Review of the species of *Trichomalus* (Chalcidoidea: Pteromalidae) associated with *Ceutorhynchus* (Coleoptera: Curculionidae) host species of European origin

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Abstract—Six species of *Trichomalus* Thomson were reared as parasitoids of Ceutorhynchinae hosts in Europe during surveys in 2000–2004. *Trichomalus rusticus* (Walker) is treated as a valid species, resurrected from synonymy under *T. lucidus* (Walker), and *T. lyttus* (Walker) is transferred from synonymy under *T. lucidus* and newly placed in synonymy with *T. rusticus*. Illustrated keys to females and males are given to differentiate the six species (*T. bracteatus* (Walker), *T. campestris* (Walker), *T. gynetelus* (Walker), *T. lucidus*, *T. perfectus* (Walker), and *T. rusticus*) except for males of *T. bracteatus* and *T. gynetelus*. A lectotype female is designated for *T. rusticus*. *Trichomalus campestris* is newly recorded as a parasitoid of *Ceutorhynchus cardariae* Korotyaev. Implications of the host–parasitoid associations recovered by the surveys are discussed relative to introduction of species to North America for classical biological control.

Résumé—Six espèces de *Trichomalus* Thomson ont été élevées en tant que parasitoïdes de Ceutorhynchinae en Europe lors de périodes d'échantillonnage entre 2000 et 2004. *Trichomalus rusticus* (Walker) est traité comme espèce valide et non plus comme synonyme de *T. lucidus* (Walker), et *T. lyttus* (Walker) est transféré de sa synonymie avec *T. lucidus* et nouvellement placé en tant que synonyme de *T. rusticus*. Une clé illustrée est fournie afin de différencier les mâles et les femelles des six espèces (*T. bracteatus* (Walker), *T. campestris* (Walker), *T. gynetelus* (Walker), *T. lucidus*, *T. perfectus* (Walker) et *T. rusticus*) à l'exception des mâles de *T. bracteatus* et *T. gynetelus*. Un lectotype femelle est décrit pour *T. rusticus*. *Trichomalus campestris* est trouvé pour la première fois parasitant *Ceutorhynchus cardariae* Korotyaev. Les associations hôte–parasitoïdes déterminées lors des échantillonnages sont discutées, et en particulier ce que ces résultats impliquent pour l'introduction d'espèces en Amérique du Nord en tant qu'auxiliaires de lutte biologique.

Introduction

Colonnelli (2004) stated that Ceutorhynchinae (Coleoptera: Curculionidae) contains 1316 species, making it one of the most speciose subfamilies of Curculionidae, itself the most speciose family of Coleoptera. Some species of Ceutorhynchinae are used worldwide as natural enemies for classical biological control of weeds to reduce their impact in crop and non-crop habitats (Julien and Griffiths

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1998), but several species are known to be herbivorous pests of high economic importance in agricultural crops (Dieckmann 1972; Mason and Huber 2002). One such species, the cabbage seedpod weevil, *Ceutorhynchus obstrictus* (Marsham) [= *Ceutorhynchus assimilis* (Paykull); see Colonnelli 2004], is a pest of oilseed rape, *Brassica napus* L. (Brassicaceae), in Europe and was accidentally introduced into western North America in the early 1930s (McLeod 1953). It is now widespread in North America (Kuhlmann *et al.* 2002), though it was only recently found in the Canadian provinces of Alberta (Cárcamo *et al.* 2001), Saskatchewan (Dosdall *et al.* 2002), Quebec (Brodeur *et al.* 2001), and Ontario (Mason *et al.* 2004). In the major canola (oilseed rape) production areas in Alberta and Saskatchewan, crop losses due to *C. obstrictus* have been reduced through registration of broad-spectrum insecticides (Mason and Huber 2002).

As an invasive alien species for North America, *C. obstrictus* was considered for classical biological control after its establishment, and in 1949 three species of larval ectoparasitoids were introduced from Europe to British Columbia, Canada (McLeod 1962). McLeod (1953) reported one of these species as *Trichomalus perfectus* (Walker) (Hymenoptera: Pteromalidae). *Trichomalus perfectus* is the most important parasitoid responsible for reducing *C. obstrictus* populations in Europe (Williams 2003) and is one of several species of *Trichomalus* Thomson known to be important members of parasitoid complexes associated with some species of Ceutorhynchinae (Murchie and Williams 1998). Although follow-up studies to prove establishment were not carried out, *T. perfectus* was considered established in North America until very recently. Gibson *et al.* (2005) verified from voucher material that *T. perfectus* was indeed introduced into British Columbia in 1949, but showed that all subsequent reports of *T. perfectus* in North America were based on misidentifications of another European species, *Trichomalus lucidus* (Walker).

Classical biological control of *C. obstrictus* is again being considered for North America to provide a reduced-risk alternative to insecticide applications. Accurate identification of natural enemies is the cornerstone of biological control and is essential when exotic species are introduced, especially when morphological differentiation among species is slight, such as for the species of *Trichomalus* associated with Ceutorhynchinae hosts. It is crucial to clarify the taxonomic status of closely related *Trichomalus* species to (*i*) accurately document ecological data on the species associated with Ceutorhynchinae hosts in Europe, the area of origin of *C. obstrictus*, and (*ii*) address safety issues in classical biological control initiatives.

In this paper we provide (*i*) illustrated keys to differentiate females and most males of *Trichomalus* species known from Ceutorhynchinae hosts in Europe; (*ii*) a list of type material examined, together with notes on concordance with specific characters of voucher specimens; (*iii*) a complete list of all voucher specimens examined; (*iv*) short diagnoses of females and males or, if required, a more comprehensive description of the species whose taxonomic status is being changed.

Material and methods

Our study is based primarily on surveys carried out during 2000–2004 in Switzerland, Germany, France, Austria, Hungary, Romania, and Ukraine, to obtain specimens of relevant species of *Trichomalus* associated with Ceutorhynchinae. "Lab ex." indicates that the specimens were obtained by dissecting Ceutorhynchinae host plants bearing a larval ectoparasitoid and then rearing the latter individually to the adult stage. "Mass collected" specimens were obtained by collecting and placing host plants in emergence boxes. Adult parasitoids emerged into glass vials and were collected, killed, air-dried, pinned, and labelled for later identification. All voucher specimens identified as collected by F. Muller, B. Klander, M. Grossrieder, and M. Cripps were obtained during the 2000–2004 field surveys and are deposited in the Natural History Museum in Bern, Switzerland (NMBE). Additional material, including type specimens of relevant species, was obtained from either NMBE or the Natural History Museum in London, United Kingdom (BMNH). A detailed list of hosts and host plants from which the various *Trichomalus* species were obtained is given in Table 1.

Descriptions are based on observations made using a Leica MZ16 binocular microscope coupled to a Leica CLS 150× incandescent light source and a light diffuser placed over the specimen to reduce glare. Several images of a specimen were taken through the binocular microscope at different focal planes using a JVC KY-F70BU triple CCD digital camera and processed using the Syncroscopy Auto-Montage™ software suite.

Table 1. List of hosts and host plants (all Brassicaceae except *T. perforatum* (Asteraceae)) from which the various *Trichomalus* species were obtained.

Trichomalus species	Host(s)	Host plant
Trichomalus bracteatus	Collected only from sweeping	
Trichomalus campestris	*Ceutorhynchus cardariae* Korotyaev and collected from sweeping	*Cardaria draba* (L.) Desv. (*Lepidium draba* L.) (root crown galls)
Trichomalus gynetelus	*Microplontus edentulus* Schultze and collected from sweeping	*Tripleurospermum perforatum* (Mérat) Laínz (stems)
Trichomalus lucidus	*Ceutorhynchus roberti* Gyllenhal	*Alliaria petiolata* (Bieb.) Cavara & Grande (stems)
	Ceutorhynchus alliariae Gyllenhal	*Alliaria petiolata* (Bieb.) Cavara & Grande (stems)
	Ceutorhynchus scrobicollis Nerensheimen and Wagner	*Alliaria petiolata* (Bieb.) Cavara & Grande (stems)
	Ceutorhynchus quadridens Panzer	*Brassica oleracea* L.
Trichomalus perfectus	*Ceutorhynchus obstrictus* (Marsham)	*Brassica napus* L. (pods)
Trichomalus rusticus	*Ceutorhynchus quadridens* Panzer	*Brassica oleracea* L.

