

Discovery of the male of *Augochloropsis* (*Glyptochlora*) Moure (Hymenoptera, Apidae, Halictinae), with a revised diagnosis for the subgenus

Cindy Julieth Celis^{1,3}; Ivo Raemakers^{2,4} & Gabriel A.R. Melo^{1,5}

¹ Universidade Federal do Paraná (UFPR), Setor de Ciências Biológicas, Departamento de Zoologia (DZ00). Curitiba, PR, Brasil.

² Independent Researcher. Gronsveld, Netherlands.

³ ORCID: [0000-0003-0213-1939](https://orcid.org/0000-0003-0213-1939). E-mail: cindy.celis1@gmail.com

⁴ ORCID: [0000-0002-3618-7394](https://orcid.org/0000-0002-3618-7394). E-mail: ivoraemakers@reivo.nl

⁵ ORCID: [0000-0001-9042-3899](https://orcid.org/0000-0001-9042-3899). E-mail: garmelo@ufpr.br

Abstract. *Augochloropsis* (*Glyptochlora*) Moure is a morphologically homogeneous and rare subgenus of Augochlorini, endemic to the Amazon Basin. So far, the subgenus was known only from females. Herein, we identified and studied the male of *Augochloropsis* (*Glyptochlora*) *peruviana* Celis & Melo. This specimen represents the first opportunity to document the male morphology of *Augochloropsis* (*Glyptochlora*). In addition to the description of the male, including genital capsule and metasomal sterna, we provide an updated diagnosis for *A. (Glyptochlora)*.

Keywords. Halictidae; Neotropical; Sweat bees; Amazon Forest.

INTRODUCTION

The subgenus *Augochloropsis* (*Glyptochlora*) Moure, 1958 is a rare clade of augochlorine bees restricted to the Amazon Basin. The group was originally proposed for the single known species, *Megalopta ornata* Smith, 1879. However, in addition to the type species, the more recent taxonomic revision of the subgenus recognized three new species, namely *Augochloropsis peruviana*, *A. ticuna* and *A. atrocyanea* (Celis & Melo, 2022). In the phylogenetic study of Celis & Cure (2017), *A. (Glyptochlora)* was recovered as the sister group of *A. (Glyptobasia)* Moure, 1940, a small clade currently known from the Atlantic forest of eastern Brazil. A more detailed account of the taxonomic history of *A. (Glyptochlora)* can be found in Celis & Melo (2022).

Since the proposal of the subgenus by Moure (1958), the males of *A. (Glyptochlora)* remained unknown. Recently, a specimen collected in Peru by the second author was identified as the male of *Augochloropsis* (*Glyptochlora*) *peruviana* Celis & Melo, 2022. The aim of this study was to give a first time description of the male of the subgenus *Glyptochlora*.

MATERIAL AND METHODS

Only one male specimen of *A. (Glyptochlora)* was available for study. Original data from the

labels are provided here with double quotation marks (" ") surrounding *ipsis litteris* transcriptions, indicating the separation between the two labels present in the specimen, and backslashes (\) indicating different lines on the same label. Abbreviation of the museum cited in the text is as follows: **MUSM**, Museo de Historia Natural de la Universidad Nacional Mayor de San Marcos, Lima, Peru.

Examination of the specimen was carried out with a stereomicroscope ZEISS Discovery.V8 using white LED ring illumination. Measurements were taken with a Leica M125 and an eyepiece micrometer. Photographs were taken with a digital camera LEICA DFC295, coupled to LEICA M125, and processed in the software Zerene Stacker (Version 1.04 Build). The morphological terminology for the descriptions follows Celis & Melo (2022). The following abbreviations were used: F (flagellomeres), T (metasomal terga) and S (metasomal sterna), followed by corresponding number (1, 2, 3, etc.). Species description proceeded in a structural organization "tagmata, segments, and sclerites", with special attention to the categories: measurements (overall dimensions of the body), color of integument (tagmata, segments, appendices and sclerites tints), pubescence (color, size and presence of ramifications), sculpture (impressions and elevations on sclerites surface) and structure (general organization). The measurements were taken following Michener (2007, fig. 10-3): head

