



## A new species of planthopper in the genus *Patara* (Hemiptera: Derbidae) on coconut palm (*Cocos nucifera*) from the island of Barbuda

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### Abstract

The island of Barbuda was recently surveyed for the presence of *Haplaxius crudus* to establish the risk of Lethal Yellowing to palms on the island. After extensive collecting, *H. crudus* was not found on the island. A new species of *Patara* Westwood was found on coconut palms on the southwest portion of Barbuda. Herein, we describe the new species as *Patara cooki* sp. n. and provide DNA sequence data for cytochrome *c* oxidase subunit I (COI) and 18S genes for it and *Patara guttata* Westwood. *Patara cooki* differed from *Patara guttata* sp. n. by 1.8% for 18S and 7.8% for COI, similar to intrageneric differences reported for other taxa. A phylogenetic analysis of available Otiocerinae near *Patara* using found *Patara cooki* sp. n. nested among other *Patara* species. We also offer commentary regarding the interpretation of forewing venation in *Patara*.

**Key words:** palms, coconut, Caribbean, Derbidae, planthopper, DNA barcoding

### Resumen

La isla de Barbuda fue recientemente muestreada con el objetivo de reportar la presencia o la ausencia de *Haplaxius crudus* y establecer el riesgo de amarillamiento letal en las palmeras de la isla. Después de un muestreo extensivo, no se encontró *H. crudus* en la isla. Sin embargo, se encontró una nueva especie de *Patara* Westwood en cocoteros en la parte suroeste de la isla. En este documento se describe la nueva especie como *Patara cooki* sp. n. y se proporcionan los datos de secuencia de ADN para la subunidad I del citocromo *c* oxidasa (COI) y los genes 18S para la nueva especie y para la especie *Patara guttata* Westwood. *Patara cooki* sp. n. se diferencia de *Patara guttata* en 1.8% para el gen 18S y 7.8% para COI, estos números son similares a las diferencias intragenéricas reportadas para otros taxones. Mediante el uso de un análisis filogenético disponible para Otiocerinae cerca de *Patara*, se encontró que *Patara cooki* sp. n. se ubica cerca de las otras especies de *Patara*. También se detallan algunos aspectos importantes sobre la interpretación de la venación del ala anterior en *Patara*.

**Palabras clave:** palmeras, coco, Caribe, Derbidae, chicharrita, código de barras genético

### Introduction

The genus *Patara* Westwood (Otiocerinae: Patarini) is a moderate sized genus, relative to other derbids, and is comprised of 13 species in the Neotropics and 11 species from Africa, 24 species in total (Bourgoin 2019). Emeljanov (1996) established Patarini as including the genera *Anapatara* Emeljanov (consisting of seven African species transferred from *Patara*), *Aquaelicium* Distant, *Patara*, and *Synavea* Emeljanov (consisting of 12 African species transferred from *Patara*). Subsequently, Banaszkiwicz & Szwedó (2005) moved *Aquaelicium* and *Synavea* into their tribe Aquaeliciini, leaving Patarini to consist of *Patara* and *Anapatara*.

The features of Patarini specified by Emeljanov (1996) are: Frons strongly compressed with lateral carinae closely approximated and divided only by a groove. Postclypeus convex with weak lateral keels. Vertex triangular. Sensory pits lacking on vertex (“coryphe”). Antennae with scape very small, pedicle robust and elongate (larger in males). Eyes emarginated near antennal bases. Pronotum short, with median and lateral (humeral) carinae. Mesonotum large, convex, median and lateral carinae weak or vestigial. Posterior tibiae without lateral teeth, apex with 6 uniform teeth, 1<sup>st</sup> and 2<sup>nd</sup> tarsomeres 5-6 teeth each. Forewings with Pcu+A1 reaching the wing margin before CuP (i.e., clavus closed). Sensory pits on Sc + R and on Pcu in clavus. Jugal margin of hindwings bearing stridulatory plate with convex external margin.

The diagnostic difference between the Patarini and Aquaeliini resides with the arrangement of the ‘procubital cell’, an anterior cubital cell formed by the forked CuA and closed by an icu crossvein (Banaszkiewicz & Szwedo 2005, fig. 40; an anterior subdivision of C5 in Bourgoïn et al. 2015) in the forewing. In Aquaeliini, the CuA forks then anastomoses to close the ‘procubital cell’, whereas in the Patarini CuA is not bifurcate and the procubital cell is absent (Banaszkiewicz & Szwedo 2005), a distinction also noted by Emeljanov (2006).

Phylogenetic relationships between species of *Patara*, among *Patara* and *Anapatara*, or more broadly among tribes of Otiocerinae has not been tested, and few molecular markers are available among included taxa. The relationship of the 11 species of *Patara* from Africa to the Neotropical *Patara*, and *Anapatara* should be examined with appropriate molecular markers to determine whether *Patara* includes both Neotropical and African taxa. Banaszkiwicz & Szwedo (2005: 224) noted that *Patara* as currently comprised is “probably paraphyletic.” Among New World taxa, there is a single Nearctic species with most of the remaining taxa are from the Caribbean (e.g., Banaszkiwicz & Szwedo 2005). *Patara* was noted to be present in canopy fogging samples from Ecuador (Barringer et al. 2019), hinting at an unexplored Neotropical fauna.

Among New World genera, *Patara* is recognized as small (typically 5 mm or less), fragile forms, lacking the cup-like fossa behind antennae found in Cenchreini; frons greatly compressed, head slightly projecting in front of eyes in lateral view, antennae lacking appendages, scape small, pedicle greatly enlarged and flattened; forewings with Pcu + A1 reaching the wing margin before CuP (i.e., clavus closed; Fennah 1952, Bartlett et al. 2014). Furthermore, *Patara* has distinct sexual dimorphism, with males having the antennal pedicle segment approximately twice as long as females, and females with a broader vertex than males.

New World *Patara* consists of the type species *P. guttata* described along with *P. albida* from St. Vincent by Westwood (1840). Subsequently Ball (1902) described *P. vanduzeei* from New York, and Fowler (1904) described *P. marmorata* from Guatemala. Fennah (1945) described *P. poeciloptera*, *P. trigona* and *P. vittatipennis* from Trinidad and Fennah (1952) described six additional species from the Caribbean basin (viz., *P. cyanea*, *P. fumipennis*, *P. gausapata*, *P. inermis*, *P. mimula* and subspecies *P. m. unicornis*, and *P. pakaraima*). Fennah (1952) also synonymized *P. guttata* with *P. albida*, noting that the color differentiation was not adequate to establish these as separate species and that there were no genitalic differences between the two.

Recently, survey work was conducted on the island of Barbuda to assess the risk of the island to the lethal yellowing (LY) phytoplasma (16SrIV-A) and lethal bronzing (LB) phytoplasma (16SrIV-D) to palms. During these survey efforts, a novel species of the genus *Patara* was discovered on coconut palms and is herein described. Molecular data for the COI and 18S loci were generated for the new species and *P. guttata* (Fig. 8) collected to help assess genus level placement of the new species.

