
LANKESTERIANA

VOL. 21, No. 1

APRIL 2021



INTERNATIONAL JOURNAL ON ORCHIDOLOGY

LANKESTERIANA

INTERNATIONAL JOURNAL ON ORCHIDOLOGY

Editor-in-Chief (Director)

DIEGO BOGARÍN
Universidad de Costa Rica, Costa Rica
diego.bogarin@ucr.ac.cr

Associate Editors

MELISSA DÍAZ-MORALES
Universidad de Costa Rica, Costa Rica
melissa.diaz_m@ucr.ac.cr

FRANCO PUPULIN
Universidad de Costa Rica, Costa Rica
franco.pupulin@ucr.ac.cr

Technical Editor

NOELIA BELFORT OCONTRILLO
Universidad de Costa Rica, Costa Rica
noelia.belfort@ucr.ac.cr

Consejo Editorial / Editorial Committee

DIEGO BOGARÍN
Universidad de Costa Rica, Costa Rica
ADAM P. KARREMANS
Universidad de Costa Rica, Costa Rica
GABRIELA JONES ROMÁN
Universidad Estatal a Distancia, Costa Rica

MELANIA FERNÁNDEZ
Universidad de Costa Rica, Costa Rica
VÍCTOR M. JIMÉNEZ
Universidad de Costa Rica, Costa Rica
JORGE WARNER
Universidad de Costa Rica, Costa Rica

Comité Científico / Scientific Committee

JAMES D. ACKERMAN
University of Puerto Rico, U.S.A.
GERMÁN CARNEVALI
Centro de Investigación Científica de Yucatán, Mexico
PHILLIP CRIBB
Royal Botanic Gardens, Kew, U.K.
CARLOS F. FIGHETTI
The American Orchid Society, U.S.A.
GÜNTER GERLACH
Botanischer Garten München-Nymphenburg, Germany
HEIKO HENTRICH
Deutsche Homöopathie-Union Karlsruhe, Germany
JULIÁN MONGE-NÁJERA
Universidad de Costa Rica, Costa Rica
DAVID L. ROBERTS
University of Kent, U.K.
ANDRÉ SCHUITEMAN
Royal Botanic Gardens, Kew, U.K.
JORGE WARNER
Universidad de Costa Rica, Costa Rica

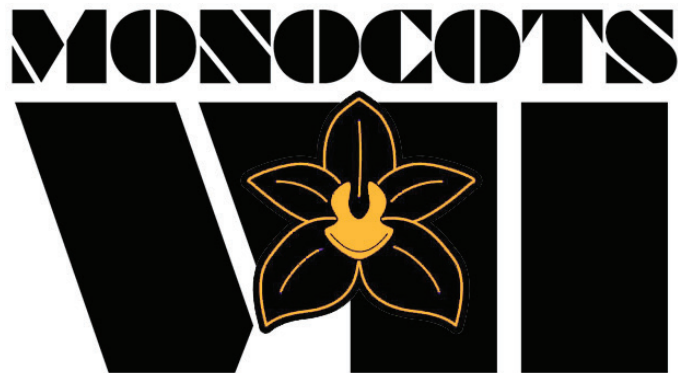
FRANCO BRUNO
Università La Sapienza, Roma, Italia
MARK W. CHASE
Royal Botanic Gardens, Kew, U.K.
ROBERT L. DRESSLER†
Universidad de Costa Rica, Costa Rica
LAUREN GARDINER
Royal Botanic Gardens, Kew, U.K.
ERIC HÁGSATER
Herbario AMO, Mexico
WESLEY E. HIGGINS
The American Orchid Society, U.S.A.
ALEC M. PRIDGEON
Royal Botanic Gardens, Kew, U.K.
GUSTAVO A. ROMERO
Harvard University Herbaria, U.S.A.
PHILIP SEATON
IUCN/SSC Orchid Specialist Group, U.K.
W. MARK WHITTEN†
Florida Museum of Natural History, U.S.A.

NORRIS H. WILLIAMS
Florida Museum of Natural History, U.S.A.

WARNING

DUE TO THE EXCEPTIONAL COVID SITUATION

DATES HAVE CHANGED



7th International Conference on
Comparative Biology
of Monocotyledons

COSTA RICA

San José, Costa Rica

March 11–15, 2024

SAVE THE DATE

LANKESTERIANA

INTERNATIONAL JOURNAL ON ORCHIDOLOGY

Copyright © 2021 Lankester Botanical Garden, University of Costa Rica

Effective publication dates ISSN 2215-2067 (electronic): February 17 – April 30, 2021 (specific dates recorded on the title page of each individual paper)

Effective publication date ISSN 1409-3871 (printed): April 30, 2021

Layout: Jardín Botánico Lankester.

Cover: *Paphiopedilum callosum* (Rchb.f.) Stein. Photograph by Diego Bogarín.

Printer: MasterLitho.

Printed copies: 285

Printed in Costa Rica / Impreso en Costa Rica

R Lankesteriana / International Journal on Orchidology
No. 1 (2001)-- . -- San José, Costa Rica: Editorial
Universidad de Costa Rica, 2001--

v.

ISSN-1409-3871

1. Botánica - Publicaciones periódicas, 2. Publicaciones
periódicas costarricenses



LANKESTERIANA

VOL. 21, No. 1

APRIL 2021

Amended description of the Sumatran endemic <i>Dendrobium bandii</i> (Orchidaceae) with notes on its conservation status and ecology MARK ARCEBAL K. NAIVE, YUDA REHATA YUDISTIRA, MALCOLM VICTORIANO and PAUL ORMEROD	1
A new <i>Pseudolepanthes</i> (Pleurothallidinae: Orchidaceae) from Northwest Ecuador MARCO F. MONTEROS, LUIS E. BAQUERO and SEBASTIÁN VIEIRA-URIBE	5
First record of a wild population of <i>Laelia dawsonii</i> f. <i>dawsonii</i> (Orchidaceae) for the state of Jalisco, Mexico MIGUEL J. CHÁZARO-BASÁÑEZ, ALEXANDER JIMÉNEZ-VÁZQUEZ and EDUARDO A. PÉREZ-GARCÍA	11
Comparative floral surface micromorphology helps to discriminate between species of <i>Paphiopedilum</i> (Orchidaceae: Cypripedioideae) from Peninsular Malaysia EDWARD E. BESI, LAM S. JIA, MUSKHAZLI MUSTAFA, CHRISTINA S.Y. YONG and RUSEA GO	17
Two new species of <i>Octomeria</i> (Pleurothallidinae) from Cordillera Del Cóndor, Zamora Chinchipe, Ecuador LEISBERTH VÉLEZ-ABARCA, MARCO M. JIMÉNEZ and LUIS E. BAQUERO	33
A new species of <i>Eurystyles</i> (Orchidaceae) is exposed by a fierce hurricane in Puerto Rico JAMES D. ACKERMAN and LUIS ORTIZ JORDAN	45
Books	51
Author instructions	55



AMENDED DESCRIPTION OF THE SUMATRAN ENDEMIC *DENDROBIUM BANDII* (ORCHIDACEAE) WITH NOTES ON ITS CONSERVATION STATUS AND ECOLOGY

MARK ARCEBAL K. NAIVE^{1,2,6}, YUDA REHATA YUDISTIRA³, MALCOLM VICTORIANO⁴
& PAUL ORMEROD⁵

¹Center for Integrative Conservation, Xishuangbanna Tropical Botanical Garden,
Chinese Academy of Sciences, Mengla, Yunnan 666303, China.

²University of Chinese Academy of Sciences, Beijing 100049, China.

³Menteng Square A20-12, Jl. Matraman No. 30E, Senen, Jakarta Pusat, 10430, Indonesia.

⁴Indonesian Carnivorous Plant Society. Jl. Manggis 52, Jakasetia, Bekasi City, 17147, Indonesia.

⁵P.O. Box 8210, Cairns, Qld., 4870, Australia.

⁶Author for correspondence: arciinaive19@gmail.com

ABSTRACT. *Dendrobium bandii* is a poorly known species endemic to the island of Sumatra, Indonesia. We studied living specimens and we provide here an amended description of the species, colour photographs, as well as information on distribution, ecology, and its provisional conservation status.

KEY WORDS: Dendrobieae, Epidendroideae, Malesian Flora, plant taxonomy, Sumatran biodiversity

Introduction. *Dendrobium* Sw., belonging to the tribe Malaxideae, subtribe Dendrobiinae, is the third largest orchid genus encompassing about 1600–1800 species distributed from Sri Lanka throughout tropical Asia and the Pacific region, north to Japan, east to Tahiti and south to New Zealand (Schuiteman & Adams 2014, Chase *et al.* 2015, Ormerod 2017). At present, the number of *Dendrobium* species in Indonesia is around 680 species (Ormerod unpubl. data). In Sumatra, the genus is represented by approximately 140 species and future fieldwork would probably result in the discovery of more species either endemic or as new records from neighbouring countries and islands (Juswara *et al.* 2018).

In the recent floristic survey conducted in the westernmost province of Indonesia by the second and third authors, an unknown *Dendrobium* species was collected in the province of Aceh, Sumatra. Upon detailed morphological examination and comparison to the relevant literature and digitized type specimens of *Dendrobium* from Indonesia and neighbouring countries, the species matches with *D. bandii* Cavestro, a poorly known species recently described.

A careful analysis of our recently collected specimen revealed that the description and line drawing provided by Cavestro (2020) are not entirely accurate: the diagnosis and some morphological characters recorded by the author (e.g. acute to obtuse leaf apex, oblong-triangular

lateral sepals, broadly ovate midlobe of the labellum, column length, among others) are probably more variable than the protologue suggests, and some morphometric features were omitted in the original description (e.g. column foot measurement, claw measurement, stielid shape and measurement and many more). Thus, to further clarify the identity of this taxon, we present here an amended description of *D. bandii*, a colour photograph to aid accurate identification, ecological notes and its provisional conservation status.

Materials and methods. The measurements and descriptions were based on freshly collected material deposited at Herbarium Bogoriense (BO). The general plant descriptive terminology follows Beentje (2016). Informal conservation status category was assessed by range size (B criterion), following IUCN Standards and Petitions Subcommittee (2019) recommendations. The extent of occurrence (EOO) and area of occupancy (AOO) were estimated using GeoCAT (Bachman *et al.* 2011).

TAXONOMIC TREATMENT

Dendrobium bandii Cavestro, Orchidee (Hamburg) 6(120): 176, 2020. TYPE: INDONESIA. North Sumatra: District of Aceh, elev. ca. 1300–1600 m,

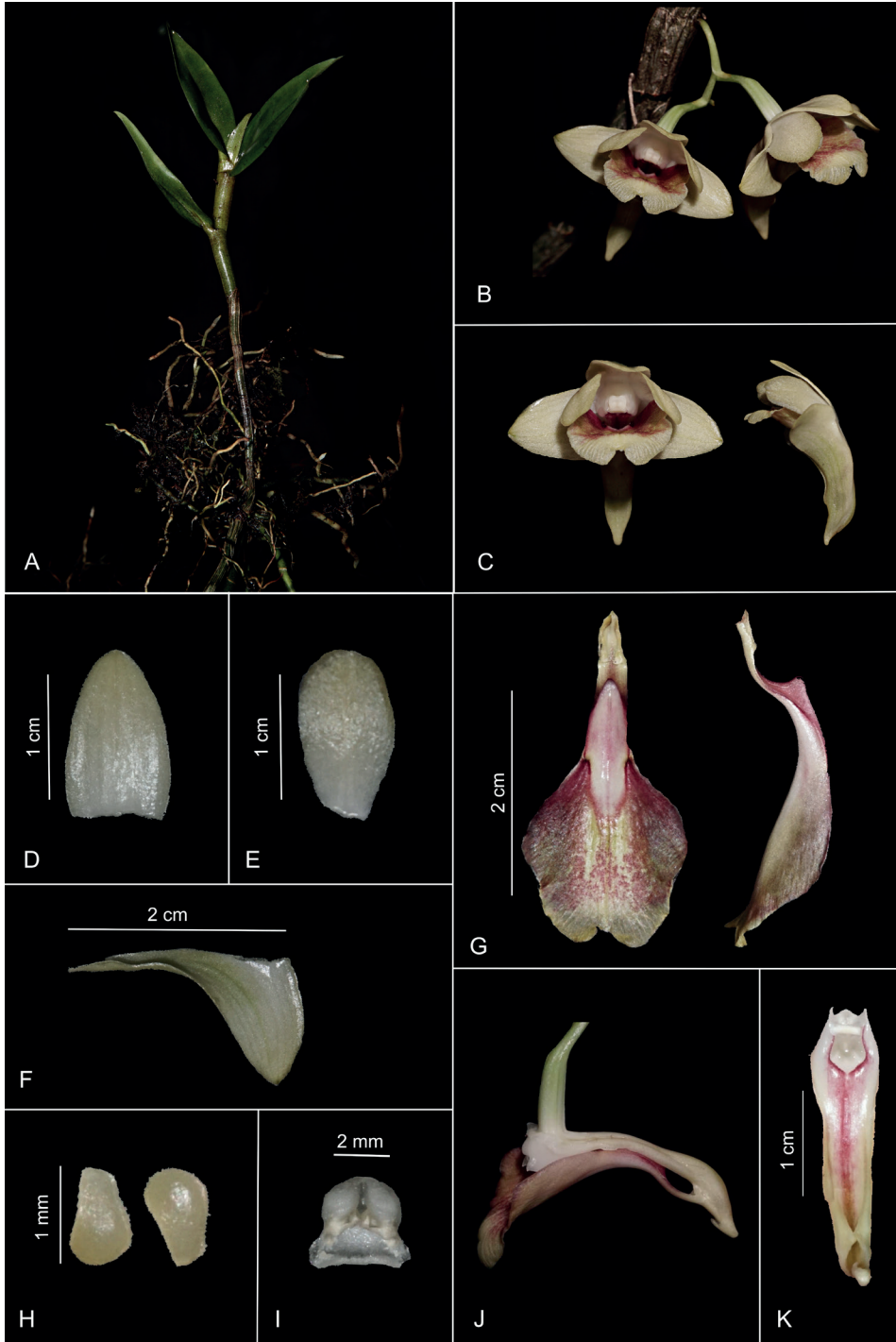


FIGURE 1. *Dendrobium bandii* Cavestro. **A.** Habit. **B.** Inflorescence. **C.** Flower (left, front view; right, profile view). **D.** Dorsal sepal. **E.** Petal. **F.** Lateral sepal. **G.** Labellum (left, top view; right, profile view). **H.** Pollinia. **I.** Anther cap. **J.** Pedicel with ovary, profile view of column, column foot and labellum. **K.** Ventral view of column and column foot. Photos by Y. R. Yudistira.

18 February 2020, *W. Cavestro and A. Marup s.n.* (holotype, ANDA). Fig. 1.

Epiphytic, pendent, *herb.* Roots elongate, *ca.* 1.5 mm long, glabrous. Stem slightly flexuous, 15–40 cm long by 0.3–1.2 cm in diameter, terete at the base, slightly flattened in $\frac{2}{3}$ of the upper part, young stem rounded, green; *internodes ca.* 1.5–4 cm long. *Leaves* distichous, deciduous; *sheaths* tubular, clasping the entire internode, brown; *leaf blades* lanceolate-elliptic, 9.5 cm long by 3.0 cm wide, with 4 veins, chartaceous, green, glabrous, margin entire, apex subacuminate to acuminate. *Inflorescence* 2- or 3-flowered, arising from the older, leafless stems; *peduncle* 10–11 mm long, terete, glabrous. *Flower* 2.5 cm across, apricot or orange pink to yellow or greenish yellow with crimson spots on the labellum and the ventral side of the column foot. *Pedicel and ovary* 13 mm long, corrugated, glabrous, pale green, whitish near apex. *Dorsal sepal* 3-veined, incurved, nodding, ovate, 15 mm long by 8–9 mm wide, glabrous, covering the column, margin entire, apex obtuse. *Lateral sepals* 7-veined, spreading, broadly falcate, 15–16 mm long by 20–23 mm wide, glabrous, forming a mentum with the column foot 20–21 mm long, margin entire, apex acute, cucullate. *Petals* 1-veined, pointing forward, obovate, 15 mm long by 5–7 mm wide, glabrous, covering the column, margin entire, apex rounded. *Lip* 3.2 cm long by 1.8 cm wide; *claw* ligulate-oblong, subsigmoid in lateral view, basal 2–3 mm excavate and joined to column foot, free part *ca.* 7–8 mm long, in total *ca.* 10 mm long by 2–3 mm wide; *blade* weakly trilobed, broadly rhombic, 13–15 mm long by 12–14 mm wide, glabrous, margins slightly undulate to entire, fleshy, apex broadly, obtusely bilobed; *callus* oblong, shallowly canaliculate, base raised, obtuse, slightly retrorse, beginning midway on the claw and terminating on the basal quarter of the blade; *mentum* narrowly-conical, 2.0–2.1 cm long, curved, acute. *Column* stout, 3–4 mm long, with a crimson stripe on the underside; *column foot* 20–21 mm long; *stelia* triangular, 1.0–1.5 mm long; *pollinia* 2, each pair can be divided into two parts, 1 mm long by 1.3 mm across, yellowish; *anther-cap* cucullate, 3 mm across, subhyaline. *Capsule* not seen.

DISTRIBUTION: Restricted to four localities, including its type locality and the highlands of Aceh Province at an

elevation of 800–1600 m a.s.l., from Aceh Tengah to Bener Meriah and Nagan Raya.

HABITAT: Growing epiphytically on trees in primary forests and secondary forests, and also found thriving in coffee plantations.

PHENOLOGY: Flowering almost all year round.

EPONYMY: The specific epithet was derived after the discoverer of the species, Subandi Bandi.

PROVISIONAL CONSERVATION STATUS: There are four localities known for this species, including the type locality. Each locality has a few populations in a limited area, giving an approximate Area of Occupancy (AOO) of 12 km² when calculated in the GeoCAT system (Bachman *et al.* 2011). Following the Red List criteria of the IUCN Standards and Petitions Subcommittee (2019), the species would fall into the IUCN category of Endangered [EN B2ab(ii)].

SPECIMEN EXAMINED: INDONESIA. Sumatra: Aceh Province, Aceh Tengah Regency, Jagong Jeget, elev. 1500 m, 20 January 2020, *Victori 004* (BO!, including spirit collection).

Dendrobium bandii was originally compared to another Sumatran species, *D. transtilliferum* J.J.Sm., but the latter taxon differs in having a broader, more open mentum, a cuneate (not clawed) labellum, and a flat, truncate suprabasal (*vs.* a raised rounded) callus. *Dendrobium bandii* is closer to *D. sanguinolentum* Lindl., sharing with it a similar mentum shape, and similar labellum shape with the callus placed in about the same area on the claw. However, *D. bandii* differs significantly in having forward-pointing, obovate petals (*vs.* spreading, spatulate petals in *D. sanguinolentum*), a narrowly conical, subacute mentum (*vs.* oblongoid, truncate mentum in *D. sanguinolentum*), and a labellum with an obtuse, slightly retrorse callus base (*vs.* acute, strongly retrorse, spine-like callus base in *D. sanguinolentum*). It also differs in having an apricot to yellow or greenish-yellow coloured flowers with crimson spots or colouration in the labellum, whereas *D. sanguinolentum* has a yellow ochre or buff flower colour with or without a variable amount of rose-red colour on the tips of sepals, petals, and lip.

ACKNOWLEDGEMENTS. We would like to thank Nur Rohman for accompanying the second author during fieldwork, Ba Vuong Truong for providing us some relevant literature used in this study, and Wewin Tjiasmanto of Tjiasmanto Conservation Fund for his unwavering support.

LITERATURE CITED

- Bachman, S., Moat, J., Hill, A., de la Torre, J. & Scott, B. (2011). Supporting Red List threat assessments with GeoCAT: Geospatial Conservation Assessment Tool. *ZooKeys*, 150, 117–126.
- Beentje, H. (2016). *The Kew plant glossary: an illustrated dictionary of plant terms*. 2nd edition. Kew, Richmond: Kew Publishing, Royal Botanic Gardens. 184 pp.
- Cavestro, W. (2020). *Dendrobium bandii* Cavestro – a new species from Aceh Province, North Sumatra, Indonesia. *Die Orchidee*, 6(20), 170–176.
- Chase, M. W., Cameron, K. M., Freudenstein, J. V., Pridgeon, A. M., Salazar, G., van den Berg, C. & Schuiteman, A. (2015). An updated classification of Orchidaceae. *Botanical Journal of the Linnean Society*, 177, 151–174.
- IUCN (2019). *Guidelines for Using the IUCN Red List Categories and Criteria*. Version 14. Prepared by the Standards and Petitions Committee. Retrieved from <http://www.iucnredlist.org/documents/RedListGuidelines.pdf> [Accessed on 21 September 2020]
- Juswara, L. S., Schuiteman, A., O’Byrne, P. & Champion, J. (2018). *Dendrobium fitrianum* (section Pedilonum, Orchidaceae), a new species from Sumatra. *OrchideenJournal*, 6(1), 3–5.
- Ormerod, P. (2017). *Checklist of Papuanian Orchids*. Australia: Nature & Travel Books.
- Schuiteman, A. & Adams, P. B. (2014). *Dendrobium*. In: A. M. Pridgeon, P. J. Cribb, M. W. Chase F. N. Rasmussen (eds.), *Genera Orchidacearum, vol. 6. Epidendroideae (Part three)*. Oxford: Oxford University Press.

A NEW *PSEUDOLEPANTHES* (PLEUROTHALLIDINAE: ORCHIDACEAE) FROM NORTHWEST ECUADOR

MARCO F. MONTEROS^{1,3,7}, LUIS E. BAQUERO¹⁻³ & SEBASTIÁN VIEIRA-URIBE⁴⁻⁶

¹ Fundación EcoMinga, 270 12 de noviembre and Luis A. Martínez, Baños, Tungurahua, Ecuador.

² Grupo de Investigación en Medio Ambiente y Salud BIOMAS, Carrera de Ingeniería Agroindustrial y Alimentos, Facultad de Ingeniería y Ciencias Agropecuarias, Universidad de Las Américas, Calle José Querí, Quito 170137, Pichincha, Ecuador.

³ Grupo de Investigación Dodson, Quito, Pichincha, Ecuador.

⁴ Grupo de Investigación Schultes, Fundación Ecotonos, Cali, Colombia.

⁵ Grupo de investigación en biodiversidad tropical - GIBIOT, Jardín Botánico de Medellín, Colombia.

⁶ Sociedad Colombiana de Orquideología, Medellín, Colombia.

⁷ Author for correspondence: mfonterosa@utn.edu.ec

ABSTRACT. A new species of the genus *Pseudolepanthes* discovered in Carchi province, northwest Ecuador, is described here. The new species is compared with *P. zunagensis* from which it is distinguished by a longer inflorescence with successive vinaceous or pale-yellow flowers, an elongate arcuate column, and a lip with an erect, thick, widely rectangular central callus.

RESUMEN. Una nueva especie del género *Pseudolepanthes* descubierta en la provincia del Carchi, noroccidente de Ecuador, es descrita aquí. La especie nueva se compara con *P. zunagensis* de la cual se distingue por tener una inflorescencia más larga con flores sucesivas, vináceas o amarillo pálido, la columna alargada, arqueada y el labelo con un callo central erecto, grueso y ampliamente rectangular.

KEYWORDS/PALABRAS CLAVE: Dracula Reserve, EcoMinga, Reserva Dracula, *Trichosalpinx*, *Trichosalpinx pseudolepanthes*

Introduction. The group of species now recognized as belonging to the genus *Pseudolepanthes* (Luer) Archila was initially placed in *Trichosalpinx* Luer, under the subgenus *Tubella* sect. *Pseudolepanthes* Luer (1986), then elevated to subgenus *Pseudolepanthes* Luer (1997) to accommodate all species of *Trichosalpinx* with small habit and non-proliferating ramicauls with lepanthiform sheaths. Morphologically, the species in the genus have successively-flowered and progressively-elongated racemes longer than the leaves, the sepals more or less membranaceous, ciliate or spiculate with lateral sepals free or variously connate below the middle; petals entire or lobed at the base; simple lips with the disc bearing a large, verrucose callus with the broad, unguiculate base firmly attached to the base of the column, the footless column is short and suberect with the anther and stigma on the front surface, except for the arcuate column of *Pseudolepanthes spathulata* Luer (Luer 1997, Karremans & Vieira-Uribe 2020). Recent phylogenetic studies which included molecular data

supported *Pseudolepanthes* as a correct genus for the species which share the characters mentioned above and also share the presence of a large, verrucose callus on the disc of the lip (Luer 1986, 1997, Bogarín *et al.* 2018, Bogarín *et al.* 2019, Karremans & Vieira-Uribe 2020). Currently, *Pseudolepanthes* includes 10 species distributed along the Andes of Colombia and Ecuador (Luer 1997). Here we present a new species of *Pseudolepanthes* discovered in a poorly explored forest protected by EcoMinga Foundation in northwest Ecuador.

TAXONOMIC TREATMENT

Pseudolepanthes bihuae M.F.Monteros & Baquero, *sp. nov.* (Fig. 1–2).

TYPE: Ecuador. Carchi: Reserva Dracula, 2042 m, 29 January 2019, *M. Monteros 203* (holotype, QCNE!).

DIAGNOSIS: *Pseudolepanthes bihuae* is most similar to *P. zunagensis* (Luer & Hirtz) Archila, but it can be

distinguished by its vinaceous or pale yellow flowers (*vs.* orange), an elongate, arcuate column (*vs.* erect, stout, shorter), the lateral sepals connate in the base, slightly free to the apex and oblique (*vs.* a shortly bifid synsepal), petals with sparsely tuberculate margins (*vs.* entire), and a lip with an elliptical blade bent down from the middle (*vs.* straight, elliptical-ovoid blade), with an erect, thick, widely rectangular central callus almost as wide as the blade (*vs.* oblong, subclavate callus much narrower than the blade).

