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Description of two new species of fig wasps (Chalcidoidea: Pteromalidae: Sycoryctinae) associated with *Ficus benguetensis*

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ABSTRACT: This study presents two new fig wasp species, *Philotrypesis taida* Wong and Shiao sp. nov. and *Sycorycteridea taipeiensis* Wong and Shiao sp. nov., which were reared from *Ficus benguetensis* Merrill in Taiwan. They are the seventh and first species belonging to the genera *Philotrypesis* and *Sycorycteridea*, respectively, to be reported in Taiwan. The holotypes and paratypes were deposited in the Department of Entomology at National Taiwan University, Taiwan.

KEY WORDS: Chalcidoidea, *Ficus*, Fig wasps, *Philotrypesis*, *Sycorycteridea*, Taiwan.

INTRODUCTION

Fig wasps belonging to the subfamily Sycoryctinae (Chalcidoidea: Pteromalidae) are highly diversified and widespread parasitoid species (Segar *et al.*, 2012). Sycoryctine fig wasps are associated with all six subgenera and at least 15 sections in *Ficus* (Jiang *et al.*, 2006). Consequently, there is an estimated species richness of 826 that is yet to be discovered in the Old World (Segar *et al.*, 2012). From a taxonomic perspective, Sycoryctinae are currently placed in the family Pteromalidae within the superfamily Chalcidoidea (Rasplus *et al.*, 1998). Sycoryctinae are then divided into four tribes: (1) Apocryptini, comprising two genera: *Apocrypta* Coquerel, 1855, and *Bouceka* Kocak and Kemal, 2008; (2) Critogastrini, comprising only one genus: *Critogaster* Mayr, 1885; (3) Philotrypesini, comprising four genera: *Dobunabaa* Boucek, 1988, *Philoverdance* Priyadarsanan, 2000, *Philotrypesis* Forster, 1878, and *Watshamiella* Wiebes, 1981; and (4) Sycoryctini, comprising seven genera: *Adiyodiella* Priyadarsanan, 2000, *Arachonia* Joseph, 1957, *Parasycobia* Abdurahiman and Joseph, 1967, *Sycorycteridea* Abdurahiman and Joseph, 1967, *Sycoryctes* Mayr, 1885, *Sycoscapter* Saunders, 1883, and *Sycoscapteridea* Ashmead, 1904 (McLeish *et al.*, 2012; Segar *et al.*, 2012).

Female sycoryctines oviposit through the fig wall with the aid of their long ovipositors, and their larvae eventually kill their host wasps or spend their larval stage inside the figs as plant-feeders (Compton *et al.*, 2015). The feeding habits of sycoryctine larvae vary considerably as they can be parasitoids, inquilines, or obligate seed predators, among other types (Tzeng *et al.*, 2008; Wang *et al.*, 2014). Sycoryctine larvae mature in galls. Males usually fight severely using their mandibles for females soon after their emergence (Murray, 1987; Bean and Cook, 2001). Male Sycoryctinae exhibit diverse adaptations in their morphology, including winged dispersers and wingless fighters (Jousselin *et al.*, 2004). Sycoryctines serve as a model organism in behavioral ecology research because of their fascinating behaviors and diverse morphologies (Moore *et al.*, 2009). Despite the ecological importance of sycoryctine fig wasps as nonpollinating species associated with fig trees, they are poorly represented in collections in Taiwan because of the special requirements for collecting, preserving, and identifying them. Consequently, only eight species of sycoryctine fig wasps have been identified in Taiwan (Chou and Wong, 1997; Chen *et al.*, 1999).

Two new fig wasp species belonging to the genera *Philotrypesis* and *Sycorycteridea*, which are associated with the fig tree *Ficus benguetensis* Merrill, are reported in this study. They are the seventh and first species belonging to the genera *Philotrypesis* and *Sycorycteridea*, respectively, reported in Taiwan.

