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A new parasitoid of the Erythrina Gall Wasp, *Quadrastichus erythrinae* Kim (Hymenoptera: Eulophidae)

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Abstract

Aprostocetus exertus La Salle (Hymenoptera: Eulophidae: Tetrastichinae) is described as a parasitoid of the invasive Erythrina Gall Wasp, *Quadrastichus erythrinae* Kim (Hymenoptera: Eulophidae: Tetrastichinae). The description is based on material originally collected in Tanzania and South Africa. This species is described because of its potential as a biological control agent against the Erythrina Gall Wasp.

Key words: Hymenoptera, Eulophidae, invasive species, *Quadrastichus*, parasitoid, *Aprostocetus*, *Erythrina*, Fabaceae

Introduction

Coral trees (Fabaceae: *Erythrina* spp.) are highly valued trees which are found throughout tropical regions of the world, with about 120 species in the genus (Mabberly 2008). They are used as ornamentals in landscaping, for windbreaks and for soil and water conservation, as well as playing an important role in folk traditions and indigenous medicine (Hartwell 1967–1971, List & Horhammer 1969–1979, Perry 1980, Rotar *et al*. 1986, Yang *et al*. 2004, Gates & Delvare 2008). The Erythrina Gall Wasp (EGW), *Quadrastichus erythrinae* Kim (Eulophidae: Tetrastichinae), induces galls on the leaves, petioles, twigs and shoots of several species of coral trees. It was first recorded from La Réunion, Mauritius and Singapore (Kim *et al.* 2004), has subsequently spread rapidly so that its range now includes Hawaii, Taiwan, Hong Kong, China, India, Thailand, American Samoa, Guam, Okinawa, Japan, Florida (USA) (Yang *et al*. 2004, Heu *et al.* 2006, Faiza *et al.* 2006, Uechi *et al*. 2007, Gates & Delvare 2008), and it has the potential for even greater range expansion in the future (Li *et al.* 2006). Severe EGW infestations can cause curling of young shoots, defoliation, and even death of afflicted trees (Yang *et al.* 2004, Heu *et al.* 2006). Its impact in Hawaii has been particularly devastating, where it is destroying and threatening with extinction the endemic species, *E. sandwicensis* O. Deg. (Gramling 2005). If it continues to spread in Japan, it could have a similar effect on the endemic *E. boninensis* Tuyama (Uechi *et al*. 2007).

The origin of EGW could only be speculated upon in earlier works (Kim *et al.* 2004, Yang *et al.* 2004,) but it is now clear that it is originally from East Africa. It was already known that a group of *Quadrastichus* species induced galls on *Erythrina* in Africa (van Staden *et al*. 1977, La Salle unpublished, Prinsloo pers. comm., Prinsloo & Kelly 2009). Foreign exploration undertaken by the Hawaii Department of Agriculture has confirmed that this group of *Quadrastichus* species which induce galls on *Erythrina* is larger than previously expected, with species throughout subtropical Africa. It has also confirmed that *Q. erythrinae* does occur naturally in Tanzania, where it has a complex of natural enemies which have potential for the biological control of this pest. One of these species, *Eurytoma erythrinae* Gates & Delvare, was recently described (Gates & Delvare 2008), and the description of another is being published in a companion paper (Prinsloo & Kelly, 2009). This paper describes a third potential biological control agent of EGW.

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Several species of Eulophidae are known to induce galls, and these have been reviewed by La Salle (2005). There is a growing list of eulophids which have become invasive within the last two decades, and these include: *Oncastichus goughi* Headrick & La Salle on Geraldton wax, *Chamelaucium uncinatum* Schauer (Headrick *et al*. 1995, Gates & Schauff 2005), *Epichrysocharis burwelli* Schauff & Garrison on eucalypts (Schauff & Garrison 2000), *Ophelimus maskelli* (Ashmead) on eucalypts (Protasov et al. 2007b), *Leptocybe invasa* Fisher & La Salle on eucalypts (Mendel *et al*. 2004), as well as the tetrastichines *Moona spermophaga* Kim & La Salle and *Leprosa milga* Kim & La Salle, both of which induce galls in eucalypt seed capsules (Kim *et al*. 2005, Kim & La Salle 2008).