## Materials and methods

**Locality and Specimen Collection.** Individuals of the novel taxon were collected from the underside of coconut (*Cocos nucifera* L.) fronds in an abandoned plantation (Fig. 1) on the Southwestern portion of the island of Barbuda (17.605594, 61.8326). Specimens were aspirated directly from coconut leaves and transferred directly to 95% ethanol in the field. Specimens were collected with permission of property owner and exported under Phytosanitary Certificate No. 2827, access and benefit sharing agreement number 1 of 2020 to the U.S.A., and imported under permit number P526-170201-001. All specimens collected were measured, photographed and dissected using a Leica M205 C stereoscope. Images of specimens and all features photographed were generated using the LAS Core Software v4.12. Voucher specimens, including primary types, are stored at the University of Florida—Fort Lauderdale Research and Education Center (FLREC) in Davie, FL, U.S.A and the Florida State Collection of Arthropods (FSCA) in Gainesville, FL, U.S.A.

**Morphological terminology and identification.** Morphological terminology generally follows that of Bartlett *et al.* (2014), except forewing venation following Bourgoïn *et al.* (2015) and with male terminalia nomenclature modified following Bourgoïn (1988) and Bourgoïn & Huang (1990). New taxa are intended to be attributed to Bahder & Bartlett.

**Dissections and DNA Extraction.** The terminalia that were dissected also served as the source of tissue for DNA extraction. The terminal end of the abdomen was removed and placed into a solution of tissue lysis buffer (buffer ATL) and proteinase K (180 µl ATL and 20 µl proteinase K) from the DNeasy® Blood and Tissue Kit (Qiagen). The abdomen was left to lyse for 24 hours at 56°C. Following lysis, eluate was transferred to a new 1.5 ml microcentrifuge tube and DNA extraction proceeded as per the manufacturer's instructions. The terminalia were then immersed in 200 µl of buffer ATL and 200 µl of buffer AL from the same kit and placed at 95°C for 24 hours to remove fat, wax, and residual tissue. The genitalia that were dissected and photographed is the same as that which was used to obtain molecular data.

**PCR Parameters, Sequence Data, and Analysis.** To obtain COI sequence data, DNA template from specimens was amplified using the primers LCO1490 (5'-GGTCAACAAATCATAAAGATATTG-3') and HCO2198 (5'-TCAGGGTGACCAAAAAAATCA-3') (Folmer *et al.* 1994). To obtain 18S sequence data, the forward primer 18SF (5'-ACTGTCGATGGTAGGTTCTG-3'), reverse primer 18SR (5'-GTCCGAAGACCTCACTAAA-3') were used. PCR reactions contained 5x GoTaq Flexi Buffer, 25 mM MgCl<sub>2</sub>, 10 mM dNTP's, 10 mM of each primer, 10% PVP-40, and 2.5U GoTaq Flexi DNA Polymerase, 2 µl DNA template, and sterile dH<sub>2</sub>O to a final volume of 25 µL. Thermal cycling conditions for 18S were as follows: 2 min initial denaturation at 95°C, followed by 35 cycles of 30 sec denaturation at 95°C, 30 sec annealing at 50°C, 2 min extension at 72°C, followed by a 5 min extension at 72°C. Thermal cycling conditions for COI were as follows: 2 min initial denaturation at 95°C, followed by 35 cycles of 30 sec denaturation at 95°C, 30 sec annealing at 40°C, 1 min 30 sec extension at 72°C, followed by a 5 min extension at 72°C. PCR products of the appropriate size were purified using the Exo-SAP-IT™ PCR Product Cleanup Reagent (ThermoFisher Scientific, Waltham, Massachusetts, USA). Purified PCR product was quantified using a NanoDropLite spectrophotometer (ThermoFisher Scientific, Waltham, Massachusetts, USA) and sequenced using the SeqStudio Genetic Analyzer (ThermoFisher). Contiguous files were assembled using DNA Baser (Version 4.36) (Heracle BioSoft SRL, Pitesti, Romania), aligned using ClustalW as part of the package MEGA7 (Kumar *et al.* 2016). A matrix of pairwise differences using number of differences among COI and 18S was calculated with MEGA7 (Kumar *et al.* 2016). The bootstrap method was used for variance estimation at 1,000 replicates and using the p-distance model. Maximum Likelihood trees were generated using the Bootstrap method at 1,000 replicates based on the Tamura-Nei model for both the COI and 18S loci.

**Taxon sampling.** COI sequence data was used from other species of *Patara* (*P. guttata* and *P. vanduzei*) for in-group comparisons while three species of *Anotia* Kirby, two species of *Otiocerus* Kirby, *Apache degeerii* (Kirby), *Saccharodite chrysonoe* Kirkaldy, and *Lydda elongata* (Fabricius) (Table 1). For 18S, these data were only available for *Anotia firebugia* Bahder & Bartlett. Phylogenetic analyses were conducted for available COI data using MEGA7, but no comparable analysis was performed using 18S data because of insufficient taxon sampling.

**TABLE 1.** Species used in the molecular analysis of the COI gene for in-group and out-group comparisons.

Species	Sequence Reference
<i>Apache degeerii</i>	BBPEC057-09 <sup>1</sup>
<i>Anotia kirkaldyi</i>	CNCHG1201-12 <sup>1</sup>
<i>Anotia firebugia</i>	MT084365 <sup>2</sup>
<i>Anotia uhleri</i>	GMGSI335-12 <sup>1</sup>
<i>Lydda elongata</i>	HEQT322-09 <sup>1</sup>
<i>Otiocerus stollii</i>	CNCHG1206-12 <sup>1</sup>
<i>Otiocerus wolfii</i>	CNCHG1204-12 <sup>1</sup>
<i>Patara vanduzei</i>	ASAHE162-12 <sup>1</sup>
<i>Saccharodite chrysonoe</i>	HEQT663-10 <sup>1</sup>

<sup>1</sup> Barcode of life database (BOLD)

<sup>2</sup> GenBank

## Systematics

### Family Derbidae Spinola 1839

### Subfamily Otiocerinae Muir 1917

### Tribe Patarini Emeljanov 1996

### Genus *Patara* Westwood 1840

Type species: *Patara guttata* Westwood 1840

**Modified Diagnosis.** Small (less than 5 mm) fragile forms. Head in lateral view rounded, frons slightly extended past eyes; in frontal view, frons greatly compressed, lateral margins touching in center; vertex triangular (broader in females than males). Sensory pits on the head absent (may be vestigial on the frons). Antennae sexually dimorphic with scape small, pedicel greatly elongated and flattened (length exceeding front margin of head); male antennae longer than female. Forewings with Pcu + A1 reaching the wing margin before CuP (i.e., clavus closed), and CuA not forked prior to m-cu crossvein such that a 'procubital cell' (i.e., a closed C5 cell, as distinct from an open marginal C5 cell) is absent. Pygofer opening lacking medioventral process. Gonostyli elongate and broadly spatulate with an elongate process on dorsal margin. Aedeagus asymmetrical, shaft more or less straight, capped with short bulbous flagellum, usually with a large process arising near base of flagellum and a variable number of additional processes. Anal segment short, not exceeding gonostyli.