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width; head length (distance from the base of clypeus to vertex apex) and clypeus maximum width and length. The remaining measurements follow Lepeco & Gonçalves (2018) and Gonçalves (2019): width of eye at eye-notch level (distance between the notch of the compound eye and its external margin), supraclypeal area length (minimum distance from upper portion of epistomal suture to the lower tangent of antennal socket); alveolo-ocellar distance (distance between upper tangent of antennal socket and lower tangent to medial ocellus); intertegular distance; maximum width of first tergum; maximum width of second tergum; and total body length (approximate summed length of head and mesosoma plus metasoma). All measurements are in millimeters. For relative pubescence length and vertex form (distance between the occipital surface from lateral ocelli), the diameter of the medial ocellus (OD) was used for comparisons (e.g., < 1 OD: less than once time the medial ocellus diameter) and the width of the tegula (TW) for dorsal width of the pronotal ridge (distance between anterior margin of the mesoscutum and lateral angle of the pronotum in comparison with the tegular width). Integument sculpture was described considering the density of the punctures, which is relative to their diameters and the abbreviation (PD) is used for puncture diameter. This measurement was classified into four types: contiguous (for punctures tightly clustered), dense (≤ 1 PD: distance between the punctures less or equal than one time the diameter of the punctures), open (> 1 PD) and sparse (> 2 PD). The size of the punctures was classified into four types: fine, coarse, and large. We also used the term foveate specifically to describe the extremely crowded large punctures, found mainly in the mesoscutum (Fig. 1C). Sculpture type of the integument among punctures was provided with the prefix "micro-" if it was visible only in magnifications above $50\times$ (resulting in the terms microtessellate, micro-punctate and microreticulate) or smooth, applied for no microsculpturing visible among punctures (Harris, 1979). "Tomentose setae" is used to describe a dense coverage of branched, short, decumbent pubescence. "Bristles" is used to describe distinctly thick simple hair, and "setae" is used to describe ordinary thin branched hairs.

The male genitalia and metasomal sterna were dissected, clarified in 10% KOH solution for 60 minutes, washed in 25% acetic acid for a few minutes, followed by washing in pure water to neutralize the pH and finally preserved in glycerin. Abbreviations for the terminalia structures follows Eickwort (1969).

RESULTS

Augochloropsis (*Glyptochlora*) Moure

Augochloropsis (*Glyptochlora*) Moure, 1958: 188. Type species: *Megalopta ornata* Smith, 1879, by original designation.

Diagnosis: Females of *A. (Glyptochlora)* are readily recognized by the diagnostic characteristics provided in the re-

vision of Celis & Melo (2022) for the subgenus. In general, the male (Fig. 1) is similar to the females and both sexes share the following morphological features: dorsal ridge of the pronotum strongly lamellate; pronotal lobe strongly depressed, forming a deep concavity; tegula oval, with posterior internal margin weakly notched, not producing a posterior tooth; mesoscutum foveate (Fig. 1C; see also fig. 7C of Celis & Melo (2022)), with sinuous elevations in lateral view (see figs. 3A, B of Celis & Melo (2022)), anterior margin strongly projected on the pronotum and lamellate, this lamella strongly emarginated medially forming a bilobed structure (see also fig. 8C of Celis & Melo (2022)), lateral regions lowered and parapsidal lines strongly elevated; axillary crest on scutellum polished and with margin strongly elevated in lateral view, near to mesoscutum; metanotum with acute posterior margin (see figs. 3C, D of Celis & Melo (2022)); propodeum with posterior vertical surface strongly excavated and carinated; metapostnotum with strong central ridge; mesepisternum medially forming an acute projection like a tooth (Fig. 2C; red arrow), and with expansion like a sheet ventrally, near to mid coxa (Fig. 2C; yellow arrow); T1 with dorso-lateral line and anterior margin flattened, apparently straight in dorsal view; T1-T4 with marginal zone glabrous, wide (reaching half length of the tergum medially), somewhat depressed laterally; dorsal surfaces of T1-T3 mostly glabrous, with scarce, minute bristles, and semierect, black longer bristles close to the anterior edge of marginal zones on T3 and T4 (Fig. 1D and Fig. 2B; see also fig. 4D of Celis & Melo (2022)); and T1 and T2 without vibrissae.

The male shows the following differences in relation to females: vertex long (1 OD) and weakly angulate; posterior surface of head, immediately behind ocelli, not vertical as in females, giving a more swollen appearance to the head in dorsal view, and forming a weak post-ocellar transverse ridge, strongly elevated medially in frontal view (similar to the elevation in *Pseudaugochlora* Michener, 1954). Elevation behind compound eye, on vertex, weakly developed and not continuous with post-ocellar transverse ridge. Tegula oval, with posterior margin smooth, centrally weakly microtessellate, inner margin with some sparse fine punctures. Propodeum with lateral angle and areas adjacent to metapostnotum entirely foveate (Fig. 2A), not carinated and with irregular edges; lateral expansions of propodeum small and not well defined; posterior vertical surface of propodeum foveate with irregular edges (Fig. 2A). Metapostnotum with irregular margin, and with entire surface covered by strong, parallel and radial plicae (Fig. 2A). Gradulus of T2 weakly constricted (Fig. 1A). Marginal zone of T1 mostly smooth, its lateral surface with sparse fine punctures, T2-T4 almost entirely smooth (Fig. 1D).

Augochloropsis (*Glyptochlora*) *peruviana* Celis & Melo, 2022

Augochloropsis peruviana Celis & Melo, 2022: 30. Holotype female, Peru: San Martin, San Antonio de Cum-baza (MUSM, examined).