Biological control opportunities

While gall inducers have not been the usual target for biological control introductions, there is no reason not to expect that success can be achieved. The chestnut gall wasp, *Dryocosmus kuriphilus* Yasumatsu (Hymenoptera: Cynipidae), was successfully controlled in Japan by *Torymus sinensis* Kamijo (Hymenoptera: Torymidae), which was introduced from China for that purpose (Moriya *et al*. 2003). Since then, there is every indication that successful control of the eucalyptus gall wasp *Ophelimus maskelli* (Ashmead) (Eulophidae: Ophelimini) is underway in the Mediterranean Basin due to the introduction of *Closterocerus chamaeleon* (Girault) (Eulophidae: Entedoninae) (Rizzo *et al.* 2006, Mendel *et al*. 2007, Protasov *et al*. 2007a, b, De Marzo 2007). Additionally, two species of parasitoids, *Quadrastichus mendeli* Kim & La Salle, and *Selitrichodes kryceri* Kim & La Salle, have recently been released and established in Israel in an attempt at biological control of another invasive gall former, *Leptocybe invasa* (Kim *et al*. 2008). It is still too early to tell if this will result in successful control.

It is interesting to note that in the case of *Ophelimus maskelli*, both the invasive pest and the main natural enemy are in the same family (Eulophidae), while with *Leptocybe invasa* the pest and main natural enemies are even within the same subfamily (Eulophidae: Tetrastichinae). With EGW it is possible that we will have another example of an invasive pest and an introduced natural enemy from the same subfamily.

Material and Methods

Taxonomy

Terminology used in this paper is taken from Gibson (1997) and Graham (1987). OOL, ocellar–ocular distance; POL, post-ocellar distance; CC, costal cell; SMV, submarginal vein; MV, marginal vein; STV, stigmal vein; PMV, postmarginal vein; F1–3, funicular segment 1–3.

Acronyms used in the text are as follows. ANIC, Australian National Insect Collection, CSIRO Entomology, Canberra, Australia; BMNH, Natural History Museum, London, UK; BPBM, Bernice P. Bishop Museum, Honolulu, Hawaii, USA; NMK, National Museums of Kenya, Nairobi, Kenya; SANC, South African National Collection of Insects, Plant Protection Research Institute, Pretoria, South Africa; USNM, United States National Museum of Natural History, Washington, D.C., USA.

***Aprostocetus exertus* La Salle sp. nov.**
(Figs 1–16)

Diagnosis. This species is easily recognized by the exerted part of the ovipositor and postcercale, which are slightly longer than the combined length of the head plus body. This character, coupled with the almost completely white fore and middle coxae, should make it unmistakeable.

Description. *Female* (Figs 1–3). Body length 1.45 – 1.75 mm from head to base of exerted part of ovipositor and extension of T7.

Head metallic green to blue, palps yellow. Antenna with scape yellow (may be brownish apically), flagellum yellow to light brown. Mesosoma mainly metallic green to blue; some of the sutures between mesosomal segments may be yellow, particular the mesopleural plates and scapula. Legs white; fore and mid coxae white, with small basal brown spot; hind coxa brown, with white spot apically. Gaster brown with green to blue shine, a yellow spot dorsally on the first gastral tergite, and a white to yellow medial triangle dorsally on the last gastral tergite just anterior to the cerci.

Head (Fig. 7). POL about 3 times as long as OOL; LOL subequal to or slightly longer than OOL. Face with weak frontofacial suture just ventral to median ocellus. Scrobal depression with weak median suture dorsally and median carina or projection ventrally. Torulus located at middle of face; slightly above the lower margin of eye; apex scape not exceeding vertex.

Gena only slightly swollen and malar sulcus straight or very slightly curved. Clypeal margin strongly bidentate. Mouth only slightly wider than length of malar space.