This enabled production of a single, composite, focused image, which allowed us to overcome the problems historically associated with inadequate depth of field for three-dimensional imaging of tiny specimens. Images obtained from the Syncroscopy Auto-montage™ software suite were retouched using Adobe Photoshop CS™ to enhance the clarity of the illustrations.

Terms for morphological features and sculpture follow Gibson *et al.* (1997) and Goulet and Huber (1993). Terms for colours of various body parts are taken from Graham (1969). Measurements of each species were taken from about 6–10 air-dried specimens, depending on availability.

The synonymy of most *Trichomalus* species is not quoted here because it is often extensive and is readily accessible electronically in the Universal Chalcidoidea Database (Noyes 2006); however, the complete synonymy is given for those species for which we introduce a nomenclatural change.

Key to females of *Trichomalus* species

1 Procoxa testaceous, much paler than dark-green body (Fig. 1*b*). Fore wing often with a dark discal cloud (Fig. 2*a*), basal fold bare, and costal-cell setal line widely broken medially . . . *T. campestris* (Walker)

— Procoxa dark green with metallic tinge, concolorous with body (Fig. 1*a*). Fore wing hyaline (Figs. 2*c*, 2*e*, 2*g*, 2*i*), basal fold and costal cell with complete setal line 2

2(1) Fore wing with marginal vein at most 1.5 times as long as stigmal vein and stigma relatively large (Fig. 2*e*). Flagellum with first funicular segment distinctly broader than pedicel in lateral view (Fig. 3*c*) . . . . . *T. perfectus* (Walker)

— Fore wing with marginal vein at least 1.6 times as long as stigmal vein and stigma smaller (Figs. 2*c*, 2*g*, 2*i*). Flagellum with first funicular segment about as broad as pedicel in lateral view (Fig. 3*a*) 3

3(2) Metacoxa densely setose dorsobasally (Fig. 4*e*) . . . . . *T. rusticus* (Walker)

— Metacoxa sparsely setose dorsobasally (Fig. 4*a*) 4

4(3) Gaster at most 2.5 times as long as broad (Fig. 5*c*). Median area of propodeum 1.25–1.4 times as broad as long . . . . . *T. lucidus* (Walker)

— Gaster about 2.4–3.4 times as long as broad (Fig. 5*g*). Median area of propodeum about 1.6–1.95 times as broad as long 5

5(4) Gaster about 1.6–1.75 times as long as mesosoma; last tergum 1.0–1.6 times as long as its basal breadth (Fig. 5*g*) . . . . . *T. bracteatus* (Walker)

— Gaster about 1.7–2.0 times as long as mesosoma; last tergum 1.7–2.15 times as long as its basal breadth . . . . . *T. gynetelus* (Walker)

Key to males of *Trichomalus* species

(Note that *T. bracteatus* and *T. gynetelus* are keyed out according to features given by Graham (1969); the male of *T. rusticus* is unknown.)

1 Procoxa testaceous, much paler than dark-green body (Fig. 1*b*). Antenna (Fig. 3*e*) with scape long and stout, only about 3 times as long as broad and broadest in middle, but about 1.0–1.2 times as long as eye height; flagellum with funicular segments 4–6, or at least 5 and 6, pale, remaining segments dark. Fore wing with basal fold bare and costal-cell setal line widely broken medially (Fig. 2*b*). Gaster with a pale transverse band basally (Fig. 5*b*) . . . . . *T. campestris* (Walker)

— Procoxa dark green with metallic tinge, concolorous with body (Fig. 1*a*). Antenna (Figs. 3*b*, 3*d*) with scape short and relatively slender, about 4 times as long as broad and slightly expanded apically, and at most 0.8 times as long as eye height; flagellum dark (Figs. 3*b*, 3*d*). Forewing with setal lines on basal fold and on lower side of costal cell complete (Figs. 2*d*, 2*f*, 2*h*). Gaster at most with a pale spot basally (Figs. 5*d*, 5*f*) 2

2(1) Gena slightly compressed and with a sharp edge near base of mandible (Fig. 6*b*). Pronotal collar almost as broad as mesoscutum (Fig. 8*b*), its antetrior margin less strongly curved when viewed from behind (Fig. 8*b*). Marginal vein 1.1–1.4 times as long as stigmal vein and stigma relatively large (Fig. 2*f*) . . . . . *T. perfectus* (Walker)

— Gena rounded, without sharp edge near base of mandible (Fig. 6*a*). Pronotal collar distinctly narrower than mesoscutum (Fig. 8*a*), its anterior margin more strongly curved when viewed from behind (Fig. 8*a*). Marginal vein 1.5–1.8 times as long as stigmal vein and stigma relatively small (Fig. 2*d*). 3

3(2) Propodeum medially about half as long as scutellum . . . . . *T. lucidus* (Walker)

— Propodeum medially slightly less than half as long as scutellum . . . . . *T. bracteatus* (Walker) and *T. gynetelus* (Walker)

Trichomalus bracteatus (Walker, 1835)

Type material

Pteromalus bracteatus (Walker, 1835: 483), lectotype female (B.M. TYPE HYM. 5.3398) in BMNH, designated by Graham 1956: 247 (examined by Baur).

Material examined

ITALY. Como: Olgiate-Com. SW Pare, 45°48′24.7″N, 8°59′42.23″E, 370 m, 15.vi.1992, H. Baur, collected by sweeping (1 ♀). **SWITZERLAND. Bern:** Boltigen, Vordere Reldigen, 46°34′37.92″N, 7°20′3.04″E, 1420 m, 12.vii.1997, H. Baur, collected by sweeping (1 ♀); Bremgarten, Hoger, 46°58′37.8″E, 7°25′50.71″E, 550 m, 21.vi.2001, H. Baur, collected by sweeping (1 ♀); Rumendingen, 47°6′29.98″N, 7°38′5.78″E, 510 m, 26.v.1992, H. Baur, collected by sweeping (1 ♀). **Jura:** La Chaud-des-Breuleux, tourbière, 47°13′12.73″N, 7°1′45.72″E, 970 m, 18.vii.1996, H. Baur, collected by sweeping (1 ♀). **Valais:** NE Hohtenn (subalpine Weide), 46°19′39.55″N, 7°46′18.17″E, 1460 m, 30.vi.1992, H. Baur, collected by sweeping (1 ♀). **Oberwald:** Gonerlital, 46°31′28.31″N, 8°21′50.31″E, 1500 m, 20.vi.1999, H. Baur, collected by sweeping (1 ♀). **Vaud:** Le Chenit, Burtignière (emergence trap), 46°33′19.2″N, 6°9′52.45″E, 1050 m, 7–14.viii.1994, C. Vaucher, collected by sweeping (1 ♀).

Diagnosis

Female

Length 2.5–3.1 mm (Fig. 7*g*). Antenna in lateral view with first funicular segment at most slightly broader than pedicel. Procoxa dark green with metallic tinge, similar to body. Fore wing hyaline (Fig. 2*i*); marginal vein 1.7–2.0 times as long as stigmal vein; stigma small; basal fold and lower side of costal cell with complete setal lines. Metacoxa sparsely setose dorsobasally (Fig. 4*d*). Propodeum with median area 1.6–1.85 times as broad as long, from almost smooth to slightly strigose. Gaster 1.6–1.75 times as long as mesosoma and 2.4–3.0 times as long as broad; length of last tergum about 1.0–1.6 times its basal breadth.

