



Article

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Review of the lady beetle genus *Phaenochilus* Weise (Coleoptera: Coccinellidae: Chilocorini) with description of a new species from Thailand that preys on cycad aulacaspis scale, *Aulacaspis yasumatsui* Takagi (Hemiptera: Sternorrhyncha: Diaspididae)

JOSÉ ADRIANO GIORGI¹ & NATALIA J. VANDENBERG²

¹Laboratório de Zoologia, Universidade Federal do Pará, Altamira, Pará, 68372-040, Brazil.

²Systematic Entomology Lab (SEL), Plant Sciences Institute, Agricultural Research Service, USDA, c/o National Museum of Natural History, Smithsonian Institution, P.O. Box 37012, MRC-168, Washington, DC 20013-7012, USA.

E-mail: Natalia.Vandenberg@ars.usda.gov

Abstract

Species of the genus *Phaenochilus* are reviewed, keyed, and illustrated, and an annotated checklist provided. A new species, *Phaenochilus kashaya* n. sp., is described from Thailand. This species feeds on an invasive pest of cycads, the cycad aulacaspis scale, *Aulacaspis yasumatsui* Takagi (Hemiptera: Sternorrhyncha: Diaspididae). The economic importance of cycads and cycad aulacaspis scale is discussed. A taxonomic history of *Phaenochilus* is provided.

Key words: biological control, Cucujoidea, ladybird, pest, predator, sago palm, systematics, taxonomy

Introduction

Cycad aulacaspis scale (CAS), *Aulacaspis yasumatsui* Takagi (Hemiptera: Sternorrhyncha: Diaspididae), is an economically important pest of cycads (sago palms and their relatives). This tiny sap-sucking insect species is highly invasive, and poses a threat to costly ornamental plantings, as well as wild cycad populations and conservation collections around the world (Orapa & Cave 2010). Although native to Thailand (Takagi 1977; Wiese *et al.* 2005), the scale has invaded many other regions through commercial movement of the host plants. CAS is currently reported from Thailand, Hong Kong, Singapore, Taiwan, Guam, Ivory Coast, Barbados, Cayman Islands, St. Kitts, Martinique, Puerto Rico, Vieques Islands, the continental U.S., U.S. Virgin Islands, and the Hawaiian Islands (Hawaii and Oahu) (Germain & Hodges 2007; Haynes 2005).

The first U.S. record of CAS occurred on several species of *Cycas* and *Stangeria* in the Montgomery Botanical Center, Miami, Florida in 1996 (Howard *et al.* 1999). Despite concerted efforts to contain the pest, it spread rapidly throughout the state, killing 80% of the king sago palms in Southern Florida (Woods 2007) and infecting more than 20 other species of cycad in 43 counties (Hodges 2006). Within the continental U.S. it moved from Florida into Alabama, Georgia, Louisiana, South Carolina, Texas, and California (Haynes 2005).

Cycads such as the king sago palm are valued in the U.S. and other countries for their beauty and functionality as landscape and container plants (McKamey 2007). In the U.S. territory of Guam, native forests of 100-year old *Cycas micronesica* serve as prime habitats for many endangered birds, reptiles, bats, land snails, insects, and other wildlife (Haynes & Marler 2005, U.S. Department of Defense, Department of the Navy 2010). Sago palm starch is an important food source for indigenous peoples in the Caribbean, Mexico, Asia, and Africa (Whiting 1963), and the plant also has many modern applications, such as the production of ethanol, glucose syrup, paper, plywood, textiles, and biodegradable plastic (Singhal *et al.* 2008).

Two exotic natural enemies of CAS were cultured and released in Florida in 1998 in an effort to suppress the scale: *Cybocephalus nipponicus* Endrody-Younga (Coleoptera: Cybocephalidae), a minute predatory beetle (Smith

& Cave 2006; Cave 2006), and *Coccobius fulvus* (Compere & Annecke), a parasitic wasp (Hymenoptera: Aphelinidae) (Wiese *et al.* 2005). Both species have become established, but a satisfactory level of control has not been achieved, and the search for new natural enemies continues. One possible candidate, a predatory lady beetle in the genus *Phaenochilus* (Coleoptera: Coccinellidae: Chilocorini), is being reared and evaluated at the Hayslip Biological Control Research and Containment Laboratory in Fort Pierce, Florida and at the Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Gainesville, Florida (Cave *et al.* 2009; Orapa & Cave 2010). This previously unknown species was discovered by Ronald D. Cave of the University of Florida and Ru Nguyen of the Florida Department of Agriculture and Consumer Services during a 2007 collecting expedition to Thailand. Both the spiny larvae and conspicuous orange adults of the new lady beetle species were found in a forest near Sub Tao, 7 km from the Sakaerat Environmental Research Center, feeding on a low density infestation of CAS on *Cycas siamensis* Miq.

In the present contribution we describe, illustrate, and diagnose the new species of *Phaenochilus* and review the systematic history of the genus. A key, distribution map, and checklist of the known species of *Phaenochilus* are provided along with relevant morphological and habitus drawings so that the different species can be easily identified and differentiated from each other and from superficially similar lady beetle species in other genera. This information will contribute to better quality control in present and future biological control programs and assist in evaluating the impact of any field releases.

Material and methods

The following acronyms are used in the text to indicate specimen depositories and institutional affiliations:

AMNH:	American Museum of Natural History, New York, USA
BPBM:	Bernice P. Bishop Museum, Department of Entomology Collection, Honolulu, Hawaii, USA
BMNH:	The Natural History Museum, London, England, UK
CASC:	California Academy of Sciences, Department of Entomology, San Francisco, California, USA
ECMP:	Entomological Collection, Bureau of Science, Manila, Philippines
ESKU:	Entomological Science Department, School of Science Kyoto University, Japan
EUCJ:	Ehime University Collection, Japan
IOZB:	Institute of Zoology, Chinese Academy of Science, Beijing, China
MCZC:	Museum of Comparative Zoology, Cambridge, Massachusetts, USA
MIZW:	Museum and Institute of Zoology, Polish Academy of Sciences, Warsaw, Poland
MNHB:	Museum für Naturkunde, Humboldt-Institut für Evolutions- und Biodiversitätsforschung an der Humboldt-Universität zu Berlin, Germany
OMNH:	Osaka Museum of Natural History, Nagai Park, Osaka, Japan
SNSD:	Senckenberg Naturhistorische Sammlungen, Dresden, Germany
TDOA:	Thai Department of Agriculture, Thailand
USNM:	United States National Entomological Collection, U.S. National Museum of Natural History, Washington, D.C., USA

Measurements were made using an ocular micrometer attached to a dissecting microscope as follows: (TL) total length from apical margin of clypeus to apex of elytra; (PL) pronotal length from the middle of anterior margin to margin of basal foramen; (PW) pronotal width at widest part; (EL) elytral length along suture, including scutellum; (EW) elytral width across both elytra at widest part; (EH) elytral height measured across the highest part of the elytra; and (HW) head width at widest part.

Dissections were performed with the aid of a stereomicroscope and standard dissection tools (forceps, scalpel, needle). Temporary mounts were prepared in glycerin for microscopic examination. Male genitalia were soaked in a 10% solution of KOH to dissolve excess tissue and partially clear opaque structures. After examination, the genitalia preparations were stored in glycerine in a genitalia vial pinned beneath the specimen. Terminology used in the description of genitalic structures follows Vandenberg (2002).

