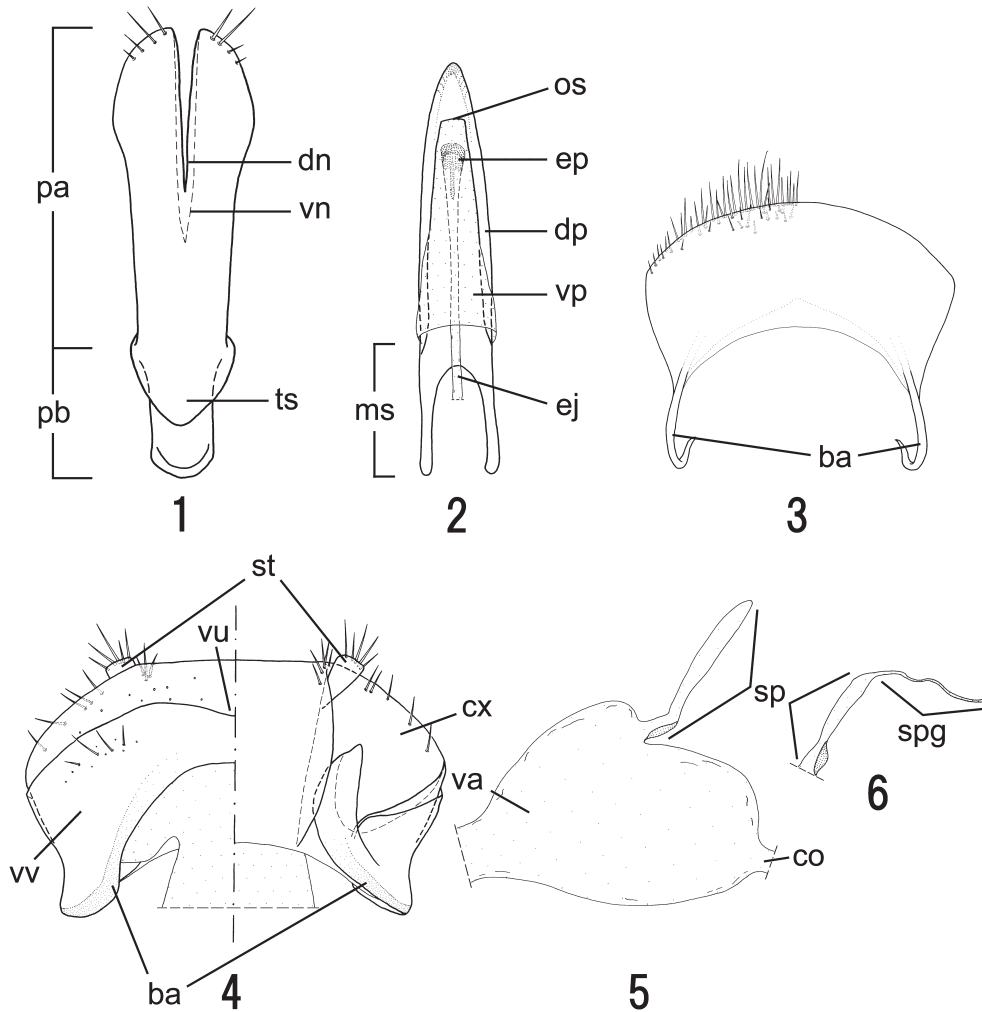
The specimens were macerated in hot water and dissected under an Olympus SHZ10 stereomicroscope to examine the male and female terminalia. The abdomen was removed from the body and then cleaned in 5% KOH solution for about 18 hours at room temperature. After washing in distilled water, the terminalia extracted from the abdomen were mounted on slides with glycerol (males) or firstly with distilled water to observe membranous parts in an inflated state by osmotic pressure and then with glycerol to observe sclerotized parts (females). The male and female terminalia were observed under an Olympus BX40 optical microscope and drawn in detail with an attached Olympus U-DA drawing tube. After observation, the terminalia of each specimen has been stored in a polyethylene or glass genitalia vial filled with glycerol and pinned below the specimen.