Antenna (Fig. 13) with 3 anelli and 3 funicular segments. Anelli closely appressed, the second anellus smallest, the third anellus subquadrate, and may have setae on external margin. All funicular segments slender and longer than broad. F1 3.6–4.0 times longer than wide, F2 2.6–2.9 times longer than wide; F3 2.1–2.5 times longer than wide (F1: F2: F3 = 1.0: 0.7–0.8: 0.6–0.7). Clava 3 segmented, 2.0–2.15 times longer than F3.

Mesosoma (Figs 8–10). Pronotum short in dorsal view, mainly in vertical plane. Mid lobe of mesoscutum with weak median line; with 2–4 (generally 3) strong, semi-erect adnotaular setae on each side; notaulus quite deep. Scutellum with distinct submedian and sublateral lines; anterior pair of setae located slightly posterior to middle; posterior pair of setae located near posterior margin. Propodeum shorter medially than median length of dorsellum; without distinct median carina; without paraspiracular carina; outer rim of propodeal spiracle partially covered by a raised flap of callus; spiracular depression open to anterior margin of propodeum. Callus with 2 setae.

Gaster (Figs 11–12) with the ultimate gastral segment (T7) greatly extended so that the length of the postcercale (that region of the last gastral segment posterior to the cerci) is longer than the combined length of the head plus body. What appears to be the exerted part of the ovipositor thus consists of the ovipositor and ovipositor sheaths, plus the extended last gastral tergite. This exerted part of the ovipositor 1.85–2.3 times as long as gaster; 1.15–1.3 times as long as gaster plus mesosoma. Apex of hypopygium extending less than half the length of gaster. Cercus with the longest setae distinctly longer than remaining setae, and slightly curved.

Wing (Fig 15). Submarginal vein with 2(–3) dorsal setae; tapering apically and joining parastigma distally to proximal end of parastigma. Marginal vein not swollen. Veins light brown to brown. Wing hyaline, with some light infuscation present near apex of stigmal vein, and at junction of basal and cubital veins. Postmarginal vein less than 0.25 length of stigmal vein. Costal cell apically with 2–4 setae on underside of wing. Marginal vein relatively long in comparison to other veins; costal cell: marginal vein: stigmal vein: postmarginal vein = 0.7–0.85: 1.0: 0.15–0.2: 0.05–0.1. Postmarginal vein 0.3–0.5 length of stigmal vein. Cubital line of setae extending to basal vein or slightly basal to junction with basal vein (speculum closed behind). Subcubital line of setae not extending basal of apical margin of speculum.

***Male*.** Body length 1.0–1.6 mm.

Body color almost the same as female; although with a larger white to yellow area at the base of the gaster. Antenna (Fig. 14) with 3 anelli; and 4 funicular segments which are all longer than broad; without whorls of long setae. Ventral plaque situated near apex of scape, length less than 0.25 length of scape. Genitalia often distinctly extended, exerted part of genitalia may equal length of gaster (fig. 16).

Type material. Holotype ♀: laboratory culture, Hawaii. Originally from TANZANIA, Arusha, Masai Camp Village, 27.i.2006, M. Ramadan, ex *Erythrina abyssinica* galls (ANIC).

Paratypes: 58♀, 55♂. Same data as Holotype (3♀,7♂ ANIC; 2♀,2♂ BMNH, 2♀,2♂ SANC, 2♀,2♂ USNM). South Africa, KwaZulu-Natal Prov., Pietermaritzburg, University Botanic Gardens, 29°36’S 30°22’E, xi.2008, D.J. Brothers or B. Muller, ex leaf galls on *Erythrina latissima* (39♀,32♂ ANIC; 2♀,2♂ BMNH, 2♀,2♂ USNM, 2♀,2♂ SANC, 2♀,2♂ BPBM, 2♀,2♂ NMK)

