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Jumping Plant Lice of the Genus *Petalolyma* Scott (Hemiptera, Triozidae) Inducing Galls on *Ilex* Species (Aquifoliaceae) in Taiwan, with Comments on *Torulus* Li

Yi-Chang Liao[1,2,3,*], Daniel Burckhardt[4], and Man-Miao Yang[3,*]

[1]*Department of Entomology, University of California, Riverside, USA. *Correspondence: E-mail: ycliaopsyllids@gmail.com (Liao)*
[2]*Back to the Wild Insect Ecosurvey CO., LTD., Taichung, Taiwan*
[3]*Department of Entomology, National Chung Hsing University, 145 Xingda Rd., Taichung 402, Taiwan.*
**Correspondence: E-mail: mmy.letsgall@gmail.com (Yang)*
[4]*Naturhistorisches Museum, Augustinergasse 2, 4001 Basel, Switzerland. E-mail: daniel.burckhardt@bs.ch (Burckhardt)*

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The triozid genus *Petalolyma* Scott, 1882 is reviewed, and the monotypic genus *Torulus* Li, 1991, syn. nov., is considered a junior subjective synonym. *Torulus sinicus* is transferred to *Petalolyma* as *P. sinica* (Li, 1991), comb. nov., producing a secondary homonym of *P. sinica* Yang & Li, 1984, for which the replacement name *Petalolyma lii* Liao & Burckhardt, nomen nov. is proposed here. Adults and fifth instar immatures of *Petalolyma vittata* Liao & Burckhardt, sp. nov. are described and illustrated. The new species induces marginal fold galls on leaves of *Ilex ficoidea* (Aquifoliaceae). The previously unknown male and female of *P. lii* and *P. nigra*, respectively, are described and illustrated, and *Petalolyma castanopsis* Li & Yang, 1991 and *P. fujianensis* Li & Yang, 1999, syn. nov., are synonymised. *Petalolyma hyalina* (Kuwayama, 1910) is considered a nomen dubium as the original description is not diagnostic and the type material cannot be found. Hence, *Petalolyma* currently includes 13 valid species whose host plant and biogeographic patterns are briefly discussed. Identification keys for the adults and fifth instar immatures are provided for the Taiwanese species.

Key words: Sternorrhyncha, Psylloidea, New species, New synonymies, Taxonomy, Marginal fold gall

BACKGROUND

Jumping plant lice or psyllids (Psylloidea) are characterised within Sternorrhyncha by their generally narrow host ranges, both at species and higher taxonomic levels (Hollis 2004; Hodkinson 2009; Burckhardt et al. 2014; Ouvrard et al. 2015). Some psyllids are known to induce galls on their host plants (Hodkinson 1984; Burckhardt 2005; Yang and Raman 2007). Gall inducers are particularly abundant in the Calophyinae, Phacopteroninae and Triozidae (Burckhardt 2005; Malenovský et al. 2007; Yang et al. 2013), and they seem more frequent in the tropics than in temperate regions. According to Docters van Leeuwen and Docters van Leeuwen-Reijnvaan (1914), in Java (Indonesia) about 5% of all galls are induced by Psylloidea. In Taiwan, more than half of the psyllid species are gallicolous with the highest numbers known to develop on Lauraceae and Myrtaceae (Yang et al. 2006). The number of gall-inducing compared to free-living psyllid species is probably underestimated as the former are often univoltine, and the period with adult presence is comparatively short (Yang et al. 2006; Carneiro et al. 2013). The effort needed to find adults

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of some species and their presence on non-hosts, due to their capacity to fly, makes the association of adults with the respective galls difficult.

A good example of the patchy knowledge on gall-inducers are the psyllids associated with *Ilex* species (Aquifoliaceae). *Ilex*, comprising 560 described species worldwide, has been independently colonised by psyllids several times. Two genera with gall inducing species are associated with *Ilex*: 1. *Gyropsylla* Brèthes (Aphalaridae, Aphalarinae) with five described species in the Americas, two of which lack host data, and one species in Asia also lacking host data; and 2. *Petalolyma* Scott (Triozidae) with 13 described species in the Oriental region, of which seven species lack host data. In addition to the two genera, one species each of *Cecidotrioza* Kieffer and *Psylla* Geoffroy, and six species of *Trioza* Foerster have been reported from *Ilex* (Ouvrard 2023) though some of these host records are doubtful and it is unknown whether any of these species induces galls.

Petalolyma is morphologically well diagnosed by adult and immature characters (see diagnosis below). Li (1991) erected the monotypic genus *Torulus* for *T. sinicus* Li, known from a single female only, collected on *Vernicia fordii* (Euphorbiaceae) in Fujian, China. It "differs from *Petalolyma* in R_1 longer than R and mesothorax with two groups of long hairs" (Li 1991). Recently, two males of *T. sinicus* and an undescribed species, morphologically intermediate between *Petalolyma* and *Torulus*, were discovered in Taiwan, the latter inducing marginal fold galls on the leaves of *Ilex ficoidea*. This new material challenges the validity of *Petalolyma* and *Torulus* as separate, monophyletic units, necessitating a review of the two genera.

Here we formally describe the new species, including the gall, and provide information of the previously unknown male and female of *T. sinicus* and *P. nigra*, respectively. We examine the phylogenetic relationships between *Petalolyma* and *Torulus*, review the Taiwanese species, for which we provide identification keys for adults and immatures, and discuss some other Oriental congeners.

MATERIALS AND METHODS

Specimens were collected by sweeping or by direct search. Galls were bagged in the field and checked monthly for emerged adults. Material is dry mounted or preserved in 70% or 99% ethanol. Some specimens were cleared in 15% potassium hydroxide and orange oil for subsequent microscopical examination in glycerol. Specimens are deposited in or reported from the National Chung Hsing University, Taichung, Taiwan (NCHU), the National Museum of Natural Science, Taichung, Taiwan (NMNS), the Naturhistorisches Museum Basel, Switzerland (NHMB), the Systematic Entomology, Hokkaido University, Japan (SEHU) and the Taiwan Agricultural Research Institute, Ministry of Agriculture, Taichung City, Taiwan (TARI).

Photographs of morphological characters were taken with a Leica DM 750 microscope equipped with a digital Canon EOS 600D camera, except for those of the wings, which were taken with a Leica MZ 125 microscope equipped with a digital Olympus EP-1 camera. The photographs were montaged using focus stacking software (Helicon Focus, Helicon Soft). The morphological terminology follows Bastin et al. (2023) and the nomenclature of plants POWO (2023).