Abbreviations used for the measurements in this paper are as follows: PL — maximum length of parameres; PW — maximum width of parameres; PbL — maximum length of phallobase; PbW — maximum width of phallobase; SL — maximum length of male sternite IX except for struts at base; SW — maximum width of male sternite IX except for struts at base; SIL — maximum length of stylus; SIW — maximum width of stylus.

Morphology and Terminology of the Male and Female Terminalia

The terminology of the external male genitalia is defined herein for *Trachys* species, because it has so far been ambiguous in the family Buprestidae.

Unless otherwise stated, here we follow LAWRENCE and ŚLIPIŃSKI (2013) for the terminology of the male genitalia, but partially follow KUBÁŇ *et al.* (2000) and SHARP and MUIR (1912) (Table 1). The aedeagus (Figs. 1 & 2) is mainly composed of tegmen and penis. The tegmen is sclerotized, comprising a pair of parameres and a phallobase. Inner lateral margins of the parameres are fused with each other from the base to near the middle, forming a single tubular piece with tegminal strut at the



Figs. 1–6. Diagram of male and female genitalia in the genus *Trachys*. — 1 & 2, Male aedeagus; 3–6, female ovipositor. — 1, Tegmen in dorsal view; 2, penis in ventral view; 3, proctiger in dorsal view; 4, coxites and ventral valve in dorsal and ventral view; 5, vagina and associated structures in lateral view; 6, spermatheca with spermathecal gland in lateral view. — Abbreviations: ba: baculum; co: common oviduct; cx: coxite; dn: dorsal notch; dp: dorsal plate; ej: ejaculatory duct; ep: endophallus; ms: median strut; os: ostium; pa: paramere; pb: phallobase; sp: spermatheca; spg: spermathecal gland; st: stylus; ts: tegminal strut; va: vagina; vn: ventral notch; vp: ventral plate; vu: vulva; vv: ventral valve.

base of the dorsal side. Unfused parts of the inner lateral margins of the parameres on dorsal and ventral sides are called as “dorsal notch” and “ventral notch”, respectively (sensu KUBÁŇ *et al.*, 2000). The phallobase is fused ventrally to the combined base of the parameres. The penis is mainly composed of two flat parts called as “dorsal plate” and “ventral plate”, respectively (sensu SHARP & MUIR, 1912). The dorsal plate is sclerotized and bears a pair of “median struts” (sensu SHARP & MUIR, 1912) basally while the ventral plate is mostly membranous. The penis opens ventrally near the apex by ostium, from which endophallus is invaginated. The membranous endophallus is furnished with a few

Table 1. Comparison of terminology used in literature for buprestid beetle aedeagus.