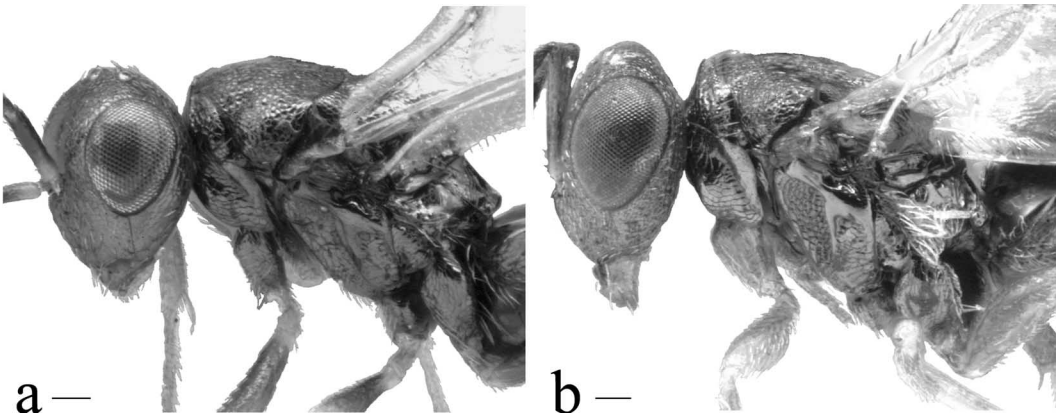
Male

See characters given in the key.

Remarks

We reared only females of *T. bracteatus* and *T. gynetelus* in our surveys. Females of these two species are differentiated only by relatively subtle differences in gastral shape as given in the key. The differences mentioned by Graham (Graham 1969) concerning the size of the forewing stigma were actually not diagnostic for our specimens.

Fig. 1. Head and mesosoma (lateral view) illustrating differences in procoxa coloration in ♀ *Trichomalus bracteatus* (*a*) and ♀ *Trichomalus campestris* (*b*). Scale bars = 100 µm.



Trichomalus campestris (Walker, 1834)

Type material

Amblymerus campestris (Walker, 1834: 343), lectotype female in BMNH, designated by Graham (Graham 1956) (not examined).

Material examined

FRANCE. Hérault: St-Guilhem-le-Désert, Les Lavagnes, 30.iii.2002, H. Baur (1 ♀). **ITALY. Novara:** 0.9 km east of Orta, 45°47′55.6″N, 8°26′30.38″E, 24.vi.1993, H. Baur (1 ♀, 1 ♂). **Varallo:** 0.5 km south of Monte Novesso, 45°50′28.13″N, 8°19′26.87″E, 27.vi.1993, H. Baur (3 ♂). **ROMANIA. Lasi:** RO12, 47°10′8.34″N, 27°28′2.10″E, 12.v.2003, em. 2–4.vii.2003, leg. M. Cripps, Lab ex. from *C. cardariae* in root-crown galls of *L. draba* (2 ♂, 1 ♀). **SWITZERLAND. Berne:** Berne, Eymatt, 46°57′49.2″N, 7°23′43″E, 20.v.2004, H. Baur (3 ♀); Bremgarten, Hoger, 46°58′37.8″N, 7°25′50.71″E, 12.v.1992, H. Baur (1 ♀), 26.v.2004, H. Baur (3 ♀). **Solothurn:** Rickenbach, 47°20′52.49″N, 7°51′5.52″E, 10.x.1995, H. Baur (1 ♀); Trimbach, Miesernbach, 47°21′56.95″N, 7°52′27.04″E, 25.iv.2002, H. Baur (2 ♀). **Valais:** Baltschieder–Kumme, 3.iv.1999, B. Merz (1 ♀); Simplon, Laggintal, 47°10′15″N, 8°04′05″E, 21.ix.1998, H. Baur (1 ♂). **UKRAINE. Crimea:** Shchebetovka, 44°57′10.80″N, 35°7′56.16″E, 17.v.2003, em. 8.vi.2003, M. Cripps, Lab ex. from *C. cardariae* in root–crown galls of *L. draba* (1 ♀).

Diagnosis

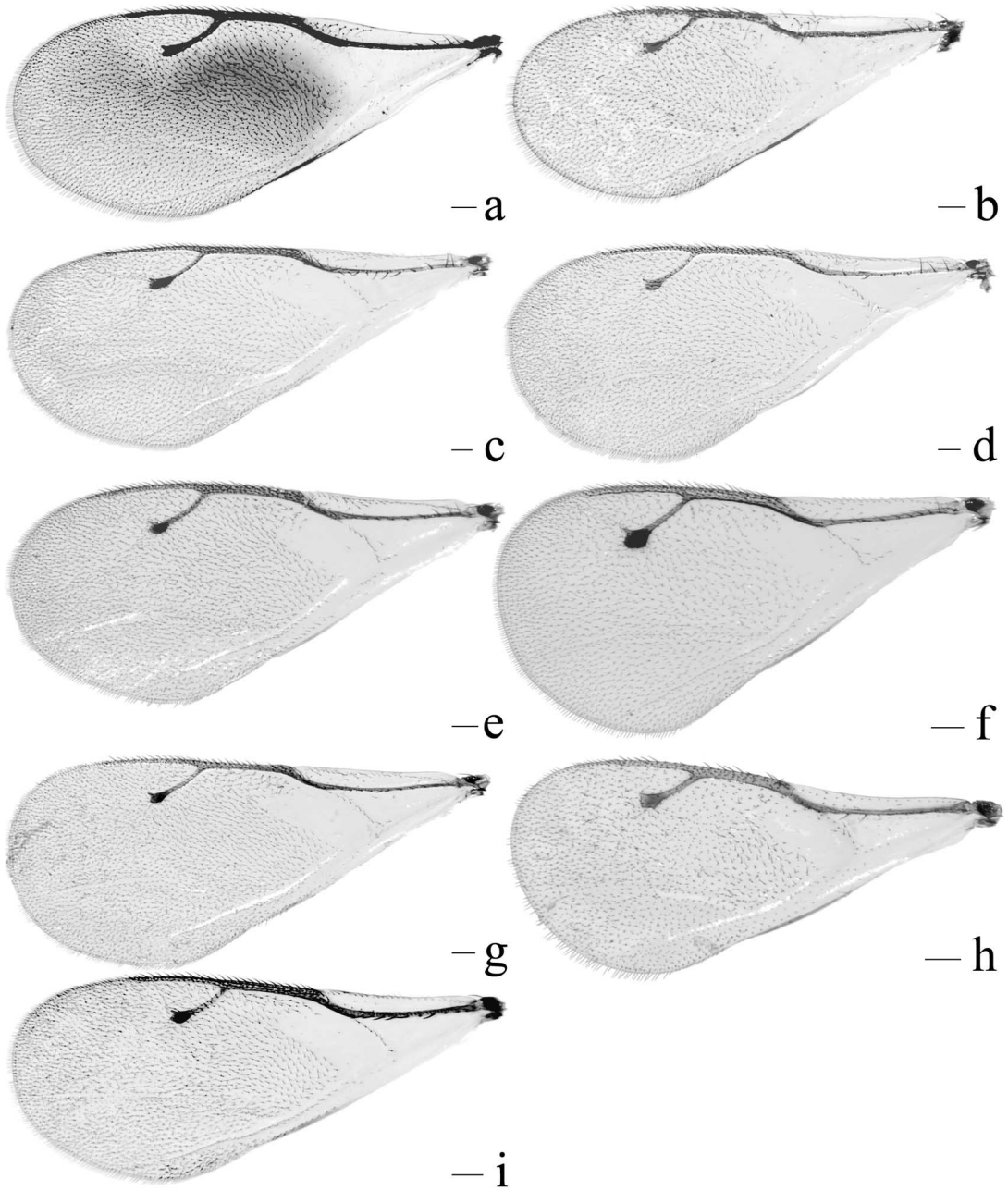
Female

Length 1.8–2.3 mm (Fig. 7*a*). Antenna in lateral view with first funicular segment about as broad as pedicel. Procoxa testaceous (Fig. 1*b*). Fore wing often with a dark discal cloud (Fig. 2*a*), marginal vein 1.1–1.5 times as long as stigmal vein (Fig. 2*a*); stigma small; basal fold bare; costal cell with setal line on lower surface widely interrupted medially. Metacoxa densely setose dorsobasally (Fig. 4*e*). Propodeum with median area 1.45–1.6 times as broad as long, weakly sculptured. Gaster about 1.4–1.6 times as long as mesosoma and 1.7–2.1 times as long as broad; length of last tergum 0.8–0.9 times its basal breadth (Fig. 5*a*).