#### *Patara cooki* sp. n.

(Figures 1–6)

**Type locality.** Island of Barbuda, southwestern side.

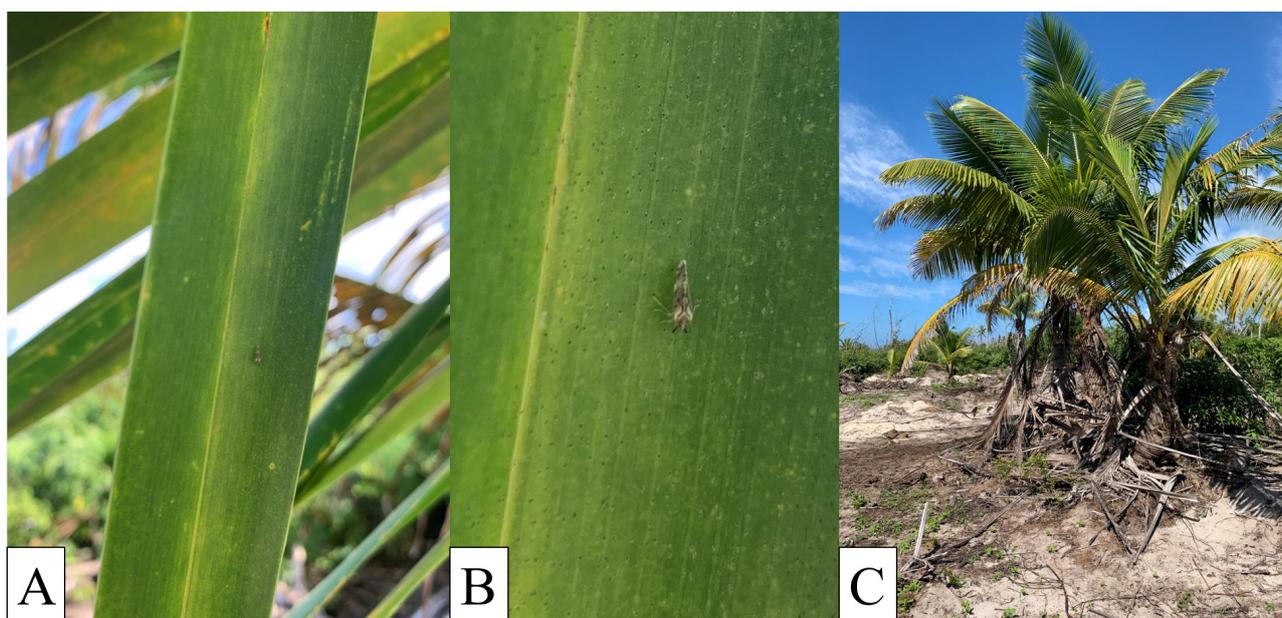
**Diagnosis.** Body pale yellow (abdomen orangish) with fuscous bands on lateral margins of mesonotum and pronotum and frons. Forewings extensively marked with irregular fuscous patches along distal and posterior region, forming a rough ovoid ring; margin bearing a series of red marks in open cells between apex of Sc to cubital cell. Distal tips of RA diffuse into a cluster of tubercles near wing margin. Gonostyli broadly spatulate with large, apically bifurcate dorsal process. Aedeagus stout and asymmetrical, bearing an elongate dorsal process and a compact flagellum appearing wrapped around the aedeagal apex, bearing 4 varied processes, of which F1 is short and bifurcate and F3 is more elongate and simple.

**Description.** *Color.* General body color pale yellow interspersed with fuscous and white, abdominal tergites orange, and sternites fuscous (Fig. 2). Head mostly white except carinae of frons diffuse fuscous, fading to yellow on vertex (small fuscous patch in front of eye); antennal pedicel dark with indistinct subapical reddish patch. Lateral fuscous bands on prothorax continued on mesothorax (fuscous in male, more yellowish in female), converging posteriorly on mesothorax, creating a median whitish vitta (Fig. 2B); thorax in lateral view with fuscous mark across coxa and adjacent pleuron. Forewings transparent with mostly pearlescent veins, diffuse fuscous patches in apical cells, anal cells, clavus (Fig. 4); well defined fuscous patches present in ovoid distribution midwing; red marks on wing margin in open cells between apex of Sc to cubital cell. Abdomen orangish dorsally, darker ventrally with terminalia paler.

*Structure.* Body length (incl. wings), males 1.98–2.00 mm; females 2.23–2.25 mm (Table 2). **Head.** In lateral view, smoothly rounded to ventral margin of frons, upturned posterior margin of vertex; head weakly projected in front of eyes (less than half eye width) (Fig. 3A). Vertex in dorsal view triangular (more broadly in females), widest at posterior margin, narrowing anteriorly to highly compressed frons, carina present at midline; vertex posteriorly angular (males) or convex (females) (Fig. 3B). Frons in frontal view greatly compressed, lateral margins in near-contact from top of eyes to clypeus, then diverging and (in frontal view) crossing genae to beneath the antennae, lateral carinae bearing weakly developed sensory pits; (Fig. 3C). In lateral view, clypeus markedly depressed relative to frons, in frontal view clypeus ovate to rounded ventral apex, lateral carinae weakly developed.

**TABLE 2.** Biometric data for adult male and female of *Patara cooki* sp. n., all values presented at in millimeters.

Character	Male		Female	
	Range	Average $\pm$ SE	Range	Average $\pm$ SE
Body length, with wings	1.98–2.00	1.99 $\pm$ 0.01	2.23–2.25	2.24 $\pm$ 0.01
Body length, no wings	1.10–1.13	1.12 $\pm$ 0.02	1.42–1.43	1.42 $\pm$ 0.01
Forewing length	1.71–1.72	1.72 $\pm$ 0.00	1.80–1.81	1.80 $\pm$ 0.01
Vertex length	0.16–0.16	0.16 $\pm$ 0.00	0.06–0.06	0.06 $\pm$ 0.00
Vertex width, basal margin	0.06–0.06	0.06 $\pm$ 0.00	0.09–0.09	0.09 $\pm$ 0.00
Vertex width, distal margin	0.01–0.01	0.01 $\pm$ 0.00	0.03–0.03	0.03 $\pm$ 0.00
Pronotum length, midline	0.07–0.07	0.07 $\pm$ 0.00	0.08–0.08	0.08 $\pm$ 0.00
Mesonotum length, midline	0.29–0.29	0.29 $\pm$ 0.00	0.33–0.34	0.33 $\pm$ 0.01
Mesonotum width	0.38–0.38	0.38 $\pm$ 0.00	0.43–0.43	0.43 $\pm$ 0.00
Frons width, dorsal margin	0.02–0.02	0.02 $\pm$ 0.00	0.04–0.04	0.04 $\pm$ 0.00
Frons width, clypeal suture	0.02–0.02	0.02 $\pm$ 0.00	0.02–0.02	0.02 $\pm$ 0.00
Frons width, widest	0.03–0.03	0.03 $\pm$ 0.00	0.04–0.04	0.04 $\pm$ 0.00
Frons width, narrowest	0.02–0.02	0.02 $\pm$ 0.00	0.02–0.02	0.02 $\pm$ 0.00
Frons length, midline	0.26–0.27	0.27 $\pm$ 0.01	0.24–0.25	0.24 $\pm$ 0.01
Clypeus length	0.15–0.16	0.16 $\pm$ 0.01	0.16–0.16	0.16 $\pm$ 0.00