Plant epiphytic, sympodial, caespitose herb up to 7 cm tall without inflorescence. *Roots* ca. 0.7 mm in diameter. *Ramicauls* erect, slender, stout, 3.5–4.0 cm, enclosed by 5–6 ciliate lepanthiform sheaths, 6–8 mm long. *Leaf* erect, coriaceous, green, suffused with purple beneath, elliptical, with two ribs parallel and close to the entire margin of the blade, the apex subacute to obtuse, emarginate, apiculate, the base cuneate into a petiole, 2.0–2.5 × 0.9–1.2 cm. *Inflorescence* a slightly sinuose, loose, successively-flowered raceme, up to 13–15 cm long, borne by a filiform, spiculate peduncle 0.5–1.0 cm long, from near the apex of the ramicaul; floral bracts spiculate, acuminate, 2–3 mm long; *pedicels* 1 mm long. *Ovary* sparsely spiculate, costate, 1 mm long. *Sepals* vinaceous or pale yellow, long-spiculate abaxially, slightly carinate to carinate along the veins on the abaxial surface. *Dorsal sepal* narrowly ovate, attenuate, concave, 3-veined, 8.0–9.0 × 1.5 mm. *Lateral sepals* narrowly ovate, attenuate, oblique, shallowly concave, connate at the base, 1-veined, 5–6 × 3 mm. *Petals* vinaceous to pale yellow, narrowly ovate, falcate, reflexed, acute, 5 × 1 mm, 1-veined, with the entire margins sparsely tuberculate. *Lip* flame-coloured, fleshy, elliptic, with an acute apex, bent down at the middle and with a thick, widely rectangular, papillose at the apex callus, the basal half with two flaps at each side lowering in height towards the base of the lip, 3.0 × 1.3–1.5 mm, the blade covered with several elongate, capitate processes at the apical half, the base smooth, shallowly concave, firmly adnate to the base of the column. *Column* green to cream, terete, slender, elongate, arcuate, 2 mm long, the anther apical and stigma ventral but facing forward. *Anther cap* yellowish, obovate, cucullate, 0.4 mm long. *Pollinia* 2, yellow, pyriform, attached to a detachable viscidium, 0.4 mm long. *Capsule* not seen.

EPONYMY: Named in honor of Bihua Chen, founder of Cormorant Asset Management in Boston, USA. Bihua loves the natural world and has fond memories of the native orchids of her childhood home in China. She has given important help to the Rainforest Trust for its efforts to preserve this new species and other orchids in Fundación EcoMinga's Dracula Reserve.

HABITAT AND ECOLOGY: *Pseudolepanthes bihuae* is, as far as we know, endemic to northwestern Ecuador, within a region that stands out for its high diversity of orchids. Only one population of this species has been found, with plants growing as epiphytes on the trunk of a tree at 2 m above the ground, in extremely humid cloud forest at 2000 m of elevation in an unexplored area within the limits of the Dracula Reserve. Other species of the subtribe Pleurothallidinae, like *Brachionidium imperiale* Luer & R.Escobar, *Lepanthes generi* Luer & Hirtz and *Lepanthes gloris* Luer & Hirtz, were found growing with *P. bihuae*. Although we compared *P. bihuae* with *P. zunagensis*, these are separated geographically; *P. zunagensis* was found in the east-central slopes of the Andes of Ecuador, while *P. bihuae* is found in the northwest Ecuadorian Andes.

PARATYPES: Ecuador. Carchi: Reserva Dracula, 2042 m, 31 September 2019, *M. Monteros 204* (paratype, QCNE-Spirit!). Ecuador. Carchi: Reserva Dracula, 2042 m, 31 September 2019, *M. Monteros 205* (paratype, QCNE!).

PHENOLOGY: This species has always been observed blooming in its habitat throughout the year, where the humidity stays constant.

Pseudolepanthes bihuae is recognized by its vinaceous or pale yellow flowers, elongate, arcuate column, and also by its lip with an elliptical blade bent down from the middle with an erect, thick, widely rectangular central callus. *Pseudolepanthes bihuae* shares with *P. zunagensis* a few characteristics, such as the long spiculate, concave, ovate, acute dorsal sepal and the slender, falcate, reflexed petals, but *P. bihuae* is easily distinguished by the vinaceous or pale yellow flowers (*vs.* orange flowers in *P. zunagensis*), the elongate, arcuate column (*vs.* short, erect, stout column in *P. zunagensis*) and the lip with an erect, thick, widely rectangular central callus (*vs.* with a

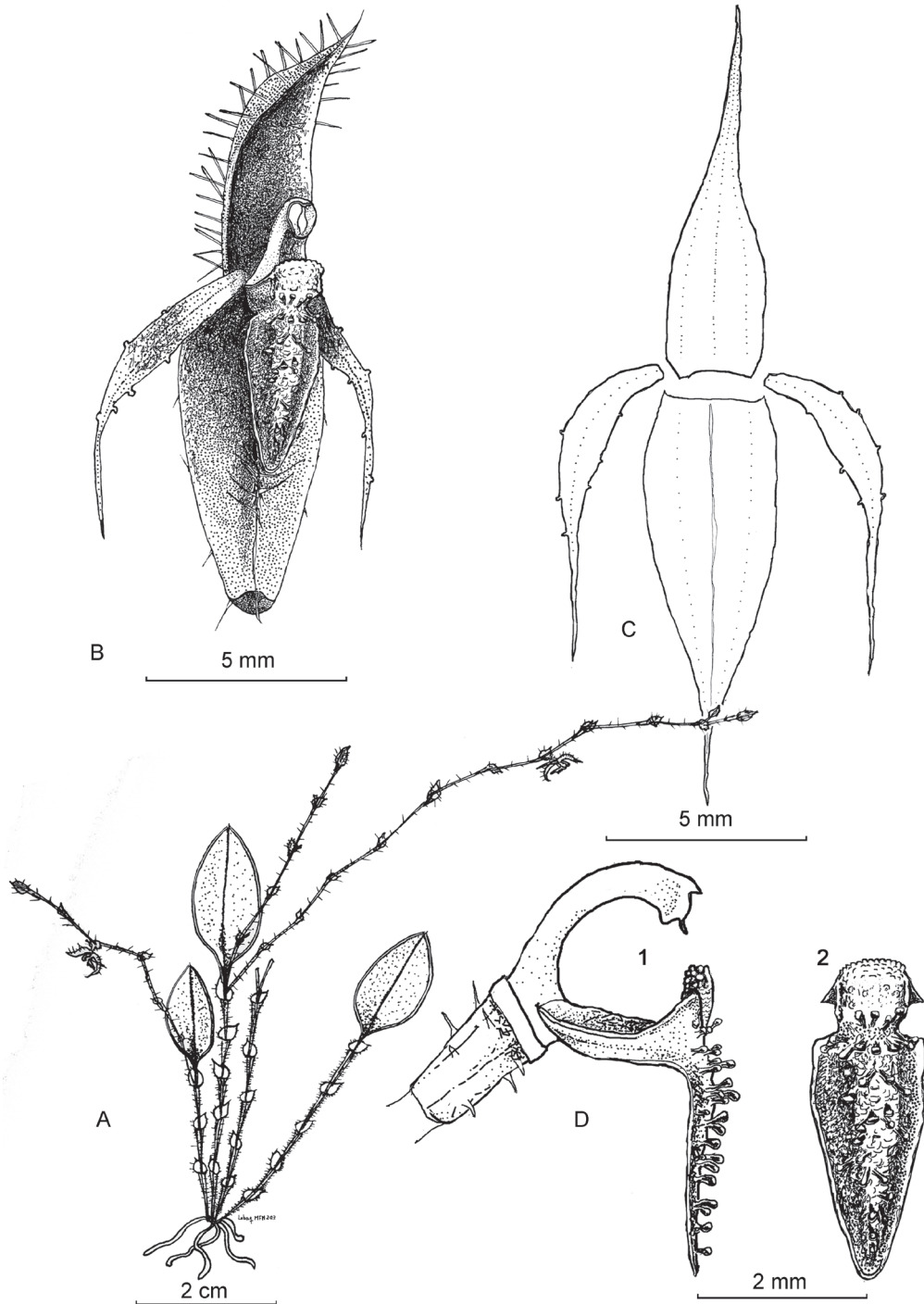


FIGURE 1. Illustration of *Pseudolepanthes bihuae* M.F.Monteros & Baquero. **A.** Habit. **B.** Flower. **C.** Dissected Perianth. **D1.** Column and lip, lateral view. **D2.** Lip, frontal view. Drawn by Marco F. Monteros and Luis E. Baquero from the plant that served as the holotype. (MFM 203, QCNE).

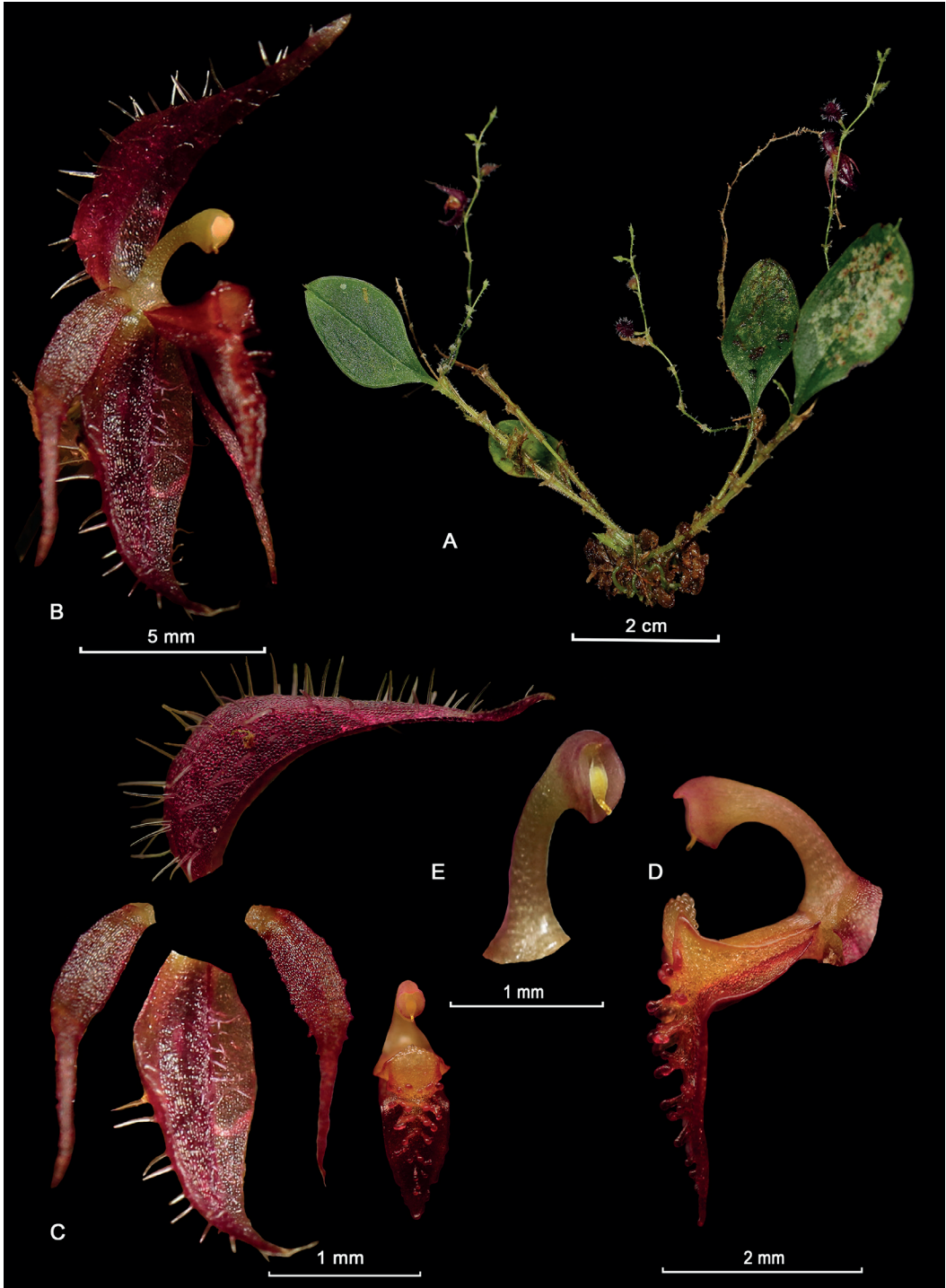


FIGURE 2. Lankester composite dissection plate of *Pseudolepanthes bihuae* M.F.Monteros & Baquero. **A.** Habit. **B.** Flower, $\frac{3}{4}$ view. **C.** Dissected perianth. **D.** Column and lip, lateral view. **E.** Column and anther, $\frac{3}{4}$ view. **F.** Peduncle and floral bract. Photographs by Marco F. Monteros from the plant that served as the holotype. (MFM 203, QCNE).

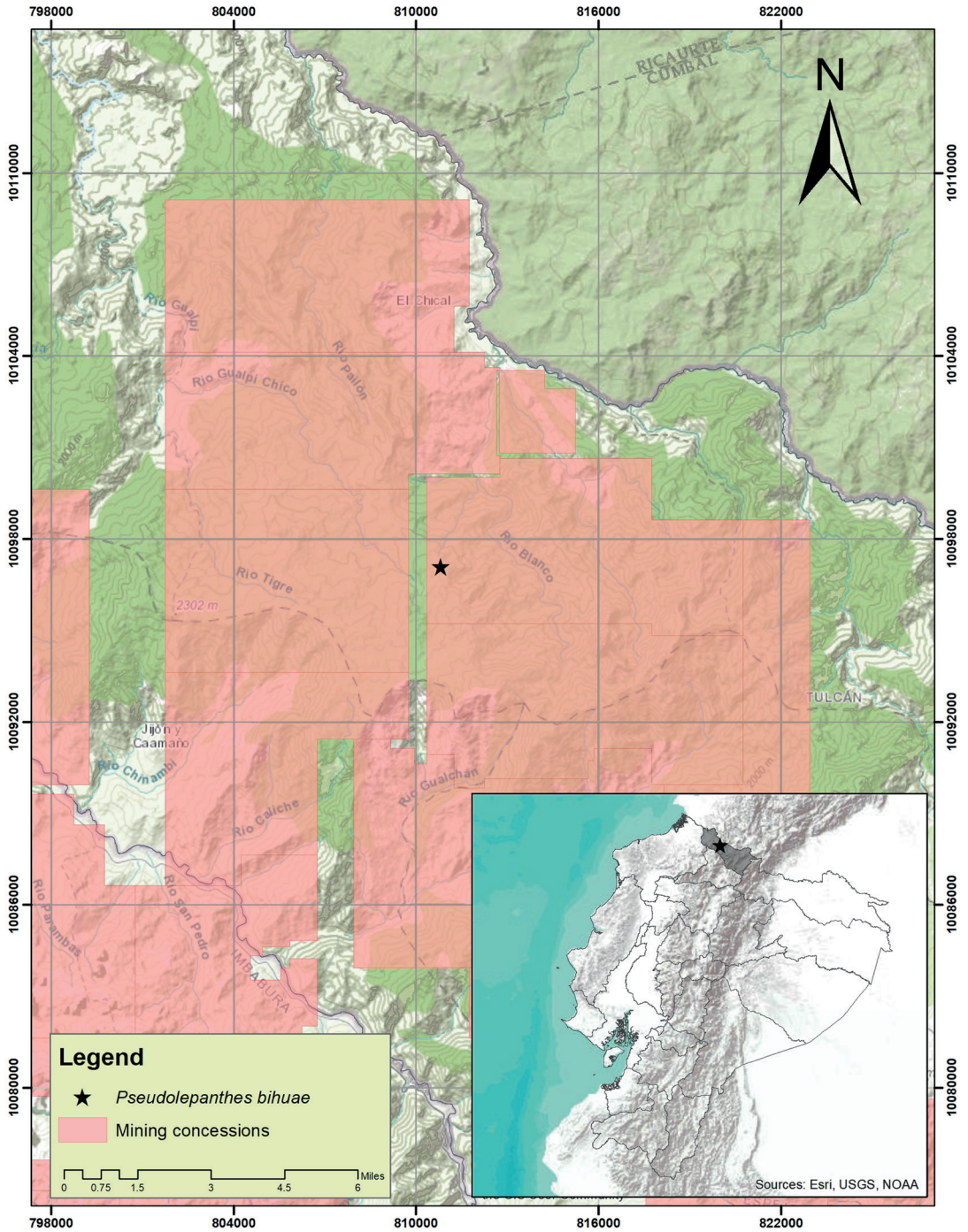


FIGURE 3. Distribution map of *Pseudolepanthes bihuae* M.F.Monteros & Baquero. Distributed in Carchi province northwest of Ecuador and mining threats. Map created by Marco F. Monteros.

verrucose callus slightly clavate at the rounded apex in *P. zunagensis*).

Pseudolepanthes bihuae represents the first record of the genus in northwest Ecuador. Nonetheless, most species of the *Pseudolepanthes* are from the western Andes of Colombia where apparently, the endemism center of this genus is located (Luer 1997). Finally, it is important to emphasize that the small population of *P. bihuae* in Ecuador is threatened, mainly by the illegal extraction of species and the mining projects that directly affect its distribution area in northwest Ecuador (Roy *et al.* 2018). For this reason, it is important and necessary to evaluate and categorize this species under the IUCN red list criteria (Fig. 3).

CONSERVATION STATUS: The principal threats to *Pseudolepanthes bihuae* are mining activity and illegal extraction of species. In Ecuador, the government owns the subsoil rights and has sold concessions in the Dracula Reserve to mining companies. Some of these mining concessions are becoming active now, and under Ecuadorian law they can work even in private

protected areas such as the Dracula Reserve, where this species lives. Also, illegal mining and associated deforestation are becoming a problem in this area. We suggest considering this species as “Critically endangered” following criteria B1a, B1b(iii) IUCN (2012) since it has only been found at a single locality in Carchi province, in northwest Ecuador. If the mining activity is not controlled, the only population of *P. bihuae* will be strongly affected by the loss of natural forest. Therefore, this population possibly might disappear in the following years (Fig. 3).

ACKNOWLEDGMENTS. To Fundación EcoMinga, Rainforest Trust, and University of Basel Botanical Garden for funding research on new and endangered species in northwest Ecuador, close to the Dracula Reserve, which it protects, and Universidad de Las Américas (UDLA) for funding orchid research in Ecuador. The Ministerio del Ambiente del Ecuador is acknowledged for issuing the Environmental Research Permit No. 008-2016-IC-FLO-DNB/MA.

LITERATURE CITED

- Bogarín, D., Karremans, A. P. & Fernández, M. (2018). Genus-level taxonomical changes in the *Lepanthes* affinity (Orchidaceae, Pleurothallidinae). *Phytotaxa*, 340(2), 128–136. <https://doi.org/10.11646/phytotaxa.340.2.2>
- Bogarín, D., Pérez-Escobar, O. A., Karremans, A. P., Fernández, M., Kruizinga, J., Pupulin, F. & Gravendeel, B. (2019). Phylogenetic comparative methods improve the selection of characters for generic delimitations in a hyperdiverse Neotropical orchid clade. *Scientific Reports*, 9(1), 1–17. <https://doi.org/10.1038/s41598-019-51360-0>
- Karremans, A. P. & Vieira-Urbe, S. (2020). *Pseudolepanthes*. In: A. P. Karremans & S. Vieira-Urbe (Eds), *Pleurothallids, Neotropical jewels*, volume I (pp. 251–258). Quito, Ecuador: Imprenta Mariscal.
- Luer, C. A. (1986). *Icones Pleurothallidarum*. I. Systematics of the Pleurothallidinae. *Monographs in Systematic Botany from the Missouri Botanical Garden*, 15, 65–68.
- Luer, C. A. (1997). *Icones Pleurothallidarum*. XV. *Trichosalpinx*. *Monographs in Systematic Botany from the Missouri Botanical Garden*, 64, 5, 105–113.
- Roy, B. A., Zorrilla, M., Endara, L., Thomas, D. C., Vandegrift, R., Rubenstein, J. M. & Read, M. (2018). New mining concessions could severely decrease biodiversity and ecosystem services in Ecuador. *Tropical Conservation Science*, 11, 1940082918780427.
- IUCN. (2012). *Categorías y Criterios de la Lista Roja de la UICN: Versión 3.1. Segunda edición*. Gland, Suiza y Cambridge, Reino Unido: IUCN. vi + 34pp. Originalmente publicado como *IUCN Red List Categories and Criteria: Version 3.1. Second edition*. (Gland, Switzerland and Cambridge, UK: IUCN, 2012).

FIRST RECORD OF A WILD POPULATION OF *LAELIA DAWSONII* F. *DAWSONII* (ORCHIDACEAE) FOR THE STATE OF JALISCO, MEXICO

MIGUEL J. CHÁZARO-BASÁÑEZ¹, ALEXANDER JIMÉNEZ-VÁZQUEZ^{1,3}
& EDUARDO A. PÉREZ-GARCÍA²

¹Laboratorio de vida silvestre, Facultad de Biología, Universidad Veracruzana, Lomas del Estadio s/n, Xalapa, Veracruz, 91000, México.

²Departamento de Ecología y Recursos Naturales, Facultad de Ciencias, Universidad Nacional Autónoma de México, Ciudad Universitaria, Coyoacán, Ciudad de México, 04510, México.

³Author for correspondence: aleko.jimenez22@gmail.com

ABSTRACT. The existence of a wild population of *Laelia dawsonii* f. *dawsonii* is recorded for the first time in the Mexican State of Jalisco. *Laelia dawsonii* has a wide geographical distribution throughout the Sierra Madre del Sur (Oaxaca, Guerrero, and Jalisco); however, the populations are very isolated, and each one has very few individuals. Until now, no wild populations of this species had been registered outside of the State of Oaxaca. The population found in Jalisco is composed of about 100 plants. Due to its horticultural importance, *L. dawsonii* has been frequently extracted from the field, and its Oaxacan populations have been decimated since the end of the 19th century. Currently, this species is considered endangered in Mexico.

RESUMEN. Se registra por primera vez la existencia de una población silvestre de *Laelia dawsonii* f. *dawsonii* en el estado de Jalisco. *Laelia dawsonii* tiene una amplia distribución geográfica a lo largo de la Sierra Madre del Sur (Oaxaca, Guerrero, y Jalisco); sin embargo, sus poblaciones están muy aisladas y cada una cuenta con muy pocos individuos. Hasta ahora, no se habían registrado poblaciones silvestres de esta especie fuera del estado de Oaxaca. La población encontrada en Jalisco cuenta con alrededor de 100 ejemplares. Debido a su importancia hortícola, *L. dawsonii* ha sido frecuentemente extraída del campo y sus poblaciones oaxaqueñas fueron diezmadas desde finales del siglo XIX. Actualmente, esta especie se considera en peligro de extinción en México.

KEYWORDS/PALABRAS CLAVE: biogeografía, biogeography, conservación, conservation, Laeliinae, *Laelia anceps*

Introduction. Among all the Mexican orchids, *Laelia dawsonii* (J.Anderson) De B.Crawshay is perhaps one of the most important from the horticultural perspective (Hágsater *et al.* 2005). However, its taxonomic recognition has been unclear, and many aspects of its life history and its distribution remain unknown (Anderson 1868, Crawshay 1902, Soto-Arenas 2008, Pérez-García 2020). Part of the lack of taxonomic clarity of this species lies in its great horticultural value, particularly because of its similarity to some cultivars of *Laelia anceps* Lindl. Until recently, *L. dawsonii* was considered a subspecies of *L. anceps* (Soto-Arenas 1993, Pérez-García 2020).

In 1836, John Lindley described *Laelia anceps* from plants imported to England from Mexico by the London firm Loddiges and Sons. These plants had no exact place of origin (Halbinger & Soto-Arenas 1997), but most likely, they came from the state of Veracruz.

The flowers of the type had the predominant coloration of that species in the Sierra Madre Oriental, which is lilac with the lip apex in a stronger tone (Fig. 1A).

Laelia anceps has a wide distribution in the Gulf of Mexico slope, from Tamaulipas to the center of Veracruz, and in the states of Guanajuato, Hidalgo, Puebla, Querétaro, San Luis Potosí, and Oaxaca's Sierra Norte (or Sierra de Juárez). In addition, there are small populations of this species on the border between Chiapas and Guatemala, but they usually have a slightly different coloration (Archila *et al.* 2014). The plants of Guatemala and Honduras have recently been considered a different species, *Laelia mottae* Archila, Chiron, Szlach. & Pérez-García. The beauty of *L. anceps* flowers has made it one of the most cultivated Mexican orchids in the world (Rose 1987, Bechtel 1990). Likewise, many horticultural varieties have been found, which have been described as taxonomic

varieties (Rolfe 1922, Soto-Arenas 1993). This most likely has been one of the problems that has led to the non-recognition of *L. dawsonii* as a correct species, particularly because of the presence of cultivars of *L. anceps* with alba and semialba flowers (Cetzal-Ix *et al.* 2020, Pérez-García 2020).