Male

Length 1.4–1.7 mm (Fig. 7*d*). Procoxa testaceous (Fig. 1*b*). Antenna with scape testaceous (Fig. 3*e*), broadest medially, only about 3 times as long as broad and 1.0–1.2 times as long as eye height; flagellum dark with funicular segments 4–6 or 5 and 6 testaceous (Fig. 3*e*). Gena rounded near base of mandible (Fig. 6*a*). Pronotal collar distinctly narrower than mesoscutum (Fig. 8*a*), its anterior margin rather strongly curved viewed from behind. Fore wing with marginal vein 1.2–1.35 times as long as stigmal vein (Fig. 2*b*); basal fold bare, costal cell with setal line on lower surface widely interrupted medially; stigma small. Metacoxa densely setose dorsobasally. Propodeum about half as long as scutellum. Gaster with a pale transverse band basally (Fig. 5*b*).

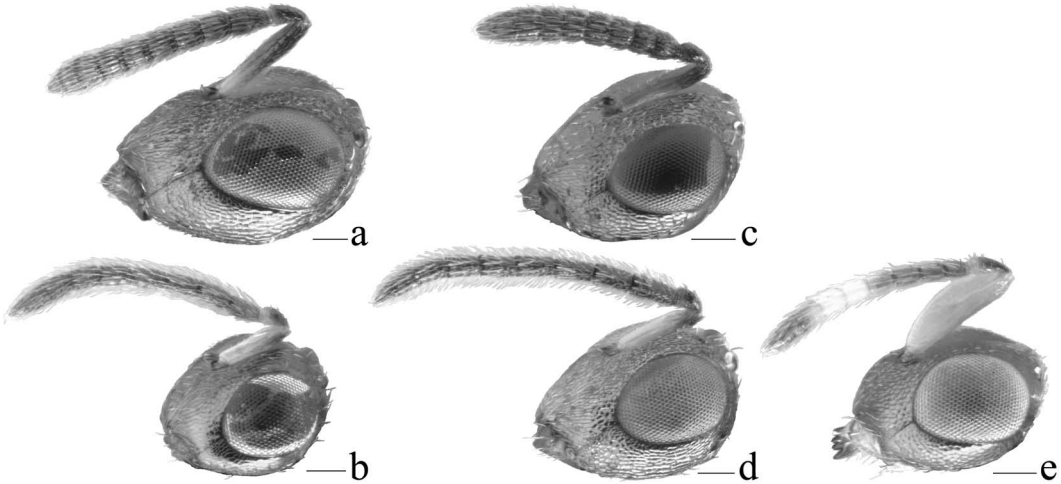
Fig. 2. Fore wings of ♀ *Trichomalus campestris* (*a*); ♂ *T. campestris* (*b*); ♀ *T. lucidus* (*c*); ♂ *T. lucidus* (*d*); ♀ *T. perfectus* (*e*); ♂ *T. perfectus* (*f*); ♀ *T. rusticus* (*g*); ♂ *T. rusticus* (*h*); and ♀ *T. bracteatus* (*i*). Scale bars = 100 μm.



Remarks

The yellowish procoxae readily differentiate both sexes of *T. campestris* from other *Trichomalus* species associated with *Ceutorhynchus* species. Females are often also differentiated by having the fore wing infumate below the marginal vein, and males are differentiated by structure of their scape, and the antennal and gastral colour pattern. Our rearing of *T. campestris* from *Ceutorhynchus cardariae* Korotyaev in root-crown galls of *Cardaria* draba (L.) (whitetop) represents a new host record for the species.

Fig. 3. Head and antennae (anterolateral view) of ♀ *Trichomalus lucidus* (*a*); ♂ *T. lucidus* (*b*); ♀ *T. perfectus* (*c*); ♂ *T. perfectus* (*d*); and ♂ *T. campestris* (*e*). Scale bars = 100 µm.



Trichomalus gynetelus (Walker, 1835)

Type material

Pteromalus gynetelus Walker, 1835: 483, lectotype female (B.M. TYPE HYM. 5.1767) in BNHM, designated by Graham (Graham 1956); paralectotypes 4 female (BMNH) (examined by Baur).

Material examined

AUSTRIA. Eisenstadt: AUS-EIS2, 15.vi.2003, F. Muller, Lab ex. *M. edentulus* Schultze in stems of *T. perforatum* (Mérat) Laínz (Asteraceae: Anthemideae) (1 ♀). **CZECH REPUBLIC. Bohemia:** Praha–Butovice, Prokopskè Udoli, 50°2′36.54″N, 14°21′20.88″E, 100 m, 7.vi.2004, H. Baur, collected by sweeping (1 ♀). **SWITZERLAND. Valais:** northeast Hohtenn (subalpine Weide), 46°19′39.55″N, 7°46′18.17″, 1460 m, 30.vi.1992, H. Baur, collected by sweeping (1 ♀); Fully, Les Follatères, 46°7′22.43″N, 7°4′16.44″E, 620 m, 18.vi.2004, H. Baur, collected by sweeping (1 ♀). **Jura:** La Chaud-des-Breuleux, La Baumatte, 47°13′12.73″N, 7°1′45.72″E, 1100 m, 18.vii.1996, H. Baur, collected by sweeping (1 ♀).

Diagnosis

Female

Length 2.4–3.1 mm (Fig. 7*h*). Antenna in lateral view with first funicular segment at most slightly broader than pedicel. Procoxa dark green with metallic tinge, similar to body. Fore wing hyaline (Fig. 2*a*); marginal vein 1.6–2.0 times as long as stigmal vein; stigma of medium size; basal fold and lower side of costal cell with complete setal lines. Metacoxa sparsely setose dorsobasally (Fig. 4*c*). Propodeum with median area 1.65–1.95 times as broad as long, from almost smooth to slightly strigose. Gaster 1.7–1.95 times as long as mesosoma and 2.9–3.4 times as long as broad; length of last tergum about 1.7–2.15 times its basal breadth.

Male

See characters given in the key.

Remarks

See *T. bracteatus*.

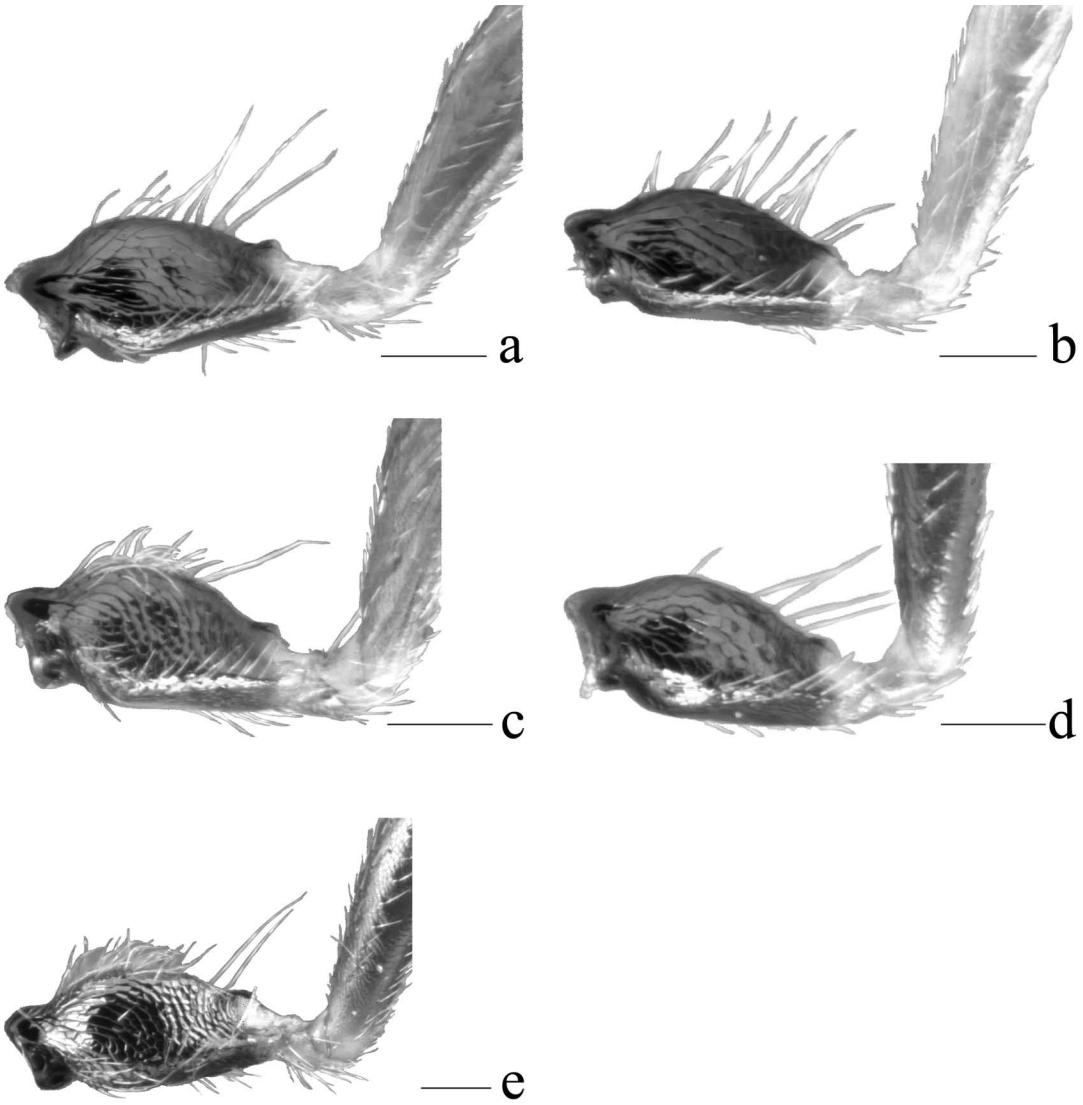
Trichomalus lucidus (Walker, 1835)