Comments: The male described here was collected in San Roque de Cumbaza, in Peru, a locality situated about 750 m above sea level and only 4 km from the type locality in San Antonio de Cumbaza. The specimen is partially damaged, lacking the left flagellum apically to the F1. After its photodocumentation, the posterior portion of the metasoma was dissected for the study of the genitalia and sterna.

In addition to the details described below, we also noted some form of sclerotization in part of the ventral bristles of the gonostylus (this can be seen as darkened portions of the bristles in Fig. 4B). Such characteristic is not exhibited by males of the other subgenera. Considering that only a section of the bristles is darkened, we are not sure whether they represent an artifact produced during genitalia preparation or an inherent feature of

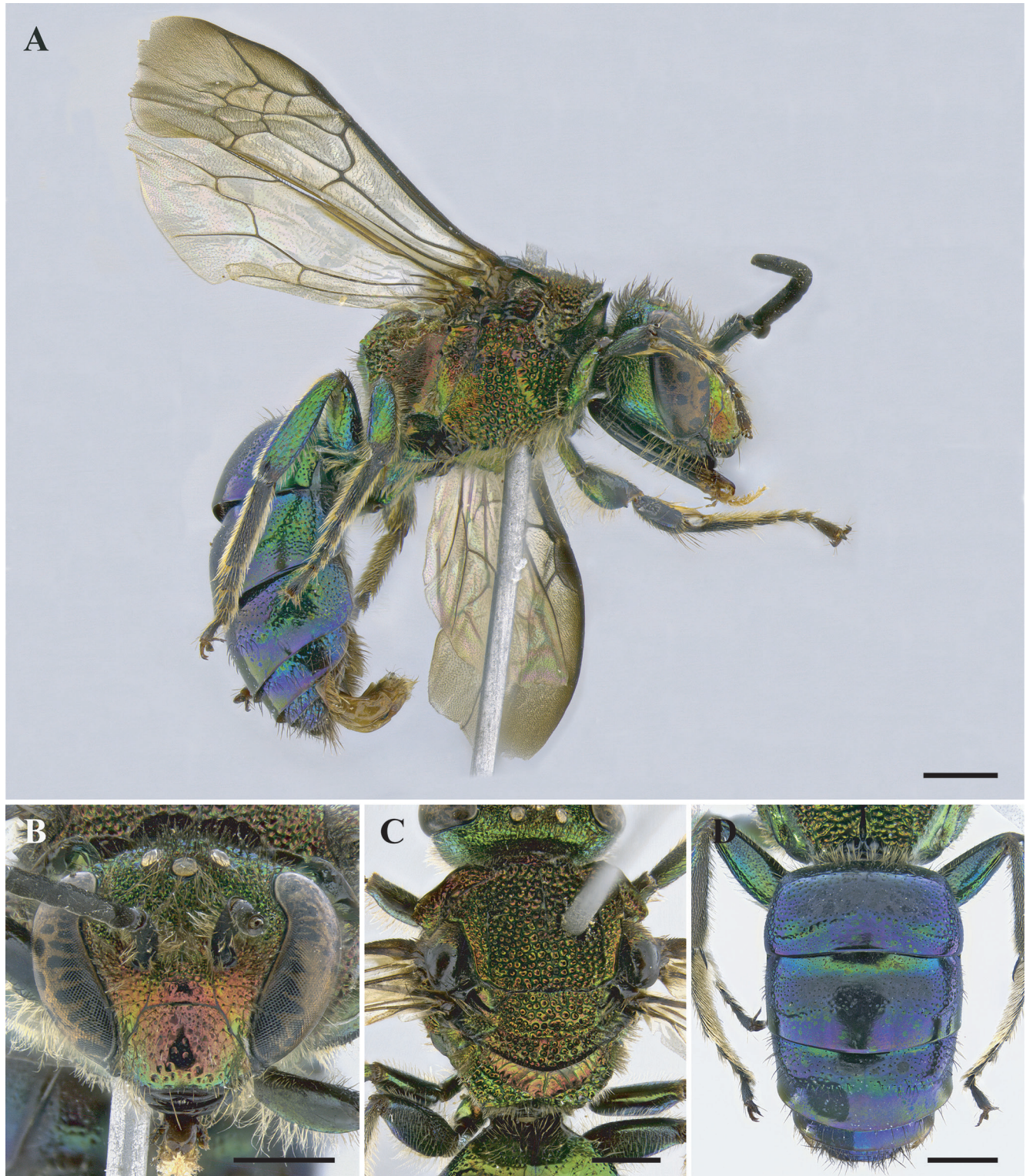


Figure 1. Male of *Augochloropsis* (*Glyptochlora*) *peruviana* Celis & Melo, 2022. (A) habitus, lateral view; (B) Head, frontal view; (C) Mesosoma, dorsal view; (D) Metasoma, dorsal view. Scale bars: 1 mm.