TAXONOMY

Family Triozidae Löw, 1879
Genus *Petalolyma* Scott, 1882

Petalolyma Scott, 1882: 459. Type species: *Psylla basalis* Walker, 1858, by original designation and monotypy.
Torulus Li, 1991: 37, 41. Type species: *Torulus sinicus* Li, by original designation and monotypy. Syn. nov.

Diagnosis: Adult. Body large and robust, beset with long pubescence. Head narrower than mesothorax; inclined from longitudinal body axis at almost 90°. Vertex subrectangular, lacking anterior transverse suture separating it from the genal processes; genal processes conical, subacute, about as long as vertex along mid-line. Eyes large, hemispherical. Antenna 10-segmented with a single subapical rhinarium on segments 4, 6, 8 and 9; 1.3–1.9 times as long as head width; flagellar segments sparsely beset with long setae; segment 10 with one terminal seta longer and one shorter than segment. Clypeus small, narrowly pyriform; hidden by procoxae and genal processes; rostrum short, in lateral view only tip of apical segment visible. Pronotum antero-medially curved downward and laterally backward; head posteriorly sometimes hiding pronotum medially. Dorsal outline of mesopraescutum, in lateral view, weakly or strongly curved. Mesosternum angularly concave antero-medially; basisternum indented postero-medially, raised laterally to form a tubercle on either side; katepisternum triangular, large; pleurosternal suture well-developed; precoxale forming a right angle. Legs relatively short and robust; metacoxa with spur-shaped meracanthus, not extended antero-medially; metatibia with a blunt tubercule at base, with 1+3 apical spurs, each on a slightly raised tubercle. Forewing lanceolate to obovate, usually with dark

pattern; vein C+M+Cu strictly trifurcating; veins beset with conspicuous setae. Hindwing about three quarters length of forewing; costal setae ungrouped; vein M+Cu developed. Abdomen with short dorsal and long ventral setae. Male proctiger strongly bulging posteriorly, beset with setae. Paramere lamellar. Proximal segment of aedeagus slender, strongly curved in basal half; distal segment with weakly inflated, curved apical dilation. Female terminalia cuneate, relatively short. Fifth instar immature. Body weakly sclerotised, elongate, 1.5–1.9 times as long as wide. Cephalothorax on either side with an area laterally delimited by eye in anterior third and an area in posterior third densely covered in small, very slender sectasetae; anterior area also has a few scattered long simple setae. Antenna 8-segmented with an apical rhinarium on segments 4 and 6, and two on segment 8. Thoracic and abdominal tergites densely covered in small, slender sectasetae. Legs robust, 4-segmented; tibiotarsus longer than femur; tarsus has two moderately sized claws; tarsal arolium longer than claws, broadly triangular, weakly concave apico-medially, with petiole and unguitractor. Forewing pad long and slender, lacking humeral lobe; with marginal stripe of dense, small and slender sectasetae and dorsal stripe in apical third of similar sectasetae. Hindwing pad with a few marginal and a stripe of dorsal, densely spaced small, slender sectasetae. Anus ventral. Outer circumanal ring moderately large, irregularly heart-shaped, slightly wavy, consisting of a single row of elongate and narrow pores. Abdominal venter beset with long normal setae.

Distribution: Oriental Region. China (Li 2011), India (Mathur 1975), Japan (Miyatake and Matsumoto 2008), Laos (Cho et al. 2017), Philippines (Crawford 1917), Taiwan (Yang et al. 2013), Nepal and Sri Lanka (unpublished NHMB data).

Host plants: *Ilex* spp. (Aquifoliaceae). The immatures induce marginal fold galls on the leaves.

Mathur (1975) reported *Petalolyma basalis* (Walker) from India "on leaves of *Quercus dilalata*" [= *Quercus floribunda* Lindl. ex A. Camus] (Fagaceae). He did not mention immatures nor provide a description of them, suggesting that *Quercus* is a casual plant rather than a host. *Castanopsis tibetana* Hance (Fagaceae) is also reported as a host of *P. castanopsis* Li & Yang by Li and Yang (1991) based on two males, representing a casual host. The host of this species is *Ilex asprella* Champ. ex Benth. (see below). Similarly, we suspect that *Vernicia fordii* (Hemsl.) Airy-Shaw (Euphorbiaceae) is a casual plant of *Torulus sinicus* (= *Petalolyma lii* Liao & Burckhardt, nomen nov.), as it is based on one specimen only (Li 1991).

Comments: *Petalolyma*, as diagnosed here, constitutes a well circumscribed, putatively monophyletic taxon within the Triozidae. Potential synapomorphies constitute the long and slender apical dilation of the distal aedeagal segment and the distribution pattern of the very slender, small sectasetae in the immature. The phylogenetic significance of these characters is, however, difficult to evaluate without a phylogenetic framework. *Petalolyma* was not included in the molecular phylogenetic analysis of Percy et al. (2018) and comparable morphological studies are also lacking. To keep *Torulus* as a separate genus would render *Petalolyma* paraphyletic, as the latter would be defined by symplesiomorphies only. To prevent this, we propose the following synonymy: *Petalolyma* Scott, 1882 = *Torulus* Li, 1991, syn. nov. We transfer *Torulus sinicus* to *Petalolyma* as *Petalolyma sinica* (Li, 1991), comb. nov., which constitutes a secondary homonym of *Petalolyma sinica* Yang & Li, 1984. We propose the replacement name *Petalolyma lii* Liao & Burckhardt, nomen nov.

Petalolyma includes in the new concept 14 previously described nominal and one new species, described here. *Petalolyma hyalina* (Kuwayama) is known only from the original description (Kuwayama 1910), and the type material cannot be traced (H. Inoue, pers. comm.; see also below). Based on the forewing shape and venation, the remaining species can be assigned to six informal, not necessarily monophyletic, species groups (Table 1). While species identification keys with illustrated descriptions are available for the Chinese and Japanese species (Miyatake and Matsumoto 2008; Li 2011), and Mathur (1975) provided an adequate description for the Indian *P. basalis*, available information on the Taiwanese species is quite incomplete (Yang 1984; Fang and Yang 1986; Yang et al. 2013). Here, identification keys are provided and the taxonomy of the Taiwanese species is reviewed.