MATERIALS AND METHODS

Fig wasp samples associated with the fig tree *F. benguetensis* were collected on the National Taiwan University (NTU) campus, Taipei from 2011 to 2013. Additional populations were collected from Fuyang Eco Park, Taipei and Hengchun Tropical Garden, Pingtung during 2014 to 2017 (Table 1). The sample figs were stored at room temperature in transparent plastic pots closed with mesh covers for 24 hours with their ostioles facing upward. The wasps' exit was confirmed by the presence of a hole, which was chewed on the surface of

Table 1: Collection point of ***Philotrypesis taida*** sp. nov. and ***Sycorycteridea taipeiensis*** sp. nov.

Date	Coordinate	Location	Host (*Ficus*)	Number of figs
2011-Oct-29	25°00'54.7"N; 121°32'11.8"E	NTU Campus	*F. benguetensis*	10
2012-Jul-26	25°00'54.7"N, 121°32'11.8"E	NTU Campus	*F. benguetensis*	15
2013-Aug-17	25°00'57.6"N, 121°33'27.0"E	Fuyang Eco Park	*F. benguetensis*	8
2014-Jul-20	25°00'57.6"N, 121°33'27.0"E	Fuyang Eco Park	*F. benguetensis*	10
2015-Jul-22	25°00'57.6"N, 121°33'27.0"E	Fuyang Eco Park	*F. benguetensis*	10
2017-May-20	21°57'45.0"N, 120°48'38.2"E	Hengchun Tropical Garden	*F. benguetensis*	15
2017-Jul-14	21°57'45.0"N, 120°48'38.2"E	Hengchun Tropical Garden	*F. benguetensis*	10

the figs. All the wasps that exited their natal figs were collected and stored in 75% ethanol. The figs were then dissected and the wasps therein were also collected. The collected wasps were dehydrated through an ethanol series (75%, 90%, and 100%) and critical-point dried (DO-11-R-269 CPD, Quorum Technologies Inc., UK) before being mounted on cards following Noyes (1982). The specimens were point-mounted on black cards and photographed to avoid the low contrast caused by a white background.

Morphological terminology followed Gibson (1997) and the Hymenoptera Anatomy Ontology (HAO) Portal (Yoder *et al.*, 2010). Images were taken using a stereomicroscope (Leica Z16 APO, Wetzlar, Germany) with a digital camera (Leica DFC490, Wetzlar, Germany) and were processed using the Helicon Focus 6.7.1. software (Helicon Soft Inc., Dominica) to combine them into a single image with increased focal depth. Physical characteristics were measured using ImageJ 1.45a software (National Institutes of Health, USA). Specimen measurements were taken with accuracy of 0.001 mm and were rounded to the nearest 0.1 mm. Holotype and paratype specimens were deposited in the Department of Entomology at NTU.

TAXONOMIC TREATMENT

Key to species of *Philotrypesis* females commonly found in Taiwan

1a. Body black; 2 anelli; mandibles 2 teeth …….. ……..…….…… ***Philotrypesis taiwanensis*** Chen
1b. Body orange; 3 anelli; mandibles 2 or 3 teeth ……..…… 2
2a. Mandible 2 teeth ……..……..… 3
2b. Mandible 3 teeth ……..… ***Philotrypesis emeryi*** Grandi
3a. Gaster VII as long as VIII (1:1) .... ***Philotrypesis okinavensis*** Ishii
3b. Gaster VII longer than VIII (3:1) ….. ***Philotrypesis taida*** sp. nov.

Philotrypesis taida Wong & Shiao, ***sp. nov.***

臺大延腹小蜂 Figs. 1–2

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***Diagnosis*:** The female of this genus can be recognized by its lengthened seventh and eighth urotergites and its subquadrate narrow pronotum. The antenna of this genus usually composed of 12–13 antennomeres (1–3 anelli), including an oval terminal flagellomere. Comparison of morphological characteristics in females between *Philotrypesis* spp. inhabiting Taiwan is provided (Table 2).