Habitus photographs of the new species were captured with a BK Imaging System using Infinity Optics (K2) and a Canon 40D Digital SLR camera (Visionary Digital). The Canon RAW files were captured with 10.1 effective

megapixels, then processed in Photoshop Lightroom 1.2 (Adobe Systems Inc.) and exported as lossless TIF files (300 dpi, 8-bit). For each image, digital photographs were taken at multiple focal planes; combined with the software application Helicon Focus Pro (Helicon Soft Ltd.) into a single, fully-focused image; and color corrected, resized, and composed in Photoshop CS2 (Adobe Systems Inc.). Digital illustrations were created in Adobe Photoshop CS2 based on reference digital photographs, camera lucida sketches made with a drawing tube attached to a Zeiss Discovery V8 stereo microscope or Zeiss compound microscope, previously published illustrations and descriptions, or a combination of the above. Habitus illustrations representing particular specimens have been idealized and “repaired,” with the elytra shown in a symmetrical and locked position even if the specimen had the elytra open, or was damaged or disarticulated. The distribution map was created by cropping a section of a free World map (vector format) using Adobe Illustrator, then importing and converting to pixel format in Adobe Photoshop, redrawing, simplifying, framing, and colorizing. The locality data points were located on a free online program (Mapquest). They were transferred to the distribution map by importing and superimposing the online map onto ours, and using distortion algorithms to align geographical features. Some illustrations were reproduced or redrawn from earlier publications as indicated in the legend. Illustrations were often produced by a team of scientific illustrators (see acknowledgments) working along with the second author (NJV).

SYSTEMATICS

Historical review

Phaenochilus is a small genus in the lady beetle tribe Chilacorini endemic to Southeast Asia, India, and Japan (Map 1). Weise (1895) proposed the genus to accommodate his new species, *P. punctifrons* Weise from Banguay Island, Malaysia and a second species *P. ruficollis* (Weise) from Sulawesi (formerly Celebes), Indonesia, which he previously described in the genus *Chilocorus* (Weise 1885). Weise characterized *Phaenochilus* as similar to *Chilocorus* in general body form, but distinguished by the narrower mouth region with a subtriangular labrum, weakly curved mandible with outer edge nearly linear, and terminal article of the maxillary palps elongate cylindrical and distally tapered, as opposed to “beilformig” (=hatchetshaped). Subsequently, Weise (1913) added a third species, *P. monostigma* Weise from Mindanao Island in the Philippines. Korschefsky proposed a new species, *Chilocorus celebensis* Korschefsky (1934) from Celebes, but synonymized it with *P. ruficollis* four years later (Korschefsky 1938) after making a direct comparison to Weise’s type.

Chapin (1965a) reviewed the genera of Chilacorini and provided a key and diagnosis for each genus. He used the strongly developed basal tooth of the tarsal claw, and broadly explanate elytral margin, as well as the unique shape of the terminal maxillary palpomere to distinguish the three recognized species of *Phaenochilus* from members of the large cosmopolitan genus *Chilocorus* and the monotypic Cuban genus *Egius*. He illustrated a number of the key morphological features of *Phaenochilus*, including the male and female genitalia of what he believed to be the type species, *P. punctifrons* (designated by Korschefsky 1932), but made no reference to having actually examined Weise’s type material. In the same year, Chapin (1965b) described a fourth species, *P. renipunctus* Chapin from Morotai Island, Indonesia.

Miyatake (1970a) revised the East Asian species of Chilacorini, relying primarily on material preserved in the California Academy of Sciences, supplemented by three other collections (EUCJ, USNM, BPBM). He described a new species *P. metasternalis* Miyatake from Hainan Island, South China, which he characterized as similar to *P. punctifrons*, but distinguishable by the male genitalia and the presence of long dense pubescence on the metasternum. He also mentioned the discovery of three additional *Phaenochilus* species from the “Asiatic continent” which he resolved to describe in subsequent publications. Two of these, taken from localities in Madras State, South India, were described later that same year (Miyatake 1970b): A melanic species, *P. flaviceps* Miyatake, and an immaculate reddish testaceous species, *P. indicus* Miyatake. The latter species was pronounced to be similar to *P. metasternalis* but distinguishable by the form of the male genitalia, the absence of dense hairs on the metasternum, the robust antenna, and more uniform coloration. As with Chapin’s papers (1965a,b), Miyatake made no reference to examining the type of *P. punctifrons*, and presumably based his concept of the latter on Chapin’s published drawings (Chapin 1965b).

Chunram and Sasaji (1980) listed *P. punctifrons* as occurring in the lady beetle fauna of Thailand based on a single specimen from Doi Pui, Chiang Mai, tentatively assigned to that species. Subsequently, Chunram (2002) included the name *P. punctifrons* and locality of Chiang Mai in a book on the lady beetles of Thailand.

Sasaji (2005) contributed the eighth and most recent species to *Phaenochilus* when he transferred *Chilocorus mikado* Lewis 1896, a melanic species from Nagasaki, Japan, to that genus. With the addition of the new species described herein, the number of known species of *Phaenochilus* comes to 9, comprising: 2 maculate species, *P. monostigma* and *P. renipunctus*; 3 melanic species, *P. ruficollis*, *P. flaviceps*, and *P. mikado*; and 4 yellow to reddish orange or ferrugineous species, *P. punctifrons*, *P. metasternalis*, *P. indicus*, and our new species.

Taxonomy

Genus *Phaenochilus* Weise 1895

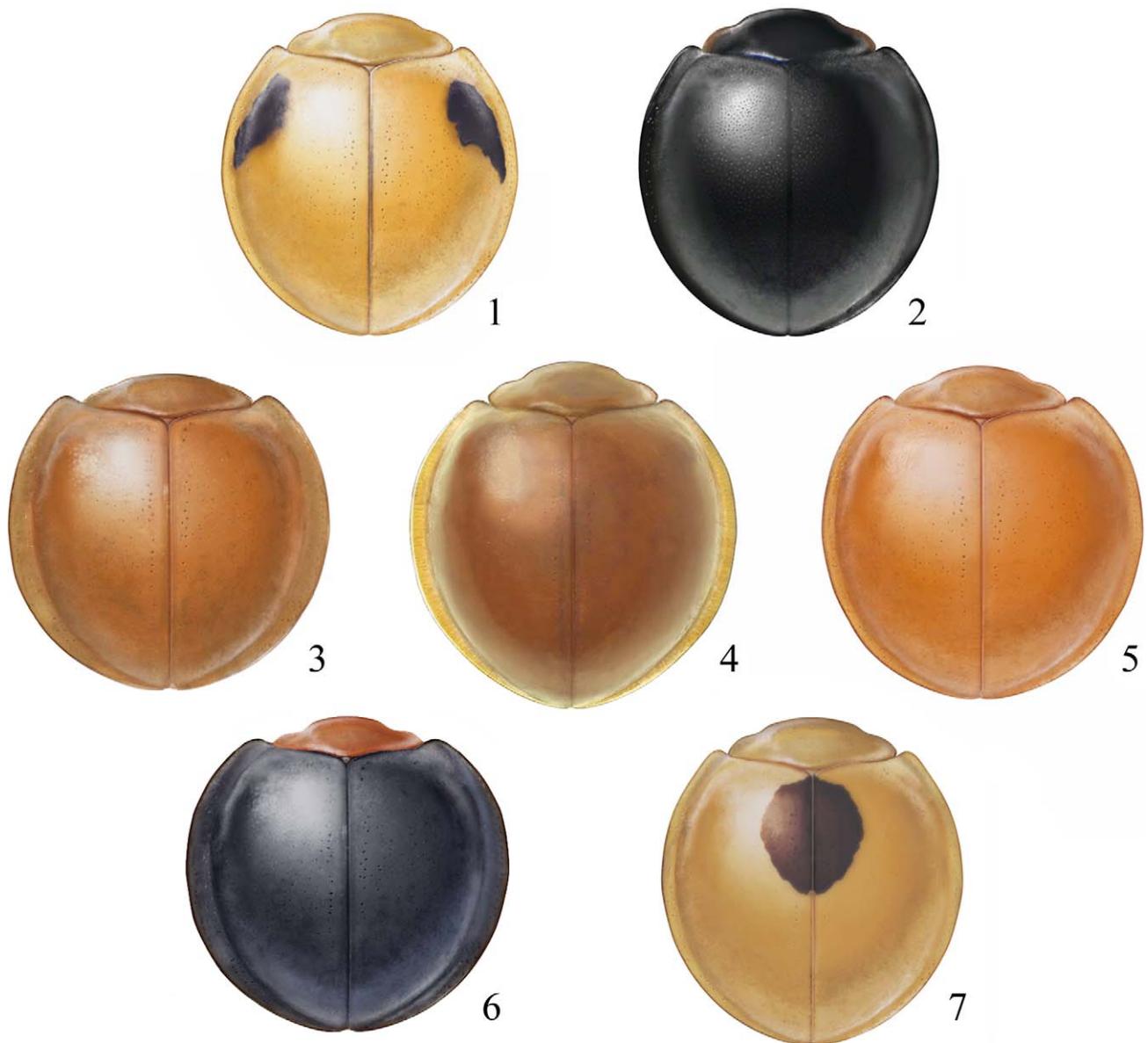
Phaenochilus Weise 1895: 135 (original description); Korschefsky 1932: 237 (catalogue); Chapin 1965a: 234–235, 267–269 (key to genera of Chilocorini; rediagnosis and historical review of *Phaenochilus*); Miyatake 1970a: 20, 49–51 (key to east Asian Chilocorini; rediagnosis and historical review of *Phaenochilus*); Poorani 2002: 7 (checklist, Coccinellidae of the Indian subcontinent). Type species: *Phaenochilus punctifrons* Weise, by subsequent designation of Korschefsky 1932.