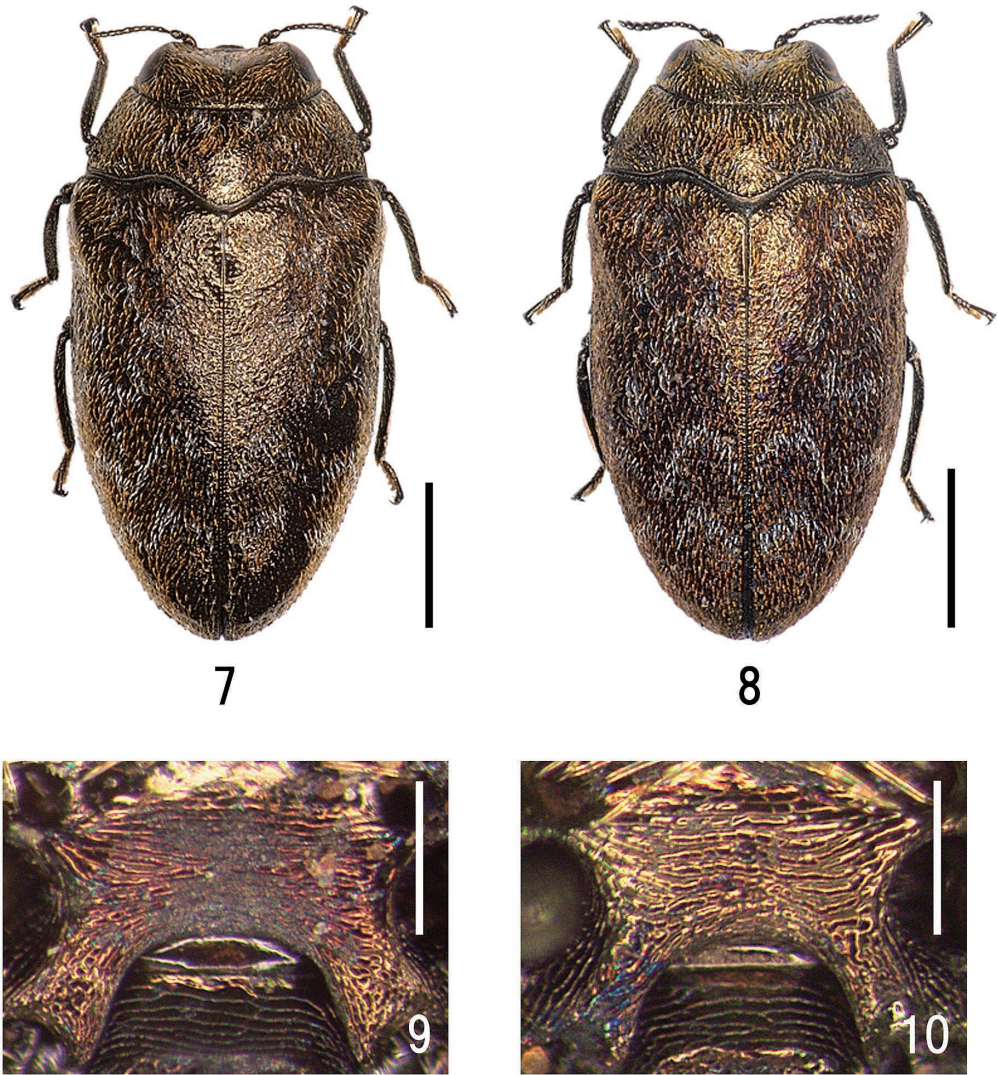
This study	LAWRENCE & ŚLIPÍŃSKI, 2013	KUBÁŇ <i>et al.</i> , 2000	SHARP & MUIR, 1912
tegmen	tegmen	tegmen	tegmen
phallobase	phallobase (basal piece)	phallobasic apodeme	basal piece
paramere	paramere (lateral lobe)	paramere	lateral lobe
tegmina strut	tegmina strut	tegmina strut	—
dorsal notch	—	dorsal notch	—
ventral notch	—	ventral notch	—
penis	penis (median lobe)	phallus	median lobe
dorsal plate	—	phallic body	dorsal plate
ventral plate	—	phallic body	ventral plate
median strut	—	phallic strut	median strut
endophallus	endophallus (internal sac)	—	internal sac
ostium	ostium	ostium	median orifice
ejaculatory duct	ejaculatory duct	—	ejaculatory duct

Table 2. Comparison of terminology used in literature for buprestid beetle ovipositor.

This study	LAWRENCE & ŚLIPÍŃSKI, 2013	KUBÁŇ <i>et al.</i> , 2000	GARDNER, 1989
proctiger (epiproct + paraprocts)	proctiger / epiproct (tergite X)	tergite X (female epiproct)	proctiger (epiproct + paraprocts)
valvifer	gonocoxite / coxite	female paraproct	valvifer
coxite	gonocoxite / coxite	—	style-bearing valve
stylus	gonostylus / stylus	style	style
ventral valve	—	valvifer	ventral valve
baculum	baculum	—	baculum
vulva	vulva	—	vulva
vagina	vagina	vagina	vagina
bursa copulatrix	bursa copulatrix	bursa copulatrix	bursa
spermatheca	spermatheca	spermatheca	spermatheca
spermathecal duct	—	spermathecal duct	spermathecal duct
spermathecal gland	spermathecal gland	spermathecal gland	—
common oviduct	common oviduct	oviduct	median oviduct

spicules and connected with ejaculatory duct.