**FIGURE 1.** *In vivo* *Patara cooki* sp. n. on coconut palm frond (A–B) and surrounding habitat (C).

**Thorax.** Pronotum short, longest at midline, with anterior margin convex, appearing angular, laterally following contour of eyes; posterior margin sinuately concave in dorsal view (in lateral view, posterior margin concave at tegula, paradiscal region quadrate), carinae obscure (Fig. 3B). Mesonotum tricarinate (carinae obscure posteriorly), lateral carinae sinuate, diverging basad (Fig. 3B), tegulae evident. Posterior tibiae without lateral teeth, apex with 6 uniform teeth, 1<sup>st</sup> and 2<sup>nd</sup> tarsomeres 5–6 teeth each. Forewing with a row of pits along Sc+R and Pcu veins (Fig. 4). Claval apex exceeding wing midlength, veins Pcu and A1 fused just beyond claval midlength, combined veins reaching wing margin well shy of claval apex. Fork of Sc+RA from RP near wing midlength, proximad of fork of MP (MP<sub>1+2</sub> from MP<sub>3+4</sub>). Branching pattern, RA 2-branched, RP 2-branched, MP 5-branched and CuA 2-branched. Branch MP<sub>3+4</sub> appears to fuse with CuA prior to fork of CuA<sub>1</sub>, and remain fused with CuA<sub>2</sub>, and MP<sub>2</sub> touches the fused MP<sub>3+4</sub>+CuA<sub>2</sub> and dog-legs (intercepting an im crossvein) to reach trailing margin of wing.



FIGURE 2. Adult male habitus *Patara cooki* sp. n.; A) body lateral view and B) body dorsal view, scale = 1 mm.

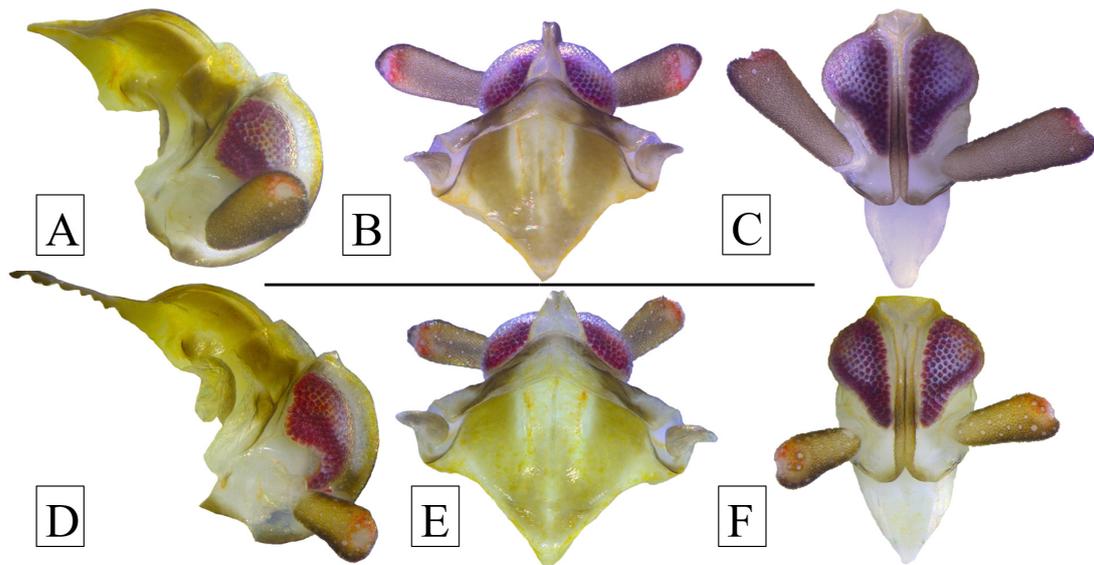


FIGURE 3. Adult *Patara cooki* sp. n.; A–C, male; D–F, female: A) head, pronotum and mesonotum lateral view, B) head, pronotum and mesonotum dorsal view, C) head frontal view, D) head, pronotum and mesonotum lateral view, E) head, pronotum and mesonotum dorsal view, and F) head frontal view.

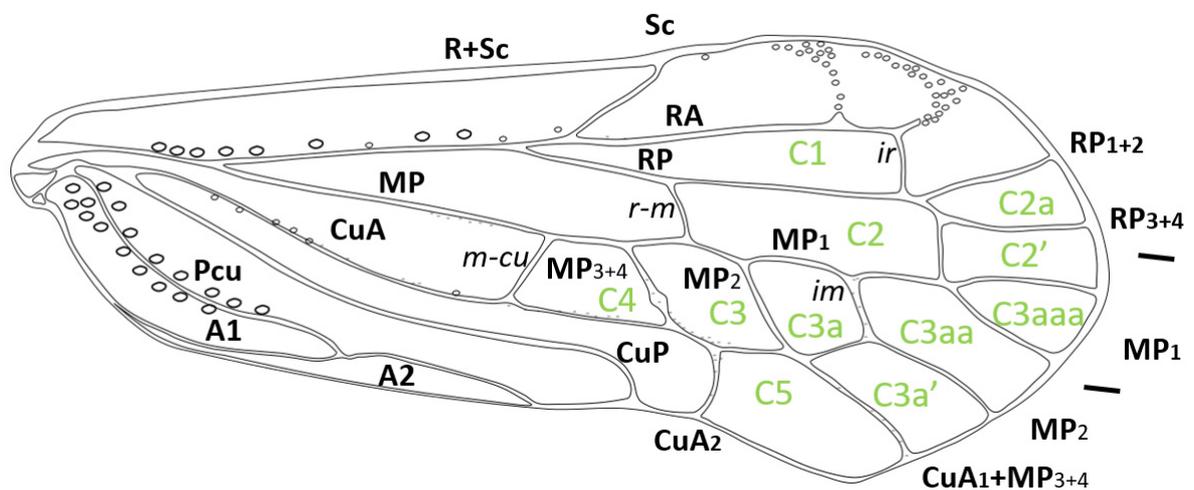
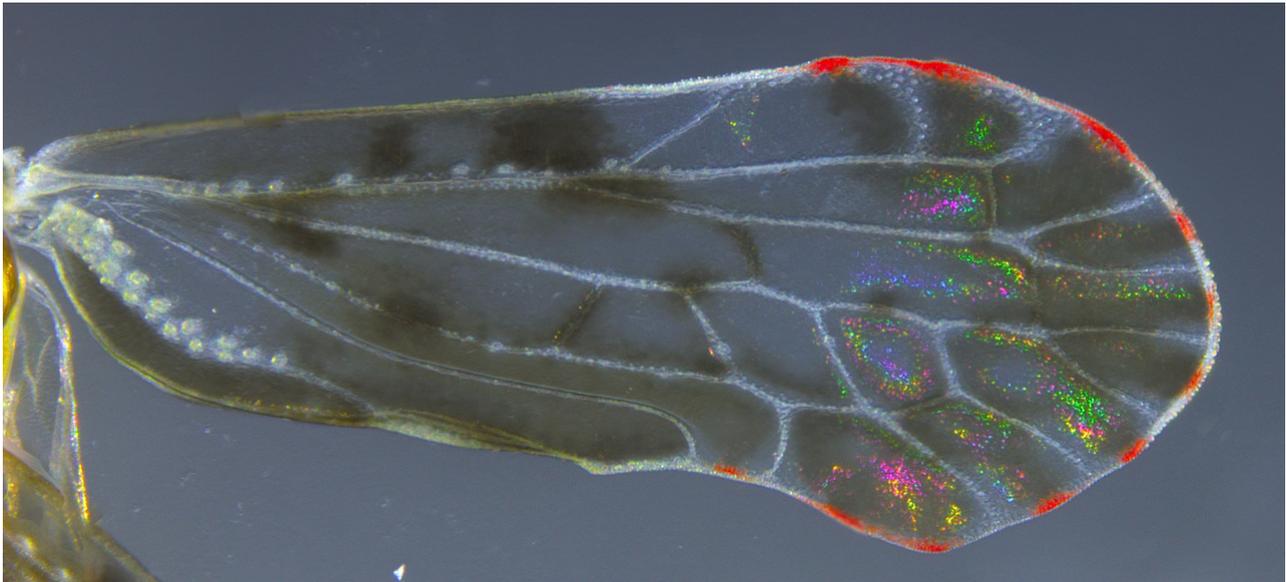