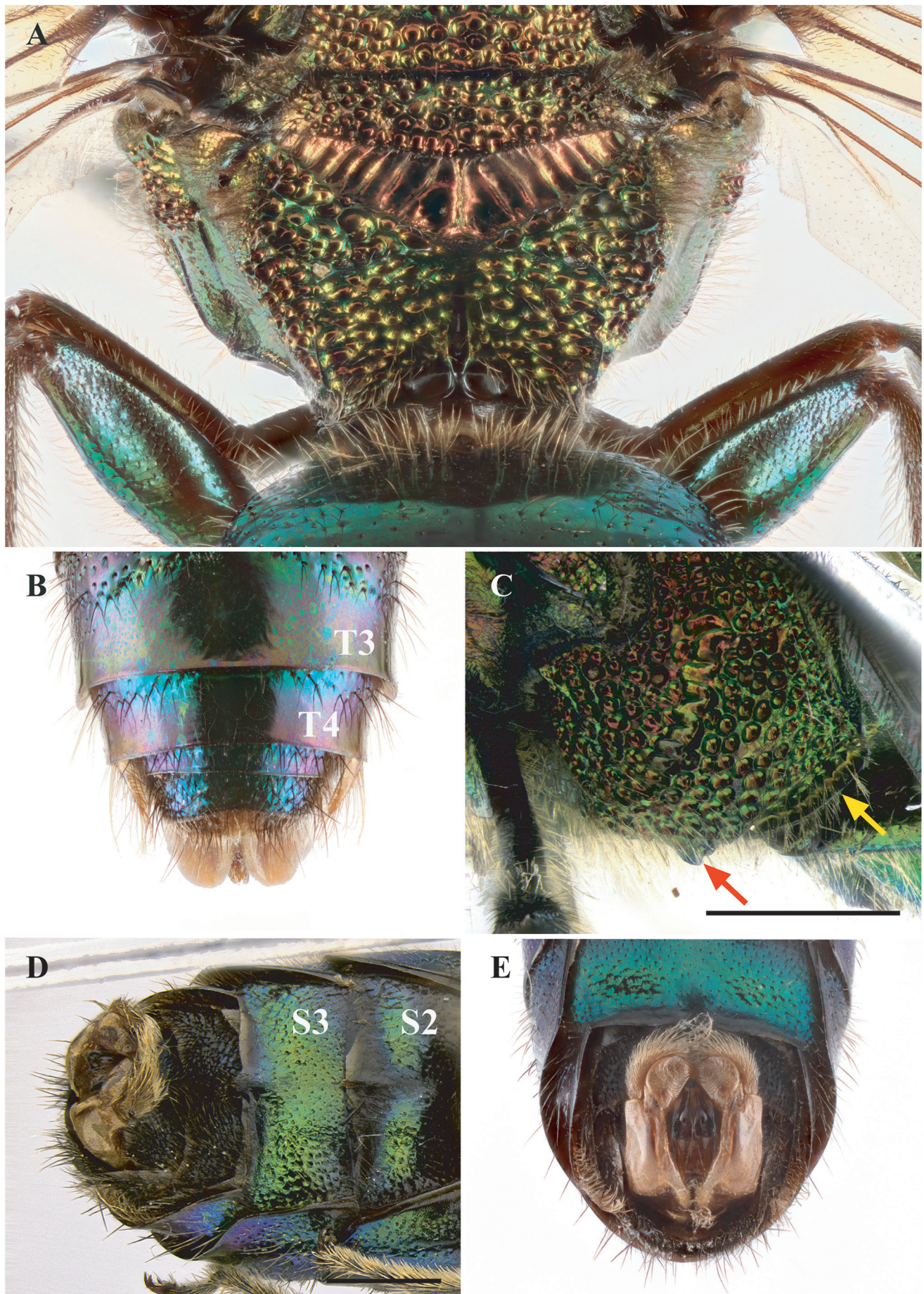


Figure 2. Male of *Augochloropsis* (*Glyptochlora*) *peruviana* Celis & Melo, 2022. (A) propodeum in posterior view; (B) Metasoma in dorsal view; (C) Mesosoma in lateral view; (D) Metasoma in ventral view; (E) Metasoma in ventral view showing the genital capsule in posterior view. Scale bars: 1 mm. Scale is lacking for figs. A, B, and E.

this group. We hope that this can be clarified with the discovery of other males of *A. (Glyptochlora)*.

Description: ♂. *Measurements:* Head width: 2.8; head length: 1.64; clypeus width: 0.84; clypeus length: 1.40; eye notch width: 0.72; supraclypeal length: 0.40; alveolo-ocellar distance: 0.68; intertegular distance: 2.20; T1 maximum width: 2.84; T2 maximum width: 2.80; body length: 8.16.