We mainly follow LAWRENCE and ŚLIPÍŃSKI (2013) for the terminology of the external female genitalia, but partially follow GARDNER (1989) (Table 2). Structures of the female genitalia of *Trachys* species are unique in the family Buprestidae. The ovipositor (Figs. 3–6) is roughly divided into sclerotized and membranous parts. The sclerotized part is composed of “proctiger” (sensu GARDNER, 1989), coxites, and “ventral valve” (sensu GARDNER, 1989). The proctiger fully fused with “paraprocts” (sensu GARDNER, 1989) has a pair of long, ventrally curved baculi at the base. The “valvifers” (sensu GARDNER, 1989) are fully fused with the proctiger as parts of the long baculi and thus not clearly recognized. The coxites fused with each other are furnished with short baculi, and with a pair of styli near the apex. The ventral valve is a very thin plate with short baculi. Lateral edges of the ventral



Figs. 7–10. *Trachys* spp. — 7 & 9, *Trachys griseofasciatus* SAUNDERS; 8 & 10, *T. yanoi* KUROSAWA. — 7 & 8, dorsal habitus; 9 & 10, clypeus in front view. Scale: 1.00 mm for 7 & 8; 0.10 mm for 9 & 10.

valve extend to dorsal side of the sclerotized part on both sides. The vulva, which is connected with membranous part, widely opens on ventral side of the sclerotized part between apical margins of the coxites and ventral valve. The membranous part is composed of vagina, common oviduct, spermatheca, and spermathecal gland. The vagina invaginated from the vulva is large and sack-shaped. The common oviduct opens into proximal end of the vagina. The spermatheca opens into the vagina dorsally. The “spermathecal duct” (sensu GARDNER, 1989) is not recognized but spermathecal gland is sometimes recognized. Also, bursa copulatrix is not recognized in the membranous part.

Results

Trachys griseofasciatus SAUNDERS, 1873

[Japanese name: Namigata-chibi-tamamushi]

(Figs. 7, 9, 11, 13, 14, 17, 19, 21 & 23)

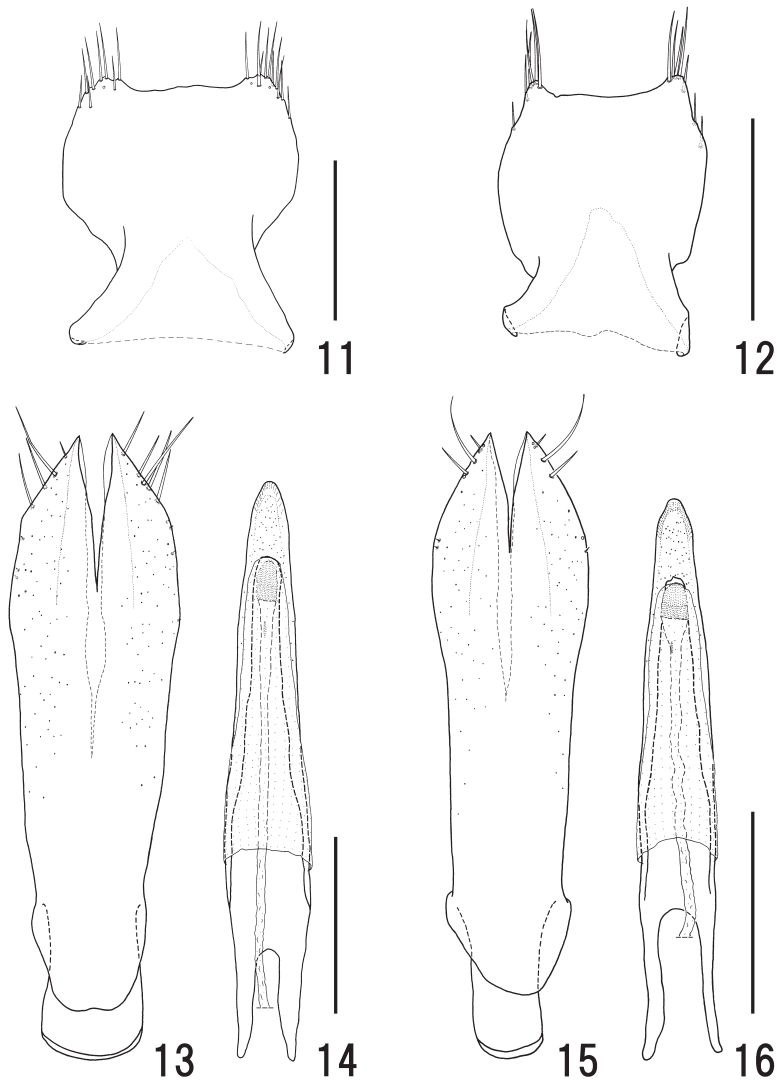
Trachys griseofasciatus SAUNDERS, 1873, 521 (type locality: “Japan”); LEWIS, 1879, 15 (cataloged); KERREMANS, 1885, 157 (cataloged); SCHÖNFELDT, 1887, 81 (cataloged); KERREMANS, 1892, 286 (cataloged); LEWIS, 1893, 338 (in systematic list); KERREMANS, 1903, 313 (cataloged); JAKOBSON, 1913, 800 (in monograph); OBENBERGER, 1918, 36 (redescription); 1926, 661 (cataloged); MIWA & CHŪJŌ, 1936, 24 (cataloged); OBENBERGER, 1937, 1380 (cataloged); CHŪJŌ & KUROSAWA, 1950, 13 (distributional records); YANO, 1952, 32, figs. 1, 2 & 4, pl.1 (descriptions of egg, larvae & pupae); KUROSAWA, 1959, 235, fig. 10 (redescription); 1976 a, 3 (note); KUROSAWA, 1985, 35, pl. 7 (in pictorial book); AKIYAMA & OHMOMO, 1997, 47 (in checklist); 2000, 284, pl. 120 (in pictorial book); KUBÁŇ, 2006, 419 (cataloged); BELLAMY, 2008, 2489 (cataloged); OHMOMO & FUKUTOMI, 2013, 168, pl. 54 (in pictorial book); KUBÁŇ, 2016, 571 (cataloged); ISHIGURO & NISHIDA, 2018, 33, figs. 2, 3 & 6 (description of aedeagus).