Laelia dawsonii.— In 1865, John Tucker sent to Europe several plants classified as *L. anceps* from the state of Oaxaca, particularly close to the city of Juquila. These specimens were mostly semi-alba flowers, with rhombic petals, thicker lip callus and three to five terminal keels, and with the mid-lobe concave and longer, it was visually a more beautiful shape (Soto-Arenas 1993, Halbinger & Soto-Arenas 1997, Pérez-García 2020). The first plant to bloom was described as *L. anceps* var. *dawsonii* by J. Anderson in 1868, and later, some other varieties were described, which to date are considered taxonomic synonyms but that in horticulture still have some use (like the *sanderiana* variety named by H. G. Reichenbach in 1887). Tucker never revealed the location of the wild populations of this new variety, and by 1892, Henry Frederick Conrad Sander would relate that all these plants would have been bought from the Oaxacan indigenous people who had cultivated them in towns near the Pacific coast for several centuries (Soto-Arenas 2008).

In 1947, Thomas MacDougall collected specimens in their natural habitat, again without revealing their location, although it is inferred that it was at some point in the Chontal region of Oaxaca (MacDougall 1943, 1948), and although the area was subsequently explored on different occasions, no wild populations have been found in that area (Halbinger & Soto-Arenas 1997). In 1987, some specimens were found in southern Oaxaca, it was a very small and threatened population, which consisted of only 12 genets (individuals or horticultural clones; Soto-Arenas 2003), but apparently, this locality has already been extirpated. *Laelia dawsonii* has just been recognized as a distinct species from *L. anceps* and was characterized as an endangered species in the most recent update of the list of threatened species in Mexico (SEMARNAT 2019). *Laelia dawsonii* presents an important morphological variation and two different forms are recognized: *L. dawsonii* f. *dawsonii* and *L. dawsonii* f. *chilapensis* (Halbinger & Soto-Arenas 1997, Cetzal-Ix *et al.* 2020).

Laelia dawsonii f. *chilapensis* (Soto Arenas) Pérez-García & Cetzal.— This form of *L. dawsonii* has a limited geographical distribution since it is only known from some specimens traditionally cultivated in the Chilapa region, Guerrero. These plants have pale pink flowers with velvety dark purple lips (Fig. 1B). To date, wild populations of *L. dawsonii* f. *chilapensis* have not been documented, which is why it is considered as probably extinct in nature (Soto-Arenas 1993, 2008, Halbinger & Soto 1997, Pérez-García 2020).

Laelia dawsonii f. *dawsonii*.— This form generally has white tepals, although some specimens have slightly pinkish tones. The lip is white with the throat with purple lines, the mid-lobe of the lip can vary in extension and be white (Fig. 1C) or magenta in different degrees of color intensity (var. *sanderiana*, Fig. 1D). It is an orchid in danger of extinction in nature (Soto-Arenas 2008). Before this publication, it was only known from a few wild populations and cultivated plants in the state of Oaxaca (Huerta Espinoza 2014). Due to its attractive flowers, many specialists and hobbyists have searched intensively for *L. dawsonii* in the wild without finding it. The *dawsonii* form was considered endemic to Oaxaca since it had only been collected from the wild in that state. However, for some time, the existence of some specimens cultivated by the locals in the state of Jalisco has been known. This prior knowledge motivated Federico Halbinger to go in 1994 to the state of Jalisco in search of these plants. In this botanical expedition, Halbinger was accompanied by Ignacio Contreras, a passionate lover of orchids from Jalisco, but they only found cultivated specimens and none in the wild.

Subsequently, several other collectors interested in the orchids of Jalisco have made expeditions in search of this species without success. For example, Salvador Rosillo de Velasco, from Guadalajara, purchased it in a house in Chiquilistlán, and made countless field trips, collecting orchids in Jalisco and neighboring states, and never found it in the wild. Likewise, Roberto González Tamayo, another prominent orchidologist at the Botanical Institute of the University of Guadalajara, explored the state of Jalisco for more than 40 years and never found it. After the expedition with F. Halbinger, Ignacio Contreras continued for more than 18 years in search of this orchid in its habitat, without being able



FIGURE 1. **A.** *Laelia anceps* type. **B.** *Laelia dawsonii* f. *chilapensis*. **C.** *Laelia dawsonii* f. *dawsonii* cultivated by locals in Jalisco. **D.** *Laelia dawsonii* f. *dawsonii* “var. *sanderiana*”.

to do so. In 1985, Rogers McVaugh only recorded the following five species of the genus *Laelia* Lindl. for the Nueva Galicia region (Jalisco and surrounding states): *L. albida* Bateman ex Lindl., *L. autumnalis* (Lex.) Lindl., *L. crawshayana* Rehb.f. (cited as *L. bancalari*), *L. rubescens* Lindl., and *L. speciosa* (Kunth) Schltr., in such a way that this great botanical work did not consider the presence in the state of *L. dawsonii* (McVaugh 1985).

Recently, L. Peraza-Flores, G. Carnevali & C. van den Berg (2016) proposed two groups within the genus *Laelia*, based in a molecular analysis. The first consists of the endemic species of Mexico, of which *L. speciosa* is the type of the generic name. The second group includes taxa mainly from Central and South America, generally known as *Schomburgkia* Lindl. Therefore, according to this proposal, the recognition of *Laelia* would only be for Mexican species close to *L. speciosa*, and the rest of the species including *L. anceps* and *L. dawsonii* to the genus *Schomburgkia*. For reasons similar to those discussed in Cetzal *et al.* (2020), in this article, we

adopt the broader constituency of *Laelia* to avoid the increase in binomials associated with the Mexican species of the genus.

Study area.— The discovery site is located in the extensive Sierra del Tigre, southeast of the state of Jalisco. The exact municipality will not be revealed to protect the population of this vulnerable orchid. The site is located at an elevation of 2100 m above sea level and is made up of lands belonging to the Tertiary period, composed of limestone, extrusive igneous rocks, rhyolite, andesite, basalt, tuff and volcanic breccia. The climate is classified as semi-dry, with dry and semi-warm autumn and winter, with no well-defined winter thermal change. The average annual temperature is 15°C, and it has an average annual rainfall of 780 mm. This natural area is represented by 8300 ha of forest, where species of *Pinus* L., *Quercus* L., and *Fraxinus* L. predominate, as well as *Enterolobium cyclocarpum* (Jacq.) Griseb. Currently, the area has a presence of drug trafficking, making botanical exploration risky.



FIGURE 2. *Laelia dawsonii* f. *dawsonii*, in situ, Jalisco, Mexico. A–B. Inflorescences in epiphytic plants. C. Ignacio Contreras with inflorescences in the field. D. Plants growing over rocky cliff. E–F. View of *Laelia dawsonii* f. *dawsonii* flowers.

Results and discussion. In order to photograph specimens of some Crassulaceae species *in situ*, on April 8, 2001, an expedition was made to the Sierra del Tigre. Thus, when looking for plants in a rocky cliff, it was observed that at the height of 20 m, there was a rupicolous orchid that at first glance looked like an *Epidendrum ciliare* L. However, when approaching the plant from the upper part of the cliff it was a specimen of the genus *Laelia*. As the specimen was in a sterile stage, a plant was collected and cultivated in Guadalajara. The plant bloomed in mid-November of that same year. Thus, it was possible to verify the identity of the species as the elusive *Laelia dawsonii* f. *dawsonii*, and to locate the first population found in the wild in the state of Jalisco. To photograph with a roll film camera and collect specimens for herbarium, a second visit was made to the Sierra del Tigre on November 20, 2001, where it was possible to observe the population in bloom and reaffirm the identity of the species in nature.

This finding, although fortuitous, is of great importance because it represents the first record with certainty for the state of Jalisco of a wild population of *L. dawsonii* f. *dawsonii* (Fig. 2), which is one of the few known populations for this species in Mexico. Interestingly, that the *dawsonii* form has a population so distant from the known localities for this species in the state of Oaxaca. In other words, Guerrero and Michoacán are skipped.

Due to the large surface area and the rugged topography of the Sierra del Tigre (both in the south of Jalisco and in the northwest of Michoacán) and the limited botanical exploration that has taken place in this geographical region, it is necessary to investigate if *L. dawsonii* f. *dawsonii* may be present in other gullies with similar conditions in the region. It is expected that in future botanical expeditions the permanence of the

population found can be verified and evaluate if this population is in a position to continue perpetuating itself, that is, with the formation of capsules and the presence of seedlings. It would also be important to perform an accurate count of the number of plants that make up the population and evaluate its dynamics, as well as their reproductive biology. All these aspects of the ecology and natural history of the species remain unknown, even for the populations of Oaxaca. *Laelia dawsonii* is one of the most spectacular orchids in Mexico, and unfortunately, also one of the most endangered. For this reason, the conservation of the Sierra del Tigre, Jalisco, should be a priority.

Specimens examined.— *Laelia dawsonii* f. *dawsonii* MEXICO: Jalisco, Sierra del Tigre, at 1900 m above sea level, growing epiphytic on *Garrya laurifolia* Hartw. ex Benth. November 20, 2001, M. Cházaro B., I. Contreras V., R. López V., J. A. Machuca N. & O. M. Valencia P. #8153 (ENCB, IBUG, IEB).

ACKNOWLEDGMENTS. To Ignacio Contreras Villaseñor, who detected the species during the first expedition in 2001 and for cultivating it until flowering. To J. A. Machuca Núñez, Óscar M. Valencia Pelayo, J. Cortés Aguilar and Raúl López Velázquez, who actively collaborated in the field work. To Fernando Rico Román for having transcribed the first manuscript on the computer, and Eduardo Sahagún Godínez who made important comments on the first versions of this manuscript. We are grateful to Tania del Rocío Ruiz Estrada for the composition of the figures. To Raúl López Velázquez for the pictures 2B and 2C. To PAPIIT-DGAPA-UNAM grant IN227319 for supporting the maintenance and photographic documentation of the orchid collection at MAS-FC-UNAM Orchidarium. M.J. C-B. appreciates the valuable financial support received during many years of academic work and botanical research in the Department of Geography and Territorial Planning of the University of Guadalajara, to be able to carry out field work in Jalisco.

LITERATURE CITED

- Anderson, J. (1868). New plants. *The Gardeners' Chronicle & Agricultural Gazette*, 2, 27.
- Archila, F., Chiron, G., Szlachetko, D., Bertolini, V. & Pérez-García, E. A. (2014). *Laelia mottae* (Orchidaceae): una nueva especie del complejo de *Laelia anceps* Lindl. *Botanical Sciences*, 92, 343–350.
- Bechtel, P. G. (1990). The Laelias of Mexico. *American Orchid Society Bulletin*, 59(12), 1229–1234.
- Cetzal-Ix, W., Carnevali, G., Jiménez-Machorro, R. & Pérez-García, E. A. (2020). *Laelia* × *meavei*: A new natural hybrid between *L. dawsonii* f. *dawsonii* and *L. rubescens* f. *peduncularis* (Orchidaceae: Laeliinae) from Oaxaca, Mexico. *Phytotaxa*, 446 (2), 81–94.
- Crawshay, B. (1902). *Laelia anceps* and its varieties. *The Gardeners' Chronicle: A Weekly Illustrated Journal of Horticulture*

- and *Allied Subjects*, ser. 3, 32, 414.
- Hágsater, E., Soto-Arenas, M. A., Salazar-Chávez, G. A., Jiménez, R., López-Rosas, M. A. & Dressler, R. L. (2005). *Las Orquídeas de México*. Mexico City: Instituto Chinoín. 304 pp.
- Halbinger, F. & Soto-Arenas, M. (1997). Laelias of Mexico. *Orquidea (Mexico City)*, 15, 1–160.
- Huerta Espinoza, H. M. (2014). Evaluación del efecto del cambio de uso del suelo en la distribución de las especies mexicanas de *Laelia* (Orchidaceae). Licenciatura en Geografía, Facultad de Filosofía y Letras, Universidad Nacional Autónoma de México. 138 pp.
- Lindley, J. (1836). *Laelia anceps*: two-edged *Laelia*. *Edwards's Botanical Register*, 21, t. 1751.
- MacDougall, T. (1943). White varieties of *Laelia anceps*. *American Orchid Society Bulletin*, 11(11), 395–396.
- MacDougall, T. (1948). White *Laelia anceps* in Mexico: a photo-story. *American Orchid Society Bulletin*, 17(10), 606–607.
- McVaugh, R. (1985). Orchidaceae. In: W. R. Anderson (ed.), *Flora Novo-Galiciana*. 16. Ann Arbor, Michigan: University of Michigan Press. 363 pp.
- Peraza-Flores, L. N., Carnevali, G. & van den Berg, C. (2016). A molecular phylogeny of the *Laelia* alliance (Orchidaceae) and a reassessment of *Laelia* and *Schomburgkia*. *Taxon*, 65(6), 1249–1262.
- Pérez-García, E. A. (2020). Die “Sanderiana”, eine Geschichte über *Laelia dawsonii*. *Die Orchidee*, 71(4), 276–285.
- Reichenbach, H. G. (1887). Plants new or noteworthy: *Laelia anceps* var. *sanderiana*. *The Gardeners' chronicle: a weekly illustrated journal of horticulture and allied subjects*, series 3, vol. 1, 104.
- Rolfe, R. A. (1922). *Laelia anceps* and its varieties. *Orchid Review*, 30, 7–11.
- Rose, J. (1987). *Laelia anceps* - The real treasure of the Sierra Madre. *American Orchid Society Bulletin*, 56(5), 483–491.
- Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). (14 de noviembre de 2019). Modificación del Anexo Normativo III, Lista de especies en riesgo de la Norma Oficial Mexicana NOM-059-SEMARNAT-2010, Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo, publicada el 30 de diciembre de 2010. *Diario Oficial de la Federación*. Recuperado de http://www.dof.gob.mx/nota_to_imagen_fs.php?codnota=5578808&fecha=14/11/2019&cod_diario=283778
- Soto-Arenas, M. A. (1993). Clasificación infraespecífica de *Laelia anceps*. *Orquidea (Mexico City)*, 13, 125–144.
- Soto-Arenas, M. A. (2003). *Laelia anceps* Lindl. subsp. *dawsonii* (J.Anderson) Rolfe f. *dawsonii*. In: E. Hágsater & M. A. Soto-Arenas (Eds.), *Icones Orchidacearum* fascicles 5 and 6, Orchids of Mexico parts 2 and 3, pl. 597. México, D.F.: Herbario AMO.
- Soto-Arenas, M. A. (2008). *Laelia anceps* subsp. *dawsonii* f. *chilapensis* Soto-Arenas. In: E. Hágsater & M. A. Soto-Arenas (Eds), *Icones Orchidacearum* 10, pl. 1035. México, D.F.: Herbario AMO.

COMPARATIVE FLORAL SURFACE MICROMORPHOLOGY HELPS TO DISCRIMINATE BETWEEN SPECIES OF *PAPHIOPEDILUM* (ORCHIDACEAE: CYPRIPEDIOIDEAE) FROM PENINSULAR MALAYSIA

EDWARD E. BESI, LAM S. JIA, MUSKHAZLI MUSTAFA, CHRISTINA S.Y. YONG
& RUSEA GO*

Department of Biology, Faculty of Science, Universiti Putra Malaysia, 43400 Serdang,
Selangor Darul Ehsan, Malaysia

*Author for correspondence: rusea@upm.edu.my

ABSTRACT. The floral micromorphology of critically endangered *Paphiopedilum* Pfitzer [*P. barbatum* (Lindl.) Pfitzer, *P. callosum* var. *sublaeve* (Rchb.f.) P.J.Cribb and *P. niveum* (Rchb.f.) Stein] were analyzed concerning either infrageneric taxonomy or physioecological demands. The first two species are phylogenetically close and superficially identical but occur with distinct phytogeographical distributions in the region. The third species is a phylogenetically distant congener that inhabits limestone areas in the northern part of Peninsular Malaysia. Using scanning electron microscopy (SEM), we investigated the surface of the dorsal sepal, synsepal, lateral petals, pouch or labellum, and staminode. Amongst the investigated features were epicuticular waxes, epicuticular ornamentation, trichome distribution and type, pustular glands, and papillae. Our study supports the distinction of *P. barbatum* from *P. callosum* var. *sublaeve*, which belong to subgenus *Paphiopedilum*, and from *P. niveum*, a species belonging to subgenus *Brachypetalum*, a separated monophyletic clade. Comparatively, *P. barbatum* has Type III non-glandular trichomes on the margin of its lateral petals, which are absent in *P. callosum* var. *sublaeve*. *Paphiopedilum callosum* var. *sublaeve* and *P. niveum* are distinguishable from *P. barbatum* by a confined distribution of papillae. The epicuticular ornamentation and distribution of trichomes on staminode discriminate between *P. barbatum* and *P. callosum* var. *sublaeve* and differentiates them from *P. niveum*. Compared to *P. barbatum* and *P. niveum*, stomata in *P. callosum* var. *sublaeve* were superficial with prominently raised guard cells. From the physioecological view, the absence of glandular trichomes, and the low occurrence of papillae and stomata on the floral parts explain the unscented flowers of *P. barbatum* and *P. callosum* var. *sublaeve*. A combination of the features examined is taxonomically valuable for delimitation of the species at the infrageneric level, although the diagnostic characters are far inadequate for a generic taxonomic revision. A study with a more extensive sampling from the three subgenera of *Paphiopedilum*, including subgenus *Parvisepalum*, is anticipated to elucidate the level of variation of the analyzed microcharacters.

KEY WORDS: physioecological importance, Peninsular Malaysia, subgenus *Brachypetalum*, subgenus *Paphiopedilum*, scanning electron microscopy, taxonomic delimitation

Introduction. *Paphiopedilum* originates from the Greek word ‘*Paphian*’ an epithet for Aphrodite, the Roman goddess known as Venus, and “*pedilon*” which means slipper (Cash 1991, Cribb 1998). Orchids in this genus are commonly known as slipper orchids because of the unique slipper or shoe-like flowers (Cash 1991, Cribb 1998, McGough *et al.* 2006). The genus *Paphiopedilum* Pfitzer comprises about 167 species, with distribution extending from Southern China to Tropical Asia (Braem 1988, Cribb 1998, Chen *et al.* 2005, Govaerts *et al.* 2021). *Paphiopedilum* gained

its popularity and investment value in the horticulture industry through its exotic appearance and production of large flowers on small plants (Cribb 1998). Most of the species are regarded as endangered and threatened with extinction due to habitat destruction, over-collection and illegal trading. They are amongst the plants listed on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES – Appendix 1). Within this list, one can find well-known Malaysian species *Paphiopedilum barbatum* (Lindl.) Pfitzer (Bearded *Paphiopedilum*) (Rankou 2015a),

Paphiopedilum callosum (Rchb.f.) Stein (*Callus Paphiopedilum*) (Rankou *et al.* 2015), *Paphiopedilum niveum* (Rchb.f.) Stein (*Snow-White Paphiopedilum*) (Rankou 2015b), *Paphiopedilum rothschildianum* (Rchb.f.) Stein (*Rothschild's Paphiopedilum*) (Rankou 2015c), *Paphiopedilum sanderianum* (Rchb.f.) Stein (*Sander's Paphiopedilum*) (Rankou 2015d) and *Paphiopedilum stonei* (Rchb.f.) Stein (Rchb.f.) Stein (*Stone's Paphiopedilum*) (Rankou & O'Sullivan 2015).

Systematically, *Paphiopedilum* is considered an early branch group due to its geographical distribution and relatively unspecialized floral structures (Rosso 1966). The subfamily Cyripedioideae is unusual amongst the Orchidaceae because of the presence of two fertile stamens, the disposition of these stamens in the inner staminal whorl lateral to the style, and the incomplete adnation of stylar and staminal tissues (Rosso 1966). A saccate labellum is usually present and is responsible for the common name "slipper orchids" so often applied to these plants (Seidenfaden & Wood 1992, Cribb 1998). Taxonomically, *Paphiopedilum* is classified based on morphological, cytological, and molecular phylogenetic data into three subgenera; *Parvisepalum*, *Brachypetalum* and *Paphiopedilum* (Cribb 1998, Chochai *et al.* 2012). Until now, only subgenus *Brachypetalum* and subgenus *Paphiopedilum* are recorded for Peninsular Malaysia. We investigate four aspects to identify an orchid species: general morphology, chromosome numbers, leaf and floral anatomy, and DNA barcoding. Species delimitation based on general floral morphology for *Paphiopedilum* species found in Peninsular Malaysia shows a clear resolution for most of the species, except for the highly resemblant ones, for instance, *P. barbatum* and *P. callosum* var. *sublaeve* (Rchb.f.) P.J.Cribb belong to subgenus *Paphiopedilum* (Seidenfaden & Wood 1992, Cribb 1998, Leong 2014). A work on DNA Barcoding of Endangered *Paphiopedilum* species of Peninsular Malaysia using four DNA barcode loci and their combinations (*rbcL*, *matK*, ITS, *trnH-psbA*) published by Rajaram *et al.* (2019) clusters each species as a monophyletic clade. The *matK* sequences discriminate the closely related *P. barbatum* and *P. callosum* var. *sublaeve*, therefore supporting the species circumscription by Cribb (1998) (Rajaram *et al.* 2019). Nevertheless, slipper orchids are infamously variable, and unusual plants may sometimes be

natural hybrids, especially when the putative parents grow sympatrically (Averyanov *et al.* 2007, Leong 2014, van der Ent *et al.* 2015). Natural hybridizations between two confusable *Paphiopedilum* species occur in Peninsular Malaysia, e.g. in between *P. barbatum* and *P. callosum* var. *sublaeve* – where the chloroplast *matK* sequence matched that of *P. barbatum* and the nuclear ITS sequence matched that of *P. callosum* var. *sublaeve* (Khew *in prep.* cited in Leong 2014).

Cytologically, the genus is characterized by significant chromosome variation, ranging from $2n = 26$ to 42 (Duncan & Macleod 1949, Karasawa 1979, Karasawa & Aoyama 1988). Pollen studies and anatomy observations on the leaf, root, stem, and inflorescence for members of subfamily Cyripedioideae are enumerated in Pfitzer (1903), Holm (1904), Cheadle (1942), Rosso (1966) and Atwood (1984). The systematic significance of inner and outer cuticular micromorphology of mottled and xeromorphic leaves of *Paphiopedilum* species is unclear for either taxonomical or ecological purposes (Guan *et al.* 2011). The floral micromorphology of this genus, on the other hand, has not been thoroughly examined, except for pollen morphology. Pollens of some *Paphiopedilum* species, including *P. barbatum*, *P. callosum* and *P. niveum*, were studied under the microscope by Williams & Broome (1976), Newton & Williams (1978), and Burns-Balogh & Hesse (1988), are taxonomically useful at the intergeneric level. The exine of *P. callosum* is formed by isolated sporopollenin particles of the thick, peripherally channelled intine. *Paphiopedilum niveum* differs by having the foveolate exine with small pits. However, studies on the micromorphology of other floral parts of the genus *Paphiopedilum* are lacking. Given the above, we employed scanning electron microscope (SEM) observations to evaluate surface microstructures' applicability in taxonomic delimitation and physioecological functions.

Materials and methods

Species selection.— Three *Paphiopedilum* species from Peninsular Malaysia were selected to predict the congeneric contrasts (Fig.1): *Paphiopedilum barbatum* and *P. callosum* var. *sublaeve* belong to section *Barbata* in subgenus *Paphiopedilum* with mottled

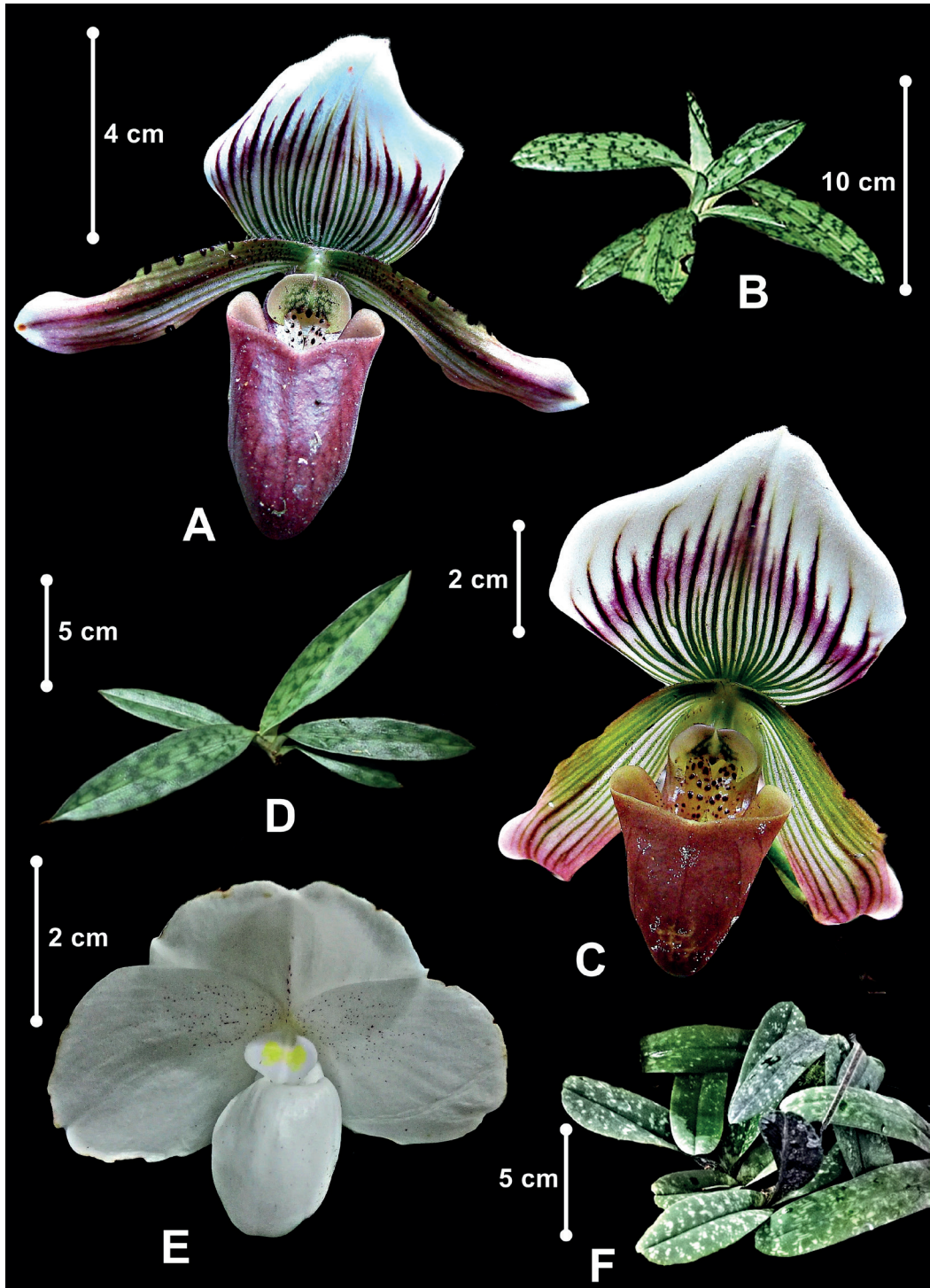


FIGURE 1. Examined species of *Paphiopedilum* from Peninsular Malaysia. A–B. *Paphiopedilum barbatum* flower (A) and leaves (B). C–D. *Paphiopedilum callosum* var. *sublaeve* flower (C) and leaves (D). E–F. *Paphiopedilum niveum* flower (E) and leaves (F). Photographs by Rusea Go and Edward Entalai Besi.