Diagnosis: Members of the genus share a similar body form (Figs 1–7) which is compact and roughly hemispherical with the elytral margin narrowly to broadly explanate. *Phaenochilus* can be easily distinguished from other Chilocorini genera by the combination of: antennae with 8 antennomeres (Figs 18–19), eyes large and elongate (Fig. 25–27, 33), frons narrow and distally tapered, interocular distance less than to 1.5X width of an eye, labrum ovotriangulate, mandible weakly curved with outer edge nearly linear, terminal maxillary palpomere (Figs 14–17) elongate, slender, with length equal to or greater than twice basal width, subcylindrical to tapered with oblique apex, or somewhat swollen with subtruncate apex, terminal labial palpomere (Fig. 20) elongate, slender, rodlike, elytral epipleuron deeply foveate for reception of femoral apices, tibial spurs lacking, tarsal claws (Fig. 21) with elongate basal tooth half to more than two thirds length of claw, male genitalia (known for 6 of 9 species) (Figs 8–13) with basal lobe weakly to distinctly asymmetrical, parameres unequal, spermatheca of female genitalia (known for 3 of 9 species) stout with an elongate appendix or apodeme on distal end of cornu.

Key to the known species of *Phaenochilus*

1. Ground color of elytron deep piceous or black, some with metallic reflections. Head and part or all of pronotum reddish or orangy ferrugineous (Figs 2, 6) 2
- Ground color of elytron yellow to reddish orange, or ferrugineous, with or without darker maculae. Ground color of head and pronotum similar to elytron (Figs 1, 3–5, 7) 4
2. Pronotum entirely reddish ferrugineous (Fig. 6). Total length 4.2–5 mm. Sulawesi, Indonesia (formerly Celebes). *Phaenochilus ruficollis* Weise
- Pronotum partly to mostly black or deep piceous, anterior and lateral margins red or orangy ferrugineous. Total length 4.1 mm or less. India and Japan 3
3. Terminal maxillary palpomere with length about 3 times basal width (Fig. 14). Pronotum black except distal edge on either side of anterior emargination narrowly orangy ferrugineous (Fig. 2). Male genitalia (Fig. 8) with blunt, moderately broad, triangular projection at apex of basal lobe; parameres digitiform. Japan. (Fig. 2) *Phaenochilus mikado* (Lewis)
- Terminal maxillary palpomere with length about 2.5 times basal width (Fig. 16). Pronotum black with lateral margins narrowly to broadly reddish ferrugineous. Male genitalia (Fig. 9) with sharp, narrow triangular projection at apex of basal lobe; parameres spoonshaped. India *Phaenochilus flaviceps* Miyatake
4. Elytra with contrasting dark maculae on a paler background (Figs 1, 7) 5
- Elytra unicolorous or with a slight gradient, but without contrasting dark maculae (Figs 3–5). 6
5. Elytra with single dark common oval sutural macula (Fig. 7). Mindanao Island, Philippines *Phaenochilus monostigma* Weise
- Each elytron with dark reniform macula on humeral callus (Fig. 1). Morotai Is., Indonesia *Phaenochilus renipunctus* Chapin
6. Antennal club compact, with last antennomere not much longer than wide (Fig. 19). Male genitalia (Fig. 10a) with basal lobe slender, ellipsoid, with pointed, asymmetrical apex. Known only from the Indian subcontinent *Phaenochilus indicus* Miyatake
- Antennal club less compact, with last antennomere at least 1.5 times as long as wide (Fig. 18). Male genitalia more robust (Figs 11a, 12a, 13a), not as described above. Not known from the Indian subcontinent 7

7. Dorsum of elytra in frontal view describing a roughly semicircular arc (Fig. 25); pronotum less expansive relative to head width (Figs 25, 28, 29), with lateral part only weakly prolonged. Male genitalia (Fig. 11) with basal lobe of phallobase about 3 times as long as wide, only slightly asymmetrical, distal end with triangular projection near midline, with both lateral margins arcuate. Banguay Island, Malaysia and Mindanao Island, Philippines. *Phaenochilus punctifrons* Weise
- Dorsum of elytra in frontal view describing a parabolic or ogival arc (Figs 26, 27); pronotum more expansive relative to head width (Figs 26, 27, 28, 30, 31), with lateral part more strongly prolonged. Male genitalia (Figs 12a, 13a) with basal lobe of phallobase about twice as long as wide, distinctly asymmetrical, distal end with triangular projection on one side, lateral margins variable 8
8. Elytral margin broadly explanate (Fig. 3). Central part of metasternum densely covered with long hairlike setae (may be lost through abrasion). Male genitalia (Fig. 12) with parameres elongate, length more than twice width in lateral view, attached to basal piece by a short narrow handle or stalk (Fig. 12b); basal lobe distinctly undulate on one side, constricted at base (Fig. 12a). China (Anhui, Guangdong, Guangxi, and Hainan provinces), Vietnam, Java, and Singapore *Phaenochilus metasternalis* Chapin
- Elytral margin narrowly explanate (Fig. 5). Central part of metasternum devoid of long hairlike setae. Male genitalia (Fig. 13) with parameres oval, not much longer than their maximum width in lateral view, attached directly to basal piece (Fig. 13b); basal lobe not or indistinctly undulate on one side, not constricted at base (Fig. 13a). Thailand *Phaenochilus kashaya*, n. sp.



FIGURES 1–7. Dorsal habitus views of *Phaenochilus* species. 1, *P. renipunctus* Chapin (holotype, female; TL=3.7 mm); 2, *P. mikado* Lewis (non-type, male; TL=4.0 mm); 3, *P. metasternalis* Miyatake (non-type, male; TL=3.4 mm); 4, *P. punctifrons* Weise (holotype, female; TL=4.0 mm); 5, *P. kashaya*, n. sp. (holotype, male; TL=3.8 mm) 6, *P. ruficollis* Weise (paratype of *P. celebensis*, female; TL=4.8 mm); 7, *P. monostigma* Weise (non-type from W. Schultze, possibly from the same series as the holotype, disarticulated, sex not determined; TL=4.2 mm).

Phaenochilus kashaya Giorgi and Vandenberg, new species

(Figs 5, 13, 17, 18, 20–24, 27, 31–34)

Phaenochilus punctifrons: Chunram & Sasaji 1980: 481; Chunram 2002: 112, not Weise 1895 (misidentification).