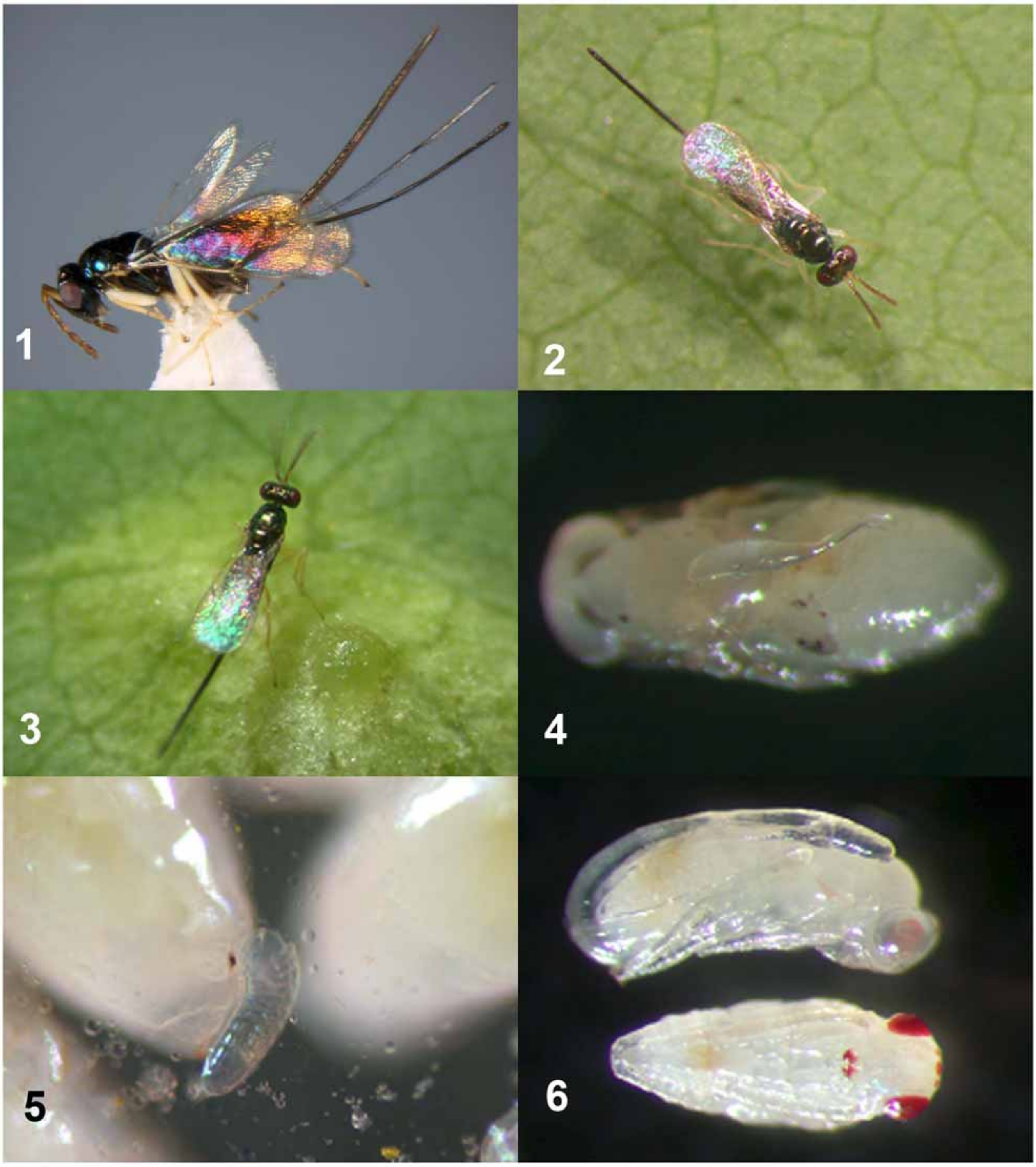

PLATE 1. *Aprostocetus exertus* La Salle. Fig. 1. ♀ Habitus. Figs 2–3. Female wasp searching for galls. Fig. 4. *A. exertus* egg on EGW pupa. Fig. 5. *A. exertus* larva feeding externally on EGW larva. Fig. 6. *A. exertus* pupae: female (above) and male (below).