TABLE 1. *Paphiopedilum* species examined including their locality, habitat and voucher.

Species	Type Locality	Habitat	Voucher Deposited
<i>P. barbatum</i>	Terengganu	Peaty areas and rocky boulder in waterfall in lower montane forest	EDW060 (UPM)
<i>P. callosum</i> var. <i>sublaeve</i>	Kedah	Highland heath forest with ground made up of granite, quartzite and sandstone	RG4574 (UPM)
<i>P. niveum</i>	Perlis	Limestone hill forest	WY125 (UPM)

leaves, mostly spotted warty petals and thick-textured labellum, and *P. niveum*, the only representative of subgenus *Brachypetalum* in Peninsular Malaysia, with mottled leaves, concolourous white flowers and thin-textured labellum. *Paphiopedilum barbatum* thrives under deep dark valleys, open areas or rocky boulders covered with humus, leaf litters or carpets of thick moss at streamside from about 200 m to 1200 m a.s.l. Both *P. callosum* var. *sublaeve* and *P. niveum* confined to the northern part of Peninsular Malaysia differ in habitat types. *Paphiopedilum callosum* var. *sublaeve* occurs in mossy forest or open vegetation with the ground covered with sphagnum mosses or coarse white sand, whereas, *P. niveum* is a calcicoles congener inhabiting limestone cliff shaded from direct sunlight at about 300 m a.s.l.

Sample collection and processing.— One individual for each species was obtained through field sampling conducted in three different localities in Peninsular Malaysia, allowed by a permit. A complete specimen for each species was processed as an herbarium specimen following techniques outlined in Bridson & Forman (2000) and deposited in the Herbarium of Universiti Putra Malaysia (UPM). The voucher numbers and attributes are listed in Table 1. Two flowers of each species were used in macro- and micromorphology examinations. The flower specimens were dissected and photographed under AM4113ZT Dino-Lite Digital Microscope. Species identification was accomplished by morphological assessment by referring to the published taxonomic monographs and the botanical illustrations of Seidenfaden & Wood (1992) and Leong

(2014). The currently accepted names of the orchids were validated through the KEW World Checklist of Selected Plant Families (Govaerts *et al.* 2021).

Micromorphology examination.— The microstructural study was carried out in Microscopy Unit (EM) in the Institute of Biological Sciences (IBS), UPM, Malaysia. The floral parts examined were dorsal sepal, synsepal, lateral petals, pouch or labellum and staminode. For SEM, the samples were processed according to a modified protocol by IBS explained in Besi *et al.* (2020): First, fragments about 1 cm × 1 cm were excised from the margin, basal, apex and middle portions of the floral parts, except for the staminode which was used entirely. The excised samples were put into separate vials and soaked in fixative (4% glutaraldehyde) for two days at 40°C. After two days, samples were washed with 0.1 M sodium cacodylate buffer for three changes of 30 min each and post-fixed in 1% osmium tetroxide for 2 h at 40°C. Then, samples were rewashed with 0.1 M sodium cacodylate buffer (three times 30 min each) before dehydration with series of acetone: 35% (30–45 min), 50% (30–45 min), 75% (30–45 min), 95% (30–45 min), and 100% (1 h for three changes). The samples were further dried using the critical dryer Leica EM CPD 030 for about 30 min. Lastly, the samples were mounted on stubs using double-sided carbon adhesive tabs and then sputter-coated with gold in auto fine coater Baltec SCD 005 Sputter Coater. The coated samples were examined under the Jeol JSM 6400 SEM (Beam voltage: 15 kV). The surface of each floral part was observed under various magnifications (15x–4000x). All the stubs prepared are housed in the EM unit in IBS, UPM, Malaysia.

The microstructures observed on the floral parts were trichomes and papillae, pustular glands, stomata, epicuticular ornamentation and waxes. Classification of stomata was according to Wilkinson (1979) and Carpenter (2005) based on shapes and patterns of the stomatal ledges flanking aperture, guard cells and peristomatal striae, and arrangement of the contact cells. Here, we have adopted the term ‘contact cell’ to take the place of the subsidiary cell and neighbouring cell, to refer to any cell, specialized or not, that is adjacent to the stoma (Upchurch 1984). The studied *Paphiopedilum* species have some stomata where

TABLE 2. Trichomes types on the floral parts *Paphiopedilum barbatum*, *P. callosum* var. *sublaeve* and *P. niveum*, including description on the morphology.

Type	Morphology description
I	Simple, uniseriate, non-glandular, unicellular, rugose, ca. 100-200 μm , narrowly clavate
II	Simple, uniseriate, non-glandular, multicellular, long, ca. 200-1,000 μm , moniliform
III	Simple, uniseriate, non-glandular, multicellular, elongated, ca. 200-2,000 μm , moniliform with topmost cell very narrow
IV	Simple, multiseriate, non-glandular, bicellular, multiseriate base, short, ca. 100-400 μm
V	Simple, uniseriate, non-glandular, bicellular or multicellular, short, ca. 100-400 μm
VI	Simple, uniseriate, glandular, unicellular, sessile, ca. 5-20 μm , barrel-shaped
Papillae globular or tall, striated	

contact cells' patterns were not shown clearly in the SEM micrographs. Thus, the stomata type was omitted from the analysis and these stomata were described based on guard cells, stomatal ledges and peristomatal striae. For the individual stomatal parameters, stoma length and width, a magnification of 500x and a measurement method in Savvides *et al.* (2011) were employed in the current study. Stoma width was chosen instead of guard cell width since the latter changes up to 50% as stomata close (Shope & Mott 2006). Meanwhile, trichomes were described and classified based on Theobald *et al.* (1979), Adedeji *et al.* (2007), and Angulo & Dematteis (2014). Comprehensive terminologies of trichome morphology follow Angulo & Dematteis (2014). The parameter measurements were done using a ruler and the values obtained were multiplied with the magnification scales. Surface's cuticular ornamentation was described following Piwowarczyk (2015), Ghimire *et al.* (2018), and Kong & Hong (2018), and description on epicuticular waxes was based on Wilkinson (1979). Assessment of the examined species and the comparative study were conducted following Ghazalli *et al.* (2019).

Results. Epicuticular ornamentation was observed on the floral parts of the selected *Paphiopedilum* species. Six different features of simple and uniseriate trichomes, vary in structure, distribution, and number of cells, except branched trichomes. Description of the epicuticular ornamentation and trichomes are in Tables 2 and 3.

TABLE 3. Epicuticular ornamentation on the floral parts *Paphiopedilum barbatum*, *P. callosum* var. *sublaeve* and *P. niveum*, including description on the morphology.

Type	Morphology description
I	Foveate outer periclinal wall; furrowed, straight and rounded anticlinal wall
II	Foveate outer periclinal wall; fibrillary, straight and rounded anticlinal wall
III	Flat outer periclinal wall; reticulate, fibrillary, straight and rounded anticlinal wall
IV	Laevigate and often striated outer periclinal wall; undulate and furrowed anticlinal wall
V	Outer periclinal wall with a complex network of undulate striae; fibrillary, straight and rounded anticlinal wall
VI	Entirely covered by hairs (Type I non-glandular trichomes)
VII	Laevigate-with-seams outer periclinal wall; furrowed, straight and rounded anticlinal wall

Species assessment under SEM.— *Paphiopedilum barbatum* (Fig. 2). *Waxes*: scattered, warty-granulated and flake-like. *Epicuticular ornamentation*: Type III, IV and VII. *Stomata formation*: same level with the epidermal wall, in parallel or random formation. *Stomata distribution*: sparsely occurred on dorsal sepal, synsepal, lateral petals, labellum and staminode. *Stomata ornamentation*: comprise a defined rosette of five to seven contact cells with radial elongation of some cells but not others or characterized by four lateral contact cells. Guard cells and ledges indistinguishable from the neighbouring stomatal apparatus in the staminode. *Stomatal cuticular striation*: smooth or slightly striated. *Stomatal size*: L (11.11–41.67 μm) \times W (4.44–33.33 μm). *Trichome distribution*: present on dorsal sepal, synsepal, lateral petals, labellum and staminode. *Trichome type*: non-glandular—Type I, II, III, and V; glandular—absent. *Pustular glands*: absent. *Papillae*: absent.

Paphiopedilum callosum var. *sublaeve* (Fig. 3). *Waxes*: scattered, warty-granulated and flake-like. *Epicuticular ornamentation*: Type II, III, IV, VI, and VII. *Stomata formation*: superficial, raised from the epidermal wall. *Stomata distribution*: sparsely occurred on dorsal sepal, synsepal and lateral petals. *Stomata ornamentation*: narrowly elliptical outer stomatal ledges with prominent guard

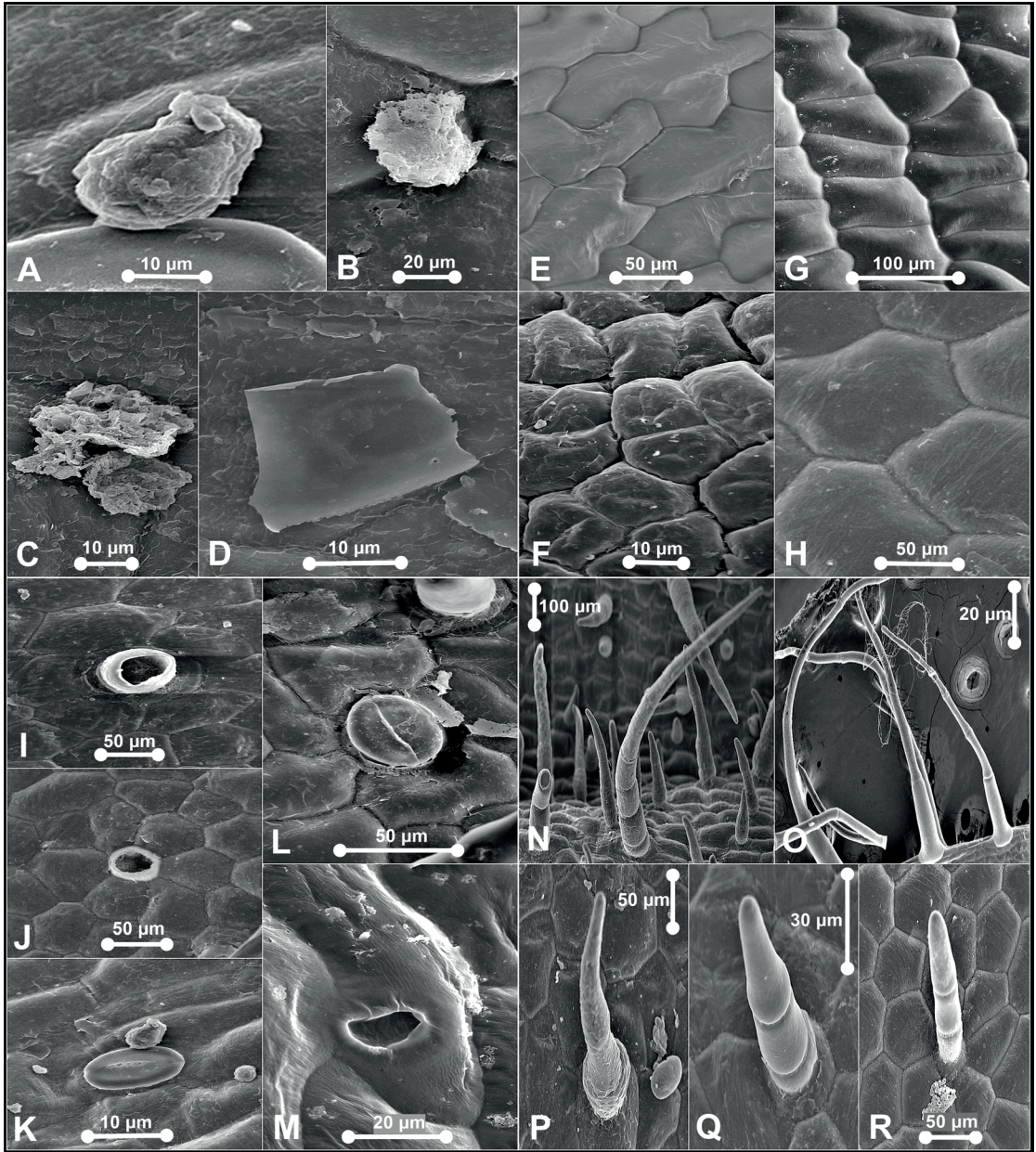


FIGURE 2. SEM observations of epicuticular waxes (A–D), epicuticular ornamentation (E–H), stomata (I–M) and trichomes (N–R) on floral parts of *Paphiopedilum barbatum*. **A.** Warty-granulated wax. **B.** Warty-granulated wax. **C.** Warty-granulated wax. **D.** Flake-like wax. **E.** Type III epicuticular ornamentation. **F.** Type IV epicuticular ornamentation. **G.** Type VII epicuticular ornamentation. **H.** Type VII epicuticular ornamentation. **I.** Aperture from by detachment of trichome on dorsal sepal. **J.** Aperture from by detachment of trichome on synsepal. **K.** Stoma on synsepal – characterized by four lateral contact cells. **L.** Stoma on synsepal – comprise a defined rosette of five to six contact cells. **M.** Nectarostoma on staminode. **N.** Trichomes on dorsal sepal – Type II. **O.** Trichomes on petal – Type II. **P.** Trichomes on dorsal sepal and staminode – Type II. **Q.** Trichomes on labellum – Type II. **R.** Trichomes on petal and labellum – Type II. Photographs by Edward Entalai Besi.

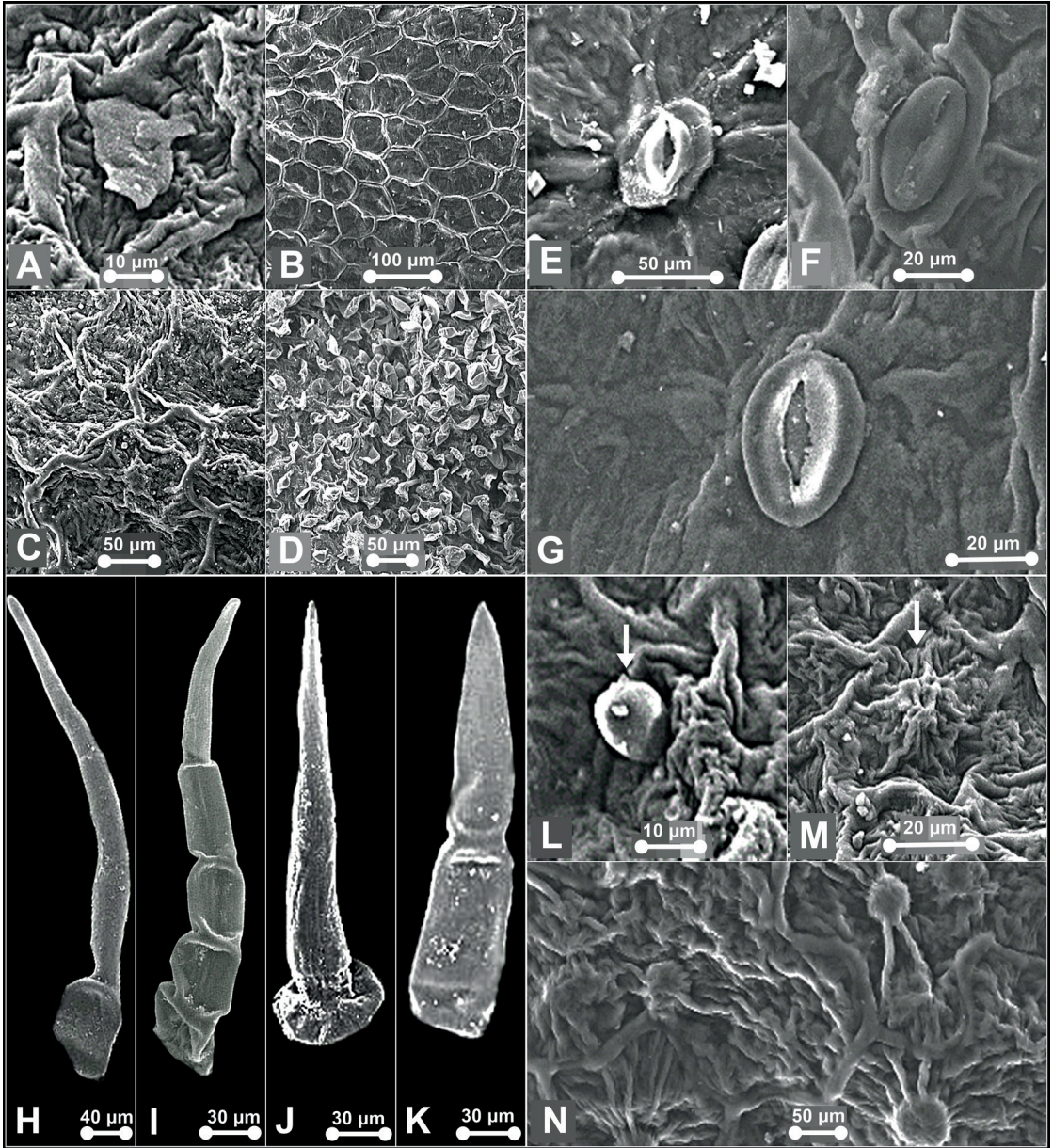


FIGURE 3. SEM observations of epicuticular waxes (A), epicuticular ornamentation (B–D), stomata (E–G), trichomes (H–L) and papillae (M–N) of *Paphiopedilum callosum* var. *sublaeve* and *P. niveum*. **A.** Flake-like wax on the pouch of *P. niveum*. **B.** Type II epicuticular ornamentation. **C.** Type V epicuticular ornamentation. **D.** Type VI epicuticular ornamentation. **E.** Stoma on dorsal sepal of *P. callosum* var. *sublaeve*. **F.** Stoma on lateral sepals of *P. niveum*. **G.** Stoma on dorsal sepal of *P. niveum*. **H.** Trichomes on synsepal of *P. callosum* var. *sublaeve*. **I.** Trichome on dorsal sepal of *P. callosum* var. *sublaeve*. **J.** Trichome on dorsal sepal of *P. niveum* – Type IV. **K.** Trichome on synsepal of *P. callosum* var. *sublaeve* – Type IV. **L.** Trichome on the pouch of *P. niveum* – Type VII. **M.** Papillae on the pouch of *P. niveum* – tall and striated. **N.** papillae on the pouch of *P. callosum* var. *sublaeve* – globular and striated. Photographs by Edward Entalai Besi and Lam Shun Jia.

TABLE 4. Features and distribution of floral-surface micromorphology characteristics of *Paphiopedilum barbatum*, *P. callosum* var. *sublaeve* and *P. niveum* (epidermal, stomata).

Species	Floral parts	Epicuticular ornamentation	Anticlinal wall features	Epicuticular striation	Stomata contact and epidermal cells ornamentation	Peristomatal rim ornamentation	Pattern of stomatal distribution
<i>P. barbatum</i>	Dorsal Sepal	III, IV	Furrowed	Smooth	Present	Present	Parallel
	Synsepal	III, VII	Furrowed	Smooth	Present	Present	Random
	Lateral Petals	IV, VII	Fibrillary, furrowed	Smooth	Present	Present	Random
	Labellum	IV	Undulate, furrowed	Smooth	Present	Present	Parallel
	Staminode	VII	Furrowed	Smooth	Present	Present	Parallel
<i>P. callosum</i> var. <i>sublaeve</i>	Dorsal Sepal	II	Fibrillary	Rugulate	Present	Present	Parallel
	Synsepal	II, VII	Fibrillary, furrowed	Rugulate	Present	Present	Parallel
	Lateral Petals	II, III	Fibrillary	Rugulate	Present	Present	Parallel
	Labellum	IV	Undulate, furrowed	Rugulate, striated	Absent	Absent	Absent
	Staminode	VI	Unclear	Unclear	Absent	Absent	Absent
<i>P. niveum</i>	Dorsal Sepal	III	Fibrillary	Densely rugulate	Present	Present	Parallel
	Synsepal	III	Fibrillary	Striated	Present	Present	Parallel
	Lateral Petals	II	Fibrillary	Rugulate, striated	Absent	Absent	Absent
	Labellum	II, V	Fibrillary	Rugulate, striated	Absent	Absent	Absent
	Staminode	VI	Unclear	Unclear	Absent	Absent	Absent

cells. Contact cells indistinguishable. *Stomatal cuticular striation*: radiating peristomatal striae in irregular orientation from ledge cells. *Stomatal size*: L (41.38–52.38 μm) \times W (22.79–31.21 μm). *Trichome distribution*: present on dorsal sepal, synsepal, lateral petals and labellum. Two major groups of trichomes were observed on the dorsal sepal; non-glandular and glandular trichomes. The long and non-glandular trichomes were mostly located marginally and glandular trichomes on the dorsal sepal. *Trichome type*: non-glandular—Type I, II, III, and V. *Pustular glands*: sessile, widely-scattered on sepals. *Papillae*: congregated on labellum, globular, striated and connected by radiating striae.

Paphiopedilum niveum (Fig. 3). *Waxes*: scattered, warty-granulated and flake-like. *Epicuticular*

ornamentation: Type II, III, V and VI. *Stomata formation*: parafacial, semi-raised from the epidermal wall. *Stomata distribution*: sparsely occurred on dorsal sepals and synsepal. *Stomata ornamentation*: narrowly elliptical outer ledges and distinct irregular quadrilateral guard cells. Contact cells indistinguishable from the neighbouring stomatal apparatus. *Stomatal cuticular striation*: long radiating buttressed striae. *Stomatal size*: L (37.98–45.45 μm) \times W (30.32–38.66 μm). *Trichome distribution*: presence on dorsal sepal, synsepal, lateral sepals, labellum and staminode. Non-glandular trichomes were dense in petals and sepals. Glandular trichomes occasionally occur on the labellum. *Trichome type*: non-glandular—Type I, II, III, IV, and V; glandular—Type VI. *Pustular glands*: occur sparsely on sepals, sessile to

subsessile, resemble subsessile trichomes, except the former commonly striated or connected by striae, or resemble papillae, except the former not prominently protruding. *Papillae*: congregated on labellum, tall striated.

Comparative study on the floral-surface micromorphology.— Prominent cuticular sculpturing was clearly observed on the epidermal surface of the selected species and varied significantly in anticlinal and periclinal wall characteristics. Stomata were present in floral parts of *P. barbatum* but only occurred occasionally for *P. callosum* var. *sublaeve* and *P. niveum*. Trichomes were observed in all studied species. All had diverse types of trichomes on their floral parts. The features and occurrence of each micromorphology are shown in Table 4 and 5.

Discussion. Questions have arisen over the usefulness of floral-surface micromorphology in the recircumscription of confusable *Paphiopedilum* species found in Peninsular Malaysia, *P. barbatum* and *P. callosum* var. *sublaeve*. At first, we discuss the taxonomic significance and then the physioecological importance of epicuticular ornamentation, stomata and trichomes. Non-glandular trichomes are classified as non-glandular for not functioned as secretory structures (Peterson & Vermeer 1984). The non-glandular trichomes occur on various floral parts (Ko *et al.* 2007, Baran *et al.* 2010). Glandular trichomes, papillae and floral stomata play essential roles in fragrance and metabolite release which offers food to ensure pollinators revisit (Davies & Turner 2004, Choi & Kim 2013, Stpiczyńska *et al.* 2018).

Taxonomic aspects.— The invariable presence of warty-granulated and flake-like epicuticular waxes without any unique types on each floral part suggests no significance systematics value for the studied species. Contrariwise, the multi-pattern epicuticular ornamentation on the floral parts offers a significant taxonomic value to discriminate the infrasubgeneric *P. barbatum* and *P. callosum* var. *sublaeve*. The epicuticular sculptures are also consistent to differentiate them from their congener *P. niveum* (Table 4).

Stomata were found in all three studied

TABLE 5. Features and distribution of floral-surface micromorphology characteristics of *Paphiopedilum barbatum*, *P. callosum* var. *sublaeve* and *P. niveum* (trichome).