Color: Mandible black. Lower paraocular area red. Frons green, differing from the remaining reddish coppery on most of face in frontal view. Supraclypeal area red. Clypeus red. Genal area greenish with weak red reflections. Scape and flagellum black. Mesoscutum, scutellum and metanotum mostly reddish coppery with green reflections. Tegula black, anterior surface reddish. Mesepisternum and metepisternum mostly reddish coppery with green reflections. Propodeum mostly green, with reddish coppery reflections on lateral surfaces; metapostnotum entirely coppery. Forewing membrane

mostly hyaline, apical one-third light brown infumated; pterostigma and venation brown. Hindwing membrane hyaline; apical margin iridescent. Coxa, trochanter, tibia and femur of fore, mid and hind legs green; tarsi black; tibial spurs black. T1-T3 mostly green, dorsally with strong bluish violet reflections; exposed dorsal surfaces of T4-T6 green; exposed dorsal surface of T7 brown. Discs of S1-S3 green, basally brown; S5 and S6 brown. **Pubescence:** Body mostly covered by dark pubescence dorsally and pale yellowish ventrally. Compound eye with sparse minute hairs. Dorsal margin of mandible with pale yellow bristles. Apical margin of clypeus with row of sparse, very short (0.5 OD) pale yellow bristles, with longer (2-2.5 OD) bristles medially, entire surface covered by sparse, long (2-2.5 OD), pale yellow bristles, denser on lateral surfaces. Supraclypeal area with dense, long, yellow setae, apical third glabrous. Lower paraocular area with short (1-1.5 OD), erect, yellow setae, intermixed with darker setae. Frons with long (1.5-2 OD), semierect, yellow setae, intermixed with darker setae. Vertex with long

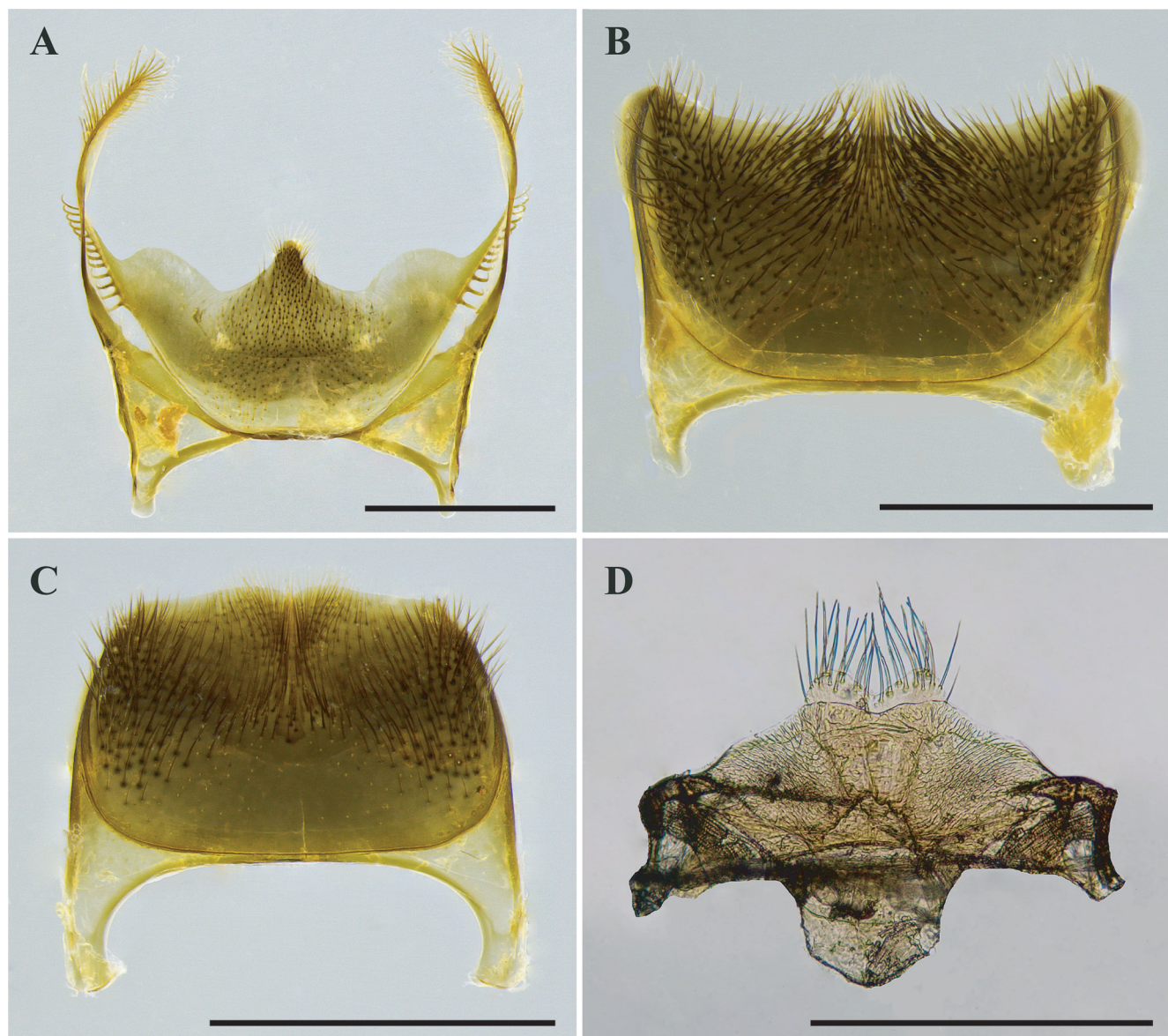


Figure 3. Male metasomal sterna of *Augochloropsis (Glyptochlora) peruviana* Celis & Melo, 2022. (A) S4; (B) S5; (C) S6; (D) S7 and S8. Scale bars: 1 mm. Posterior regions directed upwards.