Type material

Pteromalus lucidus Walker, 1835: 484, lectotype female (B.M. TYPE HYM. 5.3394) in BMNH, designated by Graham (Graham 1956) (specimen glued on rectangular card, head and mesosoma with strong coppery tinge; metacoxae covered with glue, hence some setae probably worn off; however, only a few seta sockets present) (examined by Baur).

Pteromalus brevicornis Walker, 1835: 491, lectotype female (B.M. TYPE HYM. 5.1772) in BMNH, designated by Graham (Graham 1956) (specimen glued on rectangular card, head and mesosoma with strong coppery tinge) (examined by Baur).

Fig. 4. Metacoxa (lateral view) illustrating differences in pilosity in ♀ *Trichomalus lucidus* (*a*); ♂ *T. lucidus* (*b*); ♀ *T. perfectus* (*c*); ♀ *T. bracteatus* (*d*); and ♀ *T. rusticus* (*e*). Scale bars = 100 µm.



Pteromalus chalceus Walker, 1835: 491, lectotype female (B.M. TYPE HYM. 5.1770) in BMNH, designated by Graham (Graham 1956) (specimen glued on rectangular card) (examined by Baur).

Pteromalus despectus Walker, 1835: 491, lectotype female (B.M. TYPE HYM. 5.771) in BMNH, designated by Graham (Graham 1956) (specimen glued on rectangular card) (examined by Baur).

Pteromalus mundus (Förster, 1841: 12), lectotype male in Natural History Museum, Vienna, Austria, designated by Graham (Graham 1956) (not examined; primary homonym of *Pteromalus mundus* Walker, 1836).

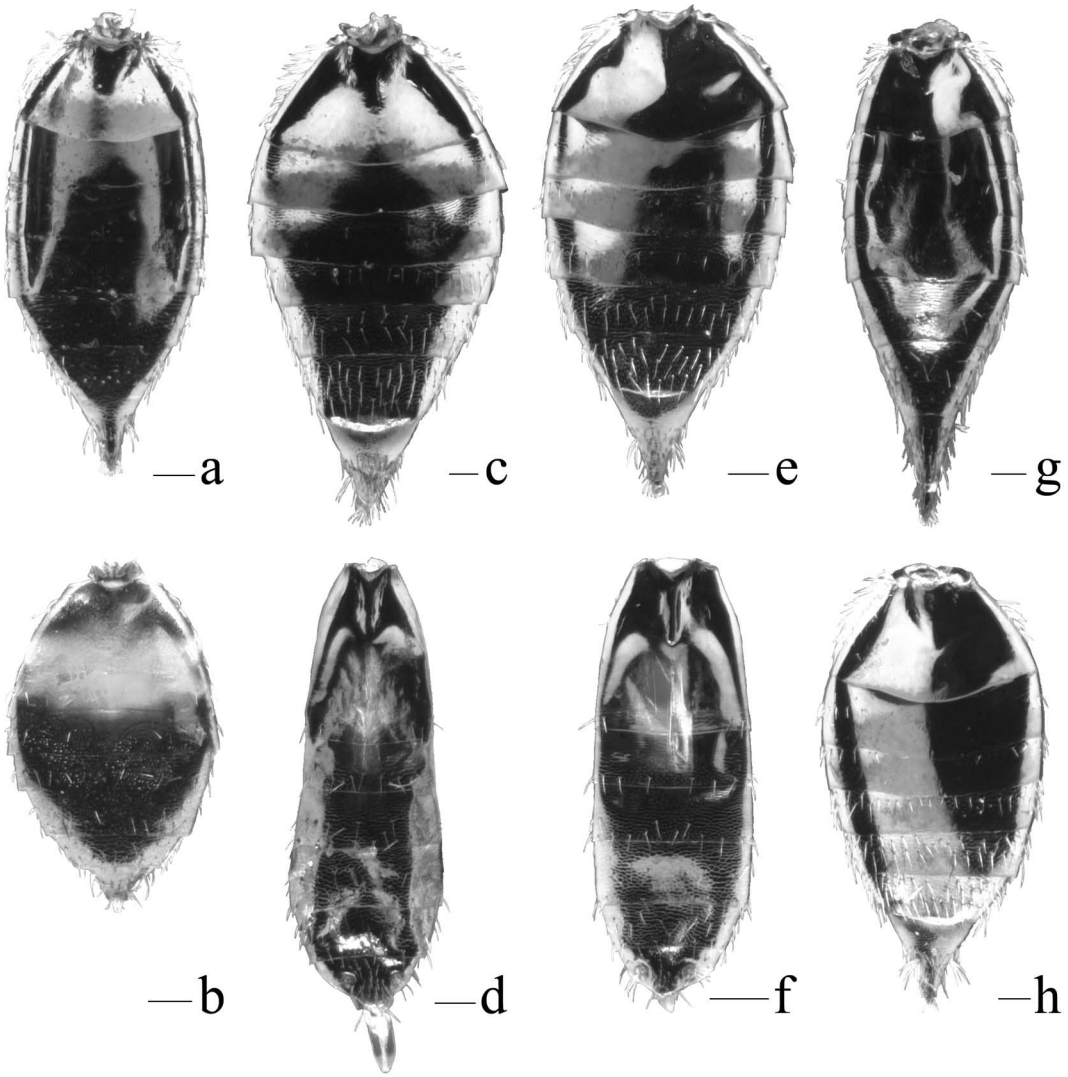
Isocyrtus (*Trichomalus*) *fasciatus* (Thomson, 1878: 139), lectotype female in Zoological Museum, Lund University, Lund, Sweden, designated by Graham (Graham 1956) (not examined).

Pteromalus purus (Dalla Torre, 1898: 144), replacement name for *Pteromalus mundus* (Förster, 1841, not Walker, 1836: 479).

Material examined

GERMANY. Baden-Württemberg: Rheintal, Müllheim, 2000, B. Klander, Lab ex.

Fig. 5. Metasoma (dorsal view) of ♀ *Trichomalus campestris* (*a*); ♂ *T. campestris* (*b*); ♀ *T. lucidus* (*c*); ♂ *T. lucidus* (*d*); ♀ *T. perfectus* (*e*); ♂ *T. perfectus* (*f*); ♀ *T. bracteatus* (*g*); and ♀ *T. rusticus* (*h*). Scale bars = 100 μm.