Diagnosis: This species is similar in appearance to three other members of the genus that share an immaculate yellow to reddish orange or ferrugineous dorsum, but it can be distinguished using external characters as follows: from *P. indicus* (Fig. 19) it differs in possessing an antennal club with terminal antennomere distinctly elongated (Fig. 18), the length about 2X width; from *P. punctifrons* (Fig. 29) it differs in possessing a more expansive pronotum with anterior pronotal margins on each side of emargination subtruncate (Fig. 31; also see comparative view, Fig. 28); from *P. metasternalis* (Figs 26, 3) it differs in possessing narrow, weakly explanate elytral margins (Figs 27, 5) and having the central part of the metasternum devoid of long hairlike setae. *Phaenochilus kashaya* can be distinguished from superficially similar members of the genus *Chilocorus* by the characters presented in the generic diagnosis, particularly in possessing the elongate, slender terminal article of the maxillary and labial palpi, narrow frons, and elongate basal tooth of the tarsal claw. The distinctive male genitalia will readily separate *P. kashaya* (Fig. 13) from any other coccinellid species. They are most similar to the genitalia of *P. metasternalis* (Fig. 12), but differ in having the parameres oval and only slightly longer than their maximum width in lateral view (Fig. 13b), and the basal lobe not constricted at base (Fig. 13a).

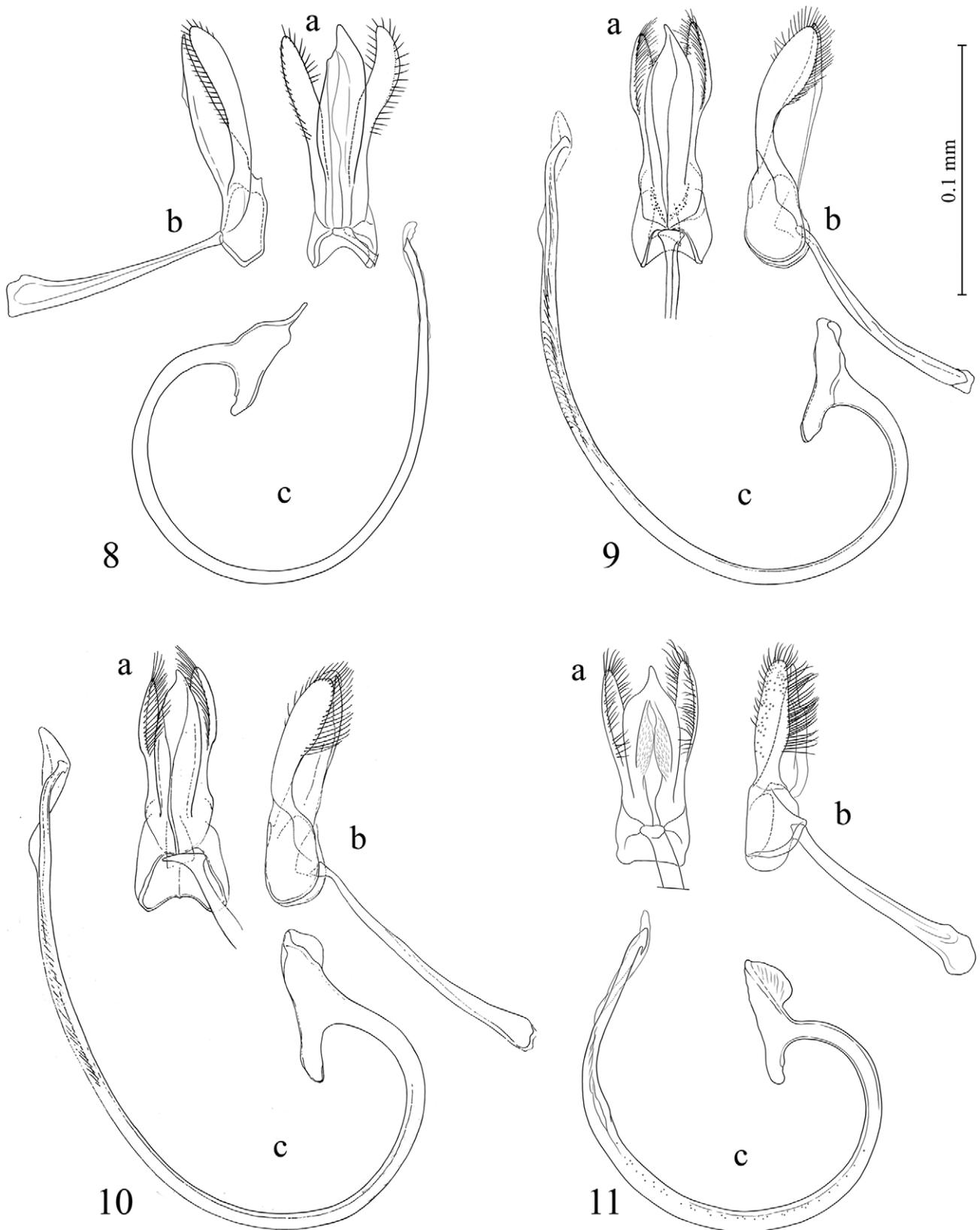
Measurements: TL/EW = 1.0; TL/EH = 1.9; PL/PW = 0.50; EL/EW = 1.7; HW/PW = 0.50; HW/EW = 0.28.

Description of holotype (male): Length 3.8 mm. Form nearly circular (Fig. 32), suprahemispherical (Figs 33, 34), with outer elytral margin weakly, narrowly explanate; humeral angles projecting anteriorly. Surfaces shiny, predominantly glabrous, distinctly punctate, polished between punctures; punctures deeper on head than on pronotum, elytron. Color orange except eye black, tip of mandible dark red; tarsal claws, extreme margins of sclerites narrowly reddish amber.

Head relatively small, width 0.50X pronotal width, 0.28X width of elytra (=maximum width); frons subtrapezoidal, tapered towards clypeus to slightly more than ½ head width; slightly depressed between eyes; punctures course, deep, about 2X diameter of single eye facet, separated by less than 0.5 puncture diameters. Eye large, elongate, length about 2X width, slightly oblique with inner margin weakly sinuous; subequal in width to minimum interocular distance. Clypeus weakly reflexed, arcuately emarginate between eyes. Terminal maxillary palpomere (Fig. 17) elongate, length 3X basal width, 2X length of penultimate palpomere; subcylindrical, weakly tapered distally, ending in oblique sensory surface. Terminal labial palpomere (Fig. 20) slender, conical, slightly shorter than penultimate palpomere. Antenna (Fig. 18) short, slightly less than ½ width of head, composed of 8 antennomeres; length of antennomeres I + II subequal to III–VI combined and to VII + VIII; antennomere I asymmetrical, slightly “S” shaped, slightly wider at apex; antennomere II robust, barrelshaped, as long as I; antennomere III narrowest, width of base about half of apex; antennomeres IV–VI becoming progressively wider, each subequal in length and about as long as III, each narrower at base than apex; antennomere VII widest, almost parallelsided, nearly as long as wide; antennomere VIII longer than VII, with length about twice basal width, tapering to a blunt point.

Pronotum well-developed, length at midline 0.50X width, strongly declivitous, in lateral view (Fig. 34) forming a smooth continuous curve with elytron, nearly vertical in distal 1/3; pronotal disc slightly flattened medially. Pronotal outline (Figs 31, 33): margins of pronotum strongly arcuate in basal 2/3, slightly inflected near scutellum; prolonged and nearly linear in apical 1/3; anterior margin deeply, subtrapezoidally emarginate at middle; transverse dimension of emargination a little more than ½ of pronotal width; anterior pronotal margin subtruncate on each side of emargination. Bordering line of pronotum running just inside of lateral margin from distal border to just short of elytral basal margin. Pronotal punctures slightly less than 2X diameter of single eye facet, separated by 0.5–1 puncture diameters, slightly deeper near anterior pronotal angles.

Scutellum (Fig. 22) subtriangular, slightly elongate. Elytron with length 0.88X width of conjoined elytra, 1.55X elytral height in lateral view; lateral margin narrowly explanate with fine transparent lateral bead; elytral base contiguous with pronotal base except dehiscent in lateral ¼; humeral angles arcuate, slightly projecting anteriorly; humeral callus distinct. Elytral punctures 1–2X diameter of single eye facet, separated by about 1.5–2.5 puncture diameters, slightly deeper near lateral margin.