Species	Floral Parts	Trichome type	Glandular trichomes	Papillae
<i>P. barbatum</i>	Dorsal Sepal	III	Absent	Absent
	Synsepal	III	Absent	Absent
	Lateral Petals	II, III	Absent	Absent
	Labellum	II, III, V	Absent	Absent
	Staminode	I, II, III	Absent	Absent
<i>P. callosum</i> var. <i>sublaeve</i>	Dorsal Sepal	I, III, V, VI	Absent	Absent
	Synsepal	I, II, III, V	Absent	Absent
	Lateral Petals	II, V	Absent	Absent
	Labellum	I, III, V	Absent	Present
	Staminode	V	Absent	Absent
<i>P. niveum</i>	Dorsal Sepal	I, IV, V	Absent	Absent
	Synsepal	I, IV, V	Absent	Absent
	Lateral Petals	II	Absent	Absent
	Labellum	II, III, V, VI	Present	Present
	Staminode	V	Absent	Absent

Paphiopedilum species. The contact cells obscurity could be a characteristic of a genus. Nevertheless, the stomata can be clearly distinguished based on the prominence of the guard cells and their shape. Solereder (1908) and Carpenter (2005) strongly emphasized the diagnostic importance of the morphology of the guard cells and their cuticular ledges. The outline of the pair of guard cells as seen in surface view is usually constant in the examined specimens and is also possible a characteristic of a genus. Also, stomata in *P. barbatum* differs significantly from *P. callosum* var. *sublaeve* and *P. niveum* by having clear and noticeably contact cells, epidermal cells and peristomatal rim but rather obscure guard cells. Here, we can also deliberately compare between *P. barbatum* and *P. callosum* var. *sublaeve* based on the stomata and stomatal formation when observed from the top view. In comparison, stomata in *P. callosum* var. *sublaeve* were superficial and stand out distinctly with prominently raised guard cells. *P. niveum* had stomata slightly raised and irregular-shaped guard

cells that may provide a unique diagnostic character at the species level. Based on the general designation of the stomatal size provided in Wilkinson (1979), the stomata present on the slipper orchids are termed as 'large', similar to *Corybas holtumii* and *Corybas selangorensis* (see Besi *et al.* 2019).

Dominance of simple non-glandular trichomes and occurrence of variegated stomata on the floral surface of the *Paphiopedilum* species may separate genus *Paphiopedilum* from other genera within the Cypripedioideae subfamily. In many cases, such trichomes were living cells whereas in others they were dead, and the protoplasm was replaced by air spaces (Fahn 1988) and easily distorted or torn as observed on the labellum of *P. callosum* var. *sublaeve*. Different types of trichomes possess varies morphological characteristics were distinctively occurred on these floral surfaces of *Paphiopedilum* species (Table 5). The simple non-glandular trichomes were dominant on the floral surface. In contrast, the papillae were scarce, localized and only occurred on the labellum of *P. callosum* var. *sublaeve* (globular and striated) and *P. niveum* (tall and striated). This suggests the presence of papillae with varied morphology on the labellum of *Paphiopedilum* are of systematic significance and can be used as a diagnostic character to distinguish them further morphologically. There were pustular glands observed on the sepals and petals that resemble either sessile trichomes or papillae. Short and rugose non-glandular trichomes were formed by two to five cell tiers. The trichomes occurred at different length ranged from 61.11 μm to 1533.3 μm for *P. barbatum*, 48 μm to 190 μm for *P. callosum* var. *sublaeve* and 100 μm to 240 μm for *P. niveum*.

The presence of different types of simple non-glandular trichomes on the floral parts of the studied *Paphiopedilum* species denotes species specificity. It provides a piece of useful evidence for delineation of the confusable *P. barbatum* and *P. callosum* var. *sublaeve*. Morphologically, *P. barbatum* differs only by having dorsal sepal broadly ovate, petals with warts on upper or both margins and sometimes on the petals blades too, whereas *P. callosum* var. *sublaeve* has dorsal sepal broadly ovate to suborbicular and petals with warts on upper margin only (Seidenfaden & Wood 1992, Leong 2014). Clearly, these diagnostic characters are inconspicuous

without a definite boundary to discriminate and sometimes misleading. Therefore, here, floral-surface micromorphology serves as a steadfast advanced technique for the taxonomic circumscription of the confusable *P. barbatum* and *P. callosum* var. *sublaeve*. Micromorphologically, *P. barbatum* varies in the diversity of non-glandular trichomes on its floral parts compared to its complex, *P. callosum* var. *laeve* (Table 5). Conspicuously, the former species has the longest Type III non-glandular trichomes (1233.3–1533.3 μm) on the margin of its lateral petals, noticeably elongated and moniliform with topmost cell very narrow, which such trichomes were absent in the latter species. Also, glandular trichomes occurred in *P. callosum* var. *sublaeve* but lacking in *P. barbatum*. Variability of the micromorphology observed on the staminode is systematically insignificant at infrasubgeneric level. Notwithstanding, a combination of the micromorphological characteristics on staminode separates *P. barbatum* and *P. callosum* var. *sublaeve* in subgenus *Paphiopedilum*.

The existence of certain trichome types allows differentiation of the *Paphiopedilum* species from different subgenera. Unlike *P. barbatum* and *P. callosum* var. *sublaeve*, *P. niveum* contrasts by having dense hairs (Type I non-glandular trichomes) along the margin of the staminode (Fig. 4). Besides having distinctive diversity of non-glandular trichomes, the confined distribution of different types of papillae found only on the labellum for *P. callosum* var. *sublaeve* and *P. niveum* are also distinguishing. The trichomes' length and papillae' diameters were not much diverse between the studied species.

Overall, the present research suggests floral-surface features to be very useful in delimitation of the infrageneric taxa from different subgenera of the genus by epicuticular ornamentation, stomata and trichomes. The data from this study laid evidence for delimiting two confusable *Paphiopedilum* species. It provides conclusive proof to support the molecular phylogenetic analyses and validates the possibility of natural hybridization occurrence in between *P. barbatum* and *P. callosum* var. *sublaeve*. Moreover, it demonstrates that the former is indeed distinct from the latter. The floral-surface characteristics differentiate species from two different subgenera to some extent based on the presence of different types

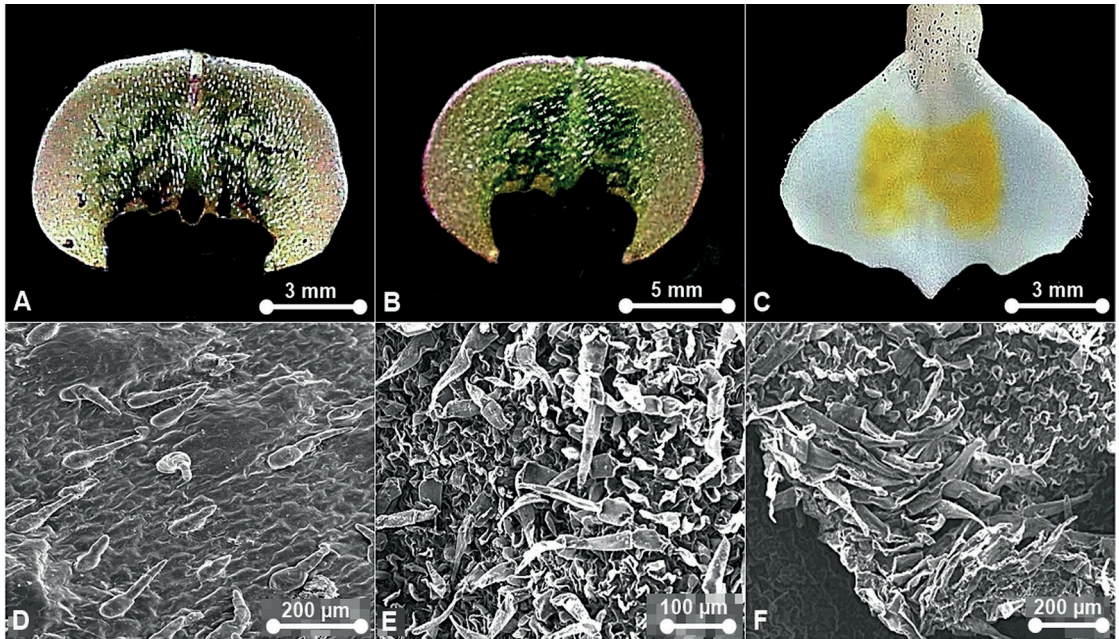


FIGURE 4. Staminode of *Paphiopedilum* and the epicuticular surface. **A, D.** *Paphiopedilum barbatum*. **B, E.** *Paphiopedilum callosum* var. *sublaeve*. **C, F.** *Paphiopedilum niveum*. Photographs by Edward Entalai Besi and Lam Shun Jia.

of epicuticular ornamentation and papillae on the labellum, and the diverse variation and distribution of the non-glandular trichomes on sepals and petals. Also, the occurrence of different formation, cuticular striation and ornamentation of stomata is of taxonomic interest in this study and can be used to identify the species.

Physioecological aspects.— The presence of dense epicuticular waxes on the floral surface of the selected Peninsular Malaysian *Paphiopedilum* species raises questions. One clear role of waxes is to protect the plant from desiccation and herbivorous insects (Davies & Turner 2004). It may or may not offer food rewards. In *Maxillaria*, one of the important ways insect attraction is achieved involves the secretion of wax-like material rich in lipids and protein (van der Pijl & Dodson 1966, Davies *et al.* 2003). It is also reported that wasps may also collect wax from the labella of *Maxillaria* (Dressler 1993). Dense waxes on the labellum of *P. callosum* var. *sublaeve* and *P. niveum* may attract potential pollinators. Male *Bactrocera* fruit flies are often observed to probe the labellum, sepals and petals of *Bulbophyllum* species. The probing and licking behaviours displayed by the flies suggests that

the pollinators' reward may be compounds released by the flower (Ong *et al.* 2011).

Orchid floral stomata are non-functional and practically closed in orchid flowers (Hew *et al.* 1980). Our finding supports this claim as the stomata found in the studied species were closed (Fig. 2K,L and Fig. 3F), or opened with a small aperture (Fig. 3E,G). Also, there were nectarostomata without a presence of guard cells (Fig. 2M), which might indicate modified stomata, cavities where the waxes are exuded through on the cuticular surface, known to occur and are of great diagnostic value in some plant species (Pant & Mehra 1965, Wilkinson 1979, Chattopadhyay *et al.* 2014, Prashanta Kumar & Krishnaswamy 2014, Baruah 2017, Verma *et al.* 2018, Besi *et al.* 2019, Besi *et al.* 2020). Notably, apertures formed by the detachment of the trichomes which could have been mistakenly identified as stomata in plant specimens (Fig. 2I,J). Waxes observed on floral surface indicates an active function of the unspecialized osmophores on the floral parts of orchid species, the regular epidermal cells secreting volatile oils (Toh *et al.* 2017). Identical to our previous finding on *Corybas* anatomical profiling work, the trichomes and stomata of the *Paphiopedilum* species offer more values on anatomical adaptations

in defence and pollination rather than for the release of fragrance (Besi *et al.* 2019). The densely hairy staminode may mimic an aphid mimicry as aphidophagous hoverflies lay eggs on false brood sites on their flowers (Bänziger *et al.* 2012, Jin *et al.* 2014). *Paphiopedilum* flowers are postulated rewardless or nectarless to the pollinators and luring hoverflies or bees by deceit (Bänziger 1996, 2011, Bänziger *et al.* 2012). This is supported by the lack of glandular trichomes, papillae and stomata occurring on the labellum and reproductive parts. However, thorough observations are lacking for Malaysian species (Leong 2014). The low occurrence of glandular trichomes, papillae and stomata on the floral parts explains the unscented flowers of *P. barbatum* and *P. callosum* var. *sublaeve*. Except, the labellum of *P. callosum* var. *sublaeve* and *P. niveum*, although lacking trichomes, are heavily clothed with papillae. Though no odour is detectable to the human nose in *P. niveum*, when a live flower is wrapped in a plastic bag for a couple of hours, *P. niveum* release a faint, pleasant fragrance (Bänziger *et al.* 2012). Therefore, the papillae may function as osmophores for *P. niveum*.

Conclusions. Features of floral parts surfaces, such as epicuticular ornamentation, stomata (formation, distribution, ornamentation and size), trichome (distribution and type) are recognized as useful to differentiate highly confusable species and delimit species from different subgenera of *Paphiopedilum*. SEM analysis of floral-surface micromorphology supports a segregation of a narrowly distributed *P. callosum* var. *sublaeve* from *P. barbatum*, a widespread species in Peninsular Malaysia. The latter species is known to produce a wide range of flower morphology

and colouration along the elevation gradients. All these diagnostic characters based on floral-surface morphology of these selected species should be used with care at intergeneric and intersubgeneric levels. It should be noted that these characters are far from being enough at this time to fully discriminate *Paphiopedilum* species in Peninsular Malaysia. A larger sampling is required to know the level of variation of the analyzed characters and to be able to make stronger conclusions. The usefulness of these floral microcharacters in biological and ecological aspects is difficult to predict based on the current preliminary finding. A further investigation on chemical compound released by *Paphiopedilum* flowers in relation to pollination mechanism is highly recommended.

ACKNOWLEDGEMENTS. We are grateful to the Forest Department Peninsular Malaysia for granting us the permit to access the studied areas. We would like to thank the UPM-KRIBB (Korea Research Institute of Bioscience and Biotechnology) Vot. 6384300 and UPM for the research funding (Putra Grant No. 9413603). Also, special gratitude to UPM and the Ministry of Higher Education Malaysia (MOHE) for sponsoring this Doctorate Degree undertaking. We thank the staffs and friends who directly or indirectly contributed to the success of this study, especially Ng Yong Jin, Tan Mui Ching, Michael Charles Rajaram, Dr. Kenny Khor and Dr. Farah Alia Nordin [Plant Taxonomist, Universiti Sains Malaysia (USM), Malaysia]. A special thanks to Dr. Mohd. Norfaizal Ghazalli [Plant Taxonomist, Malaysian Agricultural Research and Development Institute (MARDI), Malaysia] for his helpful comments on the manuscript and Prof. S.G. Tan for reviewing the manuscript and editing the English. The authors contributed equally to this paper and approved the paper for release and agree with its contents.

LITERATURE CITED

- Adedeji, O., Ajuwon, O. Y. & Babawale, O. O. (2007). Foliar epidermal studies, organographic distribution and taxonomic importance of trichomes in the family Solanaceae. *International Journal of Botany*, 3(3), 276–282.
- Angulo, M. B. & Dematteis, M. (2014). Floral microcharacters in *Lessingianthus* (Vernonieae, Asteraceae) and their taxonomic implications. *Plant Systematics and Evolution*, 300(8), 1925–1940.
- Atwood, J. (1984). The Relationships of the Slipper Orchids (Subfamily Cypripedioideae). *Selbyana*, 7, 129–247.
- Averyanov, L. V., Phan, K. L. & Nguyen, T. H. (2007). Natural intraspecific hybridization in the genus *Paphiopedilum* (Orchidaceae: Cypripedioideae) in Vietnam. *Orchids; the Magazine of the American Orchid Society*, 76, 209–219.
- Bänziger, H. (1996). The mesmerizing wart: the pollination strategy of epiphytic lady slipper orchid *Paphiopedilum villosum* (Lindl.) Stein (Orchidaceae). *Botanical Journal of the Linnean Society*, 121(1), 59–90.
- Bänziger, H. (2011). Pollination mechanisms in *Paphiopedilum* species. *Renziana*, 1, 42–43.
- Bänziger, H., Pumikong, S. & Srimuang, K. (2012). The missing link: bee pollination in wild lady slipper orchids

- Paphiopedilum thaianum* and *P. niveum* (Orchidaceae) in Thailand. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft*, 85, 1–26.
- Baran, P., Ozdemir, C. & Aktas, K. (2010). Structural investigation of the glandular trichomes of *Salvia argentea*. *Biologia*, 65, 33–38.
- Baruah, A. (2017). Peduncle, pedicel, and capsule epidermal characters of certain orchid species from North East India. *The Journal of The Orchid Society of India*, 31, 65–69.
- Besi, E. E., Lai, Y. E., Khor, H. E., Tan, M. C., Nulit, R. & Go, R. (2019). Floral-Surface Micromorphology of *Corybas selangorensis* J.Dransf. & G.Sm. and *Corybas holttumii* J.Dransf. & G.Sm. (Orchidaceae). *The Journal of The Orchid Society of India*, 33, 47–56.
- Besi, E. E., Nikong, D., Mustafa, M., Yong, C. S. Y. & Go, R. (2020). Taxonomic placement of four confusable *Crepidium* species (Orchidaceae, Malaxidinae) based on macro-and micro-morphological analyses, including a note on two new records to Peninsular Malaysia. *Phytotaxa*, 454(1), 31–44.
- Braem, G. J. (1988). *Paphiopedilum: a monograph of all tropical and subtropical Asiatic slipper orchids*. Schmersow: Brucke-Verl. 249 p.
- Bridson, D. & Forman, L. (2000). *The herbarium handbook*. 3rd Edition. Kew: Royal Botanic Gardens. 348 p.
- Burns-Balogh, P. & Hesse, M. (1988). Pollen morphology of the cypripedioid orchids. *Plant Systematics and Evolution*, 158(2-4), 165–182.
- Carpenter, K. J. (2005). Stomatal architecture and evolution in basal angiosperms. *American Journal of Botany*, 92(10), 1595–1615.
- Cash, C. (1991). *The slipper orchids*. Portland, Oregon: Timber Press. 228 p.
- Chattopadhyay, A., Pathak, P. & Mahant, K. C. (2014). Foliar features in some Indian Orchids: Subtribe Habenariinae (Orchideae, Orchidoideae). *The Journal of The Orchid Society of India*, 28, 47–59.
- Cheadle, V. I. (1942). The occurrence and types of vessels in the various organs of the plant in the Monocotyledoneae. *American Journal of Botany*, 29(6), 441–450.
- Chen, X. C., Zhu, G. H., Ji, Z. H., Lang, K. Y., Luo, Y. B. & Cribb, P. (2005). Orchidaceae. In: Z. Y. Wu & P. H. Raven (Eds), *Flora of China*. Vol. 25 (pp. 19–72). St. Louis: Science Press, Beijing and Missouri Botanical Garden.
- Chochai, A., Leitch, I. J., Ingrouille, M. J. & Fay, M. F. (2012). Molecular phylogenetics of *Paphiopedilum* (Cypripedioideae; Orchidaceae) based on nuclear ribosomal *ITS* and plastid sequences. *Botanical Journal of the Linnean Society*, 170, 176–196.
- Choi, J. S. & Kim, E. S. (2013). Structural features of glandular and non-glandular trichomes in three species of *Mentha*. *Applied Microscopy*, 43(2), 47–53.
- Cribb, P. J. (1998). The genus *Paphiopedilum*. 2nd Edition. Kota Kinabalu: Natural History Publications. 427 p.
- Davies, K. L. & Turner, M. P. (2004). Morphology of floral papillae in *Maxillaria* Ruiz & Pav. (Orchidaceae). *Annals of Botany*, 93(1), 75–86.
- Davies, K. L., Turner, M. P. & Gregg, A. (2003). Lipoidal labellar secretions in *Maxillaria* Ruiz & Pav. (Orchidaceae). *Annals of Botany*, 91, 439–446.
- Dressler, R. L. (1993). *Phylogeny and classification of the orchid family*. Massachusetts: Cambridge University Press. 314 p.
- Duncan, R. E. & Macleod, R. A. (1949). The chromosomes of the continental species of *Paphiopedilum* with solid green leaves. *American Orchid Society Bulletin*, 18, 84–89.
- Fahn, A. (1988). Secretory tissues in vascular plants. *New Phytologist*, 108(3), 229–257.
- Ghazalli, M. N., Tamizi, A. A., Esa, M. I. M., Besi, E. E., Nikong, D., Nordin, A. R. M. & Zaini, A. Z. (2019). The systematic significance of leaf epidermal micro-morphology of ten *Nepenthes* species (Nepenthaceae) from Peninsular Malaysia. *Reinwardtia*, 18(2), 81–96.
- Ghimire, B., Jeong, M. J., Suh, G. U., Heo, K. & Lee, C. H. (2018). Seed morphology and seed coat anatomy of *Fraxinus*, *Ligustrum* and *Syringa* (Oleaceae: Oleaceae) and its systematic implications. *Nordic Journal of Botany*, 36(10), e01866.
- Govaerts, R., Bernet, P., Kratochvil, K., Gerlach, G., Carr, G., Alrich, P., Pridgeon, A. M., Pfahl, J., Campacci, M. A., Baptista, D. H., Tigges, H., Shaw, J., Cribb, P., George, A., Kreuz, K. & Wood, J. J. (2021). *World Checklist of Orchidaceae*. Kew: The Board of Trustees of the Royal Botanic Gardens. Available from <http://apps.kew.org/wcsp/> [Accessed on 9 April 2021].
- Guan, Z. J., Zhang, S. B., Guan, K. Y., Li, S. Y. & Hu, H. (2011). Leaf anatomical structures of *Paphiopedilum* and *Cypripedium* and their adaptive significance. *Journal of Plant Research*, 124(2), 289–298.
- Hew, C. S., Lee, G. L. & Wong, S. C. (1980). Occurrence of non-functional stomata in the flowers of tropical orchids. *Annals of Botany*, 46(2), 195–201.

- Holm, T. (1904). The root-structure of North American terrestrial Orchideae. *American Journal of Science*, 168, 197–212.
- Jin, X. H., Ren, Z. X., Xu, S. Z., Wang, H., Li, D. Z. & Li, Z. Y. (2014). The evolution of floral deception in *Epipactis veratrifolia* (Orchidaceae): from indirect defense to pollination. *BMC Plant Biology*, 14(1), 63.
- Karasawa, K. (1979). Karyomorphological studies in *Paphiopedilum*, Orchidaceae. *Bulletin of the Hiroshima Botanical Garden*, 2, 1–149.
- Karasawa, K. & Aoyama, M. (1988). Karyomorphological studies on two species of *Paphiopedilum*. *Bulletin of the Hiroshima Botanical Garden*, 10, 1–6.
- Ko, K. N., Lee, K. W., Lee S. E. & Kim, E. S. (2007). Development and ultrastructure of glandular trichomes in *Pelargonium* × *fragrans* ‘mabel grey’ (Geraniaceae). *Journal of Plant Biology*, 50(3), 362–368.
- Kong, M. J. & Hong, S. P. (2018). The taxonomic consideration of floral morphology in the *Persicaria* sect. *Cephalophilon* (Polygonaceae). *Korean Journal of Plant Taxonomy*, 48(3), 185–194.
- Leong, P. K. F. (2014). Flora of Peninsular Malaysia – Cyripedioideae. *Malesian Orchid Journal*, 13, 113–127.
- McGough, H. N., Roberts, D. L., Brody, C. & Kowalczyk, J. (2006). An introduction to slipper orchids covered by the Convention of International Trade in Endangered Species. Kew: Royal Botanical Gardens. Available at <http://kew.org/conservation/CITES> [Accessed on November 3, 2019].
- Newton, G. D. & Williams, N. H. (1978). Pollen morphology of the Cyripedioideae and the Apostasioideae (Orchidaceae). *Selbyana*, 2(2/3), 169–182.
- Ong, P. T., Hee, A. K. W., Wee, S. L. & Tan, K. H. (2011). The attraction of flowers of *Bulbophyllum* (Section *Sestochilus*) to *Bactrocera* fruit flies (Diptera: Tephritidae). *Malesian Orchid Journal*, 8, 93–102.
- Pant, D. D. & Mehra, B. (1965). Ontogeny of stomata in some Rubiaceae. *Phytomorphology: An International Journal of Plant Morphology*, 15(3), 300–310.
- Peterson, R. L. & Vermeer, J. (1984). Histochemistry of trichomes. In: E. Rodriguez, P. L. Healey & J. Mehta (Eds.), *Biology and chemistry of plant trichomes* (pp. 71–94). New York: Plenum Press.
- Pfitzer, E. H. H. (1903). Orchidaceae-pleonandrae. In: A. Engler (Ed.), *Das Pflanzenreich*, 12(Iv. 50) (pp. 27–42). Leipzig : Verlag von Wilhelm Engelmann (Druck von Breitkopf & Härtel in Leipzig).
- Piowarczyk, R. (2015). Seed micromorphology of central European *Orobanche* and *Phelipanche* (Orobanchaceae) in relation to preferred hosts and systematic implications. *Australian Systematic Botany*, 28(3), 124–136.
- Prashanta Kumar, H. G. & Krishnaswamy, K. (2014). Preliminary leaf epidermal studies in a few epiphytic orchids. *The Journal of The Orchid Society of India*, 28, 91–97.
- Rajaram, M. C., Yong, C. S. Y., Gansau, J. A. & Go, R. (2019). DNA barcoding of endangered *Paphiopedilum* species (Orchidaceae) of Peninsular Malaysia. *Phytotaxa*, 387(2), 94–104.
- Rankou, H. (2015a). *Paphiopedilum barbatum*. *The IUCN Red List of Threatened Species 2015*, e.T43320121A43327794. Doi: <http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T43320121A43327794.en>
- Rankou, H. (2015b). *Paphiopedilum niveum*. *The IUCN Red List of Threatened Species 2015*, e.T43321552A43327924. <http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T43321552A43327924.en>
- Rankou, H. (2015c). *Paphiopedilum rothschildianum*. *The IUCN Red List of Threatened Species 2015*, e.T43322055A43327969. <http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T43322055A43327969.en>
- Rankou, H. (2015d). *Paphiopedilum sanderianum*. *The IUCN Red List of Threatened Species 2015*, e.T43322127A43327974. <http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T43322127A43327974.en>
- Rankou, H. & O’Sullivan, R. (2015). *Paphiopedilum stonei*. *The IUCN Red List of Threatened Species 2015*, e.T43322204A43327989. <http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T43322204A43327989.en>
- Rankou, H., Averyanov, L. & Svengsuksa, B. (2015). *Paphiopedilum callosum*. *The IUCN Red List of Threatened Species 2015*, e.T191704A1999308. <http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T191704A1999308.en>
- Rosso, S. W. (1966). The vegetative anatomy of the Cyripedioideae (Orchidaceae). *Botanical Journal of the Linnaean Society*, 59, 309–341.
- Savvides, A., Fanourakis, D. & van Ieperen, W. (2011). Co-ordination of hydraulic and stomatal conductance across light qualities in cucumber leaves. *Journal of Experimental Botany*, 63(3), 1135–1143.
- Seidenfaden, G. & Wood, J. J. (1992). *The orchids of Peninsular Malaysia and Singapore*. Kew: Royal Botanic Garden. 779 p.
- Shope, J. C. & Mott, K. A. (2006). Membrane trafficking and osmotically induced volume changes in guard cells. *Journal of Experimental Botany*, 57, 4123–4131.
- Solereder, H. (1908). *Systematic anatomy of the dicotyledons: a handbook for laboratories of pure and applied botany*. (Translated by L. A. Boodle & F. E. Fritsch. Revised by D. H. Scott) 2 vols. Oxford: Clarendon Press. pp. 645–1182.