C. roberti in stems of *A. petiolata* (1 ♂); Neuenburg, 31.v.2001 and 19.vi.2001, B. Klander, Lab ex. C. roberti in stems of *A. petiolata* (2 ♂, 2 ♀); Zienken, 2000, B. Klander, Lab ex. C. roberti in stems of *A. petiolata* (1 ♂). **Brandenburg–Berlin:** Berlin, Schoenebeck, 2.vi.2001, M. Grossrieder, Lab ex. *C. alliariae* in stems of *A. petiolata* (1 ♂, 1 ♀); 5.vi.2001, M. Grossrieder, Lab ex. *C. scrobicollis* in stems of *A. petiolata* (1 ♂, 1 ♀). **Brandenburg:** 19–30.v.2001, M. Grossrieder, Lab ex. *C. alliariae* in stems of *A. petiolata* (2 ♂); 19–25.v.2001, M. Grossrieder, Lab ex. *C. scrobicollis* in stems of *A. petiolata* (1 ♂, 1 ♀). **Schleswig–Holstein:** Griebel, 28.vi.2001, M. Grossrieder, Lab ex. *C. alliariae* in stems of *A. petiolata* (1 ♀); Hotzkaten, 2000, M. Grossrieder, Lab ex. *C. alliariae* in stems of *A. petiolata* (1 ♂). **SWITZERLAND. Baselland:** Grellingen, 30.v–26.vi.2001, M. Grossrieder, Lab ex. *C. roberti* in stems of *A. petiolata* (38 ♂, 19 ♀). **Fribourg:** Sugiez, 19.vi.2000, M. Grossrieder, *ex C. quadridens* in cabbage (1 ♀, 1 ♂). **Jura:** Delemont, 18.vi.2002, F. Muller, Lab ex. *C. alliariae* or *C. roberti* in stems of *A. petiolata* (1 ♀), same, 30.v.2002 (1 ♂) and 3.vi.2002 (1 ♂); Delemont, Vorbourg, 5.vi.2001, M. Grossrieder, Lab ex. *C. roberti* in stems of

Fig. 6. Head (anteroventral view) illustrating differences in the shape of the gena in ♂ *Trichomalus lucidus* (*a*) and ♂ *T. perfectus* (*b*). Scale bars = 100 µm.

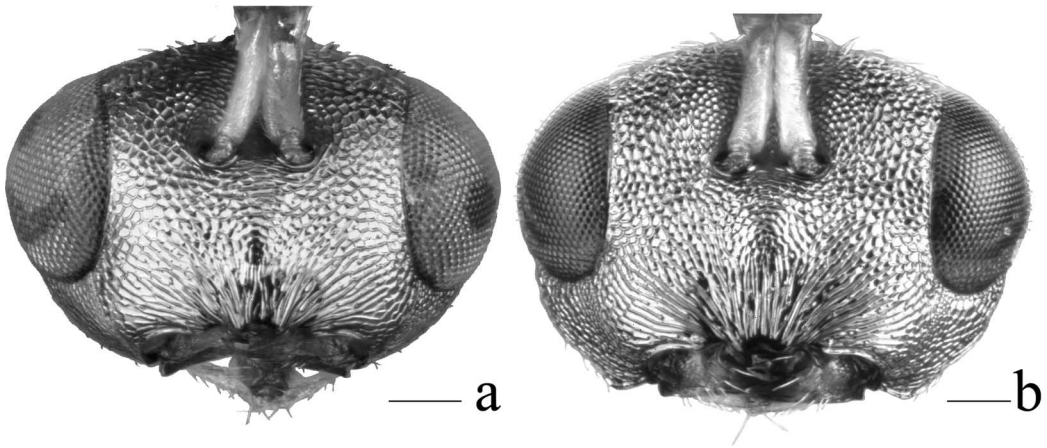


Fig. 7. Habitus of ♀ *Trichomalus campestris* (*a*); ♀ *T. lucidus* (*b*); ♀ *T. perfectus* (*c*); ♂ *T. campestris* (*d*); ♂ *T. lucidus* (*e*); ♂ *T. perfectus* (*f*); ♀ *T. bracteatus* (*g*); ♀ *T. Gynetulus* (*h*); and ♀ *T. rusticus* (*i*). Scale bars = 100 µm.

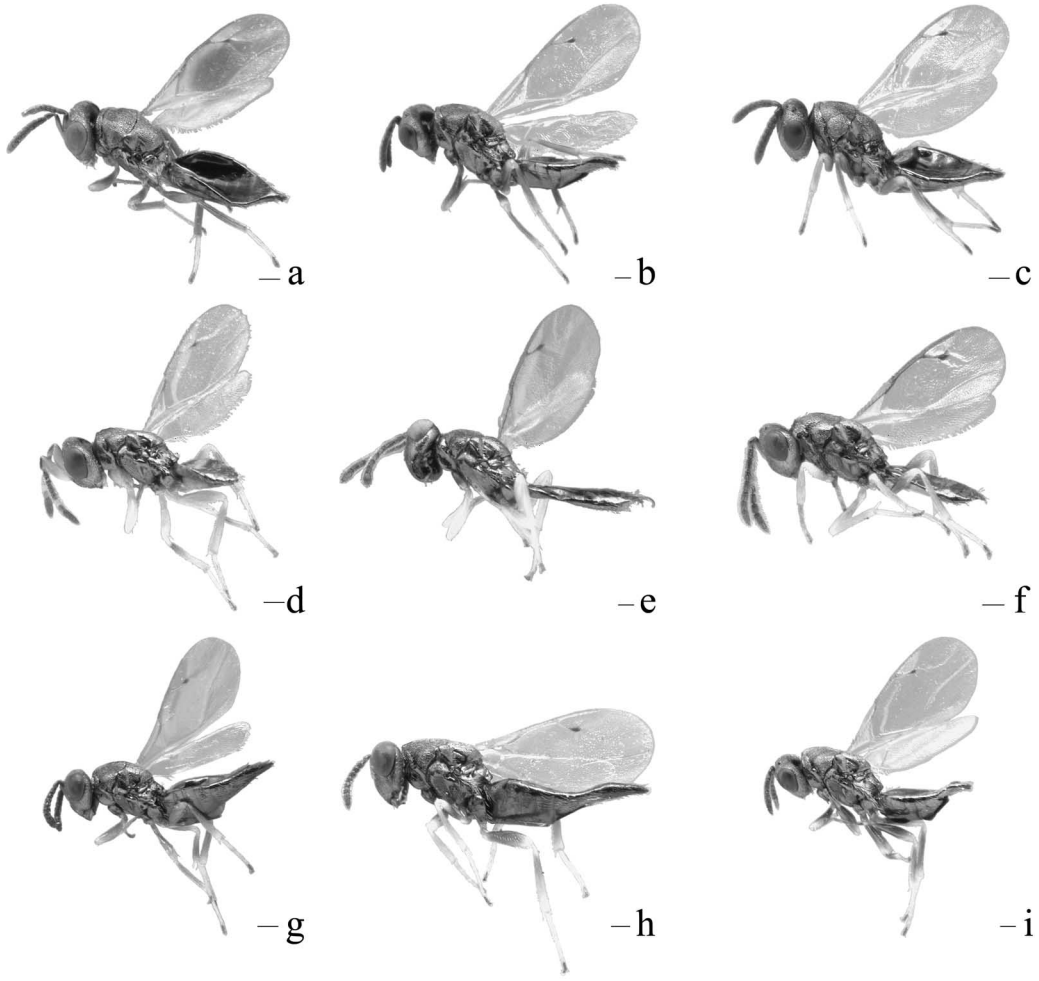
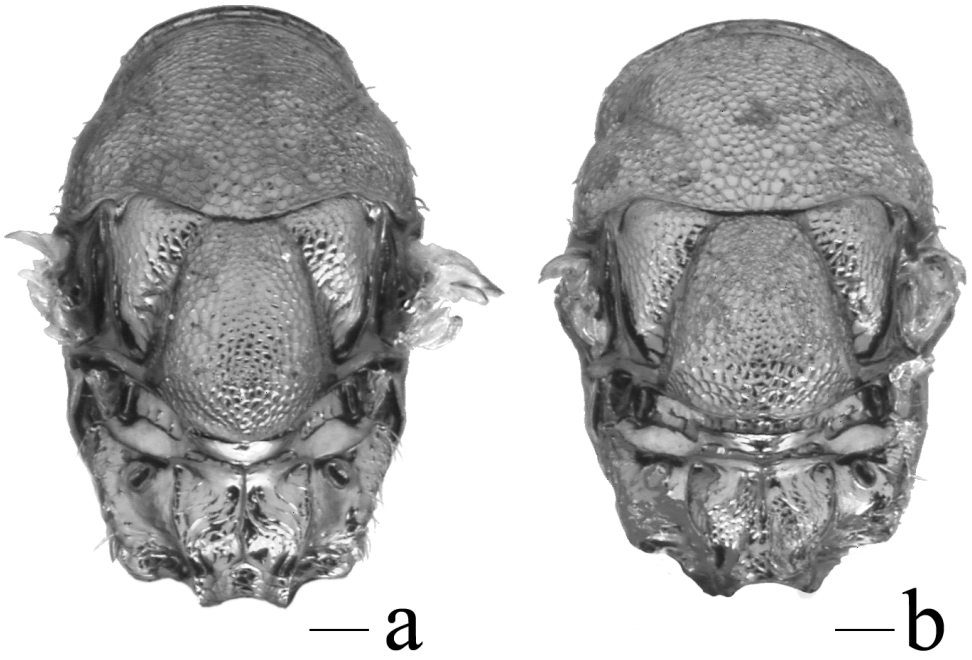