Biology. Foreign exploration work searching for EGW parasitoids in East Africa was undertaken by one of us (MR), and revealed that *Aprostocetus exertus* is one of three main parasitoids in Tanzania reducing the populations of the gall wasps of *Erythrina* species. The other two species are *Eurytoma erythrinae* Gates & Delvare (Gates & Delvare 2008), and an *Aprostocetus* species being described in a companion paper by Prinsloo & Kelly (2009). Field observations showed that *A. exertus* was not the dominant parasitoid at any surveyed locality in Tanzania; however it is an important component of the parasitoid guild because it is present at very low population levels of the gall wasps, and under a very harsh environmental condition.

Because of its exerted long ovipositor, it has the ability to reach for galls deep in the stems of *Erythrina* that other parasitoids can not reach. Also, it is known to attack EGW under native conditions, as it was found attacking *Quadrastichus erythrinae* in *Erythrina abyssinica* in the Morogoro province in Tanzania.

Biological studies undertaken by the Hawaii Department of Agriculture have shown that this species is ectoparasitic, and will attack both larvae and pupae (Figs 4–5). Specimens from South Africa emerged from leaf galls on *Erythrina latissima* (see Prinsloo & Kelly 2009).

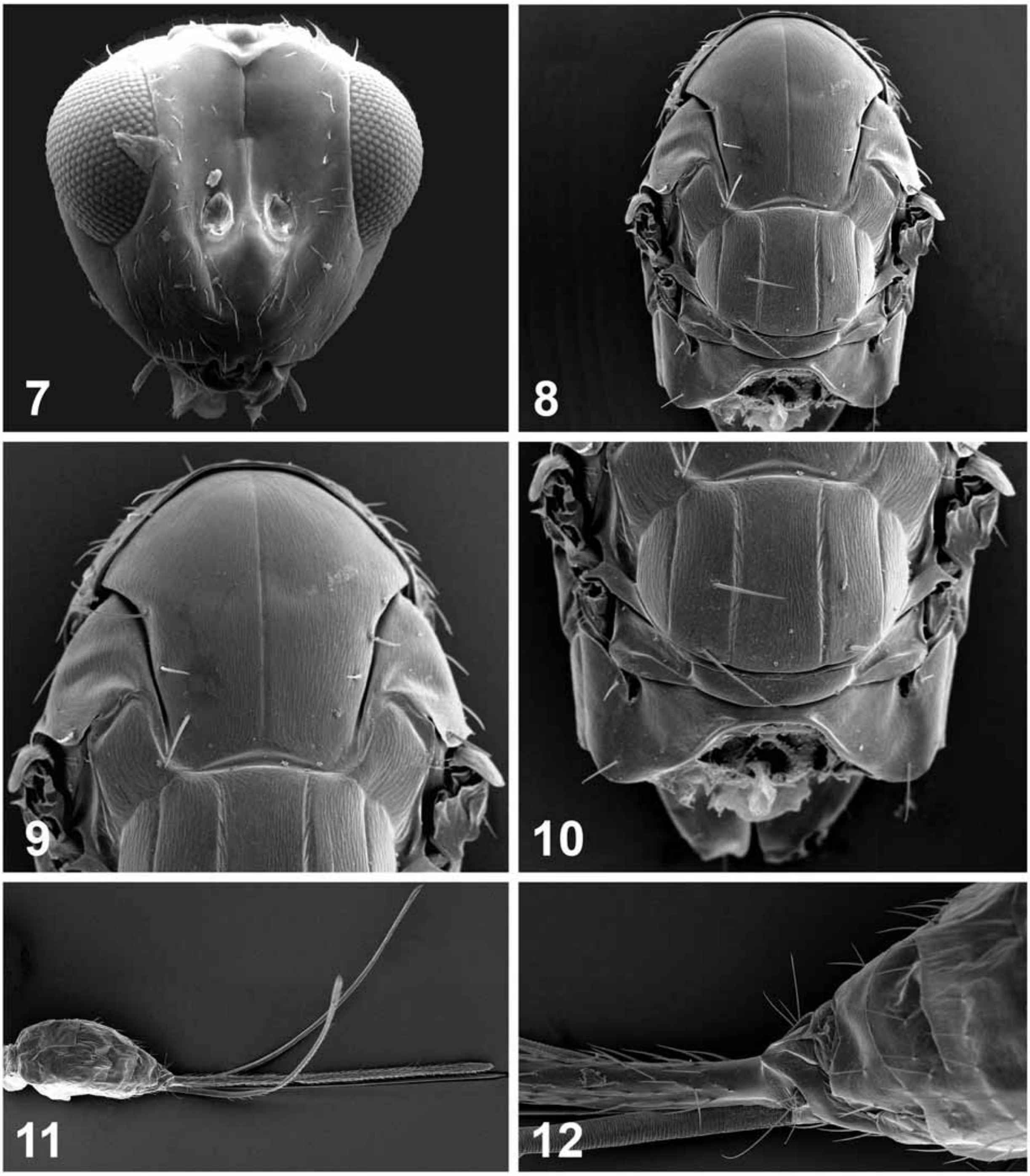

PLATE 2. *Aprostocetus exertus* La Salle ♀. Fig. 7. Head, frontal view. Fig. 8. Mesosoma, dorsal view. Fig. 9. Mesoscutum, dorsal view. Fig. 10. Scutellum and propodeum, dorsal view. Fig. 11. Gaster and ovipositor, lateral view. Fig. 12. Apex of gaster, base of postcercale, lateral view.