- Stpiczyńska, M., Plachno, B. J. & Davies, K. L. (2018). Nectar and oleiferous trichomes as floral attractants in *Bulbophyllum saltatorium* Lindl. (Orchidaceae). *Protoplasma*, 255(2), 565–574.
- Theobald, W. L., Krauhulik, J. L. & Rollins, R. C. (1979). Trichome description and classification. In: C. R. Metcalfe & L. Chalk (Eds.), *Anatomy of dicotyledons, Vol. 1, Second Edition* (294 p). Oxford: Clarendon Press.
- Toh, C., Mohd-Hairul, A. R., Ain, N. M., Namasivayam, P., Go, R., Abdullah, N. A. P., Abdullah, M. O. & Abdullah, J. O. (2017). Floral micromorphology and transcriptome analyses of a fragrant Vandaceous Orchid, *Vanda Mimi* Palmer, for its fragrance production sites. *BMC research notes*, 10(1), 554.
- Upchurch, G. R. (1984). Cuticle evolution in Early Cretaceous angiosperms from the Potomac Group of Virginia and Maryland. *Annals of the Missouri Botanic Garden*, 71, 522–550.
- van der Ent, A., van Vugt, R. & Wellinga, S. (2015). Ecology of *Paphiopedilum rothschildianum* at the type locality in Kinabalu Park (Sabah, Malaysia). *Biodiversity and conservation*, 24(7), 1641–1656.
- van der Pijl, L. & Dodson, C. H. (1966). *Orchid flowers, their pollination and evolution*. Coral Gables: University of Miami Press. 214 p.
- Verma, J., Thakur, K., Kusum, Sembi, J. K. & Pathak, P. (2018). Leaf micromorphology of some *Habenaria* Willd. *sensu lato* (orchidaceae) species from Western Himalaya. *The Journal of The Orchid Society of India*, 32, 103–112.
- Wilkinson, H. P. (1979). The plant surface (mainly leaf). In: C. R. Metcalfe & L. Chalk (Eds.), *Anatomy of dicotyledons, Vol. 1, Second Edition* (294 p). Oxford: Clarendon Press.
- Williams, N. H. & Broome, C. R. (1976). Scanning Electron Microscopy of orchid pollen. *American Orchid Society Bulletin*, August, 699–707.

TWO NEW SPECIES OF *OCTOMERIA* (PLEUROTHALLIDINAE) FROM CORDILLERA DEL CÓNDOR, ZAMORA CHINCHIPE, ECUADOR

LEISBERTH VÉLEZ-ABARCA^{1,4-5}, MARCO M. JIMÉNEZ^{2,4} & LUIS E. BAQUERO³⁻⁴

¹Carrera de Biología, Universidad Estatal Amazónica (Sede El Pangui), Luis Imaicela entre Azuay y Mayor Rene Ulloa, El Pangui, Zamora Chinchipe, Ecuador.

²Orquideario La Paphinia, Avenida del Ejército y Juan Izquierdo, Zamora, Zamora Chinchipe, 190102, Ecuador.

³Grupo de Investigación en Biodiversidad, Medio Ambiente y Salud BIOMAS, Carrera de Ingeniería Agroindustrial y Alimentos, Facultad de Ingeniería y Ciencias Agropecuarias, Universidad de Las Américas, Calle José Queri, Quito, Pichincha, 170137, Ecuador.

⁴Grupo Científico Calaway Dodson: Investigación y Conservación de Orquídeas del Ecuador, Quito, 170510, Pichincha, Ecuador.

⁵Author for correspondence: leis.alexis92@gmail.com

ABSTRACT. Two new species of orchids, *Octomeria pacii*, and *O. panguiensis* are described and illustrated from Cordillera del Cóndor, Ecuador; likewise, information is provided on their distribution, habitat, and conservation status. These species differ from other species in the genus by their floral and vegetative characteristics and their apparent reproductive strategy of cleistogamy. *Octomeria pacii* is similar to *Octomeria deceptrix*, but differs in the caespitose habit, the ramicauls compressed along their entire length, the narrowly elliptical leaves, the autogamous flowers, the translucent white sepals suffused with magenta and the obovate, white lip, marked with magenta. *Octomeria panguiensis* is similar to *O. weneri*, but differs by the larger, shortly repent plants with lanceolate leaves, the cleistogamous flowers, the translucent white-colored sepals, the 5-veined lateral sepals and the oblong-trilobed lip with the apical lobe tridentate.

RESUMEN. Dos nuevas especies de orquídeas, *Octomeria pacii* y *O. panguiensis*, se describen e ilustran de la Cordillera del Cóndor, Ecuador; así mismo, se brinda información sobre su distribución, hábitat y estado de conservación. Estas especies difieren de otras en el género por las características florales y vegetativas y por la aparente estrategia reproductiva de cleistogamia. *Octomeria pacii* es similar a *Octomeria deceptrix*, pero difiere en el hábito cespitoso, los ramicales comprimidos en toda su longitud, las hojas estrechamente elípticas, las flores autóгамas, los sépalos blancos translúcidos y teñidos de magenta y el labio blanco obovado, manchado con magenta. *Octomeria panguiensis* es similar a *O. weneri* pero se diferencia por las plantas más grandes y repentes, con hojas lanceoladas, las flores cleistógamas, los sépalos translúcidos de color blanco, los sépalos laterales con 5 nervaduras y el labelo oblongo trilobulado con el lóbulo apical tridentado.

KEYWORDS/PALABRAS CLAVE: Autocompatibilidad, self-compatibility, autopolinización, self-pollination, cleistogamia, cleistogamy, *Octomeria deceptrix*, *Octomeria weneri*

Introduction. *Octomeria* R.Br. includes around 160 species distributed from Belize to northern Argentina and the Antilles, with the center of diversity being from the Guianas to southern Brazil (Forster 2007, Forster *et al.* 2012, Karremans *et al.* 2019). Twenty-seven species are described from Ecuador, *Octomeria candidae* Vélez-Abarca, M.M.Jiménez & Baquero, being the most recent (Vélez-Abarca *et al.* 2020).

Plants of the genus are epiphytic, rupicolous, and more rarely, terricolous (Forster 2007); as well, repent to caespitose. The flowers are fasciculate to solitary, emerging from the apex of the ramicaul. The sepals and petals are generally similar in shape and color, but unequal in size, and the lateral sepals are free or occasionally connate. The column is semiterete, usually with a sub-apical anther and stigma, and the pol-

linarium is generally made up of eight pollinia, hence the generic name, except for one species (*O. splendida* Garay & Dunst.), which has six pollinia (Luer 2010).

Orchid species have evolved several floral characteristics that commonly ensure cross-pollination (Johnson & Steiner 2000). Based on some studies of the pollination systems in Pleurothallidinae, it has been possible to determine that the orchid species within the subtribe are generally self-incompatible (Borba *et al.* 2001). According to the recent phylogenetic studies of Pleurothallidinae, *Octomeria* together with *Atopoglossum*, *Brachionidium*, and *Sansonia* form an early diverging group called *Octomeria* affinity (Karremans 2016) and is believed to be mostly self-incompatible and myophilic (Karremans & Díaz-Morales 2019, dos Santos *et al.* 2020).

In a study carried out in *Octomeria grandiflora* Lindl. and *O. crassifolia* Lindl., self-incompatibility was confirmed. Also, these species are pollinated by flies of the Sciaridae family (Diptera), which are attracted by the nectar at the base of the lip (Barbosa *et al.* 2009). However, not all orchid species possess adaptations that ensure cross-pollination. Some have structural modifications in the flowers that ensure self-pollination, like a reduced or vestigial rostellum and a perianth which never opens (Catling 1990). Some examples of cleistogamy in Pleurothallidinae are: *Masdevallia cleistogama* Luer, some plants of *Pabstiella tripterantha* (Rchb.f.) F.Barros, *Pleurothallis cleistogama* Luer, and *Restrepiella lueri* Pupulin & Bogarín (Luer 1998, 2001, 2006, Pupulin & Bogarín 2007). Here, we described two new species of *Octomeria* recently discovered in the southeast of Ecuador with the adaptation to self-pollination, one of them exhibits cleistogamy.

Material and methods. Specimens were collected during a comparative study on the orchids of the Cordillera del Cóndor. Some of these were grown and photographed at the Orquideario la Paphinia in Zamora, Ecuador. The measurements of the vegetative and floral parts were made from living material. Photographs were taken using a Panasonic® FZ300 or Canon® EOS 1100D camera and Raynox DCR-150 50 mm, EFS 18-58 mm, and +10 Kernel Pro Optics 58 mm close-up lenses. The new species were compared to those previously described (Luer 2010, Luer 2011).

TAXONOMIC TREATMENT

Octomeria pacii Vélez-Abarca, M.M.Jiménez & Baquero, *sp. nov.* (Fig. 1, 2A, 3A, 4).

TYPE: Ecuador. Zamora: Chinchipe, Cordillera del Cóndor flank, 1010 m, 12 Oct. 2020, L. Vélez. LV0020 (holotype: ECUAMZ!).

DIAGNOSIS: Similar to *Octomeria deceptrix* Luer, but differs in the caespitose habit (*vs.* shortly repent), the ramicauls compressed along their entire length (*vs.* ramicauls terete below, compressed above) with narrowly elliptical leaves (1.5–2.5 cm wide *vs.* elliptical-ovate, 1.5–3.0 cm wide), the translucent white suffused with magenta sepals (*vs.* white to yellow, often suffused with rose), the obovate, white, marked with magenta lip, (*vs.* yellow, suffused with red-purple, oblong) and the laterally ribbed column (*vs.* smooth). *Octomeria pacii* is also distinguished by the autogamous flowers (*vs.* allogamous).

Plant medium in size, up to 23 cm tall, epiphytic, caespitose. *Roots* slender, undulated, 1 mm in diameter. *Ramicauls* stout, erect, 8–14 cm long, ancipitous below, with 3–5 internodes enclosed by imbricating, tubular sheaths, the lower sheath shorter than the rest. *Leaf* erect, coriaceous, narrowly elliptical 8–15 × 1.5–2.5 cm, sulcate adaxially and slightly carinate abaxially, margin entire, apex acute, cuneate below into a 0.5–1.5 cm long petiole. *Inflorescence* single-flowered, produced from a fascicle at the apex of the ramicaul, *peduncle* cylindrical 1 mm long; *floral bract* tubular, 3 mm long; *pedicel* cylindrical, 2 mm long; *ovary* 3.5–4.0 mm long, terete, longitudinally sulcate. *Sepals* translucent white suffused with magenta, free, glabrous. *Dorsal sepal* ovate, subacute 9–11 × 5–6 mm, 5-veined. *Laterals sepals* free, ovate, acute, 9–11 × 3–4 mm, 5-veined, oblique. *Petals* translucent white with suffused with magenta, elliptical-ovate, acute, 10–11 × 3–4 mm, 3-veined. *Lip* white, marked centrally with magenta, glabrous, panduriform, trilobated, with erose apical margins, the apex minutely cuspidate, 6.0 × 3.5 mm; the lateral lobes erect, oblique, subacute, antrorse, below the middle, the disc with a pair longitudinal, slightly crooked calli emerging at the middle; the base broadly truncate, hinged to the column-foot.

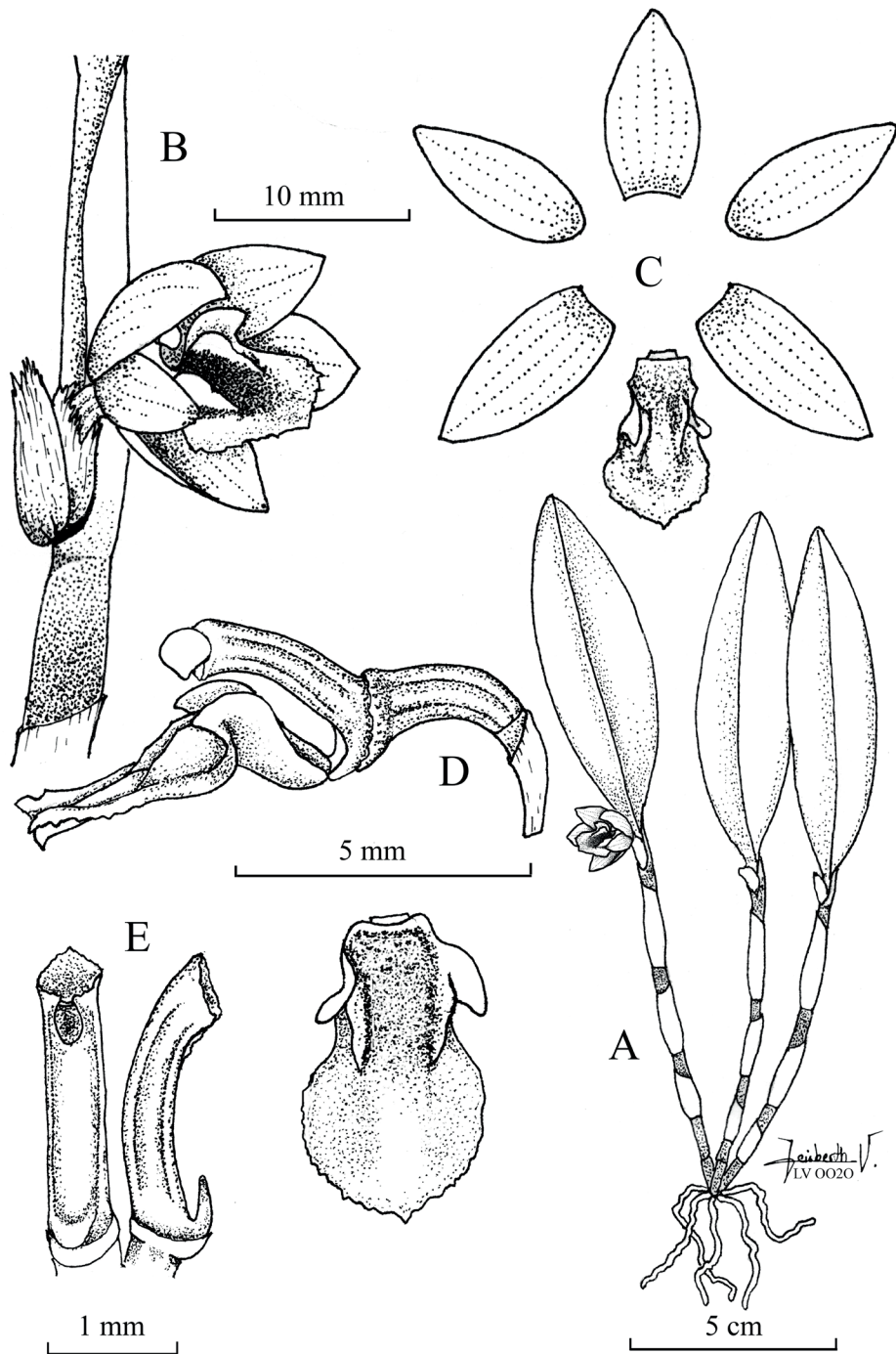


FIGURE 1. *Octomeria pacii* Vélez-Abarca, M.M.Jiménez & Baquero. **A.** Habit. **B.** Flower in 3/4 view. **C.** Dissected perianth. **D.** Part of the pedicel, ovary, column and lip in lateral view and lip adaxial view. **E.** Column in ventral and lateral view. Illustration by Leisberth Vélez, based on the holotype, *Vélez-Abarca LV-0020* (ECUAMZ).

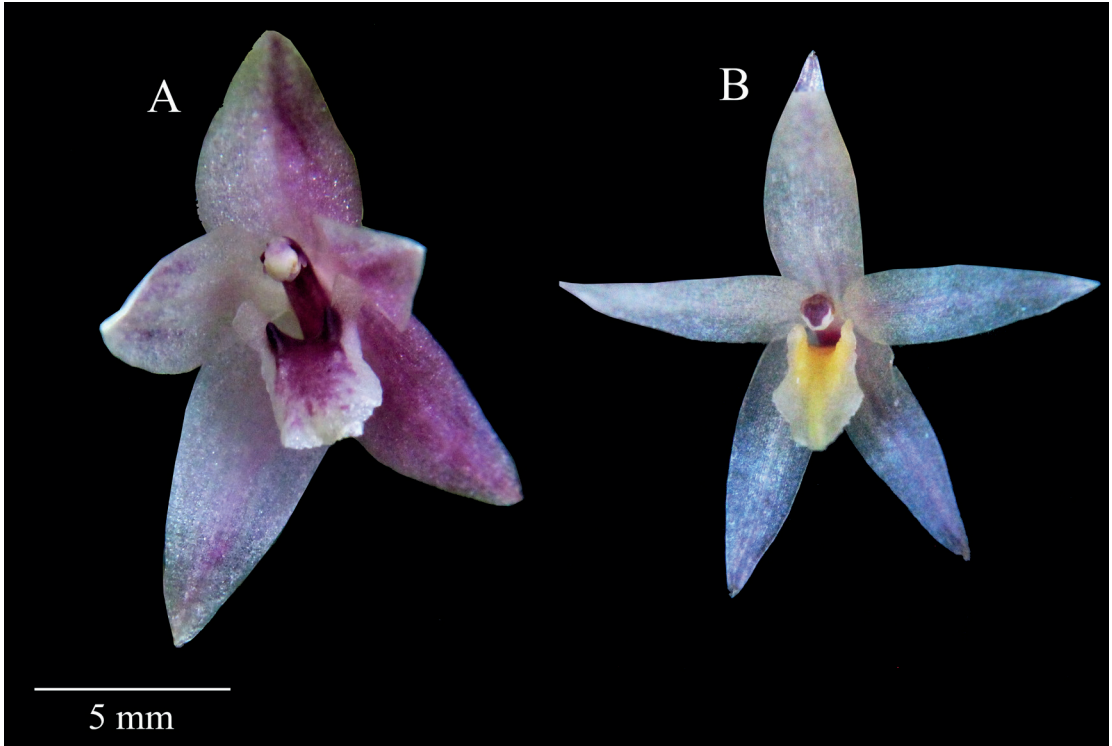


FIGURE 2. Comparison of flowers. **A.** *Octomeria pacii* Véllez-Abarca, M.M.Jiménez & Baquero, *in situ*. **B.** *Octomeria deceptrix* Luer, *in situ*. Photos by Leisberth Véllez.



FIGURE 3. Comparison of the ovary, column and lip in lateral view. **A.** *Octomeria pacii* Véllez-Abarca, M.M.Jiménez & Baquero. **B.** *Octomeria deceptrix* Luer. Photos by Marco M. Jiménez.



FIGURE 4. Comparison of the rostellum. **A.** Column of *Octomeria pacii* Vélez-Abarca, M.M.Jiménez & Baquero, with vestigial rostellum. **B.** The pollinia reaching the stigma in *O. pacii*. **C.** Column of *O. deceptrix* Luer with pronounced rostellum indicated by an arrow. Photos by Marco M. Jiménez.

Column red-purple, semiterete, ribbed longitudinally at each side, 3.0–3.5 mm long; the anther subapical and a ventral stigma, clinandrium slightly irregular, rostellum vestigial, foot 0.2–0.3 mm long. *Anther cap* white. *Pollinia* yellow, 8, in 2 sets of 4.

PARATYPE: Ecuador. Zamora-Chinchipe: near Zamora, 1278 m, 13 December 2019, M. Jiménez 843 (HUTPL!).

EPONYMY: Named after Patrick Paci, passionate lover of the forests and slipper orchids of Ecuador and generous donor and supporter of this research.

DISTRIBUTION AND HABITAT: *Octomeria pacii* grows as an epiphyte under the shade of small trees covered by mosses and lichens in premontane and lower montane forests over a sandstone plateau of the Cordillera del Cóndor. Plants generally grow in windy areas at elevations of 1000 m. This species has also been found growing in steep slopes of the eastern Andes of Ecuador, near Zamora, at an elevation of 1300 m.

Octomeria pacii is very similar to *O. deceptrix* (Fig. 2B, 3B, 4C), but it differs in the caespitose habit with an inconspicuous rhizome (*vs.* shortly repent rhizome), the compressed ramicauls (*vs.* ramicauls terete below, slightly compressed above), leaf narrowly elliptical, 8–15 × 1.5–2.5 cm (*vs.* elliptical-ovate, 5–7 × 1.5–3.0 cm), the longer ovary, 3.5–4.0 mm long (*vs.* 2.5–3.0 mm long). The flowers have translucent white sepals suffused with magenta (*vs.* white to yellow, often suffused with rose), the dorsal sepal is ovate and wider, 0.9–1.1 × 0.5–0.6 cm, 5-veined (*vs.* the elliptical-obovate dorsal sepal, 0.6–0.9 × 0.2–0.3 cm, 3-veined) and the petals are wider, 3–4 mm wide (*vs.* 2–2.5 mm wide). The lip is white, marked with magenta, glabrous, obovate, 3.5–4.0 × 6.0–6.5 mm (*vs.* the lip yellow, suffused with red-purple, oblong, 4.7–5.0 × 2.0 mm), the midlobe suborbicular with a slightly cuspidate apex, (*vs.* subpentagonal with the apex subtruncate or obtuse,) and the disc with prominent calli (*vs.* low). It is also distinguished by the laterally ribbed column (*vs.* smooth) and the autogamous flowers (*vs.* allogamous). *Octomeria pacii* shows a unique floral feature: the presence of two longitudinal ribs, one at each side of the column compared to the smooth and terete column of the rest of the species in the genus.

About one year ago, we tracked the species, and

we observed capsule production in all flowers that caught our attention. Therefore, four specimens were cultivated for eight months, and the same seed pod production was observed without withering of any flower. While dissecting the flower of the species for the line drawing, it was noted repeatedly that the pollinia easily entered the stigma (Fig. 4B). This because flowers lack a prominent rostellum that prevents self-pollination (Catling 1991) as in other *Octomeria* species (Fig. 4). *Octomeria pacii* has a vestigial rostellum (Fig. 4A) and we assume that it could influence the successful production of capsules in each flower. In the future, it should be demonstrated if the species is self-pollinated and if the seed are viable.

CONSERVATION STATUS: This species has been only recorded in the province of Zamora Chinchipe. Populations of this species grow in poorly managed and disturbed forests, where mining is practiced. Although numerous individuals have been found, the species is at risk due to its occurrence outside protected areas where habitat destruction is rampant.

Octomeria panguiensis Vélez-Abarca, M.M.Jiménez & Baquero, *sp. nov.* (Fig. 5–7A).

TYPE: Ecuador. Zamora: Chinchipe, Cordillera del Cóndor flank, 890 m, 17 Aug. 2020, L. Vélez LV 0012 (holotype: ECUAMZ!).

DIAGNOSIS: Similar to *Octomeria weneri* Luer & Thorerl in the cleistogamous flowers, but differs by the larger plants (up to 33.0 cm tall *vs.* 10.5 cm), shortly repent (*vs.* caespitose) with lanceolate leaves (*vs.* narrowly elliptical), the translucent white-colored sepals (*vs.* light rose-colored), the 5-veined lateral sepals (*vs.* 4-veined), and the oblong-trilobed lip with the apical lobe tridentate (*vs.* panduriform with subretuse apical lobe).