(1.5-2 OD), erect, black setae. Lower gena with only a few long (2 OD), yellow setae. Scape with short (1 OD) yellow setae in the basal region, intermixed with darkened setae, shorter black bristles towards the distal region. F1 with darkened sensilla; F2-F11 setose with white sensilla. Pronotal lobe with black setae. Mesoscutum with relatively short (1 OD), sparse, erect, dark setae. Scutellum covered with erect, relatively long (1.5-2 OD), sparse,

dark setae, intermixed with longer (3-3.5 OD), dark bristles. Metanotum with erect, long (1.5 OD), dark setae, denser on lateral surfaces, intermixed with erect, longer (2 OD), black bristles. Propodeum lateral surface covered by white tomentose setae; posterior vertical surface with short (1.5 OD), erect, yellow setae; metapostnotum glabrous. Forewing with sparse black microtrichia. External surfaces of coxa, trochanter and femur of fore leg with

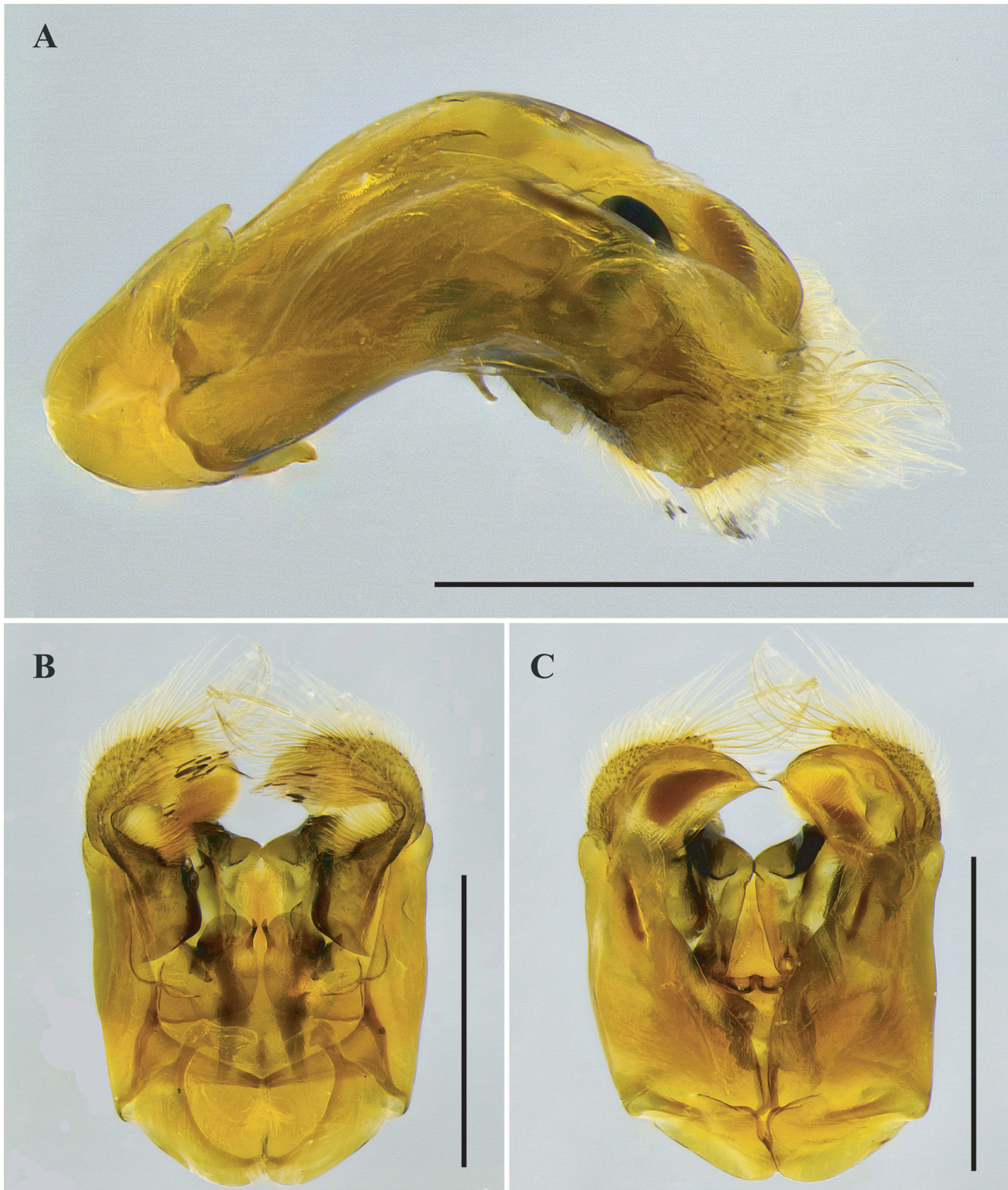


Figure 4. Male genitalia of *Augochloropsis (Glyptochlora) peruviana* Celis & Melo, 2022. (A) lateral view; (B) Ventral view; (C) Dorsal view. Scale bars: 1 mm.

very long (2 OD) pale yellow setae; those on mid leg, even longer (2-2.5 OD); inner surfaces of fore and mid legs mostly glabrous. External surface of tibiae of fore and mid legs entirely covered by dark setae; inner surface and tarsi entirely covered by yellowish setae. Coxa, trochanter and femur of hind leg with dense short yellowish setae; external surface of tibia with erect, well separated, short (1 OD) white bristles, inner surface with denser white bristles; basitarsus entirely covered by yellowish bristles, more conspicuous on its inner surface. Anterior margin of disc of T1 covered with short (1-1.5 OD), sparse, white setae, lateral margins glabrous. Dorsal surface of T1-T3 covered by minute white bristles, on T3 intermixed with black bristles. Lateral margin of T2 and T3 with white bristles. T3 and T4 with dark conspicuous bristles close to marginal zone. Marginal zone of T1-T4 glabrous. Exposed dorsal surfaces of T5-T6 entirely covered by thick, black bristles. Posterior margins of T1 and T2 without vibrissae. S2 and S3 with short, sparse, yellowish bristles, S4 and S5 with longer, denser, brown bristles.