FIGURE 4. Forewing of *Patara cooki* sp. n.; black = vein, green = cell.

**Terminalia.** Pygofer in lateral view narrow, caudal margin rounded, convex; anteriorly concave, forming strap-like arc; widest ventrally, narrowed dorsad with slight expansion at midpoint, broader at dorsum (Fig. 5A); in ventral view, medioventral process absent (Fig. 5B). Gonostyli in lateral view broadly spatulate, ventral margin sinuate, apex truncate, dorsal margin with large, bifurcate, medially arched process arising at midpoint (apices diverging, slightly sclerotized (Fig. 5A)); in ventral view, ventrolateral margins smoothly curved, ventral medial margins sinuate (left and right gonostyli asymmetrical), forming two concavities (basal longer than apical) (Fig. 5B). Aedeagus asymmetrical, shaft relatively short, dorsal and ventral margins sinuate, single elongate, sinuate process on shaft arising near base of flagellum, directed dorso-cephalad (A1, Fig. 6A–6D). Aedeagal flagellum compact, with the appearance of being wrapped around aedeagal apex, bearing a short bifid process arising on right lateral side of flagellum (F1), angled distad, posterior spine (F1a) angled slightly dorsad, anterior spine (F1b) angled slightly cephalad (Fig. 6); dorsal margin of flagellum produced dorsad with acute apex (F2) and bifid process (F3) extending cephalad from F2, with dorsal fork (F3a) angled slightly ventrad and about half length of ventral fork (F3b), F3b strongly angled ventrad (Fig. 6B); long, slender hooked sclerotized process (F4) arising on left lateral side of flagellum, apex pointing ventrad. Anal tube short (length of anal tube and paraproct combined not reaching paramere apex), in lateral view ventral margin straight, dorsal margin arching dorsad at base, forming small lobe; ventro-lateral margins projecting further than dorsal, creating pointed apices (Fig. 5a); in dorsal view anal tube broad and quadrate; paraproct stout at base, distally converging to rounded apex.

**Plant associations.** Coconut palm (*Cocos nucifera* L.), Arecaceae.

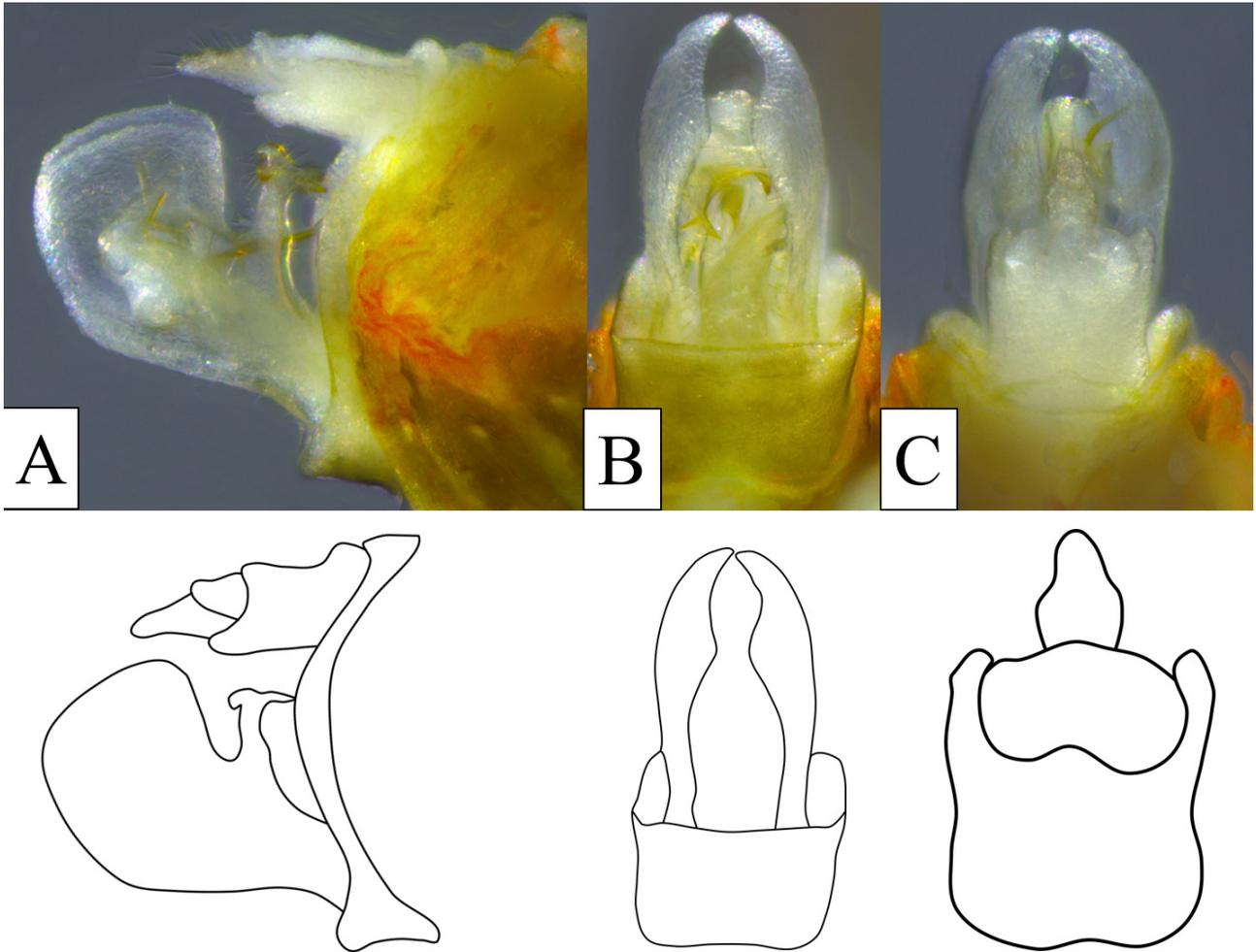


FIGURE 5. Male terminalia of *Patara cooki* sp. n.; A) lateral view, B) ventral view, and C) dorsal view anal tube.