Keys to *Petalolyma* species from Taiwan

Adults
(not including *Petalolyma hyalina*)

1. Forewing (Fig. 1A, B) with veins Rs weakly and M strongly curved, the two veins thus strongly diverging to wing apex; cell m_1 and cu_1 small: length ratio $M/M_{1+2} > 3.0$, $Cu/Cu_{1b} > 4.0$ 2
- Forewing (Fig. 1C–E) with veins Rs hardly or not, and M weakly curved, the two veins thus not strongly diverging to wing apex; cell m_1 and cu_1 large: length ratio $M/M_{1+2} < 2.0$, $Cu/Cu_{1b} < 2.0$ 3
2. Forewing (Fig. 1B) with a dark brown patch along anal margin covering cells m_1 and cu_1, respectively; broadly, irregularly rounded apically. Paramere (Fig. 2H) shorter than male proctiger ..... *P. lii* Liao & Burckhardt, nom. nov.
- Forewing (Fig. 1A) with wide black band along anal margin distal of anal break; indistinctly angular apically. Paramere (Fig. 2G) longer than male proctiger. On *Ilex ficoidea* .... *P. vittata* Liao & Burckhardt, sp. nov.

3. Forewing (Fig. 1C, D) rounded apically; wing apex in the middle of cell r_2 margin. Dorsal outline of mesopraescutum, in lateral view, strongly curved (Fig. 1J). Paramere (Fig. 2I, L), in lateral view, irregularly lanceolate with forward pointing apical hook. Female proctiger dorsally distinctly curved, blunt apically .... *P. formosana* Yang
- Forewing (Fig. 1E) pointed apically; wing apex at distal end of vein M_{1+2}. Dorsal outline of mesopraescutum, in lateral view, weakly curved. Paramere, in lateral view, lamellar with forward pointing apical hook. Female proctiger relatively straight dorsally, subacute apically 4
4. Vein M about 1.2 times as long as M_{1+2}. Paramere blunt apically. On *Ilex asprella* ..... *P. castanopsis* Li & Yang
- Vein M_{1+2} longer than M. Paramere obliquely truncate apically ... . *P. nigra* Yang

Fifth instar immature
(not including *Petalolyma formosana*, *P. hyalina*, *P. lii*, *P. nigra*)

1. On *Ilex asprella* ..... *P. castanopsis* Li & Yang
- On *Ilex ficoidea* ..... *P. vittata* Liao & Burckhardt, sp. nov.

Petalolyma castanopsis Li & Yang, 1991

Petalolyma castanopsis Li & Yang, 1991: 16.
Petalolyma fujianensis Li & Yang, 1999: 480; syn. nov.
Trichochermes bicolor sensu Fang & Yang, 1986: 157, nec Kuwayama, 1910: 54; Yang & Li 1984: 129, 130.

Material examined: **Taiwan**: 6 ♀, Nantou, Jihyeutan (Sun Moon Lake), 10-III-1985 (S. J. Fang) (NCHU, dry mounted); 4 ♂, 3 ♀, Pingtung, Shizi, Neiwen Village, South Link Highway, N22°14'36.327", E120°49'56.988", 480 m, 1-XII-2023 (D. Burckhardt) #23-33(-) (NHMB, 70% ethanol); 1 ♂, 2 ♀, same but Neiwen Village, Dongyuan Road, N22°14'36.575", E120°50'12.992", 450 m, #23-34(-).

Description: Adult. Yang (1984); Li (2011); Yang et al. (2013). Fifth instar immature. Fang and Yang (1986). Member of the *divisa* species group.

Distribution: Taiwan (Nantou) (Fang and Yang 1986; Yang et al. 2013), Pingtung (present paper); China (Fujian Province) (Li 2011).

Host plant: *Ilex asprella* Champ. ex Benth. (Aquifoliaceae) (Li 2011).

Comments: Li and Yang (1999), when describing *P. fujianensis* (*divisa* species group), listed differences in the forewing venation to *P. zhejiangana* Yang & Li (*bicolor* species group) but did not mention *P. castanopsis* (*divisa* species group). Li (2011) pointed out the misidentification of *Trichochermes bicolor* from Taiwan by Fang and Yang (1986), referring the Taiwanese species to *P. fujianensis*, and separated the latter from *P. castanopsis* in couplet 6 of the identification key of *Petalolyma* species, suggesting that the two are morphologically most similar. According

Table 1. Forewing characters defining species groups of *Petalolyma*. M/M_{1+2} = length ratio of veins M and M_{1+2}; Cu/Cu_{1b} = length ratio of veins Cu and Cu_{1b}; m_1/r_2 = width ratio of cells m_1 and r_2 measured at wing margin

Species	Wing apex	M/M_{1+2}	Cu/Cu_{1b}	m_1/r_2	References
basalis species group					
basalis (Walker, 1858)	rounded, middle of cell margin r_2	< 2.0	1.4–2.9	< 2.0	Mathur (1975)
sinica Yang & Li, 1984	rounded, middle of cell margin r_2	< 2.0	1.4–2.9	< 2.0	Li (2011)
bicolor species group					
bicolor (Kuwayama, 1910)	angular, near M_{1+2} apex	< 2.0	3.0–4.0	< 2.0	Miyatake and Matsumoto (2008)
zhejiangana Yang & Li, 1984	angular, near M_{1+2} apex	< 2.0	3.0–4.0	< 2.0	Li (2011)
divisa species group					
castanopsis Li & Yang, 1991 = *fujianensis* Li & Yang, 1999, syn. nov.	angular, near M_{1+2} apex	< 2.0	1.4–2.9	< 2.0	Yang (1984); Li (2011); Yang et al. (2013)
divisa (Crawford, 1917)	angular, near M_{1+2} apex	< 2.0	1.4–2.9	< 2.0	Miyatake and Matsumoto (2008)
nigra Yang, 1984	angular, near M_{1+2} apex	< 2.0	1.4–2.9	< 2.0	Yang (1984); Li (2011); Yang et al. (2013)
formosana species group					
indent Yang, 1984	rounded, middle of cell margin r_2	< 1.3	1.4–2.9	< 2.0	Yang (1984); Li (2011); Yang et al. (2013)
lii species group					
lii Liao & Burckhardt	rounded, middle of cell margin r_2	> 3.0	> 4.1	< 2.0	present paper
vittata Liao & Burckhardt	angular, near M_{1+2} apex	> 3.0	> 4.1	< 2.0	present paper
yunnanana species group					
shibatai Miyatake & Matsumoto, 2008	rounded, middle of cell margin r_2	< 2.0	1.4–2.9	> 2.0	Miyatake and Matsumoto (2008)
variegata Li & Yang, 1999	rounded, middle of cell margin r_2	< 2.0	< 1.3	> 2.0	Li (2011)
yunnanana Yang & Li, 1984	rounded, middle of cell margin r_2	< 2.0	1.4–2.9	> 2.0	Li (2011)
nomen dubium					
hyalina (Kuwayama, 1910)					