See BELLAMY (2008) for other synonymy.

Description of terminalia. M a l e (n = 5 for all measurements). Tergite VIII semicircular, roundly concave along posterior margin, covered with short setae in apical half, with a spiracle at each side of apical half. Sternite VIII semicircular, roundly concave along posterior margin and densely setiferous along anterior margin which is faintly concave in middle. Proctiger transversely subreniform, with shallowly round anterior margin, densely setiferous along anterior margin, with a pair of short baculi at base. Sternite IX (Fig. 11) wide, SL/SW 0.69–0.84 (mean 0.79), roundly concave along anterior margin, furnished with several setae on each side of anterior margin. Tegmen (Fig. 13) slender; parameres PL/PW 2.50–2.71 (mean 2.63), sparsely setiferous on antero-lateral margins, with sides which are gently dilated anteriorly from base to widest point at apical third, then slightly narrowed anteriorly to subapical part, and finally rather sharply convergent to apices; phallobase wide, PbL/PbW 1.60–1.79 (mean 1.69), about 1/4 length of tegmen. Penis (Fig. 14) slender, slightly shorter than tegmen; dorsal plate feebly bisinuate on sides which are gradually narrowed to subapical part, and then arcuately convergent apicad, round at apex, basally with median struts about 1/3 length of penis; ventral plate weakly sclerotized as a patch in middle of apical 1/4.

F e m a l e (n = 5 for all measurements). Tergite VIII semicircular, roundly concave along posterior margin, covered with short setae in apical half, with a spiracle at each side of apical half. Sternite VIII semicircular, roundly concave along posterior margin and densely setiferous along anterior margin which is faintly concave in middle. Ovipositor (Figs. 17, 19, 21 & 23) short; proctiger transversely subreniform, with shallowly round anterior margin, densely setiferous along anterior margin, basally with a pair of long, ventrally curved baculi; coxites transversely subhexagonal, sparsely setiferous on each side of anterior margin, ventrally with wide depression in apical part; styli subtrapezoidal, wide, SIL/SIW 1.67–2.20 (mean 2.05), furnished with several setae apically, visible either in dorsal or ventral view; ventral valve slightly concave along anterior margin, sparsely setiferous on each side of subapical part; vagina sack-shaped, moderately expanded dorsally from base to middle; spermatheca tubular, with spermathecal gland apically.