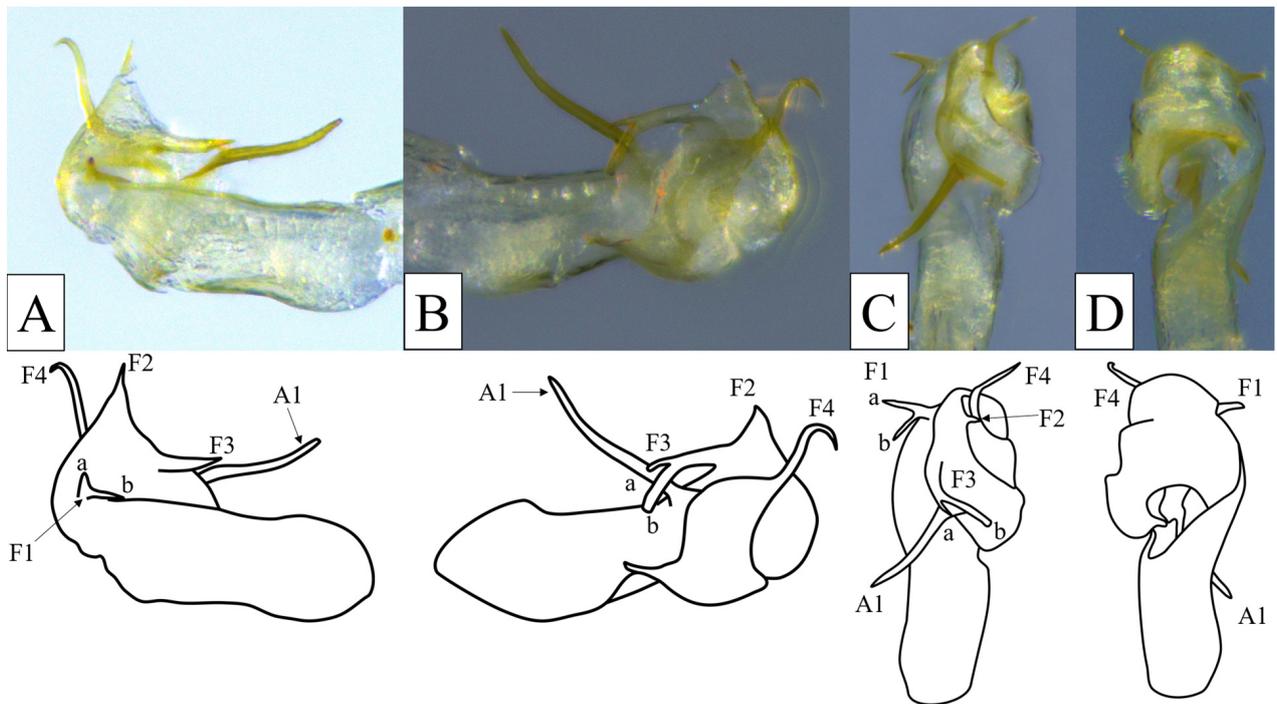


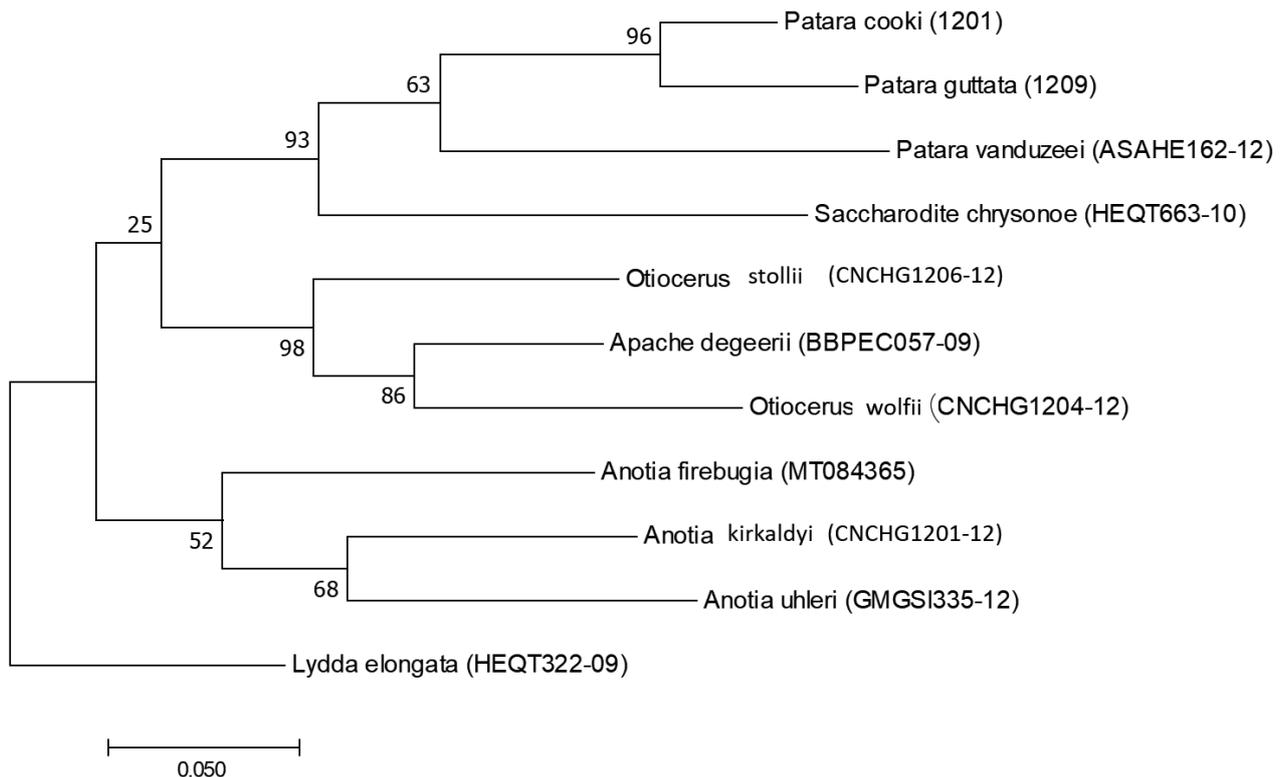
FIGURE 6. Aedeagus of adult male *Patara cooki* sp. n.; A) right lateral view, B) left lateral view, C) dorsal view, and D) ventral view.

**Distribution.** Island of Barbuda, Antigua and Barbuda

**Etymology.** The specific name is given in honor of Mr. Kenneth Cook who arranged for the lead authors expedition to Antigua and Barbuda.

**Material examined.** Holotype male “Barbuda, SW part of island/Coll.: B.W.Bahder/30.I.2020/Host: *Cocos nucifera*//Holotype/*Patara cooki*” (FSCA); Paratypes, 10 males, 17 females, Barbuda coconut plantation [30 January 2020] (FLREC).