***Types*:** Holotype, ♀, TAIWAN: Taipei City: Daan District: NTU campus, 25°00'54.7"N; 121°32'11.8"E, Alt. 0–10 m, October 29, 2011, D.M. Wong; Paratypes, 5♀ and 5♂, the same locality and data as holotype. All specimens deposited in the Department of Entomology at NTU.

***Description*:** *Female* - Body length 2.0–2.2 mm. Body color variable. Head and antenna orange. Mandible bidentate. Mesosoma and metasoma usually brownish orange, sometimes metallic black. Coxae concolorous with mesosoma. Wings hyaline. The 7th and 8th segment in ratio 3:1. Ovipositor sheath length 3.0–3.6 mm.

Head. Head width 0.4–0.5 mm (Fig. 1A). Antenna with 13 antennomeres, antennal formula: 11353 (Fig. 1B). Scape clavate 4× longer than goblet pedicel. Funicular segments slightly longer than wide. Terminal antennomere conspicuous. Face sculpture smooth. Antenna inserted at the bottom line of compound eyes. Toruli apart, distance between toruli larger than diameter of one torulus. Eye red, longer than gena. Clypeal margin flattened. Mandible bidentate.

Mesosoma. Body length 2.0–2.2 mm (Fig. 1C); Coxae concolorous with mesosoma. Hind tibia at its distal end provided with apical spur and about 8× as long as its own thickness (Fig. 1D). Wings length 1.3–1.5 mm and finely pubescent (Fig. 1E). Postmarginal vein 3× longer than stigmal vein. Pronotum sculpture smooth (Fig. 1F). Pronotum longer than high in lateral view. Notauli complete. Mesoscutellum trapezoidal. Axilla triangular and small. Scutellum round. Propendeum transverse.

Metasoma. Without petiole. The 7th and 8th segment in ratio 3:1. Ovipositor sheath length 1.5× longer than body.

Male - Head width 0.3–0.7 mm and covered long seta (Fig. 2A). Head as long as wide across eye. Mandible length 0.1–0.4 mm. Eye black, one-fourth of head length. Antenna toruli situate in a shallow depression above epistomal margin, with 1 keel in the middle. Body orange, apterous and body length 2.8–3.6 mm (Fig. 2B–C).

***Etymology*:** The specific name refers to the pinyin (Chinese pronunciation) abbreviation of "National Taiwan University."