Sculpture: Clypeus punctate, with sparse fine punctures; integument smooth in between; coarser and denser punctures centrally. Supraclypeal area with contiguous coarse punctures; smooth in the apical third. Frons with contiguous coarse punctures. Mesoscutum foveate. Anterior margin of tegula punctate, weakly microtessellate centrally, smooth posteriorly. Scutellum and metanotum foveate. Lateral angle and posterior vertical surface of propodeum foveate. Metapostnotum with strong, parallel and radial plicae on its entire surface. Dorsal surfaces of T1-T3 with sparse fine punctures, integument smooth in between; denser and coarser punctures on lateral surfaces. Marginal zones of T1-T4 smooth, on T1 with some open punctures on lateral surfaces. S2-S4 with dense fine punctures and substrigulate surfaces basal- and distally.

Structure: Vertex weakly acuminate (1 OD), posterior surface of head, immediately behind ocelli, almost vertical; with weak post-ocellar transverse ridge, strongly elevated medially. Vertex, near to upper margin of the compound eye weakly elevated in frontal view, forming an angulation, which is not continuous with post-ocellar transverse ridge. Clypeus and supraclypeal area weakly convex. Apex of clypeus not prolonged over apical border. Dorsal ridge of pronotum strongly lamellated (> 0.5 TW) and weakly sinuous; with dorsolateral angle strongly curved, rounded and weakly notched, produced as an inconspicuous acute corner; pronotal lobe strongly expanded beyond the tegula, forming a right angle. Anterior margin of mesoscutum broad, strongly lamellate medially and projected over the pronotum, this lamella strongly emarginated medially forming a bilobed structure; lateral surfaces lowered in relation to disc, parapsidal lines elevated and reaching the posterior margin of mesoscutum. Metapostnotum medially with an elevated crest, weakly depressed, and entirely delimited by irregular edges. Hind tibial spur serrated. Posterior margin of S2 with small elevation medially covered by a tuft of small white setae (Fig. 2D); posterior margin of S3 with triangular small central projection, covered by a tuft of minute white bristles (Fig. 2D).