**Sequence Data.** For the COI locus, 619 bp product was generated for *P. cooki* sp. n. (GenBank Accession No. MW332651) and *P. guttata* (GenBank Accession No. MW332650). The phylogenetic analysis showed strong bootstrap support (96) for *P. cooki* sp. n. resolving close to *P. guttata* and strong support (93) for the genus *Patara* using the COI locus (Fig. 7). The pairwise comparison demonstrated that *P. cooki* sp. n. differed by 7.8% to *P. guttata* and 15.8% to *P. vanduzeei* (Table 3).



**FIGURE 7.** Maximum likelihood phylogenetic tree (1,000 replicates) exhibiting the relationship of *Patara cooki* sp. n. to other members of the Otiocerinae based on COI sequence data.

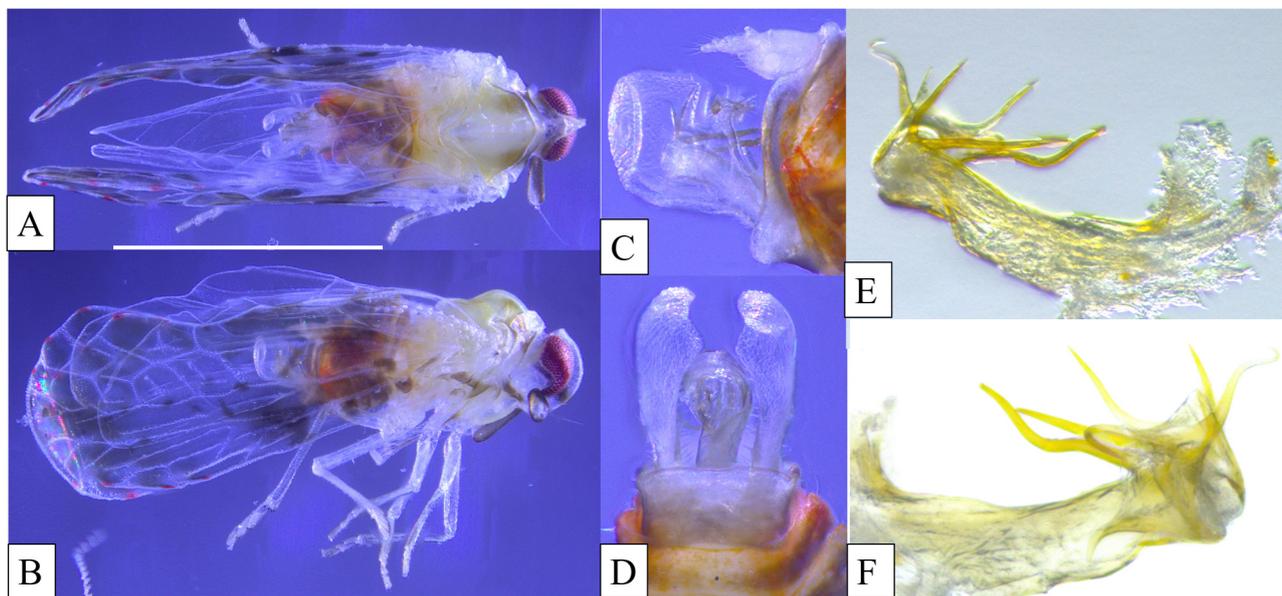
For the 18S locus, a 1,405 bp product was generated for *P. cooki* sp. n. (GenBank Accession No. MW333024) and a 1,365 bp product for *P. guttata* (GenBank Accession No. MW333025). No phylogeny was constructed for the 18S locus due to lack of 18S data for Otiocerinae; however, the difference between the 18S locus between *P. cooki* sp. n. and *P. guttata* is 1.8%. *Anotia firebugia* differs by 14.2% and 14.5% from *P. cooki* sp. n. and *P. guttata*, respectively.

**Remarks.** The species of *Patara* appear most readily diagnosed by features of the aedeagus, dorsal process of the gonostyli and coloration. Also, wing venation appears to differ among the species. Unfortunately, these features are not readily available for all the described taxa of *Patara*.

Based on the descriptions of *Patara* species (and available specimens of *P. guttata* and *P. vanduzeei*), *P. cooki* sp. n. seems most similar to the taxa described by Fennah (1952) from the Caribbean, and in particular *Patara mimula* (viz. Fennah 1952, fig. 23C–F), especially the form from Montserrat. *Patara cooki* sp. n. differs structurally from *P. mimula* by the dorsal process on the gonostyli, which in *P. mimula* is distally anvil-shaped (prolonged caudally instead of anteriorly) and that the processes associated with the aedeagal apex, while comparable take on different forms, viz., in *P. mimula* the process F1 is divided into 2 processes (in the Dominican form of *P. mimula* F1b is greatly prolonged and distally bifurcated), F3 is either absent (Dominica) or prolonged and bifid (Montserrat), and both forms of *P. mimula* appear to bear a short process on the lateral margin of the right side, absent in *P. cooki* sp.

**n.** The forewing of *P. mimula* (Fennah 1952, fig. 24D) is similar to *P. cooki* **sp. n.** except that the red markings on the tegmina of *P. cooki* **sp. n.** appear to be absent in *P. mimula*, and (if Fennah's drawing is accurate), many of the veins are at different angles such that the cells take differing shapes, e.g., cells C2', C3aa, and C3a are all more elongate in *P. mimula* and the apex of vein MP<sub>3+4</sub> more strongly curved in *P. mimula*.

A remarkable feature of *P. cooki* **sp. n.** is that the RA vein apices appear to dissolve and expand into a cone-shaped patch of tubercles that reach the wing margin.



**FIGURE 8.** Adult male *Patara guttata*; A) habitus dorsal view, B) habitus lateral view, C) lateral view of terminalia, D) ventral view of terminalia, E) right lateral view of aedeagus, and F) left lateral view of aedeagus, scale = 1mm.

## Discussion

The discovery of a novel species of planthopper on the island of Barbuda highlights the potential for species discovery on isolated islands in the Caribbean. Many of the species in genus *Patara* described from the Caribbean have many shared characteristics. Even the novel taxon is superficially very similar to *P. guttata*. Interestingly, the genetic variability between *P. cooki* **sp. n.** and *P. guttata* is significantly less than what is generally observed among derbid species in the same genus. However, the difference between both *P. cooki* **sp. n.** and *P. guttata* to *P. vanduzeei* based on the COI locus show that North American taxa are very distinct from the Caribbean species based on the data available. While a more robust sampling and analysis is needed, this lower level of variability between *P. cooki* **sp. n.** and *P. guttata* might suggest that the taxa in the West Indies are more recently diverged taxa.