Fig. 8. Mesosoma (dorsal view) illustrating differences in the pronotal collar in ♂ *T. lucidus* (*a*) and ♂ *T. perfectus* (*b*). Scale bars = 100 µm.



A. petiolata (2 ♂); Undevelier, 25.v.2001, M. Grossrieder, Lab ex. *C. roberti* in stems of *A. petiolata* (1 ♂).

Diagnosis

Female

Length 2.5–3.1 mm (Fig. 7*b*). Antenna in lateral view with first funicular segment at most slightly broader than pedicel (Fig. 3*a*). Fore wing hyaline (Fig. 2*c*); marginal vein 1.7–2.0 times as long as stigmal vein (Fig. 2*c*); stigma small; basal fold and lower side of costal cell with complete setal lines. Procoxae dark green with metallic tinge, similar to body (Fig. 1*a*). Metacoxa sparsely setose dorsobasally (Fig. 4*a*). Propodeum 1.25–1.4 times as broad as long, median area weakly sculptured. Gaster 1.25–1.4 times as long as mesosoma and 2.1–2.4 times as long as broad; length of last tergum about 0.7–0.9 times its basal breadth (Fig. 5*c*).

Male

Length 1.9–2.5 mm (Fig. 7*e*). Procoxa dark (Fig. 1*a*). Antenna with scape testaceous, distinctly expanded apically (Fig. 3*b*), about 4 times as long as broad and about 0.75 times eye height; flagellum dark. Gena rounded near base of mandible (Fig. 6*a*). Pronotal collar distinctly narrower than mesoscutum (Fig. 8), its anterior margin rather strongly curved when viewed from behind. Fore wing with marginal vein 1.55–1.8 times as long as stigmal vein; basal fold and lower side of costal cell with complete setal lines (Fig. 2*d*); stigma small. Metacoxa sparsely setose dorsobasally (Fig. 4*b*). Propodeum about half as long as scutellum. Gaster with a pale spot basally (Fig. 5*d*).

Remarks

Of the lectotypes listed above that we examined, all agree well with the diagnosis of *T. lucidus* and are therefore considered conspecific. We accept the synonymy of Graham (1969) for the other names. Females of *T. lucidus* and *T. rusticus* are very similar, as is discussed under the latter species.

Trichomalus perfectus (Walker, 1835)

Type material

Pteromalus perfectus Walker, 1835: 488, lectotype female (B.M. TYPE HYM. 5.1798) in BMNH, designated by Graham (1956: 250) (examined by Gibson).

Material examined

FRANCE. Alsace: Faverois, FAV, 47°31′8.21″N, 7°3′11.94″E, 6.vii.204, F. Muller, mass collected, *ex C. obstrictus* in pods of *B. napus* (7 ♂, 10 ♀), Lab ex. from larval parasitoids, *ex C. obstrictus* in pods of *B. napus* (2 ♂, 3 ♀); Boron, BRN3, 47°32′11.34″N, 7°0′24.09″E, 21.vi.2004, F. Muller, Lab ex. from larval parasitoids, *ex C. obstrictus* in pods of *Brassica napus* L. (1 ♀). **GERMANY. Schleswig–Holstein:** Rastorfer Passau, 54°16′58.80″N, 10°20′60.00″E, 3–28.vi.2002 and 1–10.vii.2002, F. Muller, Lab ex. from larval parasitoids, *ex C. obstrictus* in pods of *B. napus* (15 ♂, 7 ♀); Kiel, 24.vi.1999, B. Klander *ex C. obstrictus* in pods of *B. napus* (1 ♀), same, 5.vi.2000 (2 ♂). **SWITZERLAND. Jura:** Chatillon, La Prîre, CHA11, 47°20′3.43″N, 7°19′56.28″E, 8.vi.2004, F. Muller, Lab ex. from larval parasitoids, *ex C. obstrictus* in pods of *B. napus* (1 ♀); CHA12, 47°19′46.64″N, 7°19′53.44″E, 22.vi.2004, F. Muller, Lab ex. from larval parasitoids, *ex C. obstrictus* in pods of *B. napus* (1 ♂); CHA14, 47°20′20.18″N, 7°19′56.51″E, 15.vi.2004, F. Muller, Lab ex. from larval parasitoids, *ex C. obstrictus* in pods of *B. napus* (2 ♂); CHA-LP2, 20.vi.2003, F. Muller, Lab ex. from larval parasitoids, *ex C. obstrictus* in pods of *B. napus* (1 ♂, 6 ♀); 28.vi.2002, F. Muller, Lab ex. from larval parasitoids, *ex C. obstrictus* in pods of *B. napus* (1 ♂, 1 ♀); CHA-LP3, 9–25.vi.2002 and 1.vii.2002, F. Muller, Lab ex. from larval parasitoids, *ex C. obstrictus* in pods of *B. napus* (8 ♂, 3 ♀); CHA-1, 9, 18, 19, 22, 26, and 28.vi.2002 and 1.vii.2003, F. Muller, Lab ex. from larval parasitoids, *ex C. obstrictus* in pods of *B. napus* (7 ♂, 6 ♀); Delémont, Le Chavelier DEL-DOM, 10–13 and 20.vi.2003, F. Muller, Lab ex. from larval parasitoids, *ex C. obstrictus* in pods of *B. napus* (11 ♂, 5 ♀); Courgenay, CGY1, 47°24′14.40″N, 7°9′24.25″E, 21.vi.2004, F. Muller, Lab ex. from larval parasitoids, *ex C. obstrictus* in pods of *B. napus* (1 ♂). **Fribourg:** Galmiz, Gal, 46°59′20.40″N, 7°5′60.00″E, 28.vii.2004, F. Muller, Lab ex. from larval parasitoids, *ex C. obstrictus* in pods of *B. napus* (1 ♂, 1 ♀).

Diagnosis

Female

Length 1.65–2.9 mm (Fig. 7*c*). Antenna in lateral view with first funicular segment distinctly broader than pedicel (Fig. 3*c*). Procoxa dark green with metallic tinge, similar to body (Fig. 1*a*). Fore wing hyaline (Fig. 2*e*); marginal vein 1.35–1.5 times as long as stigmal vein (Fig. 2*e*); stigma of medium size, on average slightly larger than in *T. lucidus* (Figs. 2*c*, 2*e*); basal fold and lower side of costal cell with complete setal lines. Metacoxa densely setose dorsobasally (Fig. 4*c*). Propodeum with median area 1.45–1.6 times as broad as long, strigose-reticulate. Gaster 1.2–1.4 times as long as mesosoma and 1.8–2.1 times as long as broad; length of last tergum 0.8–0.95 times its basal breadth (Fig. 5*e*).