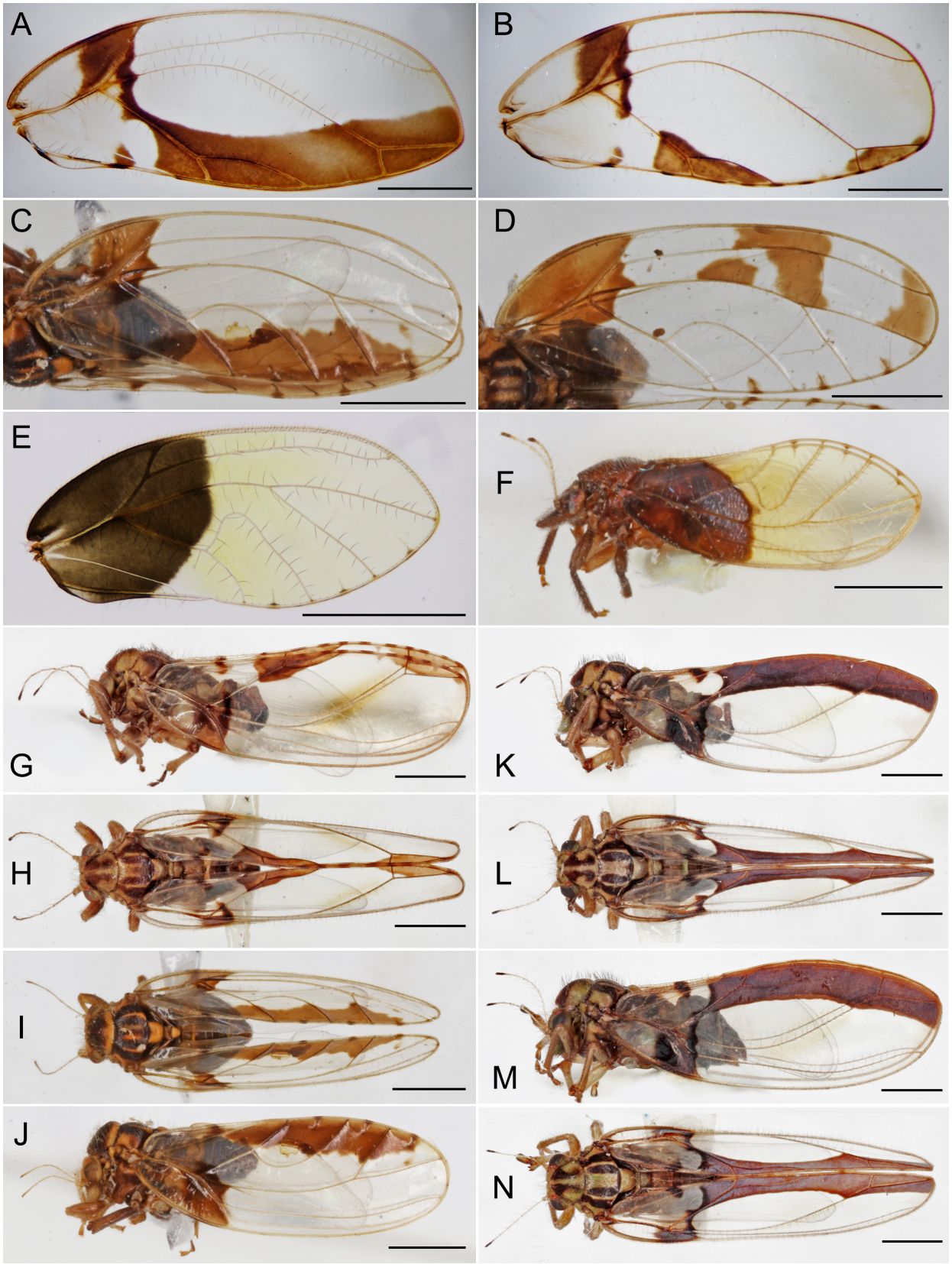

Fig. 1. Forewing (A–E) and habitus (F–N) of *Petalolyma* spp. A, K–N. *P. vittata* Liao and Burckhardt, sp. nov. B, G, H. *P. lii* Liao and Burckhardt, nomen nov. C, D, I, J. *P. formosana*. E, F. *P. nigra*. Scale bar = 1 mm.

to Li's (2011) key, the species differ in the length ratio of veins Cu_{1a}/Cu: 1.29 in *P. castanopsis* versus 1.83 in *P. fujianensis*. These values appear wrong according to our measurements of Li's (2011) drawings: 1.33 in *P. castanopsis* versus 1.36 in *P. fujianensis*. The difference in the posterior outline of the male proctiger listed by Li (2011) reflects minor intraspecific variation. As the two nominal species are morphologically identical, we propose the following synonymy: *Petalolyma castanopsis* Li & Yang, 1991 = *Petalolyma fujianensis* Li & Yang, 1999, syn. nov.