Our interpretation of the forewing venation of *Patara* is based not only on *P. cooki* **sp. n.**, but also on the available illustrations of *Patara* forewings along with images of 3 undetermined specimens, possibly new species, from Costa Rica, which we attempted to interpret consistently using Bourgoin et al. 2015). The most curious aspects of *Patara* forewings (perhaps unsurprisingly) is the variation in the branches of CuA, MP and potentially the placement of the m-cu crossvein. We have interpreted the first fork of MP as that of MP<sub>1+2</sub> from MP<sub>3+4</sub> (and the subsequent branch of MP<sub>1+2</sub> to be MP<sub>1</sub> from MP<sub>2</sub>). In some cases (e.g., *Patara pakaraima*, Fennah 1952, fig. 25A), MP<sub>2</sub> extends directly to the wing margin, although connected to the MP<sub>3+4</sub>+CuA<sub>1</sub> by an im crossvein; but in most cases; MP<sub>2</sub> directly touches or fuses with the combined MP<sub>3+4</sub>+CuA<sub>2</sub>, and (as we have interpreted it) subsequently branches from the combined vein and arches to the wing margin, intercepting an im crossvein along the way, giving a dog-legged appearance. The fork of MP<sub>1+2</sub> from MP<sub>3+4</sub> in *Patara* appears to reliably preceded by an m-cu crossvein, and MP<sub>3+4</sub> intercepts CuA, creating an interpretational problem with a subsequent fork, which we have interpreted as CuA<sub>1</sub> branching from MP<sub>3+4</sub>+CuA<sub>2</sub>, which then encloses an open marginal cell C5 (a marginally branched CuA appears to be widely present in Derbidae, e.g., Emeljanov 1996, and preserving that interpretation seems less fraught than assuming it was lost). Other interpretations might be possible, and a broad taxonomic review of derbid forewing venation would be valuable to establish interpretational rules.

In *Aquaelicism typicum* Distant (Aquaeliciini, Banaszkiwicz & Szwedo 2005, fig. 40), if their interpretation is followed, it would appear that the m-cu crossvein and subsequent branched of MP are shifted distally, implying that *Synavea* Emeljanov has one fewer branch of MP than *Patara*; however, if the first vein of MP is interpreted as being MP<sub>3+4</sub> with m-cu connecting MP<sub>3+4</sub> and CuA (or CuA<sub>1</sub>) then the ‘procubital cell’ would be seen as absent in *Synavea* (if that is the case, then *Synavea* may belong to Patarini instead of Aquaeliciini if the tribes are defined based on the presence or absence of a procubital cell).

An important note concerning the survey efforts on Barbuda is that no specimens of *Haplaxius crudus* were observed or collected. Three sites with significant human disturbance where grasses and coconut were in abundance had no detectable populations of *H. crudus*. However, *H. crudus* was collected in high numbers on palms in Antigua on the same date. Due to the pristine nature of Barbuda, the absence of *H. crudus* from habitat where it is known to persist, and its presence in high numbers in Antigua at the same time of year, it appears that *H. crudus* is absent from Barbuda. This finding is fascinating given the widespread distribution of *H. crudus* in the Caribbean.

The results of this survey document a novel taxon of planthopper associated with palms in the Caribbean basin. These findings further highlight the need for continued survey work in the Neotropics to document novel taxa of planthoppers, some of which could have potential economic impacts on palm production.

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## References

- Ball, E.D. (1902) New genera and species of N. A. Fulgoridae. *Canadian Entomologist*, 34, 259–266.  
<https://doi.org/10.4039/Ent34259-10>
- Banaszkiwicz, M. & Szwedo, J. (2005) Notes on Otiocerinae with description of a new tribe from Madagascar and Africa (Hemiptera: Fulgoromorpha: Derbidae). *Annales Zoologici*, 55 (2), 223–241.
- Barringer, L.E., Bartlett, C.R. & Erwin, T.L. (2019) Canopy assemblages and species richness of planthoppers (Hemiptera: Fulgoroidea) in the Ecuadorian Amazon. *Insecta Mundi*, 0726, 1–16.
- Bartlett, C.R., O’Brien, L.B. & Wilson, S.W. (2014) A review of the planthoppers (Hemiptera: Fulgoroidea) of the United States. *Memoirs of the American Entomological Society*, 50, 1–287.
- Bourgoin, T. (1988) A new interpretation of the homologies of the Hemiptera male genitalia illustrated by the Tettigometridae (Hemiptera, Fulgoromorpha). In: Vidano, C. & Arzone, A. (Eds.), *6<sup>th</sup> Auchenorrhyncha Meeting, Turin, Italy, 7–11 September 1987, Proceedings*. Consiglio Nazionale delle Ricerche, Turin, pp. 113–120.
- Bourgoin, T. (2019) FLOW (Fulgoromorpha Lists on The Web): a world knowledge base dedicated to Fulgoromorpha. Version 8. Available from: <http://www.hemiptera-databases.org/flow/> (accessed 26 August 2020)
- Bourgoin, T. & Huang, J. (1990) Morphologie comparee des genitalia males des Trypetimorphini et remarques phylogénétiques (Hemiptera Fulgoromorpha : Tropiduchidae). *Annales de la Société Entomologique de France, Nouvelle Serie*, 26 (4), 555–564.
- Bourgoin, T., Wang, R.R., Asche, M., Hoch, H., Soulier-Perkins, A., Stroinski, A., Yap, S. & Szwedo, J. (2015) From micropterism to hyperpterism: recognition strategy and standardized homology-driven terminology of the forewing venation patterns in planthoppers (Hemiptera: Fulgoromorpha). *Zoomorphology*, 134 (1), 63–77.  
<https://doi.org/10.1007/s00435-014-0243-6>
- Emeljanov, A.F. (1996) On the system and phylogeny of the family Derbidae (Homoptera, Cicadina). *Entomological Review*, 75 (2), 70–110. [1994, English translation of *Entomologicheskoe Obozrenie*, 73 (4), 783–811 from Russian]
- Fennah, R.G. (1945) The Fulgoroidea, or lanternflies, of Trinidad and adjacent parts of South America. *Proceedings of the United States National Museum*, 95 (3184), 411–520.  
<https://doi.org/10.5479/si.00963801.95-3184.411>
- Fennah, R.G. (1952) On the generic classification of Derbidae (Fulgoroidea), with descriptions of new Neotropical species. *Transactions of the Royal Entomological Society of London*, 103 (4), 109–170.  
<https://doi.org/10.1111/j.1365-2311.1952.tb01063.x>
- Folmer, O., Black, M., Hoeh, W., Lutz, R. & Vrijenhoek, R. (1994) DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. *Molecular Marine Biology and Biotechnology*, 3 (5), 294–299.
- Fowler, W.W. (1904) Order Rhynchota. Suborder Hemiptera-Homoptera. (Continued). *Biologia Centrali-Americana*, 1, 77–

84.

- Kumar, S., Stecher, G. & Tamura, K. (2016) MEGA7: Molecular Evolutionary Genetics Analysis version 7.0 for bigger datasets. *Molecular Biology and Evolution*, 33, 1870–1874.  
<https://doi.org/10.1093/molbev/msw054>
- Muir, F.A.G. (1917) The Derbidae of the Philippine Islands. *Philippine Journal of Science*, 12, 49–105.
- Spinola, M. (1839) Essai sur les Fulgorelles, sous-tribu des Cicadaïres, ordre des Rhyngotes. *Annales de la Société Entomologique de France*, 8, 133–337.
- Westwood, J.O. (1840) Observations on the genus *Derbe* of Fabricius. *The Transactions of the Linnean Society of London*, 1, 82–85.