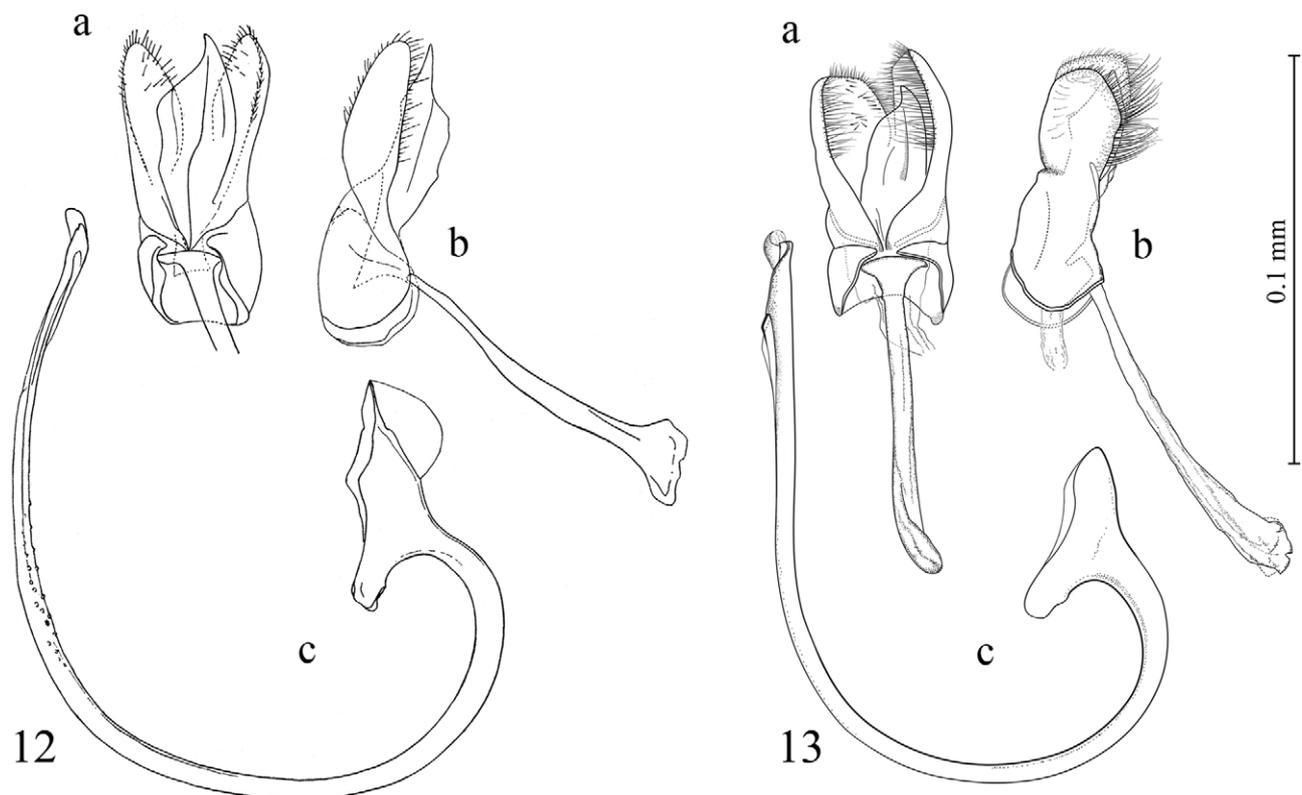


FIGURES 8–11. Male genitalia of *Phaenochilus* species. 8, *P. mikado* Weise (redrawn from Kamiya 1959, Sasaji 1971): a, ventral view of phallobase; b, left lateral view of phallobase; c, left lateral view of siphon. 9, *P. flaviceps* Miyatake: a, ventral view of phallobase; b, right lateral view of phallobase; c, right lateral view of siphon (reproduced from Miyatake 1970b). 10, *P. indicus* Miyatake: a, ventral view of phallobase; b, right lateral view of phallobase; c, right lateral view of siphon (reproduced from Miyatake 1970b). 11, *P. punctifrons* Weise: a, ventral view of phallobase; b, right lateral view of phallobase; c, right lateral view of siphon (specimen from Surigao, Mindanao). Scale bar applies to figs 9–11.

Venter mostly glabrous, with occasional fine scattered setae; distinctly setose only on sides, apex of abdomen; with scattered coarse punctures concentrated medially on metathorax; first abdominal segment with coarse punctures slightly larger than 2X diameter of single eye facet, separated by 1–2 puncture diameters; remaining surfaces smooth to indistinctly punctate. Pronotal hypomerion with distinct but shallow fovea. Elytral epipleuron with deep foveae for pro-, meso-, metafemora; surface concave in basal ½; oblique beyond posterior fovea, becoming nearly vertical at elytral apex. Prosternum with intercoxal process as wide as lateral arms at narrowest point, 0.5X distance between mesocoxae, convex, parallelsided, apically truncate, with lateral bead. Mesosternum weakly emarginate at middle of anterior border. Legs robust, relatively short; femur nearly as long as tibia, about 0.26X body length; meso-, metatibiae angulate at apical 1/5 of outer margin, bearing tuft of converging setae; tarsus slender, together with claws, distinctly shorter than tibia.

Abdomen with 6 ventrites (Fig. 23), ventrite I as long as II–IV combined; II, III, IV subequal in length; V as long as III–IV combined, truncate, superficially emarginate at middle; VI narrowly exposed, distinctly emarginate at middle. Postcoxal line not reaching posterior margin of ventrite I, running parallel, disappearing just before lateral margin.

Male genitalia (Fig. 13): Phallobase short, about 0.7X as long as trabes. Basal lobe broad and strongly asymmetrical, distal end with triangular projection on one side, with lateral margin of opposite side weakly undulate, not constricted basally. Parameres oval, slightly longer than maximum width in lateral view; with inner surfaces scooped, differing in size and shape; longer paramere visibly longer than basal lobe, with apex obliquely truncate; shorter paramere subequal to basal lobe with apex rounded. Trabes about 1.5X longer than basal lobe. Sipho slender, long; of even diameter, curved in basal ½, straight in apical ½; arms of capsule subequal, inner broadly rounded at apex, outer more acute.