Male

Length 1.6–2.2 mm (Fig. 7*f*). Procoxa dark (Fig. 1*a*). Antenna with scape testaceous, distinctly expanded apically (Fig. 3*d*), about 4 times as long as broad and about 0.75 times eye height; flagellum dark (Fig. 3*d*). Gena slightly compressed and with sharp edge near base of mandible (Fig. 6*b*). Pronotal collar almost as broad as mesoscutum (Fig. 8*b*), its anterior margin only weakly curved when viewed from behind. Forewing with marginal vein 1.1–1.4 times as long as stigmal vein; basal fold and lower side of costal cell with complete setal lines (Fig. 2*f*); stigma relatively large. Metacoxa densely setose dorsobasally. Propodeum about half as long as scutellum. Gaster with a pale spot basally (Fig. 5*f*).

Remarks

Individuals of *T. perfectus* are differentiated from other species of *Trichomalus* associated with *Ceutorhynchus* species by a combination of features as given in the key.

Trichomalus rusticus (Walker, 1836), revised status

Type material

Pteromalus rusticus (Walker, 1836: 482), lectotype female (B.M. TYPE HYM. 5.3396) in BMNH, **present designation**; labelled "Pteromalus rusticus Walker; Stood under this name in old B. M. C. Waterhouse [back side of former label]; *Pteromalus rusticus* W. LECTOTYPE M. de V. Graham 1956; B.M. TYPE HYM. 5.3396″ (specimen glued on rectangular card, lacking right metacoxa and gaster; badly covered with dust, colour of legs and venation partly darkened, certainly an artefact) (examined by Baur).

Pteromalus lyttus (Walker 1848: 125), 194, lectotype female (B.M. TYPE HYM. 5.1773) in BMNH, designated by Graham (Graham 1956) (specimen glued on rectangular card, body with rather strong coppery tinges) (examined by Baur) **syn. nov.**

Material examined

SWEDEN. Akarp: 17.i.1962, H. von Rosen (1 ♀). **Lomma;** 17.i.1962 and 1.i.1964, H. von Rosen (5 ♀). **SWITZERLAND. Neuchatel:** St-Blaise, 10.iv.1978 and 13–16.iv.1979, J. Casas, collected by sweeping (6 ♀); Sugiez, 19.vi.2000, B. Klander, found in cabbage, *ex Ceutorhynchus quadridens* (1 ♀). **Solothurn:** Hüniken, S. Tannfeld, 20.ix.1993, H. Baur (1 ♀).

Diagnosis

Female

Length 2.3–2.9 mm (Fig. 7*i*). Antenna with scape dark in apical three quarters, pedicel and flagellum dark; scape 0.75–0.9 times eye height; pedicel about 1.8 times as long as broad in lateral view; pedicel plus flagellum 0.85–1.0 times as long as head breadth; flagellum slender, slightly clavate; first funicular segment rather slender, about 1.25 times as long as broad, only slightly broader than pedicel in lateral view; last funicular segment distinctly transverse, about 0.8 times as long as broad. Head 2.1–2.2 times as broad as long, 1.2–1.35 times as broad as mesoscutum, finely reticulate with minute and high meshes on vertex; postocellar length 1.6–1.8 times ocellocular length; eye 1.3–1.4 times as high as broad, separated by 1.25–1.4 times their height; malar space 0.44–0.53 times as long as eye height; clypeus striate, weakly emarginate medially. Body dark metallic green (Fig. 7*i*); legs testaceous except coxae concolorous with body and femora slightly darker. Mesosoma 1.6–1.7 times as long as broad. Pronotal collar about one seventh as long as mesoscutum length. Mesoscutum 1.45–1.55 times as broad as long, reticulate with sculpture consisting of small meshes anteriorly and larger ones posteriorly; scutellum 0.9–0.95 times as broad as long, reticulate. Fore wing hyaline (Fig. 2*g*); marginal vein 1.6–1.8 times as long as stigmal vein; stigma small, separated by about 2.5–3.1 times its height from hind margin of postmarginal vein; basal fold and lower side of costal cell with complete setal lines; speculum open below. Metacoxa densely setose dorsobasally (Fig. 4*e*); metafemur about 3.8–4.4 times as long as broad. Propodeum with complete plicae, median area finely alutaceous, about 1.2–1.4 times as long as broad and 0.5–0.6 times as long as scutellum; costulae indicated laterally, sometimes complete; nucha weakly reticulate; callus moderately hairy. Gaster (1.3–) 1.5–1.9 times as long as broad (Fig. 5*h*) and 0.9–1.17 times as long as mesosoma, ovate and acuminate; length of last tergum about 0.55–0.8 times its basal breadth; sides of basal tergum with conspicuous patch of whitish hairs basally.

Male

Unknown.

Remarks

Pteromalus rusticus was listed by Graham (1969) among the synonyms of *T. lucidus*, but the lectotype designation was not published in that or any other paper (see Delucchi and Graham 1956; Graham 1969). Hence, the specimen is regarded as a syntype, which is herein designated as lectotype. *Trichomalus rusticus* is very similar to *T. lucidus*, but we consider it is a distinct species. Although males are unknown, females of *T. rusticus* can be differentiated from those of *T. lucidus* by the following features (with features of *T. lucidus* in brackets): Femora, especially metafemur, infuscate in basal half [mostly testaceous]. Sculpture on vertex, mesoscutum and scutellum relatively strong, with high meshes [sculpture finer]. Marginal vein usually shorter, 1.6–1.8 times as long as stigmal vein [1.7–2.0 times]. Base of metacoxa with thick batch of setae that extend somewhat towards outer aspect of coxa [setae sparse and confined to dorsal aspect]. Gaster normally 1.5–1.9 times as long as wide; however, one specimen has a ratio of only 1.3 [about 2–2.4 times].

Discussion

The results of our study have direct implications for documenting ecological baseline data of parasitoid – Ceutorhynchinae host associations, which is essential for a renewed classical biological initiative against *C. obstrictus* in Canada. *Trichomalus lucidus* is confirmed as a parasitoid of *Ceutorhynchus alliariae* Brisout, 1860 (Coleoptera: Curculionidae) and *Ceutorhynchus roberti* Gyllenhal, 1837 (Coleoptera: Curculionidae), two candidate classical biological

control agents used against *Alliaria petiolata* (Bieb.) Cavara & Grande (garlic mustard) (Gerber *et al.* 2003), which poses a severe threat to the biodiversity of forest habitats (Blossey *et al.* 2002) in much of the eastern and midwestern United States of America. We did not rear *T. lucidus* from *C. obstrictus* in our surveys, though Klander (2001) reported that 1.7% of the parasitoids she reared from *C. obstrictus* on *B. napus* from Schleswig-Holstein, Germany, in 2000 were *T. lucidus*, and this species is purportedly one of the major parasitoids of *C. obstrictus* in North America (Gibson *et al.* 2005). Based on this apparent ecological difference, molecular analyses are warranted for specimens identified as *T. lucidus* in Europe and North America to test whether the populations actually represent two cryptic species. Also, for the first time we record *T. campestris* as a parasitoid of the gall-forming weevil *C. cardariae*, a potential agent for classical biological control of *C. draba* in North America. We reared *T. perfectus* only from *C. obstrictus*, which is its main host; it has only rarely been recorded from other *Ceutorhynchus* spp. hosts in Europe (Klander 2001). Consequently, this species could be considered for introduction to North America for classical biological control of *C. obstrictus*.

The number of concerns regarding potential nontarget effects of biological control agents used against arthropods has risen during the last decade, during which time an increasing number of studies have dealt with this topic (Babendreier *et al.* 2005). The clarification of the taxonomy of *Trichomalus* species presented here provides a sound basis for understanding these dynamics, leading towards the safe use of *Trichomalus* species in future biological control approaches against pest species of Ceutorhynchinae. In addition, understanding the population dynamics of Ceutorhynchinae species of economic importance is still hampered by insufficient knowledge of the natural enemy complexes that may play an important role in the regulation of these herbivorous insects (Vidal 2003). Our results constitute a first step in understanding these dynamics.

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