Plant large, up to 33 cm tall, epiphytic, shortly repent. *Rhizome* stout, 6–8 mm thick, 6–12 mm long between ramicauls. *Roots* slender, flexuous, 1 mm in diameter. *Ramicauls* stout, suffused with purple, erect, 12–20 cm long, compressed, ancipitous below, with 4–5 internodes enclosed by imbricating, tubular sheaths, the lower one shorter than the others, which tear with age. *Leaf* erect, coriaceous, narrowly elliptical to lanceolate, 15–22 × 2.5–3.5 cm,

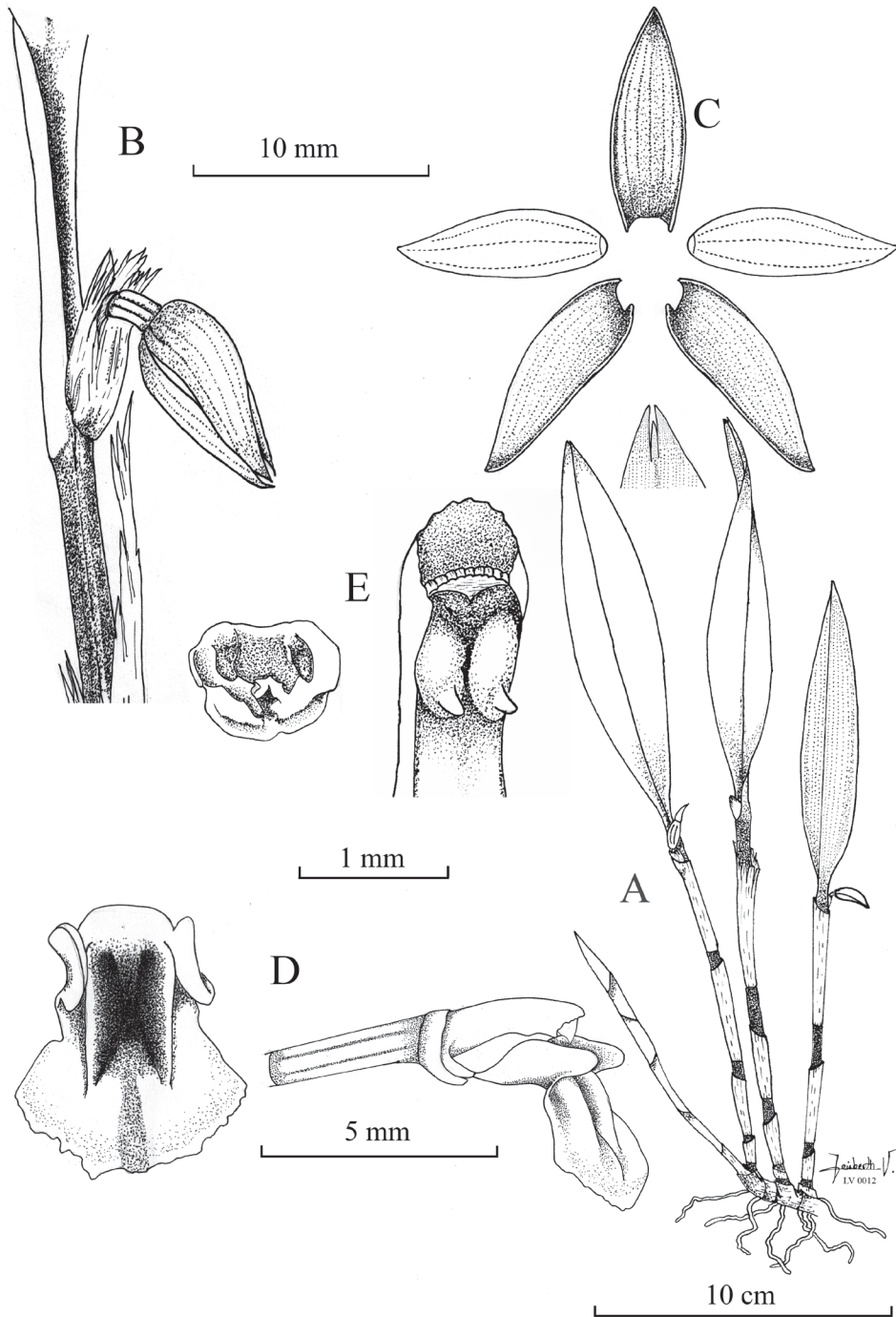


FIGURE 5. *Octomeria panguiensis* Vélez-Abarca, M.M.Jiménez & Baquero. **A**. Habit. **B**. Autogamous flower in 3/4 view. **C**. Dissected perianth. **D**. Lip in adaxial view and part of the pedicel, ovary, column and lip in lateral view. **E**. Anther cap in abaxial view and column in abaxial view and apex of the column in ventral view. Illustration by Leisberth Vélez, based on the holotype, *Vélez-Abarca LV-0012* (ECUAMZ).

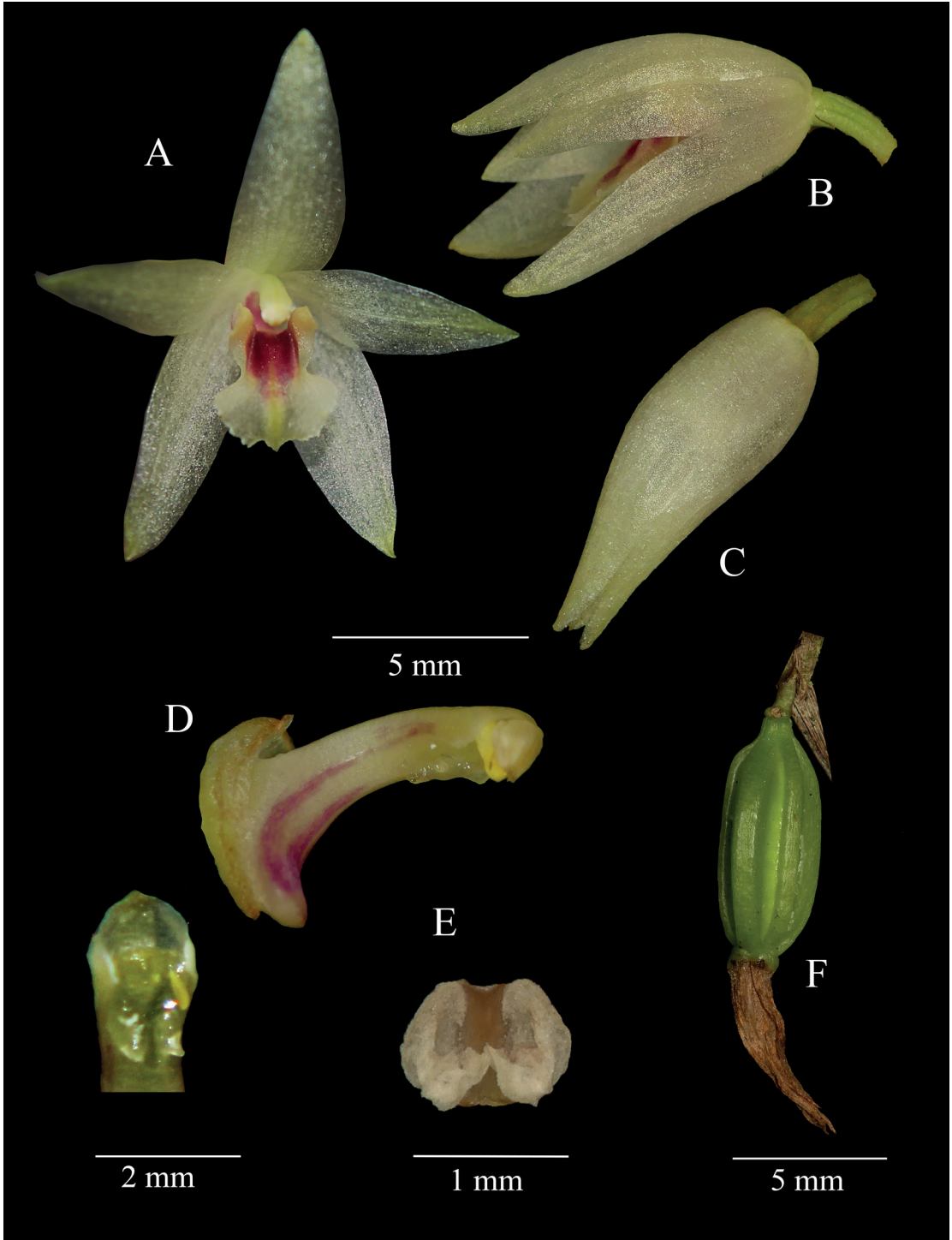


FIGURE 6. Flower parts and fruit of *Octomeria pangiensis* Vélez-Abarca, M.M.Jiménez & Baquero. **A.** Flower fully open. **B.** Flower in partially open state. **C.** Flower fully closed. **D.** Column viewed laterally. **E.** Anther cap seen abaxially. **F.** Capsule. Figure by Leisberth Vélez from photos by Lesiberth Vélez and Marco M. Jiménez.

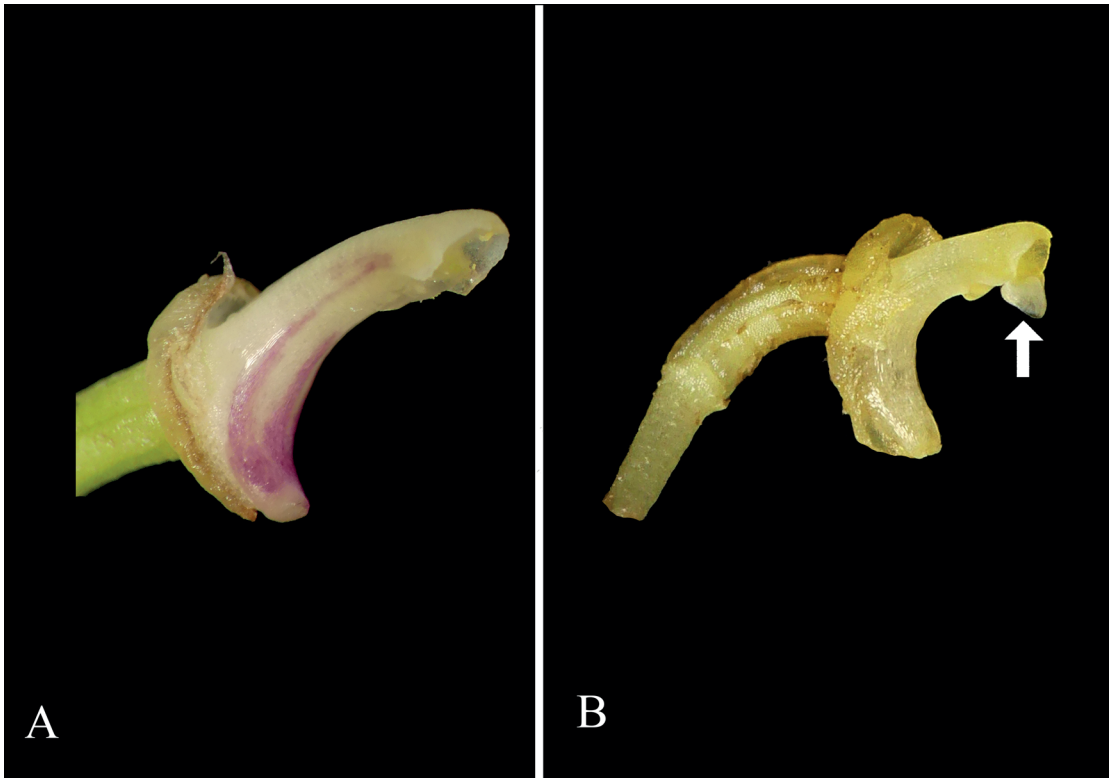


FIGURE 7. Comparison of the rostellum. **A.** *Octomeria panguiensis* Vélez-Abarca, M.M.Jiménez & Baquero, with vestigial rostellum. **B.** *Octomeria doucetteana* Doucette ex L.E.Matthews, with pronounced well-developed rostellum. Photos by Marco M. Jiménez.

cuneate below into a 1.0–1.5 cm long petiole, the mid-vein sulcate adaxially and slightly carinate abaxially, margin entire, involute, apex tridentate, and slightly acuminate. *Inflorescence* 1–3 single simultaneous flowers in a fascicle from the apex of the ramicaul, cleistogamous, rarely partially opened, peduncle cylindrical, 1.0–1.5 mm long; *floral bract* tubular, 3 mm long; *pedicel* cylindrical, 4 mm long; *ovary* 5–6 mm long, terete, longitudinally sulcate. *Sepals* translucent white-colored, with yellowish-green apex, free, glabrous, slightly concave. *Dorsal sepal* elliptical, acute 1.0–1.2 × 0.3–0.4 cm, 5-veined. *Lateral sepals*, elliptical, acute, slightly oblique, 1.0–1.2 × 0.3–0.4 cm, 5-veined. *Petals* translucent white, elliptic to ovate, apex yellowish green, acute, 0.8–0.9 × 0.3–0.4 cm, 3-veined. *Lip* whitish yellow, the disc marked with red-purple, glabrous, oblong-trilobed, erose margins towards the apex, 5–6 × 3–4 mm, the lateral lobes erect, oblique, rounded at the tip, antrorse; the middle lobe, broadly

spatulate, broadly tridentate at the apex, the margins minutely erose, the disc with a pair of longitudinal calli born close to the base which extend up to the second third of the lip; the base broadly truncate, hinged to the tip of the column foot. *Column* white semiterete, 3.5–4.0 mm long, stigma ventral, with two short, fang-like structures at the lower side of the stigma, clinandrium slightly irregular, rostellum vestigial. *Anther cap* subapical 1.0 × 0.8 mm, white. *Pollinia* 8, in 2 sets of 4, yellow. *Fruit* cylindrical to fusiform with three longitudinal keels, 6 × 3 mm.

Eponymy: Named after El Pangui canton, in southeast Ecuador, where the species was discovered.

Distribution and Habitat: *Octomeria panguiensis* is known only from the Shagmi mountain range in the Cordillera del Cóndor region, Zamora Chinchipe province, southern Ecuador. It grows as an epiphyte, forming dense populations at the bases of trees on the slopes of a sandstone plateau. The elevation range of

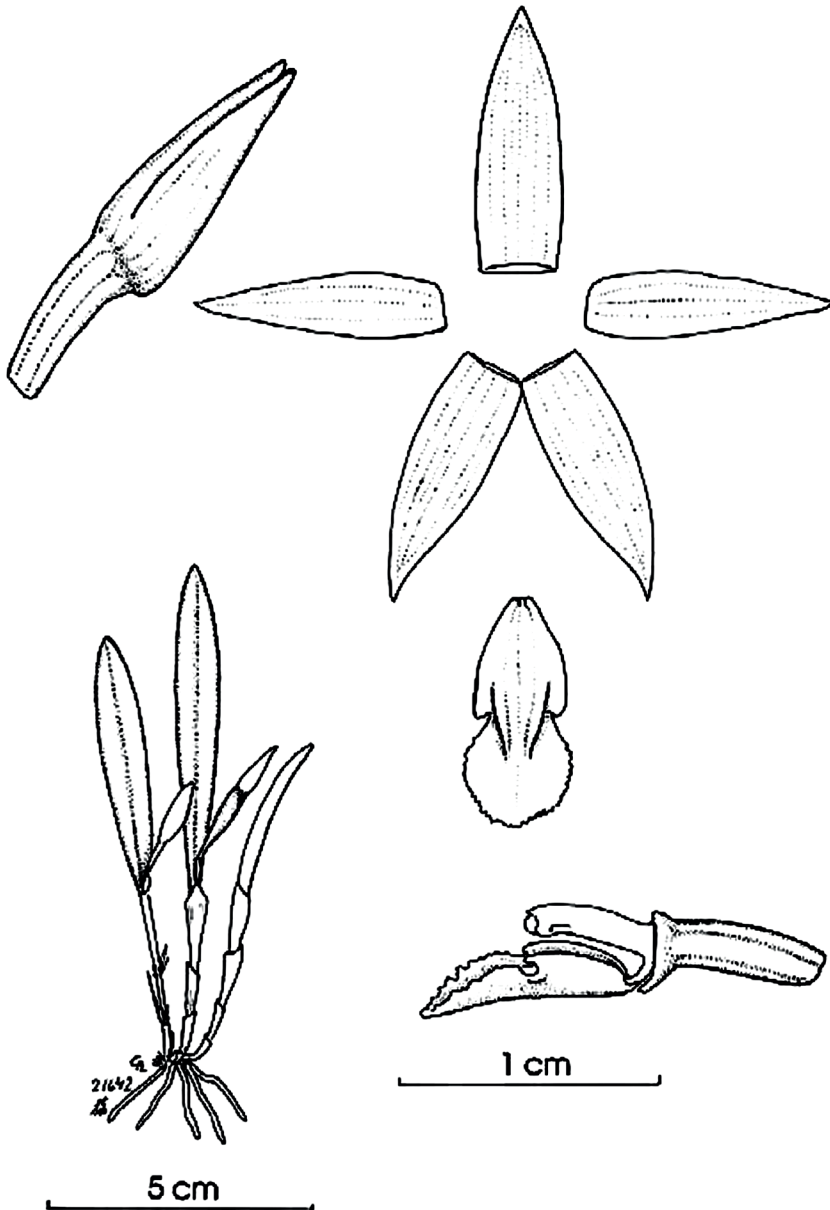


FIGURE 8. Drawing of *Octomeria weneri* Luer & Thoele. Original drawings by Carlyle Luer, Courtesy of the Harvard University Herbaria.

this species goes from 890 to 1000 m of elevation. It is not selective in its host.

The most similar species to *Octomeria panguiensis* is *O. weneri* (Fig. 8); both species are found in south-eastern Ecuador and are cleistogamous. The main feature that distinguishes them is the size of the plants and flowers, *O. panguiensis* triples in size to *O. weneri*. Also, the leaf-ramicaul ratio is different, *O. panguiensis* has shorter leaves than the ramicauls; in contrast, *O. weneri* has longer leaves than the ramicauls.

Octomeria is mainly characterized by being self-incompatible (dos Santos *et al.* 2020). Luer (2011) published the first cleistogamous species of the genus from Ecuador, naming it *O. weneri*. *Octomeria panguiensis* is the second Ecuadorian species that bears cleistogamous flowers (Fig. 6C) and is self-pollinated. Ordinarily, the rostellum acts as a mechanical barrier that prevents contact between the pollinarium and the stigmatic cavity of the flower, avoiding self-pollination (Catling 1991, Arditti 1992), for example, *Octomeria doucetteana* Doucette ex L.E. Matthews, has a fairly developed rostellum (Fig. 7B). In *O. panguiensis*, cleistogamy happens because most of the flowers never open (except for two observed flowers since it was discovered) and due to the presence of a vestigial rostellum (Fig. 6D, 7A) that would malfunction as a mechanical barrier between the pollinarium and the stigma, thus allowing autogamy. It has been possible to observe the flowers of *O. panguiensis* in three states: from about 100 observed flowers *in situ* belonging to 40 specimens, the most common state was with completely closed flowers. In contrast, partially open and completely open has been observed only once for each case (Figs. 6A–B). No partially open to open flowers have been observed *in situ*.

CONSERVATION STATUS: The primary forests of the El Pangui canton are characterized by severe human im-

pact due to timber and mineral extraction, which leads to the modification and loss of the native vegetation. *Octomeria panguiensis* is known from a single population in the Cordillera del Cóndor. Considering the high endemism of several taxa in the Pleurothallidinae (for example *Octomeria condorensis* Luer & Hirtz, *Masdevallia condorensis* Luer & Hirtz, *Porroglossum dactylum* Luer, *Pleurothallis paquishae* to) at the Cordillera del Cóndor and one year long *in situ* research, *O. panguiensis* is not expected to grow elsewhere. Adding that the site where *O. panguiensis* is known from and other potential areas are under mining activities (both legal concessions by the Ecuadorian government and illegal mining), the species described here is considered under threat. Based in the IUCN categorization by applying the B1 criteria (extent of occurrence) and the conditions bi, ii, and iii (continuing decline observed, estimated, inferred or projected in any of (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals) and ci, ii and iii (extreme fluctuations in any of (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals) *O. panguiensis* is recommended as an endangered species.

ACKNOWLEDGMENTS. We acknowledge Mark Wilson for helping with language corrections and other observations to the manuscript. To the Ministerio del Ambiente (MAE) for granting the Research Permits No. 037-2019-IC-FLO-FAU-DPAZCH-UPN-VS/MA and 21-2019-IC-FLO-FAU-DPAZCH-UPN-VS/M. We thank the staff of Harvard University Herbaria for letting us use the drawing of the species for comparisons. We thank Universidad Estatal Amazónica (UEA) and Universidad de las Américas (UDLA) for promoting and funding orchid research in Ecuador. We also acknowledge the reviewers of this manuscript for helping with comments and corrections.

LITERATURE CITED

- Arditti, J. (1992). *Fundamentals of Orchid Biology*. New York, USA: John Wiley & Sons.
- Barbosa, A. R., de Melo, M. C. & Borba, E. L. (2009). Self-incompatibility and myophily in *Octomeria* (Orchidaceae, Pleurothallidinae) species. *Plant Systematics and Evolution*, 283(1–2), 1.
- Borba, E. L., Semir, J., Shepherd, G. J. (2001). Self-incompatibility, inbreeding depression and outcrossing potential in five species of *Pleurothallis* (Orchidaceae). *Annals of Botany*, 88, 89–99
- Catling, P. M. (1990). Auto-pollination in the Orchidaceae. In J. Arditti (Ed.), *Orchid biology: reviews and perspectives*. V (pp. 121–158). Portland, OR, USA: Timber Press.

- Catling, P. M. (1991). A synopsis of breeding systems and pollination in North American orchids. *Lindleyana*, 6, 187–210.
- dos Santos, T. F., Amano, E., dos Santos Forstner, A. C., Toscano de Brito, A. L. V. & Smidt, E. D. C. (2020). Estudios florales en *Octomeria* R.Br. (Orchidaceae: Pleurothallidinae). *Feddes Repertorium*, 131(2), 101–110.
- Forster, W. (2007). Estudo taxonômico das espécies com folhas planas a conduplicadas do gênero *Octomeria* R.Br. (Orchidaceae). Ph.D. Thesis, Universidade de São Paulo, São Paulo, 270 pp.
- Forster, W., Castro, V. & de Barros, F. (2012). Three new species of *Octomeria* (Orchidaceae: Pleurothallidinae) from northern South America. *Kew Bulletin*, 67, 487–493.
- Johnson, S. D. & Steiner, K. E. (2000). Generalization versus specialization in plant pollination systems. *Trends in Ecology and Evolution*, 15, 140–143.
- Karremans, A. P. (2016). *Genera Pleurothallidarum*: an updated phylogenetic overview of Pleurothallidinae. *Lankesteriana*, 16(2), 219–241.
- Karremans, A. P. & Díaz-Morales, M. (2019). The Pleurothallidinae: Extremely high speciation driven by pollinator adaptation. In A. M. Pridgeon & A. R. Arosemena (Eds), *Proceedings of the 22nd World Orchid Conference* (pp. 363–388). Guayaquil, Ecuador: Asociación Ecuatoriana de Orquideología.
- Karremans, A.P., Aguilar-Sandí, D., Artavia-Solís, M., Cedeño-Fonseca, M., Chinchilla, I. F., Gil-Amaya, K., Rojas-Alvarado, G., Solano-Guindon, N. & Villegas-Murillo, J. (2019). Nomenclatural notes in the Pleurothallidinae (Orchidaceae): miscellaneous. *Phytotaxa*, 406(5), 259–270.
- Luer, C. A. (1998). *Icones Pleurothallidarum* XVII. Systematics of Subgen. *Pleurothallis* Sect. *Abortivae* Sect. *Truncatae* Sect. *Pleurothallis* Subsect. *Acroniae* Subsect. *Pleurothallis* Subgen. *Dracontia* Subgen. *Unciferia*: Addenda to *Dracula*, *Lepanthes*, *Masdevallia*, *Porroglossum* and *Scaphosepalum*. *Monographs in Systematic Botany of the Missouri Botanical Garden*, 72, 1–121.
- Luer, C. A. (2001). *Icones Pleurothallidarum* XXII. Systematics of *Masdevallia*. Part Three. *Monographs in Systematic Botany from the Missouri Botanical Garden*, 86, 510–780.
- Luer, C. A. (2006). *Icones Pleurothallidarum* XXVIII. Reconsideration of *Masdevallia*, and the Systematics of *Specklinia* and vegetatively similar genera (Orchidaceae). *Monographs in Systematic Botany from the Missouri Botanical Garden*, 105, 1–274.
- Luer, C. A. (2010). *Icones Pleurothallidarum* XXXI. *Lepanthes* of Bolivia, Systematics of *Octomeria* Species North and West of Brazil, Addenda: New Species of *Brachionidium*, *Lepanthes*, *Masdevallia*, *Octomeria*, *Platystele*, *Pleurothallis*, and *Porroglossum*. Corrigenda. *Monographs in Systematic Botany from Missouri Botanical Garden*, 120, 1–154.
- Luer, C. A. (2011). Miscellaneous new species in the Pleurothallidinae (Orchidaceae) excluding species from Brazil. *Harvard Papers in Botany*, 16(2), 311–360.
- Pupulin, F., & Bogarín, D. (2007). A second species of *Restrepiella* (Orchidaceae: Pleurothallidinae). *Willdenowia*, 37(1), 323–329.
- Vélez-Abarca, L., Jiménez, M. M., & Baquero, L. E. (2020). *Octomeria candidae* (Orchidaceae: Pleurothallidinae), a new species from the Cordillera del Cóndor, Ecuador. *Lankesteriana*, 20(3), 345–351.

A NEW SPECIES OF *EURYSTYLES* (ORCHIDACEAE) IS EXPOSED BY A FIERCE HURRICANE IN PUERTO RICO

JAMES D. ACKERMAN^{1,3} & LUIS ORTIZ JORDAN²

¹Department of Biology, University of Puerto Rico, 17 Avenida Universidad Suite 1701, San Juan, Puerto Rico 00925-2537, U.S.A.

²815 Promenade Way, Apt 204, Jupiter, FL 34458, U.S.A.

³Author for correspondence: ackerman.upr@gmail.com

ABSTRACT. A new species of *Eurystyles* (Orchidaceae: Orchidoideae, Cranichideae, Spiranthinae) is proposed, *E. luisortizii* Ackerman *sp. nov.*, which is most similar to *E. ananassocomos* (Rchb.f.) Schltr. from which it differs by a suite of floral traits. This species represents the first confirmed record of the genus for the island of Puerto Rico, bringing the *Eurystyles* species count for the West Indies to four.