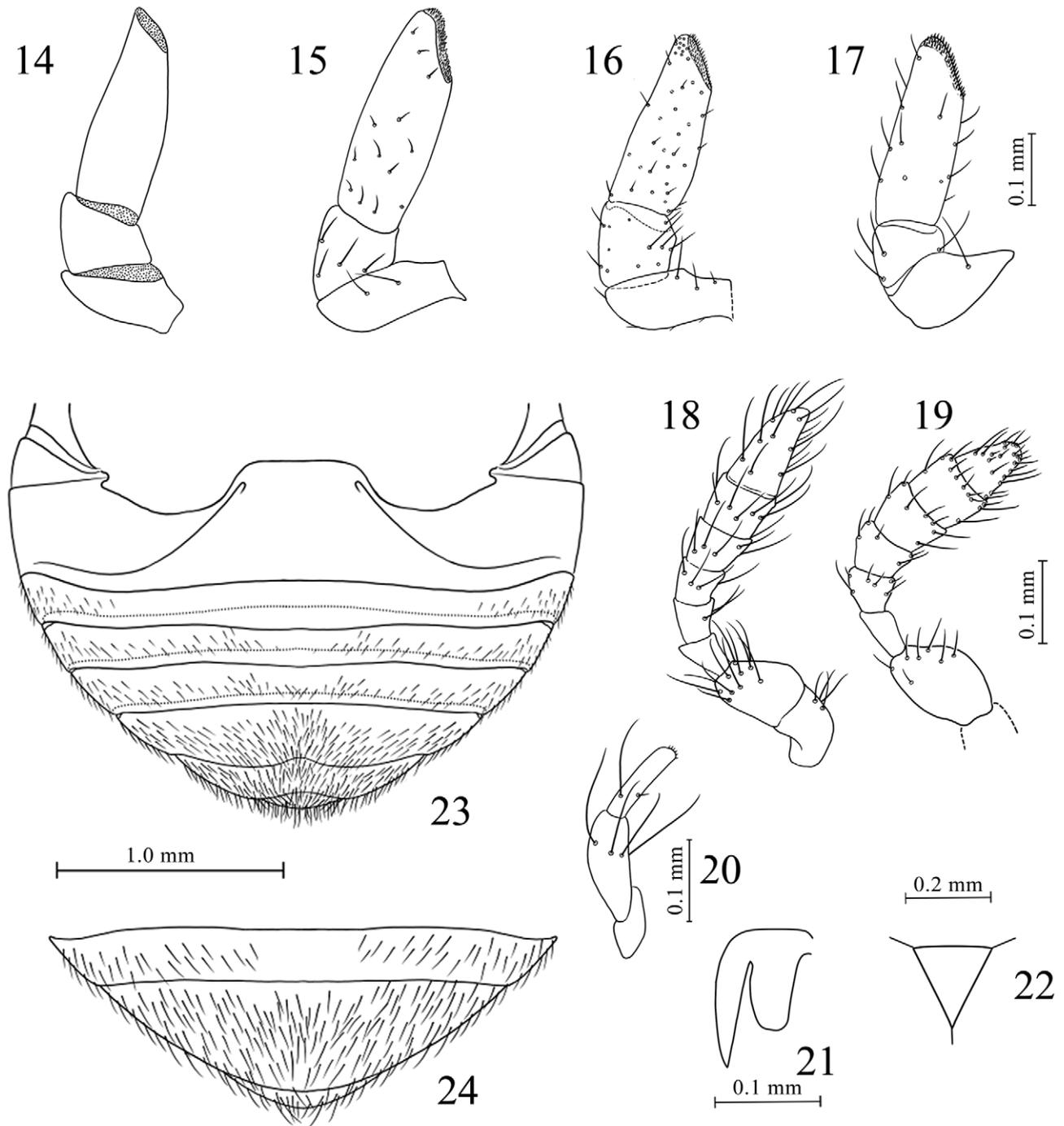
FIGURES 12–13. Male genitalia of *Phaenochilus* species. 12, *P. metasternalis* Miyatake: a, ventral view of phallobase; b, right lateral view of phallobase; c, right lateral view of siphon (reproduced from Miyatake 1970b). 13, *P. kashaya*, n. sp.: a, ventral view of phallobase; b, right lateral view of phallobase; c, right lateral view of siphon (holotype). Scale bar applies to figs 12–13.

Female: Same as male except abdominal ventrite V longer, subtriangulate, rounded at apex, covering most of VI (Fig. 24). Female genitalia typical for the genus.

Variation: Length of males 3.5–4.3, females 4.2–4.8.

Etymology: The species name is a reference to the beetle's color. *Kashaya* (Sanskrit): Hidden desires, earthly passion, based on “*kasha*” (=worldly life) + “*aya*” (=gain). A deep saffron or orange color found in the robes of many Buddhist monks in Thailand, Sri Lanka, and Cambodia, or, by extrapolation, the robe itself.

Prey species: Larvae and adults were observed in the field feeding on cycad aulacaspis scale, *Aulacaspis yasumatsui*. In laboratory tests, when offered a variety of potential prey, they consumed only armoured scales and a few whitefly nymphs (Cave *et al.* 2009).



FIGURES 14–24. Morphological details of *Phaenochilus* species. 14–17, maxillary palpus: 14, *P. mikado* Weise, setae omitted (redrawn from Sasaji 2005); 15, *P. punctifrons* Weise, drawn from SEM of holotype; 16, *P. flaviceps* Miyatake (reproduced from Miyatake 1970b); 17, *P. kashaya*, n. sp. (paratype). 18–19, antenna: 18, *P. kashaya*, n. sp. (dissected specimen from same series as types); 19, *P. indicus* Miyatake (redrawn from Miyatake 1970b). 20, labial palpus of *P. kashaya* n. sp. 21, tarsal claw of *P. kashaya* n. sp. 22, scutellum of *P. kashaya* n. sp. 23–24 ventral view of abdomen of *P. kashaya* n. sp.: 23, male; 24, female (last two ventrites). Scale bars apply to all structures within a set.

Type material: Holotype (male) (USNM) and 14 paratypes (8 males, 6 females) all with labels: “THAILAND: Nakhon, Ratchasima, Sub Tao, N 14°29.45’ E 101°58.60’, 5 October 2007, RD Cave” (2, USNM; 2, AMNH; 2, CASC; 2, TDOA; 2, ECMP; 2, EUCJ; 2, IOZB)

Annotated checklist of the *Phaenochilus* species

1. *Phaenochilus flaviceps* Miyatake 1970

Phaenochilus flaviceps Miyatake 1970b: 111 (original description; morphological details and male genitalia figured).

Type material: Holotype, male (BPBM); paratype, female (BPBM). Type locality: “Coimbatore, Madras State, South India.”

Remarks: This is one of three known *Phaenochilus* species with black to piceous elytra, and the only one of that coloration known to occur in India. It differs from *P. ruficollis* in having the median part of the pronotum black instead of red, and from *P. mikado* in having the basal lobe of the male genitalia (Fig. 9) with a sharply pointed median apical projection, and the parameres spoonshaped. It resembles *Chilocorus nigrinus* (Fabricius), but differs in possessing the slender terminal article of the maxillary and labial palpi, narrow frons, and elongate basal tooth of the tarsal claw.

2. *Phaenochilus indicus* Miyatake 1970

Phaenochilus indicus Miyatake 1970b: 113 (original description; morphological details and male genitalia figured).

Type material: Holotype, male (EUCJ). Type locality: “Chinchona, Anamalai Hills, 1,050 m (3,500 ft.), Madras State, South India.”

Remarks: Three other congeners possess immaculate yellow to reddish orange or ferrugineous elytra, but this is the only species of that appearance known to occur in India. It also differs from the similarly colored species in possessing a more compact antennal club with the last antennomere not much longer than wide (Fig. 19). The male genitalia (Fig. 10) and morphological details illustrated by Miyatake (1970b) suggest a close relationship to the melanic *P. flaviceps* (Fig. 9), also described from Madras State.

3. *Phaenochilus kashaya* Giorgi & Vandenberg, new species

Phaenochilus kashaya Giorgi & Vandenberg, current article (original description; adult habitus, morphological details, and male genitalia figured).

Phaenochilus punctifrons: Chunram & Sasaji 1980: 481 (provisional ID in a checklist of the Coccinellidae of Thailand) (misidentification); Chunram 2002: 112 (habitus photo) (misidentification), not Weise 1895.

Type material: Holotype, male (USNM); paratypes (14 total), 8 males, 6 females (2, USNM; 2, AMNH; 2, CASC; 2, TDOA; 2, ECMP; 2, EUCJ; 2, IOZB). Type locality: THAILAND: Nakhon, Ratchasima, Sub Tao, N 14°29.45’ E 101°58.60’

Remarks: The broad oval parameres of the male genitalia (Fig. 13) will distinguish this species from congeneric species with a similar yellow to reddish orange or ferrugineous coloration. *Phaenochilus kashaya* further differs from *P. metasternalis* in possessing narrow, weakly explanate elytral margins (Figs 5, 27, 32–34), and from *P. punctifrons* in possessing a more expansive pronotum with the anterior pronotal margins on each side of the emargination subtruncate (Figs 28, 31).