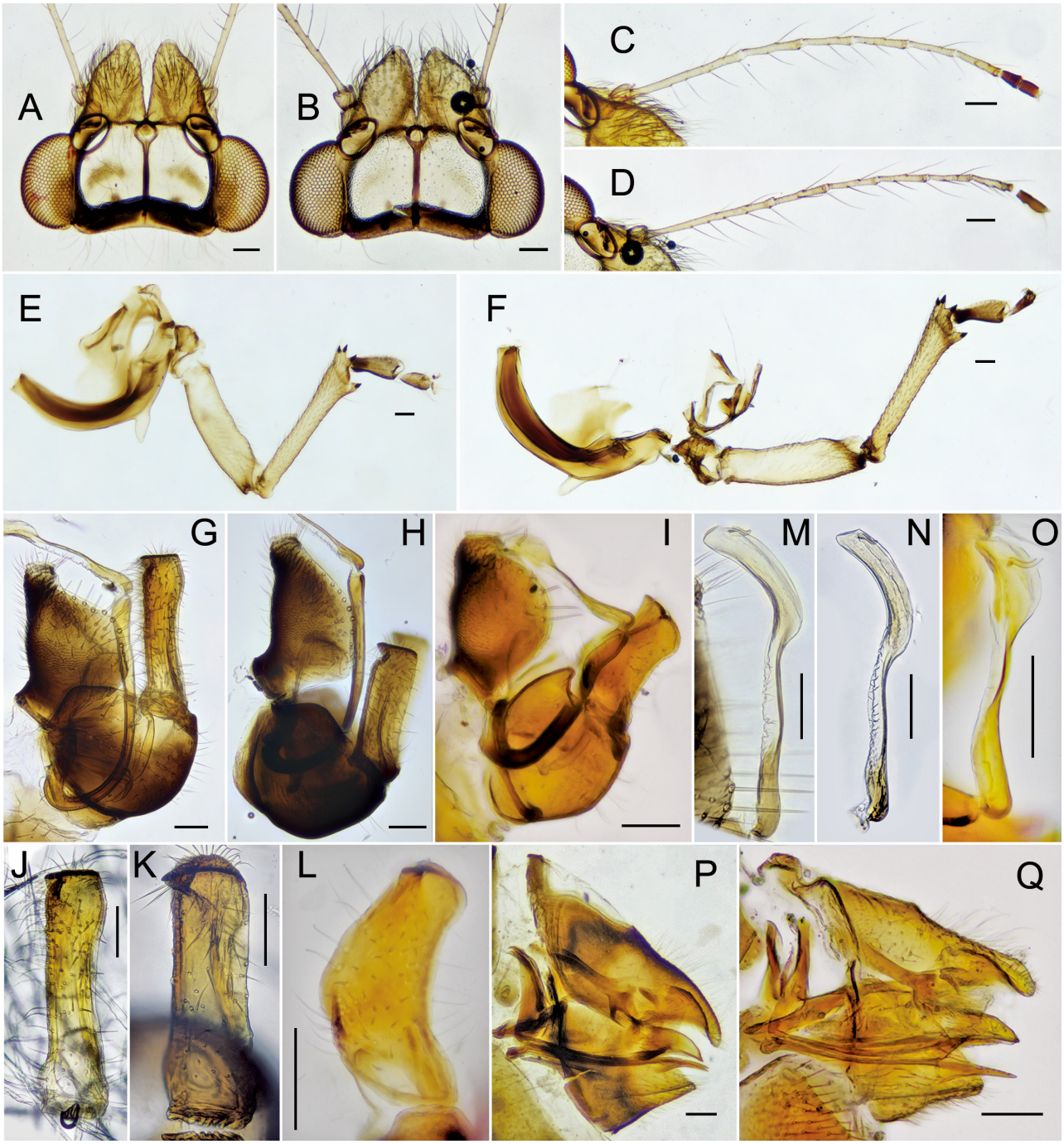

Fig. 2. Head (A, B), antennae (C, D), hindlegs (E, F), male terminalia (G–I), male paramere (J–L), distal segment of aedeagus (M–O), female terminalia (P, Q) of *Petalolyma* spp. A, C, E, G, M, J, P. *P. vittata* Liao and Burckhardt, sp. nov. B, D, F, H, N, K. *P. lii* Liao and Burckhardt, nomen nov. I, L, O. *P. formosana*. Q. *P. nigra*. Scale bar = 0.1 mm.

Petalolyma formosana **Yang, 1984**

(Figs. 1C–D, I–J, 2I, L, O)

Petalolyma formosana Yang, 1984: 234.

Material examined: **Taiwan**: Holotype ♂, paratypes 9 ♂, 9 ♀, Taichung, Anmashan, 22-VII-1982 (C. T. Yang) (NCHU, dry); 1 ♂ 1 ♀, same but 6-VIII-1987 (C. T. Yang) (NCHU, dry); 2 ♂, Nantou, Meifeng, 2150 m, 2–4-VI-1980 (L. Y. Chou & C. C. Chen) (TARI, dry); 1 ♂ 1 ♀, Nantou, Tsuifeng, 2300 m, 3-VI-1980 (L. Y. Chou & C. C. Chen) (TARI, dry); 1 ♂, same but 25-27-VI-1981 (K. S. Lin & W. S. Tang) (TARI, dry).

Description: Adult. Yang (1984); Yang et al. (2013). In the type series, the dark forewing pattern is restricted to the basal quarter of the wing with an occasional faint narrow light brown band along the anal margin (Yang 1984; Yang et al. 2013). In some recently collected specimens at hand (TARI), the pattern is more expanded with a broad, well defined dark patch along the anal margin (Fig. 1C) or two patches along the costal margin (Fig. 1D). Fifth instar immature. Unknown. Member of the *formosana* species group.

Distribution: Taiwan (Nantou, Taichung) (Yang 1984; Yang et al. 2013).

Host plant: Unknown.

Petalolyma hyalina **(Kuwayama, 1910), nomen dubium**

Trichochermes hyalina Kuwayama, 1910: 55.
Petalolyma hyalina, Yang and Li (1984): 130, 137.

Comments: Kuwayama (1910) described *Trichochermes hyalina* based on two males from "Formosa". No further specimens of this species have been reported in the literature. Yang and Li (1984) transferred the species to *Petalolyma* but it is not clear on what evidence this decision was based.

The original description is not diagnostic and the examination of the types is therefore indispensable to uncover the identity of the species. According to H. Inoue (pers. comm.), the two type specimens are missing from Kuwayama's collection (SEHU) since 2012, making *Petalolyma hyalina* a nomen dubium.

Petalolyma lii **Liao & Burckhardt, nomen nov.**

(Figs. 1B, G, H, 2B, D, F, H, N, K)
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Torulus sinicus Li, 1991: 37, 41.
Petalolyma sinica (Li, 1991), comb. nov. = junior secondary homonym of *Petalolyma sinica* Yang & Li, 1984: 131, 138.

Material examined: **Taiwan**: 1 ♂, Nantou, Meifeng, 24°03'43.8"N, 121°9'55.8"E, 1972 m, 13-II-2012, swept from *Eriobotrya deflexa* (Y. C. Liao) (NCHU, dry); 1 ♂, same but Mt. Beidongyen, 24°04'25.8"N, 121°07'37.2"E, 2095 m, 25-I-2017 (Y. C. Liao & C. Y. Chien) (NCHU).

Description: Male. Colouration (Fig. 1B, G, H). Body and head greenish brown. Antenna yellow with apex of segment 8 and totality segments 9 and 10 black. Thorax yellowish brown. Mesopraescutum with two black longitudinal stripes. Mesoscutum with five black longitudinal stripes, the median one shortest. Pro- and mesotibia yellow. Forewing hyaline, with a dark brown patch at the apex of cell c+sc, and on cells m_2 and cu_1. Hindwing hyaline. Abdomen dark brown dorsally and light yellow ventrally.

Structure: Member of the *lii* species group. Body (Figs. 1G, H) length 5.3 mm. Vertex 1.4–1.5 times as wide as long; genal process (Fig. 2B) 1.0 times as long as vertex along midline, bearing long hairs. Antenna slender, 1.8 times as long as head width, sparsely covered with long setae (Fig. 2D); relative length of flagellar segments as 1.0: 0.4: 0.4: 0.4: 0.4: 0.3: 0.2: 0.2. Thorax covered with long setae. Legs (Fig. 2F) robust; metatibia 0.9 times as long as head width; metacoxa bearing blunt meracanthus. Forewing (Fig. 1B) oval, 2.6 times as long as wide, 5.2–5.6 times as long as head width, widest in the middle, broadly, irregularly rounded apically; veins sparsely covered with long setae; relative length of veins M_{1+2}, M_{3+4}, Cu and Cu_{1b} as 5.2: 1.6: 7.4: 1.8. Male proctiger (Fig. 2H) robust, concave anteriorly, strongly bulging posteriorly; subgenital plate (Fig. 2H) subglobular; paramere (Fig. 2K), in lateral view, lamellar and thick, shorter than proctiger, truncate apically, incised anteriorly and subapically; distal segment of aedeagus (Fig. 2N) slender, weakly inflated and curved in apical two fifths.