Specimens examined. 1 ♀, Nurumizu, Atsugi-shi, Kanagawa-ken, Honshu, Japan, 30.XI.2014, Y. TAMADERA leg. 7 ♂♂, 1 ♀, Kamiyamaguchi, Tokorozawa-shi, Saitama-ken, Honshu, Japan, 13.VI.2015, Y. TAMADERA leg. 1 ♂, 6 ♀♀, the same locality, 25.VIII.2018, Y. TAMADERA leg. 1 ♂, 2 ♀♀, Aburagi-machi, Nagasaki-shi, Nagasaki-ken, Kyushu, Japan, 16.III.2017, N. YAMAMOTO leg.



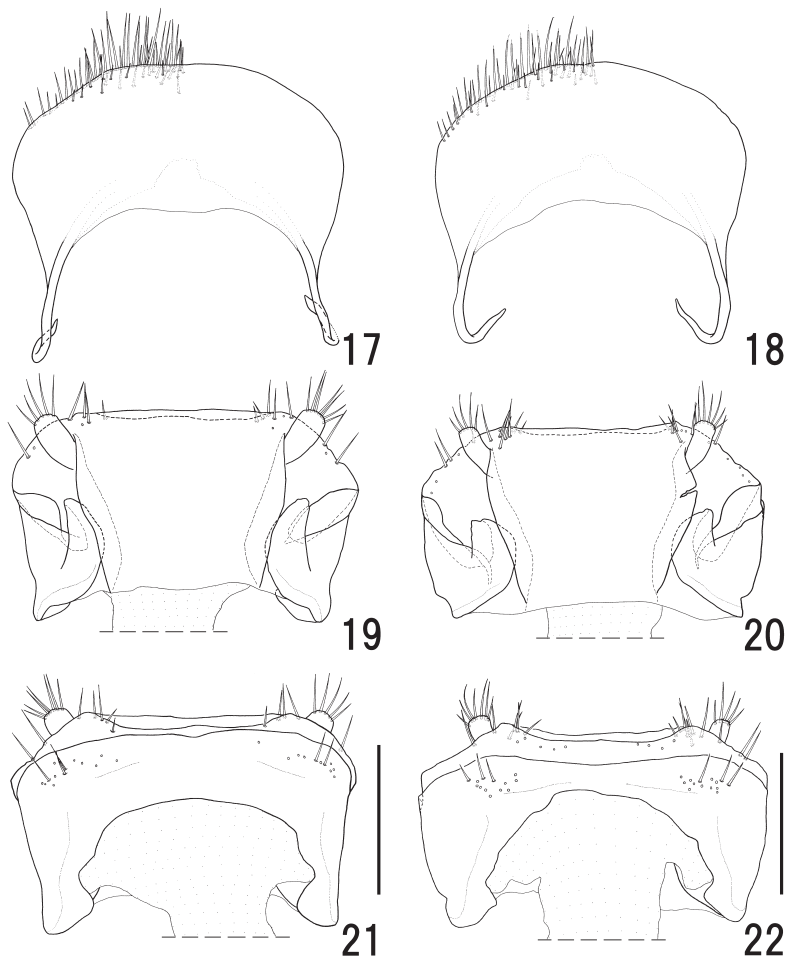
Figs. 11–16. Male terminalia of *Trachys* spp. — 11, 13 & 14, *Trachys griseofasciatus*; 12, 15 & 16, *T. yanoi*
 — 11 & 12, Sternite IX in ventral view; 13 & 15, tegmen in dorsal view; 14 & 16, penis in ventral view.
 Scale: 0.25 mm.