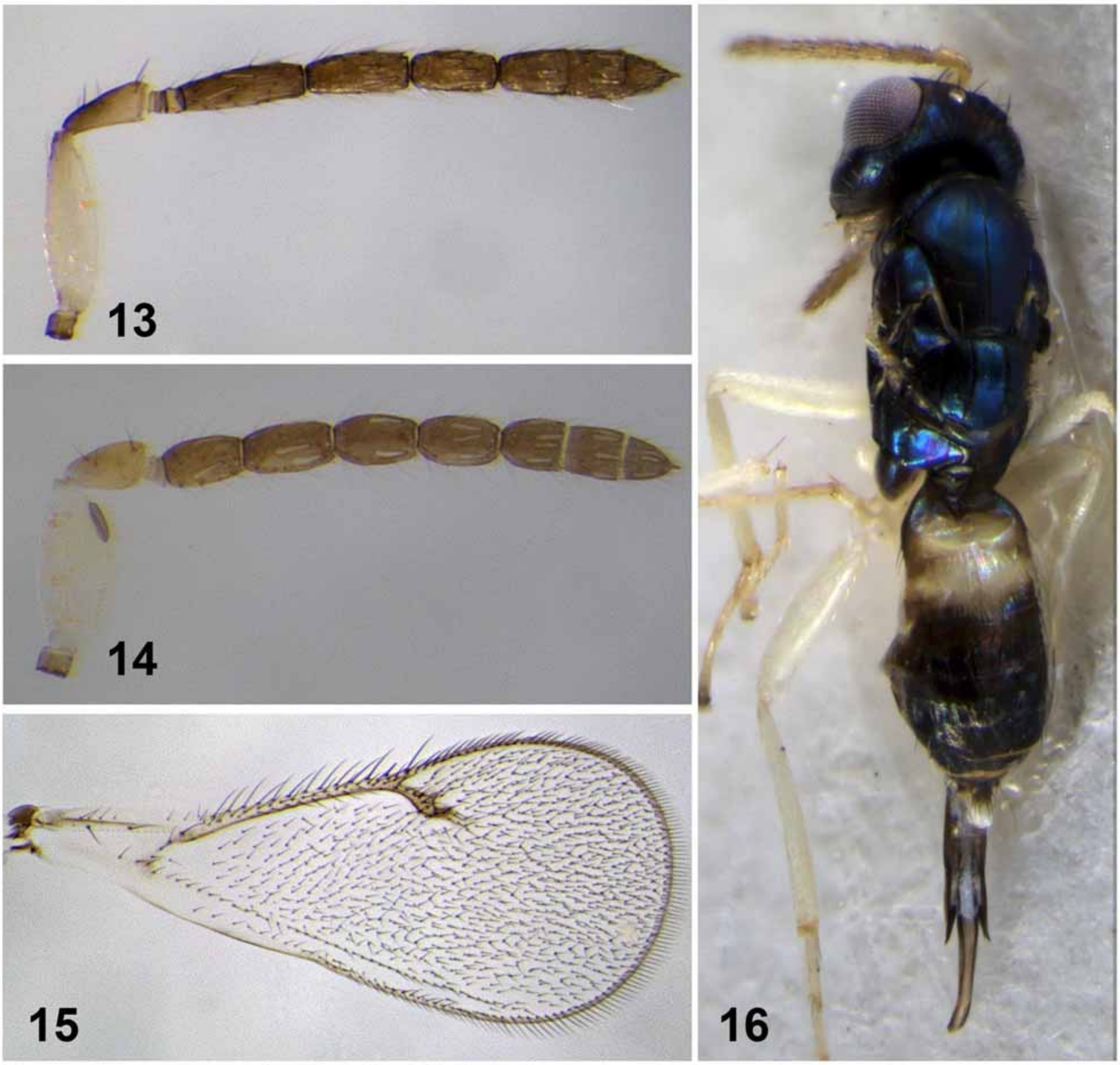

PLATE 3. *Aprostocetus exertus* La Salle. Fig 13. ♀ Antenna. Fig 14. ♂ Antenna. Fig. 15. ♀ Forewing. Fig. 16. ♂ Habitus (wings removed), showing exerted genitalia.

Distribution. Africa: Tanzania, South Africa.

Etymology. The species name *exertus* is indicative of the extremely long and exerted ovipositor in this species.

Discussion. *Aprostocetus* is the largest genus in the Tetrastichinae (indeed, one of the largest genera in the Chalcidoidea), and it is biologically and morphologically diverse. Its identity in a modern sense was established by Graham (1987, 1991), and this interpretation of the genus has been followed by subsequent authors (e.g. Bouček 1988, La Salle 1994, Schauff et al. 1997). Currently the genus contains 6 subgenera (Graham 1987, La Salle 1994).

Aprostocetus exertus is treated in this paper as belonging to the subgenus *Aprostocetus*, but it does not completely agree with previous definitions of this group, and appears to share some characters with the subgenus *Ootetrastichus*. Graham (1987) distinguished *Ootetrastichus* from *Aprostocetus* s.s. as follows: midlobe of mesoscutum usually without a median line; subcubital line of setae reaching or nearly reaching basal vein; speculum small; propodeal spiracle generally small, with or without their outer rim partially covered by a raised flap on the callus; ovipositor sheaths slightly to greatly exerted; always with one of the cercal setae distinctly longer than the others; usually with 3 or more setae on the SMV, but occasionally with 2 (or even 1); generally elongate, brightly metallic species. *A. exertus* displays a combination of these characters, so that it does not comfortably fit in either *Ootetrastichus* or *Aprostocetus* ss. Clearly, there are some research opportunities remaining in African tetrastichines.

Biologically, *Ootetrastichus* seem to form a distinct group in that species are egg parasitoids of Hemiptera (Delphacidae, Cicadellidae), Orthoptera (Gryllidae), Odonata and Coleoptera (Dytiscidae), and some species can parasitize eggs in aquatic situations. There is, however, one exception: the African *Aprostocetus* (*Ootetrastichus*) *theionerus* (Masi) is a hyperparasitoid on stem borers (La Salle 1993).

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