Measurements in mm (2 ♂): Head width 0.83–0.89; antennal length 1.48–1.65; metatibia length 0.75–0.83; male proctiger length 0.43; paramere length 0.85; length of distal aedeagal segment 0.46.

Female described by Li (1991); Li (2011).

Fifth instar immature: Unknown.

Distribution: China (Fujian) (Li 2011), Taiwan (Nantou) (new record).

Host plant: Unknown. The single female from China was collected on *Vernicia fordii* (Hemsl.) Airy-Shaw (Euphorbiaceae) (Li 2011) and one male from Taiwan on *Eriobotrya deflexa* (Hemsl.) Nakai (Rosaceae). Both are unlikely hosts.

Comments: The dark forewing pattern of the female appears slightly more expanded, judging from the original description (Li 2011). We consider these differences intraspecific variation also observed in other

Petalolyma species (Mathur 1975; Yang and Li 1984; Li 2011).

***Petalolyma nigra* Yang, 1984**

(Figs. 1E, F, 2Q)

Petalolyma nigra Yang, 1984: 237.

Material examined: **Taiwan**: Holotype ♂, Taichung, Anmashan, 22-VII-1982 (C. T. Yang) (NCHU, slides); 1 ♀, Nantou, Chiehitashan, 14-VI-1987 (I. C. Hsu) (NCHU, dry); 2 ♀, Nantou, Meifeng, 2150 m, 24–26-VI-1981 (K. S. Lin & W. S. Tang) (TARI, dry); 1 ♀, same but 15-VII-1982 (S. C. Lin & C. N. Lin) (TARI, dry); 1 ♂ 2 ♀, Hsinchu, Beidelaman, 30-IV-2011 (C. T. Tang) (NCHU, dry, glycerol)

Description: Male. Yang (1984), Yang et al. (2013). Member of the *divisa* species group.

Female: Female terminalia (Fig. 2Q) cuneate. Proctiger 0.9 times as long as head width; dorsal margin, in lateral view, almost straight distal to circumanal ring except for apex which is slightly downcurved and subacute; beset with long setae in basal third laterally, very long setae in median third and short setae in apical third. Circumanal ring cruciform in dorsal view, 0.5 times as long as proctiger; consisting of a single row of elongate pores. Subgenital plate irregularly triangular in lateral view, 0.3 times as long as proctiger; ventral margin weakly concave; apex truncate; beset with long hairs. Dorsal valvula cuneate; dorsal margin has small dorsal nick. Ventral valvula straight with about 10 dorsal teeth. Lateral valvula membranous, irregularly rounded apically.

Fifth instar immature: Unknown.

Distribution: Taiwan (Nantou) (Yang 1984; Yang et al. 2013).

Host plant: Unknown.

***Petalolyma vittata* Liao & Burckhardt, sp. nov.**

(Figs. 1A, K–N, 2A, C, E, G, M, J, P, 3)

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Material examined: Holotype ♂, **Taiwan**: Nantou, Mt. Beidongyen, 24°04'.33.2"N, 121°08'04.8"E, 1940 m, 25-I-2017, *Ilex ficoidea* (Y. C. Liao & C. Y. Chien) (NCHU, dry).

Paratypes: **Taiwan**: 7 ♂, 7 ♀, same data as holotype but (NCHU, NMNS, NHMB, dry, glycerol, slide); 1 ♀, same but 18-II-2014, *Ilex ficoidea* (Y. C. Liao) (NCHU, dry); 6 ♂, 3 ♀, 4 immatures, same but 19-I-2017, *Ilex ficoidea* (Y. C. Liao) (NCHU, 70% ethanol); 6 ♂ 3 ♀, 5 immatures, same but 17-II-2017, *Ilex ficoidea* (Y. C. Liao) (NCHU, 70% ethanol).

Material not included in type series: **Taiwan**: adult (NCHU, 70% ethanol), New Taipei, Yulu (Fish Road) Historical Trail, 27-I-2005, *Ilex ficoidea* (M. M. Yang, M. F. Lou & C. C. Shen) GA050127-4; empty gall, Taichung, Mt. Daxue 20K, 8-IX-2008, *Ilex ficoidea* (C. T. Tang) GA080908-4; early instar immatures extracted from galls, Hsinchu, Rubi, 24°39'59.4"N, 121°16'46.1"E, 1420 m, 12-VIII-2011 (Y. C. Liao) (NCHU, 70% ethanol); same but Hsinchu, Beidelaman, 24°44'15.7"N, 121°16'58.8"E, 1160 m, (Y. C. Liao) (NCHU, 70% ethanol); same but Taichung, Mt. Daxue: 32 K, 24°13'34.0"N, 120°58'20.9"E, 1970 m, 3-V-2012 (Y. C. Liao) (NCHU, 70% ethanol); same but 14-X-2018, (Y. C. Liao) (NCHU, 70% ethanol).

Description: Adult: Colouration (Figs. 1A, K–N, 3A). Body and head greenish brown. Antenna light yellow with apical two segments black. Thorax yellowish brown. Mesopraescutum with two black markings. Mesoscutum with four black longitudinal stripes. Pro- and mesotibia yellow. Forewing hyaline, with a dark brown patch at the apex of cell c+sc and a broad dark brown band along anal margin stretching from anal break to apex. Hindwing hyaline. Abdomen brown.