***Trachys yanoi* KUROSAWA, 1959**

[Japanese name: Yano-namigata-chibi-tamamushi]

(Figs. 8, 10, 12, 15, 16, 18, 20, 22 & 24)

Trachys yanoi KUROSAWA, 1959, 233, figs. 9 & 10 (type locality: Yokohama, Kanagawa Pref.); 1976 b, 4 (note); KUROSAWA, 1985, 35, pl. 7 (in pictorial book); AKIYAMA & OHMOMO, 1997, 49 (in checklist); 2000, 285, pl. 120 (in pictorial book); KUBÁŇ, 2006, 421 (cataloged); BELLAMY, 2008, 2533 (cataloged); OHMOMO & FUKUTOMI, 2013, 168, pl. 54 (in pictorial book); KUBÁŇ, 2016, 574 (cataloged); OHSAWA, 2017, 1 (biology); ISHIGURO & NISHIDA, 2018, 33, figs. 2, 3 & 6 (description of aedeagus).

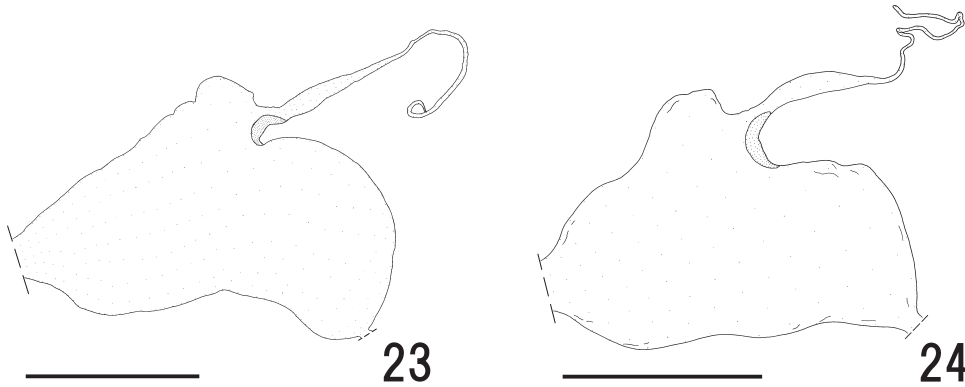


Figs. 17–22. Female terminalia of *Trachys* spp. — 17, 19 & 21, *Trachys griseofasciatus*; 18, 20 & 22, *T. yanoi*
 — 17 & 18, Proctiger in dorsal view; 19 & 20, coxites and ventral valve in dorsal view; 21 & 22, ditto, in ventral view. Scale: 0.25 mm.

Description of terminalia. M a l e (n = 5 for all measurements). Sternite IX (Fig. 12) narrower, SL/SW 0.86–1.03 (mean 0.94). Tegmen (Fig. 15) slenderer; parameres PL/PW 3.11–3.37 (mean 3.20), with sides which are gently dilated anteriorly in basal half, then weakly arcuately expanded to subapical part, and finally gradually convergent apicad; phallobase narrower, PbL/PbW 1.82–2.00 (mean 1.86). Otherwise practically as in *T. griseofasciatus*.

F e m a l e (n = 5 for all measurements). Ovipositor (Figs. 18, 20, 22 & 24) with narrower styli, SIL/SIW 2.25–2.75 (mean 2.55); vagina moderately expanded dorsally in middle. Otherwise practically as in *T. griseofasciatus*.

Specimens examined. 6 ♂♂, 6 ♀♀, Mt. Takao-san, Takao-chô, Hachiôji-shi, Tokyo-to, Honshu, Japan, 4.IX.2015, Y. TAMADERA leg. 1 ♂, 3 ♀♀, near Ishikawa Insect Museum, Inu, Yawata-machi, Hakusan-shi, Ishikawa-ken, Honshu, Japan, 15.VI.2016, Y. TAMADERA leg. 4 ♂♂, Mt. Goten-yama, Kanbara, Shimizu-ku, Shizuoka-shi, Shizuoka-ken, Honshu, Japan, 30.III.2017, H. NAGANO leg.



Figs. 23 & 24. Female terminalia of *Trachys* spp. — 23, *Trachys griseofasciatus*; 24, *T. yanoi* — 23 & 24, Vagina and the associated structures in lateral view. Scale: 0.50 mm.