Terminalia: S4 with posterior margin strongly sinuous in the sub-lateral region, medially with long triangular projection, ending in an acute tip entirely covered by long bristles; with long lateral process, thin, and spatula-shaped, apically covered with very long bristles, those placed mostly apically branched and curved; with a deep cleft between its lateral margin and the postgradular area, margin of postgradular area with a row of thick hooks, similar to hamuli (Fig. 3A). Posterior margin of S5 weakly emarginated, postgradular region covered by conspicuous dark bristles, protruding beyond the posterior margin and more concentrated in the central region (Fig. 3B). S6 without apical postgradular flanges and without medial notch on the posterior margin, postgradular region covered by dense dark bristles laterally and finer bristles medially (Fig. 3C). S7 and S8 small and weakly sclerotized; posterior margin of S7 narrowed and medially emarginated, forming two bilobed projections bearing long bristles at their tips (Fig. 3D), apodemes posteriorly curved; S8 anteriorly with spiculum projected as a keel and rounded in its more anterior margin (Fig. 3D). Genitalia with gonostylus ventrally occupying about half the total length of the capsule (Fig. 4B); posterior region strongly bent and with very closed C-shape, inner margin and the most posterior region entirely covered by long dense bristles, shorter towards external margin; ventral parapepial lobe forming a very conspicuous plate, projected towards the central region of the capsule and with strong sclerotized margin. Gonostylus dorsally strongly convex, forming a rounded plate and with its ventral surface with a dark area composed of minute bristles forming a dense patch with a velvety appearance (Fig. 4C). Penis valves strongly curved and projected ventrally forming a sclerotized hook; dorsally without valvar tooth and with dorsal crest strongly sclerotized but poorly developed, not protruding in relation to the gonocoxites when seen laterally (Fig. 4A). Genitalia ventrally with ventral gonobasal bridge (Fig. 4B).

Examined material: One male (MUSM), "450" Peru, San Roque de \ Cumbaza 24.i.2015 \ Long. -76.43 Lat. -6.37 \ Leg. Ivo Raemakers" "*Glyptochlora* sp. ♂ \ det. Ivo Raemakers".

DISCUSSION

The discovery of a male of *A. (Glyptochlora)* brings new morphological evidence for the understanding of relationships within the genus *Augochloropsis*. The opportunity to study the male morphology allowed us to recognize the similarity of *A. (Glyptochlora)* with *A. (Glyptobasia)* and *A. (Paraugochloropsis)* Schrottky, 1906 in relation to the genitalia and the metasomal sterna. The genitalia in these three subgenera exhibit a rounded C-shaped gonostylus due to its strong curvature ventrally, and entirely covered by dense bristles; ventral surface of gonostylus with a dark area composed of minute bristles forming a dense patch with a velvety appearance (dark triangular macula seen by transparen-

cy on the left gonostylus in Fig. 4C); penis valve dorsally without valvar tooth and with dorsal crest strongly sclerotized but poorly developed, not protruding in relation to the gonocoxites when seen laterally. Such similarity in male genitalia have led authors, as Eickwort (1969) and Michener (2007), to propose that *A. (Glyptobasia)* and *A. (Glyptochlora)* should be treated as junior synonyms of *A. (Paraugochloropsis)*.

In relation to the metasomal sterna, males of *A. (Glyptochlora)*, *A. (Glyptobasia)* and *A. (Paraugochloropsis)* have the posterior margin of sternum 3 straight or weakly projected medially (as compared to the strongly projected margin in *A. (Augochloropsis)*). However, *A. (Glyptochlora)* is the only group within *Augochloropsis* s. l. in which the sternum 3 has a small triangular medial projection, covered by a tuft of minute white bristles. The sternum 4 of *A. (Glyptochlora)* shows the typical morphology seen in some species of *A. (Paraugochloropsis)*, with lateral spatulate-shaped long projections, covered with very long bristles apically and separated from the postgradular area by a deep cleft along its basal lateral margin; margin of postgradular area with a row of thick hooks (these hooks being thicker and more conspicuous in *A. (Glyptochlora)*). These features of the sternum 4 are not present in *A. (Glyptobasia)*. The sternum 5 of *A. (Glyptochlora)*, *A. (Glyptobasia)*, and *A. (Paraugochloropsis)* has the posterior margin emarginate forming an open U-shape and their sternum 6 lacks apical postgradular flanges (these flanges are found only in *Augochloropsis* s. str.). The remaining sterna (S7 and S8) of these three subgenera call attention for the long bristles at the apex, in comparison to the short setae exhibited by males of *Augochloropsis* s. str.

In summary, the study of the male of *A. (Glyptochlora) peruviana* provides further support to the phylogenetic hypothesis of Celis & Cure (2017), in which *A. (Glyptochlora)*, *A. (Glyptobasia)* and *A. (Paraugochloropsis)* formed a clade, with *Augochloropsis* s. str. being their sister group. Although members of *A. (Glyptochlora)* were not included in the study of Gonçalves *et al.* (2022), their topology recovered a clade formed by *Augochloropsis* s. str. + (*A. (Glyptobasia)* + *A. (Paraugochloropsis)*), a result congruent with the morphological hypothesis obtained by Celis & Cure (2017).

A formal phylogenetic analysis incorporating the morphological data presented here for the male of *A. (Glyptochlora)* is beyond the scope of this contribution and it will be carried out in a forthcoming study dealing with a broader representation of the entire genus *Augochloropsis*.

AUTHORS' CONTRIBUTIONS: CJC: Methodology, Visualization, Data Curation, Formal Analysis, Investigation, Writing – original draft; CJC, GARM: Conceptualization; GARM: Supervision; CJC, GARM, IR: Writing – review & editing. All authors actively participated in the discussion of the results, they reviewed and approved the final version of the paper.

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