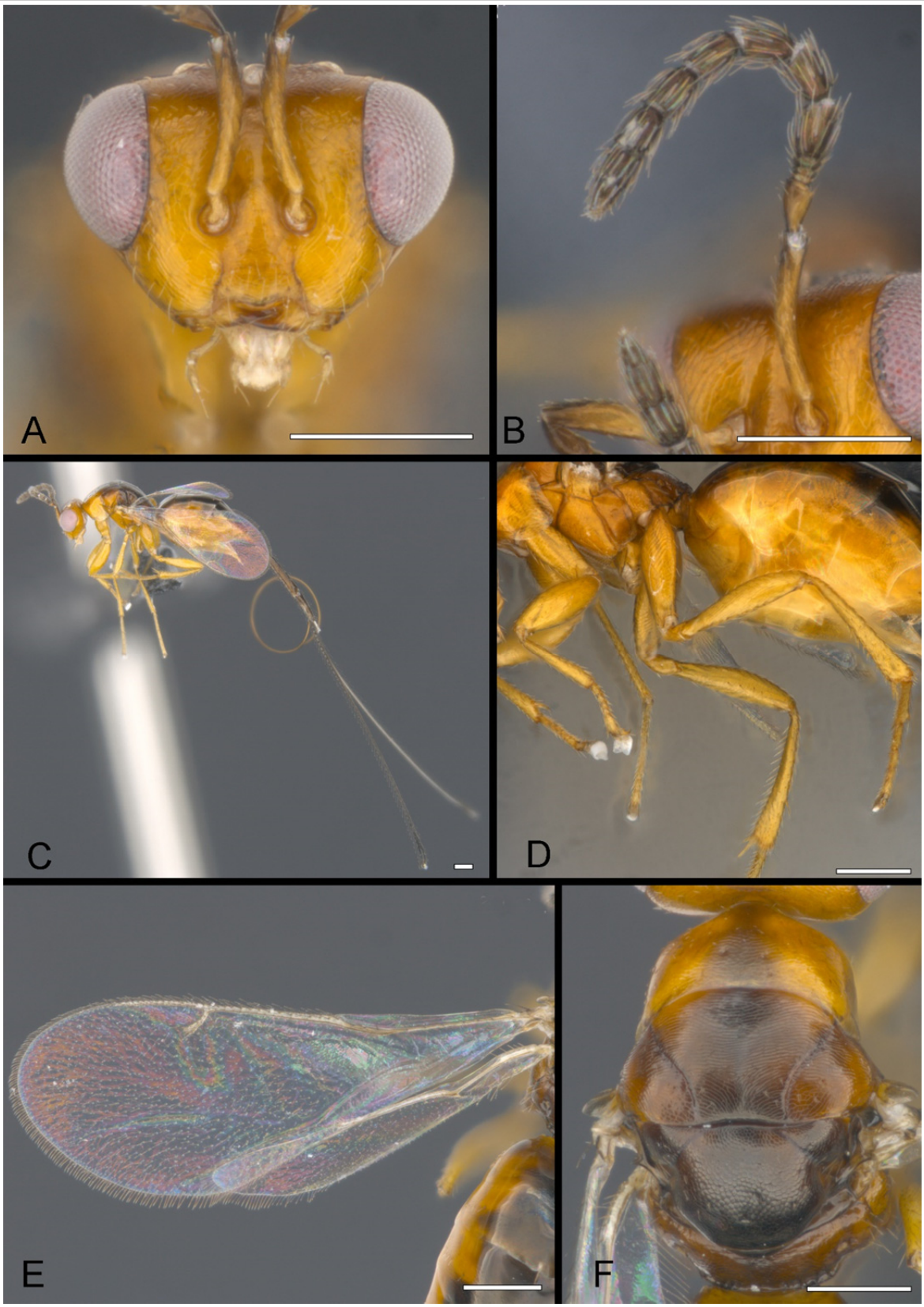

Fig. 1. Female ***Philotrypesis taida*** sp. nov. **A**: Head frontal view; **B**: Antenna; **C**: Lateral view; **D**: Hind leg; **E**: Wings; **F**: Dorsal view of mesosoma. Scale bar = 0.2 mm.

Fig. 2. Male ***Philotrypesis taida*** sp. nov. **A**: Head frontal view; **B**: Dorsal view of mesosoma; **C**: Lateral view. Scale bar = 0.2 mm.

***Host*:** Reared from syconia of *F. benguetensis*.

***Biology*:** This species could be the parasitoids or inquilines of other fig wasps associated with fig sections, such as *Conosycea*, *Ficus*, *Galoglychia*, *Sycidium*, *Sycocarpus*, and *Urostigma*.

***Distribution*:** Taiwan. According to host specialization of fig wasps and the geographical distribution of *F. benguetensis*, we assume that this species is also distributed in Malesia and Ryukyu islands.