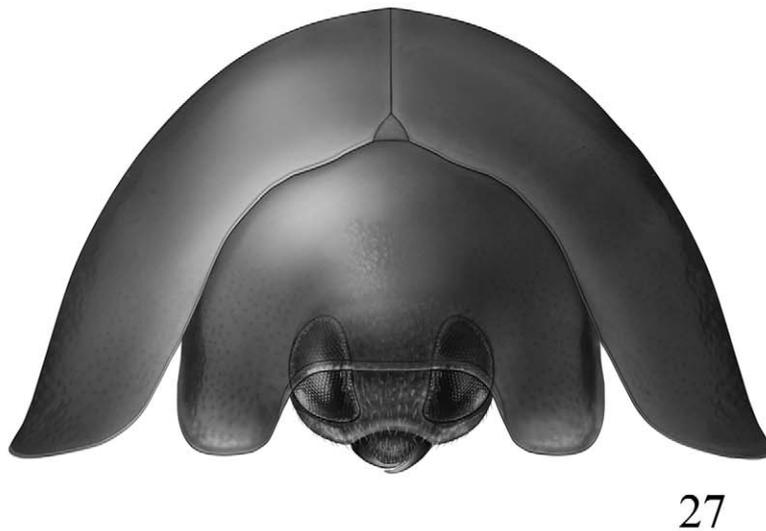
Chunram and Sasaji (1980) tentatively assigned a specimen from Chiang Mai Province to *P. punctifrons*, and subsequently published a photographic image of a specimen from the same locality in a book on the lady beetles of Thailand (Chunram 2002), but we believe these records to be a misidentification of *P. kashaya*.



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FIGURES 25–27. Frontal views of *Phaenochilus* species, males (for comparative purposes, size adjusted to constant head width using outer margin of eyes as a landmark). 25, *P. punctifrons* Weise; 26, *P. metasternalis* Miyatake; 27, *P. kashaya*, n. sp.

4. *Phaenochilus metasternalis* Miyatake 1970

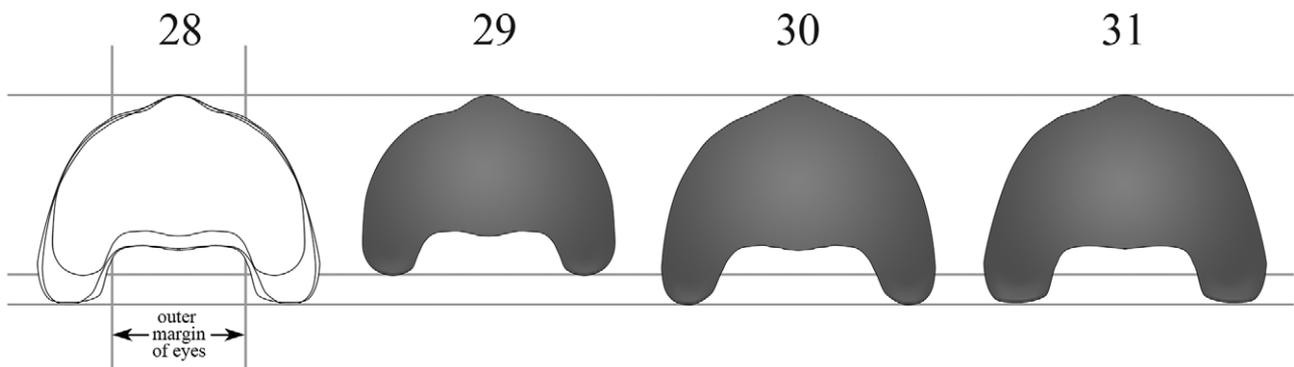
Phaenochilus metasternalis Miyatake 1970a: 50–52 (original description; male and female genitalia figured); Hoang 1981: 12, 15, 16 (first report from Vietnam); Ren Shunxiang *et al.* 2009: 138–139 (photos of dorsal habitus, male genitalia, abdominal postcoxal line).

Phaenochilus punctifrons: Chapin 1965b: 267 & Fig. 18A–G (female genitalia and morphological details figured) (misidentification).

Type material: Holotype, male (CASC); paratypes (2 total), 1 male, 1 female (CASC). Type locality: “Ta Hau, Hainan Is., S. China.”

Remarks: This species can be distinguished from similarly colored congeners by the broadly explanate elytral margins (Figs 3, 26), the central part of the metasternum densely covered with long hairlike setae (may be lost through abrasion), and the male genitalia which has the basal lobe distinctly undulate on one side and constricted near base (Fig. 12a).

A small black leather notebook associated with Chapin’s slide collection (USNM) documents that he performed a whole body dissection of a female of “*P. punctifrons*” from Java (Java, Feb. 1911, R.L. Woglum). Although we could not find the resulting slide mounted material which he designated “X-15,” the remaining specimens from Java, Buitenzorg (=Bogor), and Singapore in the series that Chapin studied all belong to *P. metasternalis*. Ren Shunxiang *et al.* (2009) report the presence of *P. metasternalis* in the Chinese provinces of Yunnan, Anhui, Guangdong, Guangxi, and Hainan. Hoang (1981) reports this species from Trung Quoc, Viet Nam. (See also “Remarks” section for *P. ruficollis*, below.)



FIGURES 28–31. Pronota of *Phaenochilus* species (size adjusted to constant head width using outer margin of eyes as a landmark): 28, overlapping outlines of all three of the species shown separately at right; 29, *P. punctifrons* Weise; 30, *P. metasternalis* Miyatake; 31, *P. kashaya* n. sp.

5. *Phaenochilus mikado* Lewis 1896

Chilocorus mikado Lewis 1896: 32 (original description); Kurisaki 1921: 39; Mader 1955: 738; Kamiya 1959: 101 (male genitalia figured); Kamiya 1966: 77 (key to scale and mite feeding Coccinellidae of Japan and the Ryukyus); Sasaji 1971: 225, pl. 10 (dorsal habitus, male genitalia figured); Osaka Natural History Museum 2012 (online key to Coccinellidae of Osaka Prefecture).

Chilocorus micado: Korschefsky 1932: 240 (catalogue) (typo).

Phaenochilus mikado: Sasaji 2005: 64 (morphological details figured); Shiyake 2009: 14–36 (key to Coccinellidae of Japan).

Chilocorus nigrinus: Lewis 1873: 56, not Fabricius 1798, nomen nudum; Crotch 1874: 184 (in part).

Type material: Unique syntype, sex unknown (BMNH). Type locality: “Nagasaki.”

Remarks: This melanic species can be distinguished from *P. flaviceps* by the male genitalia which have a more blunt triangular projection at the apex of the basal lobe and digitiform parameres (Fig. 8). It differs from *P. ruficollis* in having the median part of the pronotum black or deep piceous (Fig. 2) as opposed to reddish (Fig. 6). According to the Japanese Red Data Retrieval System (2012), the species is known from Nagasaki Prefecture, Island of Kyushu, and Nara and Kyoto Prefectures, Island of Honshu in Japan.

This species was originally confused with *Chilocorus nigrinus* F. by Crotch (1874) who applied that name to a male specimen from Nagasaki in the collection of G. Lewis. Lewis (1873) published Crotch's determination one year prior, listing it in a note as "*Chilocorus nigrinus*, Crotch (sp. n.)." Subsequently (Lewis 1896) published the full description under the new name *Chilocorus mikado* Lewis.



FIGURES 32–34. Habitus views of *P. kashaya*, n. sp., holotype: 32, dorsal view; 33, frontal view; 34, left lateral view.

6. *Phaenochilus monostigma* Weise 1895

Phaenochilus monostigma Weise 1895: 241 (original description); Schultze 1916:38 (catalogue of Philippine Coleoptera).

Type material: Holotype, sex unknown (?ECMP). Type locality: "Agusan River, Mindanao."

Remarks: This is the only species of *Phaenochilus* with a single common dark sutural spot on the elytra (Fig. 7). The male genitalia are unknown.

Weise indicated that the type of this species was from the collection of W. Schultze and was deposited in the collection of the Bureau of Science, Manila. The USNM has a specimen that was acquired with the Korschefsky collection bearing the labels "Mindanao, P. I. / *Phaenochilus monostigma* Ws. Det W. Schultze" that may belong to the same series as the type. The specimen is disarticulated and mounted on two points.