Structure: A member of the *lii* species group. Body (Fig. 1K–N) length 6.0–7.0 mm. Vertex 1.5–1.6 times as wide as long; genal process (Fig. 2A) 1.0–1.1 times as long as vertex along midline, bearing long hairs. Antenna slender, 1.6 times as long as head width, sparsely covered with long setae; relative length of flagellar segment as 1.0: 0.5: 0.5: 0.5: 0.4: 0.4: 0.2: 0.2. Thorax covered with long setae. Metatibia 0.8–1.0 times as long as head width; metacoxa with thumb-like meracanthus (Fig. 2E). Forewing (Fig. 1A) oval, 2.6–2.7 times as long as wide, 5.2–6.0 times as long as head width, widest in the middle, subacute subapically; veins sparsely beset with long setae; relative length of veins M_{1+2}, M_{3+4}, Cu and Cu_2 as 6.0: 2.0: 7.6: 1.5. Male proctiger (Fig. 2G) 0.4 times as long as head width, thick, in lateral view, weakly sinuate anteriorly, strongly produced posteriorly; subgenital plate (Fig. 2G) subglobular; paramere longer than proctiger, narrowly lamellar, truncate apically, almost straight anteriorly, incised subapically, truncate apically, slightly wavy posteriorly; distal segment of aedeagus (Fig. 2M) straight basally, weakly dilated and curved in apical third. Female proctiger (Fig. 2P) 0.9–1.0 times as long as head width, in lateral view, longer than subgenital plate, strongly narrowing and curved downward at apical quarter; rhomboidal in dorsal view; anus cruciform in dorsal view, almost half as long as proctiger; subgenital plate cuneate, acute at apex.

Measurements in mm (7 ♂, 7♀): Head width 0.90–1.05; antennal length 1.40–1.65; metatibia length

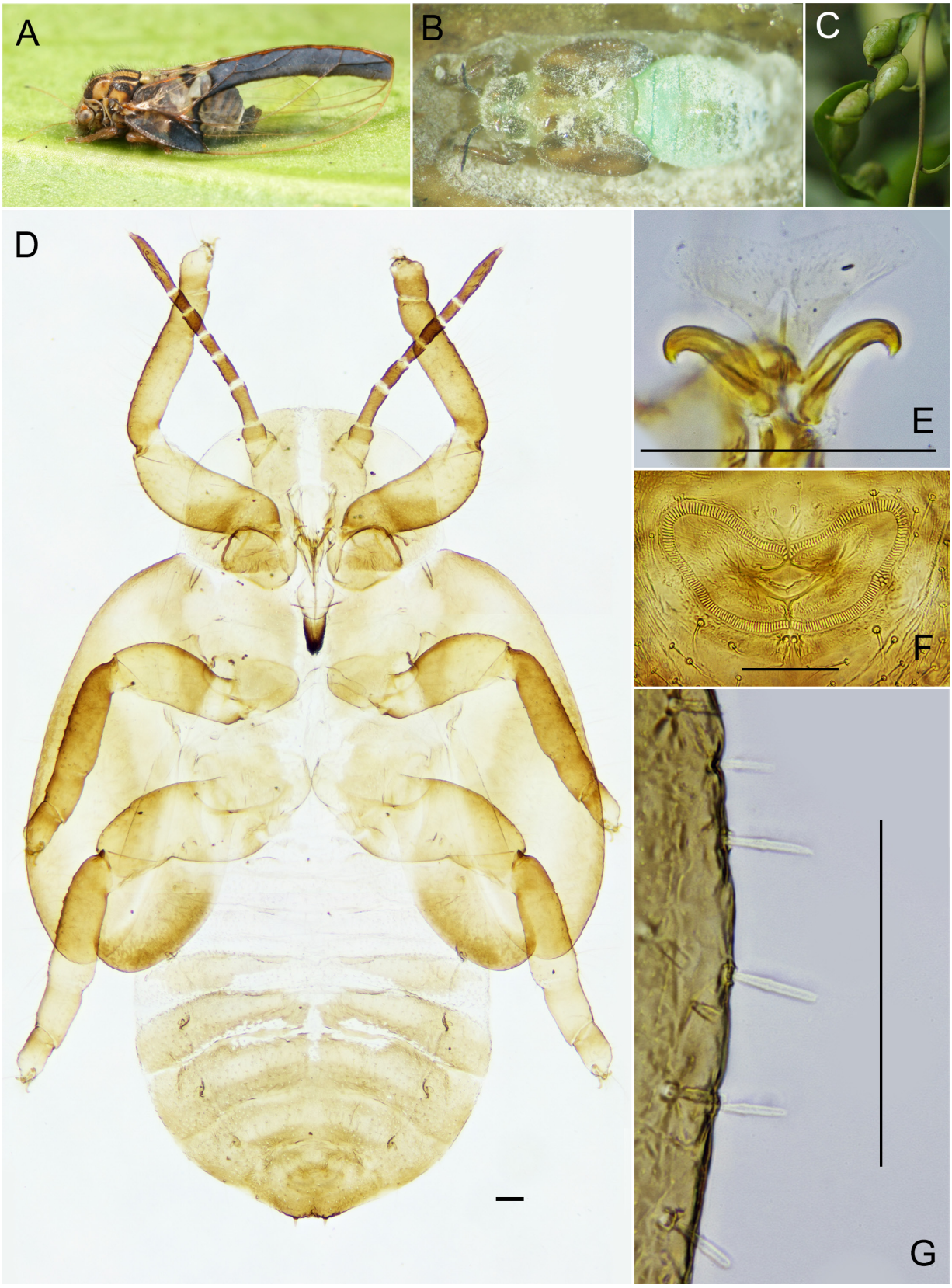

Fig. 3. Habitus and immature of *P. vittata* Liao and Burckhardt, sp. nov. A, male. B, last instar immature in a gall. C, plant galls. D, immature. E, arolium. F, circumanal ring. G, sectasetae on forewing pad. Scale bar = 0.1 mm.

0.80–0.93; forewing length 5.13–6.19; paramere length 0.43; length of distal aedeagal segment 0.43–0.45; female proctiger length 0.85–0.93; female subgenital plate length 0.50–0.53; length of female circumanal ring 0.38.

Fifth instar immature (Fig. 3B–G): Colouration. Head and body pale green. Antenna and wing pads brown.

Structure: Body 1.5 times as long as wide. Antenna 0.7 times as long as forewing pad; relative length of antennal segments 3–8 as 1.0: 0.8: 0.7: 0.8: 0.7: 1.8, segments 3–7 each bear a long, simple dorsal and ventral seta, segment 3 bears two dorsal and one ventral long simple setae. Small and very slender, apically blunt sectasetae on forewing pad covering a relatively broad band along lateral margin. Tibiotarsus longer than femur. Abdominal margin bearing two short sclerotised spurs apically.

Measurements in mm (3 immatures): Body length 2.98–3.23; body width 2.05–2.20; antenna length 0.98–1.05; metatibiotarsus length 0.65–0.70; forewing pad length 1.55–1.58; caudal plate length 0.98–1.08; caudal plate width 1.30–1.43; circumanal ring width 0.23–0.28.

Etymology: From Latin vittatus = wearing or carrying a band or ribbon, referring to the dark brown stripe on the forewing.

Distribution: Taiwan (Nantou, Taichung, Hsinchu).