Discussion

In this study, we investigated differences in structures of the male and female terminalia for two morphologically similar *Trachys* species, *T. griseofasciatus* and *T. yanoi*. The two target species show a close similarity in the structures, with no significant interspecific differences in most parts. However, we revealed by detailed morphological examination that they can be distinguished by the following points: 1) the male sternite IX (Figs. 11 & 12) is wider in *T. griseofasciatus* (SL/SW about 0.8) than in *T. yanoi* (SL/SW about 0.9); 2) the male parameres (Figs. 13 & 15) are slightly wider in *T. griseofasciatus* (PL/PW about 2.6) than in *T. yanoi* (PL/PW about 3.2), and the lateral contour is shaper in *T. griseofasciatus* than in *T. yanoi*; 3) the phallobase in the male genitalia (Figs. 13 & 15) is slightly wider in *T. griseofasciatus* (PbL/PbW about 1.7) than in *T. yanoi* (PbL/PbW about 1.9); and 4) the female styli (Figs. 19 & 20) are slightly wider in *T. griseofasciatus* (SIL/SIW about 2.1) than in *T. yanoi* (SIL/SIW about 2.6). Also, the two species are clearly distinguished from other congeners in Japan by the slenderer male penis (Figs. 14 & 16). Additionally, it is noteworthy that the two species share the female spermatheca with the spermathecal gland (Figs. 23 & 24) which is not recognized in one of the congeners, *T. minutus minutus* (KASAP & CROWSON, 1975; KOLIBÁČ, 2000). Here we do not mention about the taxonomic significance of the shape of vagina because we might be not able to observe the structures in a fully inflated state.

Differing from our observation, ISHIGURO and NISHIDA (2018) concluded that there are only slight interspecific differences in the male genital structures between *T. griseofasciatus* and *T. yanoi*. Judging from the figures shown by the authors, however, it is quite evident that their conclusion was deduced by rough examination lacking an adequate dissection technique to investigate subtle morphological differences in the male genital structures between the two species.

To date, for *Trachys* species, there have been only a few studies on structures of the male terminalia (KOLIBÁČ, 2000; LEVEY, 2012; ISHIGURO & NISHIDA, 2018) and fewer studies on those of the female terminalia (KASAP & CROWSON, 1975; KOLIBÁČ, 2000). The result of our study strongly suggests that the structures of the male and female terminalia, especially of the male sternite IX and tegmen and the female styli, are useful for species identification in the genus *Trachys*.

Presently, five species groups established by DESCARPENTRIES and VILLIERS (1965) are recognized in the genus *Trachys*, based mainly on differences in the elytral vestiture (BELLAMY, 2008). However, the intrageneric classification of the genus is rather confused with ill-defined species

groups, as well as with many species which are unplaced in or unable to be applied to the currently recognized groups. For example, *T. griseofasciatus* is placed in the *mixtipilis* species group at the moment (BELLAMY, 2008), while its close relative, *T. yanoi*, is not yet placed in any species group. Generally, *Trachys* species are so similar in external morphology that it is difficult to recognize species complexes within the genus. Therefore, a comprehensive revision based on detailed observations on characters of the external morphology and terminalia of both sexes is necessary to improve the intra-generic classification system of the genus *Trachys*.

Acknowledgments

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要 約

瑤寺 裕・吉武 啓：ナミガタチビタマムシ *Trachys griseofasciatus* SAUNDERS とヤノナミガタチビタマムシ *T. yanoi* KUROSAWA (鞘翅目タマムシ科) の雌雄腹部末端節の形態的特徴の記載とその分類学的重要性。——— 外観が酷似するナミガタチビタマムシ *Trachys griseofasciatus* SAUNDERS とヤノナミガタチビタマムシ *T. yanoi* KUROSAWA の雌雄の腹部末端節 (terminalia) の構造を詳細に観察し、比較検討を行った。また、それに伴い、チビタマムシ属 *Trachys* における雌雄の交尾器形態に関する用語を定義した。観察の結果、雌雄腹部末端節の構造に種差が認められ、とくに雄の腹部第9腹節 (sternite IX) と雄の包片 (tegmen)、雌の尾突起 (styli) の形状が両種の同定に有用であることが明らかになった。

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