Table 2: Characteristics of four ***Philotrypesis*** species inhabiting Taiwan

Species (*Philotrypesis*)	*P. taida*	*P. taiwanensis*	*P. okinavensis*	*P. emeryi*
Body color	Orange	Black	Orange	Orange
Antenna toruli	Across eye area	Below eye area	Below eye area	Below eye area
Anelli	3	2	3	3
Mandible teeth	2	2	2	3
Gaster VII : VIII	3:1	3:2	1:1	3:1
Host (*Ficus*)	*F. benguetensis*	*F. microcarpa*	*F. microcarpa*	*F. microcarpa*

Sycorycteridea taipeiensis Wong & Shiao**, *sp. nov.***
臺北細尾小蜂 Figs. 3 & 4

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***Diagnosis*:** The female of this genus can be recognized by the long slender ovipositor and its sheaths, slightly swollen at the apex, the whole length of the ovipositor being covered by the extended last tergite. Tarsi distinctly shorter than tibia. Comparison of morphological characteristics in females between *Sycorycteridea taipeiensis* sp. nov. and *Sycorycteridea keralensis* is provided (Table 3).

***Types*:** Holotype ♀, TAIWAN: Taipei City: Daan District: NTU campus, 25°00'54.7"N; 121°32'11.8"E, Alt. 0–10 m, October 29, 2011, D.M. Wong; Paratypes, 5♀, 5♂, same locality and data as holotype. All specimens deposited in the Department of Entomology at NTU.

***Description*:** *Female* - Body length 1.0–1.5 mm. Body color variable. Antenna yellow. Head and mesosoma yellow to metallic black. Metasoma usually yellow, sometimes metallic black. Coxae concolorous with mesosoma. Wings with short and sparse pilosity. Ovipositor sheath length 3.0–3.2 mm.

Head. Head width 0.2–0.3 mm (Fig. 3A). Antenna with 12 antennomeres, antennal formula: 11163 (Fig. 3B). Scape clavate 3× longer than goblet pedicel. Funicular segments slightly longer than wide. Terminal antennomere conspicuous. Antenna inserted at the bottom line of compound eyes. Toruli contiguous, distance between toruli smaller than diameter of one torulus. Ecdysial cleavage conspicuous. Eye red, longer than gena. Face sculpture smooth. Clypeal margin protruded. Mandible bidentate.

Mesosoma. Body length 1.0–1.5 mm (Fig. 3C); Coxae concolorous with mesosoma. Hind tibia at its distal end provided with apical spur and about 6× as long as its own thickness (Fig. 3D). Tarsi distinctly shorter than tibia. Wings length 0.9–1.0 mm with short and sparse pilosity (Fig. 3E). Postmarginal vein 2.5× longer than stigmal vein. Pronotum sculpture smooth (Fig. 3F). Pronotum longer than high in lateral view. Notauli incomplete. Mesoscutum trapezoidal. Axilla triangular. Scutellum round. Propendeum transverse.

Metasoma. Without petiole. Ovipositor sheath length 3× longer than body.

Male - Head width 0.2–0.6 mm and pear shaped with short seta (Fig. 4A). Head longer than wide. Mandible length 0.1–0.3 mm. Eye red, one-seventh of head length. Body yellow, apterous and body length 2.6–3.5 mm. (Figs. 4B–C).

***Etymology*:** The specific name refers to the type of locality of Taipei City in Taiwan.

***Host*:** Reared from syconia of *F. benguetensis*.

***Biology*:** This species could be parasitoid fig wasps in the *Ceratosolen*, *Eupristina* and *Kradibia* genera. This species may have some strong seasonal variation in abundance and distribution.

***Distribution*:** Taiwan. According to host specialization of fig wasps and the geographical distribution of *F. benguetensis*, we assume that this species is also distributed in Malesia and Ryukyu islands.