Host plant: *Ilex ficoidea* Hemsl. (Aquifoliaceae), a common species in forests at mid-elevation in Taiwan.

Biological notes: This species is univoltine and lives in mountain habitats from 1500 to 2000 m. Adults emerge from the end of January to mid-February. The immatures induce a marginal fold producing a closed gall on the leaves. Each gall contains a single immature. When the final instar is ready to hatch, the gall unrolls and the immature leaves the gall and emerges.

Comments: *Petalolyma vittata* Liao & Burckhardt, sp. nov. differs from other congeners in the combination of a dark brown band on the forewing, the pointed forewing and the small forewing cells m_1 and cu_1. It can be distinguished from other Taiwanese species according to the key.

DISCUSSION

Petalolyma, including *Torulus*, constitutes a morphologically homogenous and well defined genus of Triozidae with 13 species recognised here (Table 2). Most species display a conspicuous forewing pattern which can vary quite considerably within a species

Table 2. Host plants and distribution of *Petalolyma* spp. Host plants confirmed by the presence of immature and galls are marked with *. Species known from a single locality only are marked with ‡

Species	Host plant	Distribution	References
basalis species group			
basalis (Walker, 1858)	unknown	India (Uttarakhand), Laos	Mathur (1975); Cho et al. (2017)
sinica Yang & Li, 1984	*Ilex macrocarpa* Oliv.	‡China (Yunnan)	Li (2011)
bicolor species group			
bicolor (Kuwayama, 1910)	**Ilex chinensis* Sims, **I. integra* Thunb.	Japan	Miyatake and Matsumoto (2008)
zhejiangana Yang & Li, 1984	*Ilex* L.	‡China (Zhejiang)	Li (2011)
divisa species group			
castanopsis Li & Yang, 1991 = *fujianensis* Li & Yang, 1999, syn. nov.	*Ilex asprella* Champ. ex Benth.	China (Fujian, Guangxi), Taiwan	Li (2011)
divisa (Crawford, 1917)	*Ilex hayatana* Loes.	Japan, the Philippines (Luzon)	Miyatake and Matsumoto (2008)
nigra Yang, 1984	unknown	Taiwan	Yang et al. (2013)
formosana species group			
formosana Yang, 1984	unknown	Taiwan	Yang et al. (2013)
lii species group			
lii Liao & Burckhardt	unknown	China (Fudjian), Taiwan	Li (2011); present paper
vittata Liao & Burckhardt	**Ilex ficoidea* Hemsl.	Taiwan	present paper
yunnanana species group			
shibatai Miyatake & Matsumoto, 2008	**Ilex macropoda* Miq.	Japan	Miyatake and Matsumoto (2008)
variegata Li & Yang, 1999	unknown	‡China (Fujian)	Li (2011)
yunnanana Yang & Li, 1984	*Ilex macrocarpa* Oliv.	‡China (Yunnan)	Li (2011)
nomen dubium			
hyalina (Kuwayama, 1910)	unknown	Taiwan	Kuwayama (1910)

as shown for *P. basalis* by Mathur (1975); and for *P. sinica*, *P. variegata* Li & Yang, *P. yunnanana* Yang & Li and *P. zhejiangana* by Li (2011) or for *P. formosana* (present work).

Marginal leaf fold galls are documented from four *Ilex* species induced by three *Petalolyma* species: on *I. chinensis* and *I. integra* by *P. bicolor* (Kuwayama), on *I. ficicola* by *P. vittata* Liao & Burckhardt, sp. nov. and on *I. macropoda* by *P. shibatai* Miyatake & Matsumoto. In Taiwan, galls were also observed on *Ilex formosana* Maxim., *I. goshiensis* Hayata, *I. hayatana* Loes., *I. rotunda* Thunb. and *I. uraiensis* Yamam., but could not be attributed to a particular *Petalolyma* species due to the lack of adult psyllids. *Ilex* has been reported as host of another five *Petalolyma* species, but these records are not confirmed by the presence of immatures. For the remaining species, no or unlikely host information is available (Table 2). From the existing data, all species appear to be monophagous with the exception of the Japanese *P. bicolor* (Kuwayama) which was reported from *Ilex chinensis* and *I. integra* (Miyatake and Matsumoto 2008). *Ilex macrocarpa* appears to host two species, *Petalolyma sinica* and *Petalolyma yunnanana* Yang & Li, which were collected together at the same locality in China (Yunnan) (Li 2011). This host relationship needs to be verified by the presence of immatures.

Distribution information is similarly incomplete. Four species have been reported from two countries, four from several localities of a single country and five species are known only from a single locality (Table 2). Both host plant and distributional patterns probably largely reflect poor faunistic knowledge due to the difficulty of efficiently sampling galls and their corresponding adult psyllids in tandem. Part of the observed pattern may, however, be due to endemism in the mountains of China (4 of 6 spp.) and Taiwan (3 of 5 spp.), and a centre of diversity in China and Taiwan (9 spp.) compared to Japan (3 spp.), and India, Laos and the Philippines (1 sp. each). *Petalolyma* occurs also in Nepal and Sri Lanka, each represented by one unidentified species without host data or immatures (unpublished NHMB data).

CONCLUSIONS

Psyllids are generally highly host specific and often induce galls on their hosts. A sound taxonomic base is necessary to investigate these patterns, but is often lacking. The small Asian genus *Petalolyma* exemplifies this issue. Together with the monotypic *Torulus*, which is formally synonymised, *Petalolyma* constitutes a putatively monophyletic group. It consists of 13 species attributed to six species groups based on forewing characters. In this study, we describe and illustrate a new species, *Petalolyma vittata* sp. nov., as well as the previously unknown male of *P. lii* and female of *P. nigra*. The synonymy of *Torulus* with *Petalolyma* creates a secondary homonym, *P. sinica*, for which we propose the replacement name *Petalolyma lii*. Additionally, *P. castanopsis* and *P. fujianensis* are synonymised, and *P. hyalina* is considered a nomen dubium.

Petalolyma species develop, as far as known, on *Ilex* species, where they induce pouch galls. These psyllids are monophagous or narrowly oligophagous. Pouch galls from several *Ilex* species cannot be attributed to any of the known *Petalolyma* species due to the lack of corresponding adults. Additional studies, including targeted field work, are needed to discover the existing diversity of *Petalolyma* and unravel its relationships to *Ilex*.

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Consent for publication: All the authors consent to the publication of this manuscript.

Ethics approval consent to participate: This research followed the guidelines specified by the research permits from the Forestry Bureau (of Nantou, Taichung and Hsinchu), Council of Agriculture in Taiwan regarding the collection of insects.

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