Recuenco-Adorada (2008) contributed a paper on Philippine Chilocorini, but apparently misidentified or confused some of the species. The included redescription and habitus illustration of *P. monostigma* portray a specimen with an immaculate elytral disc and narrow black lateral border on the basal two thirds of each elytron. The male genitalia (lateral views of the siphon and phallobase) and anatomical details incorporated on the same plate suggest instead the species *P. punctifrons*, although we have not seen a comparable example with the dark elytral border. In the same publication, another plate labeled *Eguis* sp. shows a specimen which matches the USNM example of *P. monostigma* in such details as the dorsal color pattern and the shape of the maxillary palpomeres, antenna, pronotum, prosternum, abdominal postcoxal line, and tarsal claw.

7. *Phaenochilus punctifrons* Weise 1895

Phaenochilus punctifrons Weise 1895: 136 (original description); Chapin 1965b: 267, in part (illustration of male genitalia).

Type material: Syntype, female (MNHB) (digital images of dorsal habitus and SEMs of morphological details taken by P. Laczynski (MIZW) examined). Type locality: "Insula Banguay."

Remarks: Both *P. metasternalis* and *P. kashaya* have been confused with this species in the past (see the corresponding remarks sections, above). *Phaenochilus punctifrons* can be distinguished from both of these other species by the less expansive pronotum with the lateral part on each side of the head only weakly prolonged and tightly, evenly rounded apically (Figs 25, 28, 29), by the roughly semicircular shape of the elytral dorsum in a frontal view (Fig. 25), and by the nearly symmetrical basal lobe of the male genitalia (Fig. 11a).

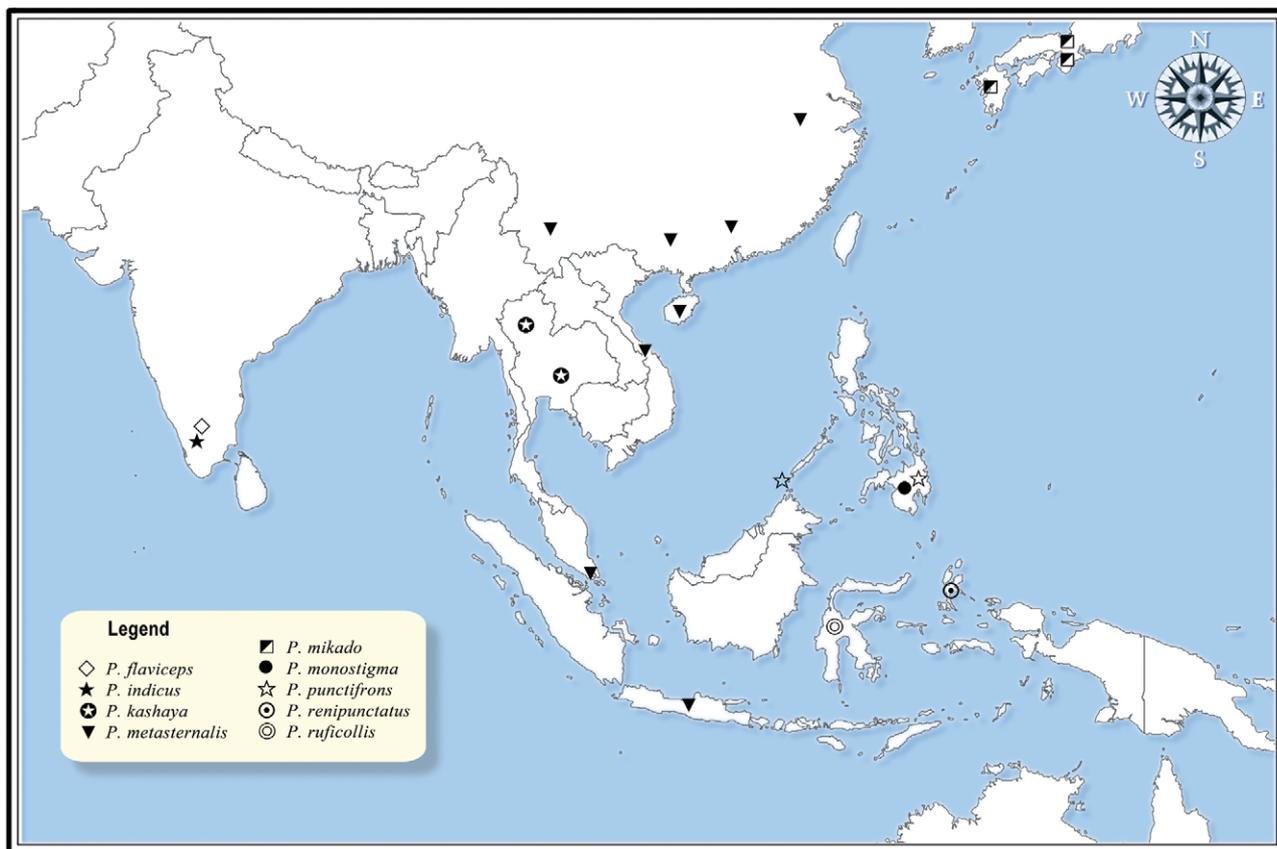
The male genitalia of *P. punctifrons* were illustrated by Chapin (1965b) based on an individual from Mindanao Island which he recorded as “Mindanao, Kolambugan, C.F.Baker #16609” in his little black notebook, and designated as “X-14” (see also remarks under *P. metasternalis*, above). This slide could not be located in Chapin’s slide cabinet (USNM), but a second specimen from Mindanao Island labeled “Surigao, Mindanao, Baker” was dissected and found to have matching male genitalia except for the shape of the siphon. When we transferred our new dissection between media of different viscosities, the siphon temporarily assumed an S-shape matching Chapin’s drawing, apparently due to a difference in the hydrostatic pressure on the outside and inside of the siphonal tube. When allowed to equilibrate, the structure resumes the simple curved shape seen in our figure (Fig. 11c). (See also “Remarks” section for *P. monostigma*, above.)

8. *Phaenochilus renipunctus* Chapin 1965

Phaenochilus renipunctus Chapin 1965b: 151 (original description, dorsal habitus figured).

Type material: Holotype, female (MCZC) (digital images examined, MCZC Type Database @ Harvard Entomology 2010). Type locality: “Morotai I., Indonesia.”

Remarks: This is the only species of *Phaenochilus* with a dark reniform macula on the humeral callus of each elytron (Fig. 1). The male genitalia are unknown.



MAP 1. Distributions of *Phaenochilus* species.

9. *Phaenochilus ruficollis* Weise 1885

Chilocorus ruficollis Weise 1885: 230–231 (original description).

Phaenochilus ruficollis (Weise): 1895: 136.

Chilocorus celebensis Korschefsky, 1934: 108 (original description); 1938: 40 (synonymy).

Type material: *C. ruficollis*, 2 syntypes, sex unknown (MNHB). Type locality: “Celebes: Minahassa.” *C. celebensis*, holotype, sex unknown (MNHB); paratype, female (USNM) (examined). Type locality: “Ahua–Bach, S.O. Celebes.”

Remarks: This melanic species differs from *P. mikado* and *P. flaviceps* in the larger body size (TL=4.2–5.0 mm) and the pronotal coloration which is entirely reddish ferrugineous (Fig. 6). The male genitalia are unknown.

Recuenco-Adorada (2008) included *P. celebensis* in a paper on Philippine Chilocorini, but apparently misidentified the species. In this work, the redescription and habitus illustration of *P. ruficollis* were based on specimens from Luzon and Mindanao measuring 2.59–2.72 mm, with an ochreous colored head, pronotum, and elytron. These characteristics, along with the broadly explanate elytral margin shown in the habitus illustration, and the exact shape of some of the other morphological details given, suggest slightly small individuals of *P. metasternalis*.

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