Table 3: Characteristics comparison between female ***Sycorycteridea taipeiensis*** and ***S. keralensis***

	S. taipeiensis	*S. keralensis*
Body color	Yellow	Metallic green
Anellus	1	1
Epistomal margin	Protruded	Protruded
Ovipositor : body	3 : 1	5 : 1
Stigmal knob	Not elongate	Not elongate
Host (*Ficus*)	*F. benguetensis*	*F. callosa*

DISCUSSION

Fig wasps are pantropically distributed and play a pertinent role within tropical plant communities (Bain *et al.*, 2015). Fig wasps and their host fig trees have long been used as an example in studies on interspecific interactions. These fascinating interactions include classic obligate mutualism to antagonistic parasitism. These trophic relationships of the figs and wasps sometimes include up to 20 taxa on a single fig species (Chen *et al.*, 1999). Because plant–herbivore–parasitoid associations are a major component of terrestrial biodiversity, intensive taxonomical research is hence pertinent for understanding how fig wasp communities interact and evolve.

Although some examples of host switching have been found, fig wasps belonging to Sycoryctinae are the largest nonpollinating wasps conservatively associated with fig trees in Old World regions (Segar *et al.*, 2012). Despite being geographically widespread, the taxonomy of sycoryctine fig wasps is poorly understood and is less advanced than that of pollinating fig wasp species. Sycoryctine fig wasps inhabiting the Indomalayan region have received less taxonomical attention compared with those from other biogeographical realms, such as the Afrotropics and Neotropics and Australasia (Bouček, 1988; van Noort and Rasplus, 1997; Farache *et al.*, 2013). The lack of taxonomical knowledge has hampered the understanding of the ecology and evolution of fig wasps inhabiting this speciose region.

Given that there are 26 species of native *Ficus* in Taiwan, an estimated 70 species of sycoryctine fig wasps are yet to be discovered. Taxonomical studies of Taiwanese fig wasps were discontinued in 1999. Only eight species of sycoryctine fig wasp have been identified in Taiwan. Two new sycoryctine species associated with *F. benguetensis* are described and illustrated in this paper. The female *Philotrypesis* can easily be assigned to Philotrypesini because of the presence of tubular urotergites of the terminal segments (7th and 8th segments) and its ovipositor. The extraordinarily long ovipositor not only functions as an

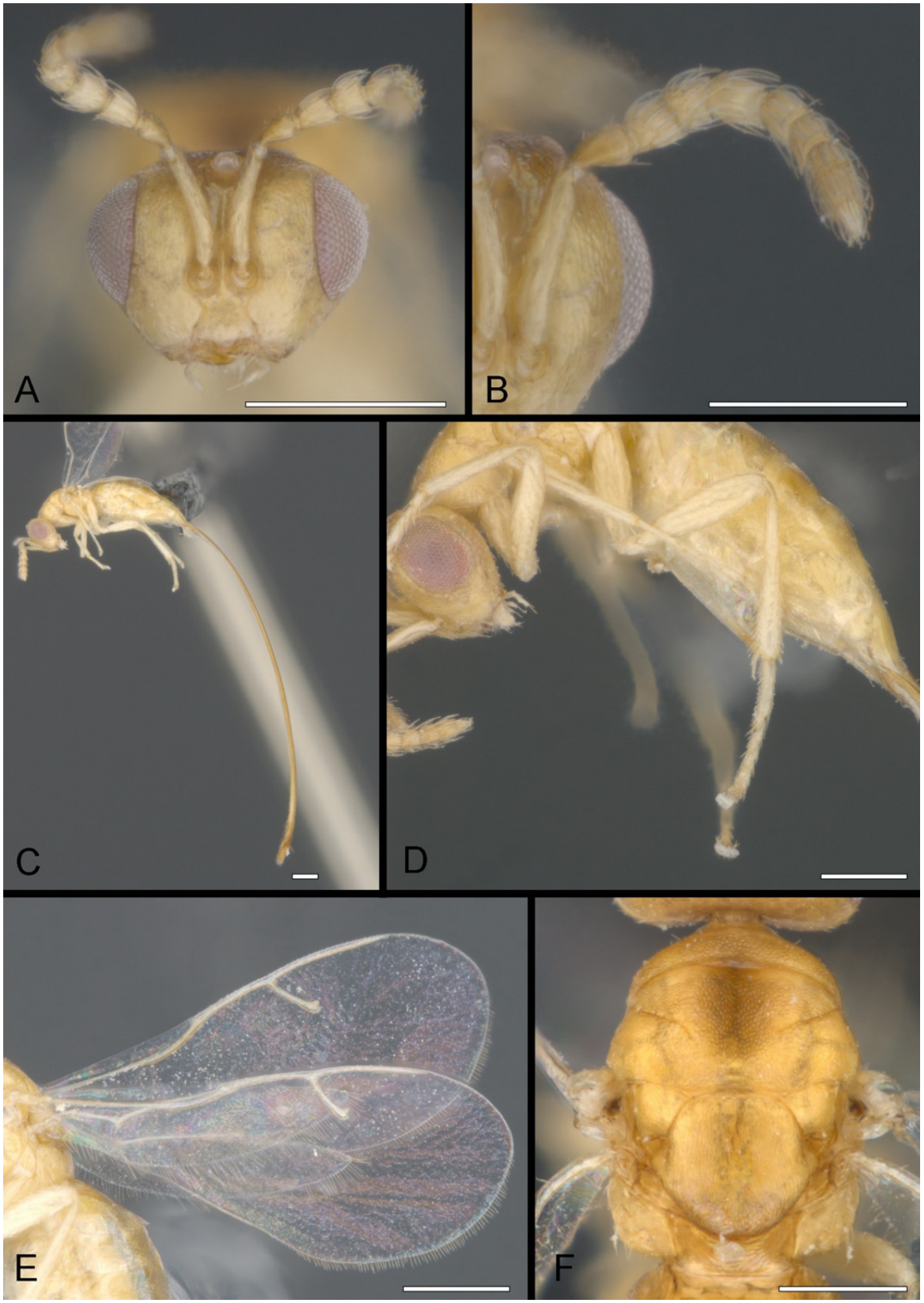

Fig. 3. Female ***Sycorycteridea taipeiensis*** sp. nov. **A**: Head frontal view; **B**: Antenna; **C**: Lateral view; **D**: Hind leg; **E**: Wings; **F**: Dorsal view of mesosoma. Scale bar = 0.5 mm.

Fig. 4. Male ***Sycorycteridea taipeiensis*** sp. nov. **A**: Head frontal view; **B**: Dorsal view of mesosoma; **C**: Lateral view. Scale bar = 0.2 mm.

egg-laying apparatus but is also capable of piercing the fig wall. Distinguishing male *Philotrypesis* is sometimes difficult because of polymorphism; moreover, some resemble male *Sycoscapter*. *Sycorycteridea* was first established by Abdurahiman and Joseph (1975), later Bouček (1988) synonymized *Sycoscapter*, *Sycoryctes*, *Arachonia*, *Sycoscapteridea* and *Sycorycteridea* into a single genus *Sycoscapter*, but Segar et al. (2012) in their study on global molecular phylogeny for the Sycoryctinae reinstated all of the former names. These genera are difficult to distinguished due to morphological conservatism. Female *Sycorycteridea* can be differentiated from other Sycoryctini species by their anellus number and long slender, slightly swollen at the apex of its ovipositor; male *Sycorycteridea* males exhibit a pear-shaped head, which is quite different from the square-shaped male *Philotrypesis*.

Although *Philotrypesis taida* sp. nov. and *Sycorycteridea taipeiensis* sp. nov. both inhabit the same host (*Ficus benguetensis*), their relationships with each other as well as with pollinating species remain unclear. To determine the trophic level of these two nonpollinating species, a precision-cut tissue slice technique may be required to acquire evidence of their feeding habits. Collecting *Sycorycteridea taipeiensis* sp. nov. is rare because it is sporadically distributed. Extensive collection of *Sycorycteridea taipeiensis* sp. nov. is therefore encouraged to enhance knowledge about this species.

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