RESUMEN. Se propone una nueva especie de *Eurystyles* (Orchidaceae: Orchidoideae, Cranichideae, Spiranthinae), *E. luisortizii* Ackerman *sp. nov.*, la cual es similar a *E. ananassocomos* (Rchb.f.) Schltr., de la que se diferencia por un conjunto de rasgos florales. Esta especie representa el primer registro confirmado del género para la isla de Puerto Rico, lo que eleva el recuento de especies de *Eurystyles* para las Indias Occidentales a cuatro.

KEYWORDS/PALABRAS CLAVE: Cranichideae, Flora de Puerto Rico, Orchidoideae, orquídeas de las Indias Occidentales, Puerto Rico flora, Spiranthinae, West Indies orchids

Introduction. The genus *Eurystyles* Wawra (Orchidaceae: Orchidoideae: Cranichideae; Spiranthinae) comprises of approximately 24 species and is widely distributed from Mexico, Greater Antilles, Central America to South America (Salazar *et al.* 2018, Bogarín 2020). Recently, three species have been reported for the West Indies (Ackerman *et al.* 2014). While no previous specimens of *Eurystyles* from Puerto Rico are known, there has been an unpublished report of the *E. ananassocomos* (Rchb.f.) Schltr. from the early 1970s. Professor Roy Woodbury of the University of Puerto Rico, Río Piedras, found a specimen on Cerro La Santa of the Sierra de Cayey, displayed it at a local orchid show but did not make a specimen of it. Unfortunately, the plant perished, and the locality was soon cleared and flattened to construct communication towers (Woodbury *pers. com.* 1981). Subsequent searches by Woodbury and others (including JDA) proved unsuccessful (Ackerman 1995). While Woodbury was a very good floristic botanist with a special interest in orchids, his determination that the plant was *E. ananassocomos* may be doubtful. Until Donald D. Dod (1977, 1978) studied the genus in Hispaniola, all *Eurystyles* in the West Indies were regarded as *E. ananassocomos*. We now know that there are at least three

species in the Greater Antilles, and *E. ananassocomos* is verified for only Jamaica (the type locality) and Hispaniola (Ackerman *et al.* 2014).

For nearly five decades, no new sightings of *Eurystyles* in Puerto Rico had been made until two months after the devastating September 2017 Hurricane María, a category four storm with sustained winds 250 km/h. One of us (Luis) was hiking on a ridge above Lago Garzas in the municipality of Adjuntas near his family's coffee farm. While walking the trail and climbing over and around broken and fallen tree trunks and branches, he found several plants of *Eurystyles* on a tree trunk. Luis looked among the numerous broken trees in the area but did not find other plants of *Eurystyles*. Then in the next season (December 2018), with Luis no longer on the island, JDA located the trail using Luis's geographical coordinates. Unfortunately, the forest was so damaged that the trail was impassable due to fallen trees, massive invasive grasses, and smothering vines that had grown up since the storm.

Upon examination of the specimens that Luis collected, we concluded that they were similar to the specimen of *E. ananassocomos* that Bobbi Angell illustrated for the Orchid Flora of the Greater Antilles, but differed by having slightly smaller flowers, a lip lack-

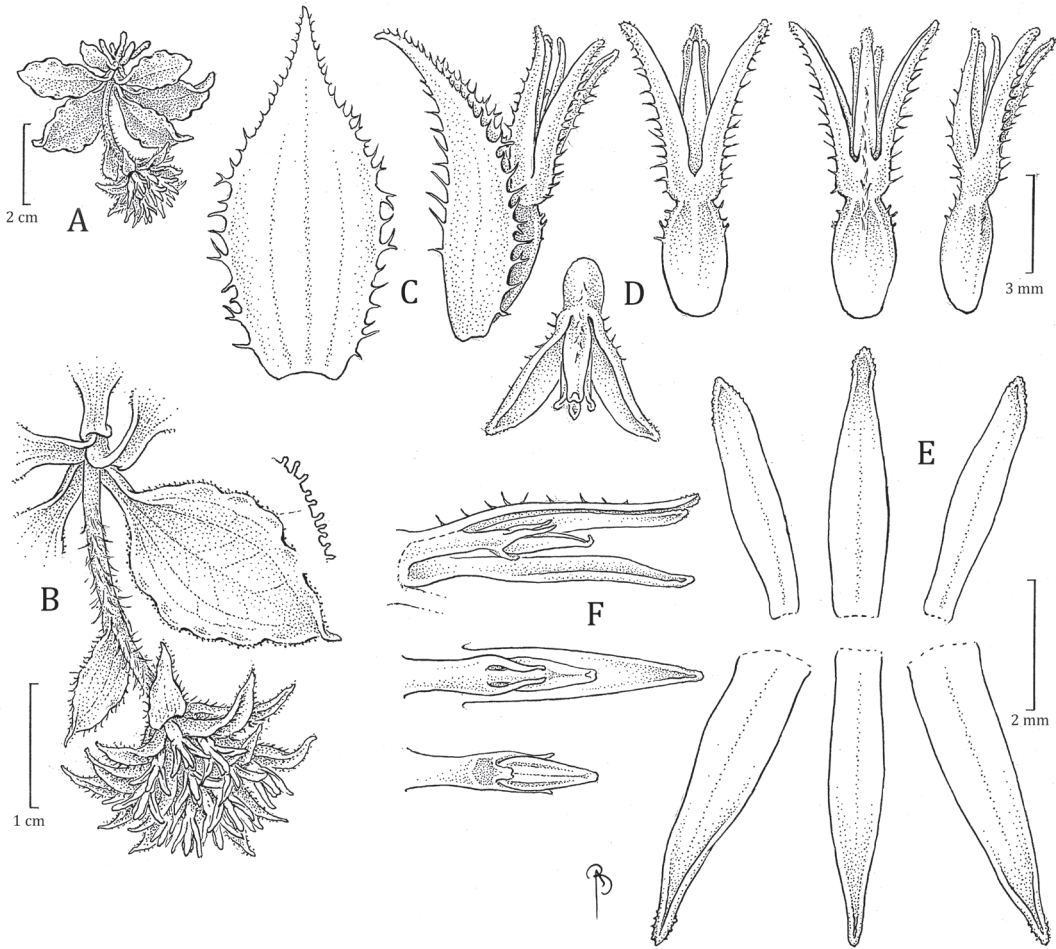


FIGURE 1. *Eurystyles luisortizii* Ackerman. **A.** Plant habit. **B.** Inflorescence and detail of leaf margin. **C.** Floral bract. **D.** Flower, left to right: front, ventral, dorsal and lateral views. **E.** Perianth, clockwise from upper left: petal, dorsal sepal, petal, lateral sepal, labellum, lateral sepal. **F.** Dissected flower, top to bottom: lateral view with one sepal and petal removed exposing the column; dorsal view of column with labellum; ventral view of column. Based on pickled material of holotype collection, *L. Ortiz Jordan s.n.* (US, UPRRP). Illustrated by Bobbi Angell.

ing basal auricles, and being single-veined, rather than having small basal auricles and 3 veins; and by having simple, erect staminodes, not bifurcated and curled.

We propose to designate these plants as representing a new species since flower morphology is both consistent and easily distinguishable from other *Eurystyles* species, especially those from the West Indies, which have been studied in detail (Ackerman *et al.* 2014). Bobbi Angell illustrated both the specimen from the Dominican Republic, which was published in *Orchid Flora of the Greater Antilles* (Fig. 51 in Ackerman *et*

al. 2014), and the Ortiz specimens examined here (Fig. 1). We can only speculate whether Woodbury collected the same thing five decades ago on Cerro La Santa, which is some 75 km east of the Adjuntas type locality.

TAXONOMIC TREATMENT

Eurystyles luisortizii Ackerman, *sp. nov.* (Fig. 1–3.)

TYPE: Puerto Rico. Municipality of Adjuntas: above Lago Garzas, trail from Rd 518 to bridge across the lake, 18°08'2.43"N, 66°44'23.43"W, wet secondary



FIGURE 2. *Eurystyles luisortizii* Ackerman. Inflorescence, side view; inflorescence head-on. Photographed by Jonathan López, reproduced with permission.

forest, elev. 783 m, originally collected in November 2017, flowered in cultivation 28 November 2018, *L. Ortiz Jordan s.n.* (holotype: US; isotype: UPRRP).

DIAGNOSIS: *Eurystyles luisortizii* Ackerman is vegetatively similar to *Eurystyles annassacomos* (Rchb.f.) Schltr. but differs florally by having a narrower lip (0.6–0.8 mm vs. 1.5–2.0 mm), a single-veined lip vs. 3-veined, lip lacking basal auricles vs. being auriculate, and the staminodes simple and erect vs. bifurcated and curved (Fig. 1).

An epiphytic, bromeliad-like, pendent, caespitose herb up to 4 cm long including the inflorescence. *Roots* few, short, fleshy 6–9 mm long, 2.0–2.5 mm in diameter. *Stem* covered by leaf bases, ca. 3–4 mm long. *Leaves* up to 7, rosulate; petioles from an expanded, sheathing base, broad, canaliculate, ca. 4.5 × 2.0 mm; blades waxy, shiny grayish-green, soft-textured, ovate-elliptical, cuneate, acute with an apiculate tip, with five main arching veins, the mid vein pinnate, 18–25 × 12.5–23.0 mm, margins undulate, pectinate-ciliate. *Inflorescences* terminal, solitary, pendulous; *peduncles* terete, densely ciliate, about 16–20 mm long, 1 mm diameter; *bracts* foliaceous 1–2, elliptical, acuminate, denticulate-ciliate from broad-based hairs, ca. 10.0 ×

4.5 mm; *racemes* subcapitate, congested, with 10–20 flowers opened more or less simultaneously; *floral bracts* slightly exceeding the length of the flowers, foliaceous, elliptical, acuminate when spread, funnel shaped enveloping flower, margins pubescent, hairs with a broad base, denticulate-ciliate, 3.7–4.0 × 1.6–2.0 mm. *Flowers* inconspicuous, non-resupinate, tubular, sepals, petals, and lip white. *Ovary* green, sessile, obovoid, glabrous below, sparsely ciliate above near junction with perianth, somewhat flattened-obovoid, 3.0–3.4 × 1.5–1.7 mm. *Dorsal sepal* lanceolate, minutely warty at apex, otherwise glabrous, 4.0–4.5 × 1 mm. *Lateral sepals* slightly gibbous and fused at the base for 0.5 mm, dorsally hirsute along mid vein, canaliculate, lanceolate, acuminate, dorsally keeled at apex, 4–5 × 0.8 mm when spread. *Petals* narrowly oblanceolate, acute-obtuse, adhering to the dorsal sepal, 4.0 × 0.5 mm. *Lip* narrowly elliptic, lacking basal auricles, apex acuminate, canaliculate, slightly thicker than the rest of the lip and minutely warty, 4.0–4.5 × 0.6–0.8 mm. *Column* subterete, glabrous, 2.8–3.0 mm long, *rostellum* triangular-ovate, acuminate, 0.5 × 0.2–0.3 mm at base, *staminodes* aciculate, erect, 1.1 mm long *anther* subsessile, 1.5 mm long, *pollinia* 2, clavate, mealy, 1.1 mm long. *Fruits* not seen; post-anthesis



FIGURE 3. *Eurystyles luisortizii* Ackerman. Plant habit *in situ*. Photographed by Luis Ortiz Jordan.

swollen ovaries *ca.* 4 mm long, 2.5 mm in diameter. Seeds not seen. Description based on three plants.

ETYMOLOGY: The specific epithet is named for the discoverer, Luis Ortiz Jordan, an avid native orchid enthusiast. He has a Master of Science in Environmental Management and works as an environmental scientist in Florida, USA.

PHENOLOGY: Flowers appear from November to February. Fruiting was not observed. New shoots begin to form as leaves senesce and flowering ends.

REPRODUCTIVE BIOLOGY: The ovaries of all flowers in the two inflorescences we have studied were swelling, yet they all had intact pollinaria, suggesting apomixis or autogamy may occur, a phenomenon that appears to be common in the genus (Szlachetko 1992). However, despite the plants doing very well in cultivation since late 2017, none of them have produced mature fruits, which of course may mean they require pollinator-mediated pollination. In the 2020–2021 flowering season, we self-pollinated five flowers. The ovaries became swollen, but no seeds formed so the flowers may be self-incompatible. If reproduction is verified to be pollinator-dependent, then attraction is likely based on deception. We carefully dissected flowers to detect nectar, but no free liquid was evident. Vigorous plants in cultivation produce scentless flowers to the human nose and last 4–6 weeks unpollinated. In cultivation under insect-free conditions, ovaries appear to swell somewhat, but fruits do not mature.

DISTRIBUTION AND ECOLOGY: Known only from the type locality, where they grow epiphytically on tree trunks in wet tropical montane forests. If the *Eurystyles* previously reported by Professor Woodbury was *E. luisortizii*, then elevational range is up to 900 m.

CONSERVATION STATUS: We think that the situation for *Eurystyles luisortizii* is dire. Only three plants were found 2 m up on the trunk of a severely damaged tree,

the consequence of Hurricane María. Most of the forest canopy was destroyed on ridges and those slopes that faced the brunt of the storm. Winds were so strong that those trees left standing (primarily palms) had the appearance of being power-washed. Epiphytes were ripped off or fell with their hosts, as has happened with other strong hurricanes (Migenis & Ackerman 1993). Nevertheless, small pockets of forest were somewhat intact, and until the forest recovers sufficiently to make detailed surveys of the area, we regard the conservation status of *E. luisortizii* to be data-deficient (DD) but likely endangered.

KEY TO THE SPECIES OF *EURYSTYLES* OF THE WEST INDIES
(MODIFIED FROM ACKERMAN ET AL. 2014)

1. Sepals distinctly inflated basally; high elevations (> 1500 m) *E. alticola*
- 1a. Sepals not inflated basally; lower elevations (< 1000 m) 2
2. Labellum pandurate with a distinct suborbicular apex *E. domingensis*
- 2a. Labellum narrowly elliptic to oblanceolate, with a keel-like acuminate apex 3
3. Labellum basally auriculate, 3-veined; staminodes bifid, the dorsal lobe incurved over the anther *E. ananassocomos*
- 3a. Labellum lacking auricles, 1-veined; staminodes simple, straight *E. luisortizii*

ACKNOWLEDGEMENTS. We thank Jonathan López Colón for permission to use his photographs and Bobbi Angell for permission to use her elegant illustrations. Unfortunately, the New York Botanical Garden Press did not respond to our request to use Bobbi's previously published illustration of *E. ananassocomos* in *Orchid flora of the Greater Antilles* (Ackerman *et al.* 2014). Plant collection was made under the auspices of the Departamento de Recursos Naturales y Ambientales, Gobierno de Puerto Rico, permiso científico: 2017-IC-056.

LITERATURE CITED

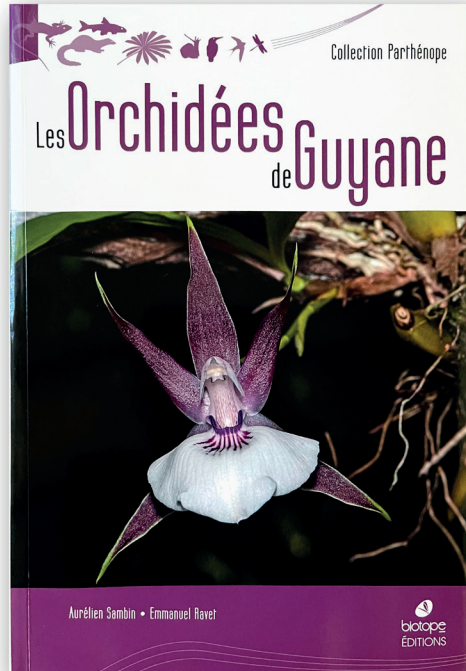
- Ackerman, J. D. (1995). An orchid flora of Puerto Rico and the Virgin Islands. *Memoirs of the New York Botanical Garden*, 73, 1–203.
- Ackerman, J. D. & Collaborators (2014). The orchid flora of the Greater Antilles. *Memoirs of the New York Botanical Garden*, 109, 1–625.
- Bogarín, D. (2020). A new species of *Eurystyles* (Orchidaceae: Spiranthinae) from Costa Rica. *Blumea*, 65, 65–68. doi:

10.3767/blumea.2020.65.01.07

- Dod, D. D. (1977). Orquídeas Dominicanas nuevas. II. *Moscosoa*, 1(2), 39–54.
- Dod, D. D. (1978). Orquídeas Dominicanas nuevas. III. *Moscosoa*, 1(3), 49–63.
- Migenis, L. E. & Ackerman, J. D. (1993). Orchid-epiphyte relationships in a forest watershed in Puerto Rico. *Journal of Tropical Ecology*, 9, 231–240. doi: 10.2307/2559295
- Salazar, G. A., Batista, J. A. N., Cabrera, L. I., van den Berg, C., Whitten, W. M., Smidt, E. C., Busatto, C. R., Singer, R. B., Gerlach, G., Jiménez-Machorro, R., Radins, J. A., Insaurralde, I. S., Guimarães, L. R. S., de Barros, F., Tobar, F., Linares, J. L., Mújica, E., Dressler, R. L., Blanco, M. A., Hágsater, E., & Chase, M. W. (2018). Phylogenetic systematics of subtribe Spiranthinae (Orchidaceae: Orchidoideae: Cranichideae) based on nuclear and plastid DNA sequences of a nearly complete generic sample. *Botanical Journal of the Linnean Society*, 186, 273–303. doi:10.1093/botlinnean/box096
- Szlachetko, D. L. (1992). Notes on *Eurystyles* (Orchidaceae), with a description of a new species from Mesoamerica. *Fragmenta Floristica et Geobotanica*, 37, 13–19.

BOOKS

Les Orchidées de Guyane, by Aurélien Sambin and Emmanuel Ravet. Mèze, France, Éditions Biotope (Collection Parthénope), 2021. ISBN: 978-2-36662-248-5. Volume in octavo, 24 × 16.8 cm, 669 pp., hundreds of color photographs and black and white drawings. In French. Paperbound. 69,00€. Ordering: <https://leclub-biotope.com/fr/>



Les Orchidées de Guyane is a book with many merits. First of all, the two authors are specialists who, combining their skills, add more than thirty years of activity in the study and documentation of the French Guiana Orchids. Sambin created and directed the Guiana Botanical Garden, where he gathered the largest living orchid collection in the whole country. Ravet, with a particular interest in the scent of orchid flowers, has gathered in over twenty years of research a rich collection of photographs of native species, often taken in the field, many of which illustrate this beautiful book. Secondly, as it was legitimate and right to expect from two authors living in the country of study, the orchids included in their book were actually

documented in French Guiana, which represents a huge advantage for the specialist and the enthusiast specifically interested in the floristic composition of the South American country. Last but not least, the book is a very complete catalog of the Guianese orchid flora.

In a beautiful volume of almost 700 pages, which, however, has been designed to be “almost” portable, the authors present 357 species of orchids, inventoried so far in the French Guiana area, for the most part, collected and documented expressly for this book, partly through the study of the historical collections of French Guiana herbaria and the natural history museum collections of continental France.

According to a somewhat classical structure, the book begins with a chapter dedicated to French Guiana, in which the geographical situation, the topography, the climate, and the salient aspects of the vegetation and orchid habitats of the South American country are treated. It is a relatively short chapter, of about ten pages, but well-illustrated and which offers the essential hints to a first approach to the geographical complexity and the consequent floristic richness of French Guiana. This is followed by a chapter specifically dedicated to the threats affecting the local orchid flora and the protective measures necessary to preserve it for the future. A short list of 13 species gathers those officially protected by a ministerial decree, now twenty years old.

The third chapter of the book, succinct but well-illustrated, is dedicated to describing the general morphological characters of orchids, with a brief note on their pollination. Of particular interest are a couple of excellent photographs depicting a fly removing the pollinarium from *Specklinia grobyi*. The fourth chapter presents a dichotomous key for identifying the genera of orchids of French Guiana, which leads to the identification of 120 genera. The key is obviously aimed at a specialist reader, but this is, I would say, inevitable for any type of dichotomous key dedicated to Orchidaceae, which necessarily requires prior knowledge of some details of plant morphology and of the terminology used to describe it, to be used with success. Some of the genera, such as *Apedium*, *Mapinguari*, or *Rhinorchis*, to name a few, will be less familiar to the reader, especially the non-specialist one because they have been used less frequently and have received less general acceptance in the field of botany.

With the fifth and more substantial (almost 600 pages) chapter of this treatment, the individual presentation of the genera begins, offered according to the systematic arrangement proposed by Chase *et al.* (2015), with a dichotomous key to Guianese species, followed by the treatment of individual species. In the case of large genera, as for example, *Epidendrum*, the key is organized by phylogenetic “groups”, and the species are treated accordingly to allow for easier comparison among closely related taxa. For each of the species, the name of the taxonomic authority is presented as well as the bibliographic details relating to its publication, the basonym with its original

publication date, data on the collection location of the type specimen, and, when necessary, a list of synonyms. The description of each taxa follows, generally based on French Guiana material, where their morphometric characters are indicated. Only some of the taxa could not be identified to the species level, and they are therefore presented as related to known species (aff.) or as “sp.” when the authors suspect they are taxonomic novelties. Mode of growth, size, density, and local geographic distribution, notes on the scent of flowers and phenology, complete the presentation of each individual species.

All the species, and this is certainly a great merit of the volume, are presented with one or more illustrations, in most cases photographs (many of them *in situ*), but often accompanied by useful floral diagrams prepared by the main author based on local material. In the rare cases where a photograph was not available, the authors present an illustration, often taken by the original protologue. As far as I can understand, since I am not a specialist in the flora of the Guyanas, the identifications seemed to me in most cases to be completely ascertained. I would just point out that the two photographs of *Cochleanthes guyanensis* on p. 293 depict in my opinion, two different species, as well as the photographs of *Mormolyca rufescens* (pp. 376–377). I also suspect that the photograph of *Trichocentrum fuscum* in the inset of page 271 could represent a different taxon. The photographs of *Dichaea pendula* (pp. 302–303) show a species completely different from what has been treated under this name for the flora of Costa Rica (Pupulin 2010), but considering that the type of *Limodorum pendulum* is exactly from French Guiana, I guess we will have to reconsider the application of this name in the Costa Rican flora...

With very rare exceptions, the photographs are of excellent quality, frequently offered in numerous different views for each species, almost always with an additional image of the habit, and allow for an easy identification of the treated species. In several cases, they also offer a clue about the variation of the species: a look at the photographs of *Pescatoria violacea* on pp. 322–323 should convince you about my impression. Out of the hundreds of photographs, I could only spot a couple that were printed upside-down (i.e. *Kegeliella houtteana*, on p. 419). The volume ends with a short

glossary, biographical references (reduced to a minimum), and an index of scientific names.

Taken this volume as a whole, it presents an extraordinarily illustrated catalog of the orchids of French Guiana, by force of things uncomplete considering the difficulty of exploration of a country that is still largely covered by virgin forests, but absolutely complete as to our current botanical knowledge. Noteworthy is the relative scarcity of documented Pleurothallids, of which only 63 species were recorded, compared to 41 species in *Epidendrum* alone. *Les Orchidées de Guyane* is an instrumental reference work, both for the naturalist interested in the flora of the Guyanese region as well as for the specialist. This treatment occupies an area of botanical knowledge that other recent works on these same regions had not covered, in my opinion, in a sufficiently rigorous way. The work of Sambin and Rovet will for a long time represent an essential reference work on the

French Guiana region, and I believe it should not be missing in any library specializing in Neotropical flora and orchid systematics.

Franco Pupulin

Lankester Botanical Garden
University of Costa Rica

Chase, M. W., Cameron, K. M., Freudenstein, J. V., Pridgeon, A. M., Salazar, G., van den Berg, C. & Schuiteman, A. (2015). An updated classification of Orchidaceae. *Botanical Journal of the Linnean Society*, 177(2), 151–174.

Pupulin, F. (2010). *Flora Costaricensis*. Family #39 Orchidaceae: Tribe Cymbidieae: Subtribe Zygopetalinae. *Fieldiana, Botany, New Series*, 49.

LANKESTERIANA

AUTHOR INSTRUCTIONS

LANKESTERIANA is a peer-reviewed journal. Each manuscript will be critically evaluated by two or more external reviewers under the double-blind model. An Editor in charge is assigned to each manuscript, who performs editorial tasks to improve the accordance of the manuscript to the general style of the journal, and follows the editorial process from the submission to the final decision, to ensure the quality of every publication.

Please read the following Instructions carefully and check the appropriate items to be sure your manuscript is formatted according to the journal style. Manuscripts that do not conform to the Instructions, both in format and contents, will be sent back to the authors for formatting prior to the reviewing process. This would represent a significant delay in the times required to eventually publish your manuscript.

General Instructions

- Type manuscript in Word (or Word compatible word processor) on 8.5" by 11" document with at least 1" (2.5 cm) margin on all sides.
- Use Times New Roman 12- point type, double-space throughout, including tables, figure legends, and literature cited. Do not justify the right margin. Authors are responsible for diacritical marks.
- Assemble in this order: 1) Title, Author(s) and affiliation(s) page; 2) abstract [+ optional abstract in the second language], key words and running title page; 3) Text, 4) Acknowledgments, 5) Literature cited, 6) Tables, 7) Appendices, 8) Figure legends, 9) Figures.
- Authors not fluent in written English should have their manuscripts carefully checked for correct language use before submission.
- If the paper includes newly described taxa, they must be illustrated, preferably by line drawings. Gray-scale drawings are difficult to be correctly reproduced by the printer and may result difficult to understand, and they are generally not accepted for publication.
- Include the collect permits and the corresponding institution that granted them in the cases of newly described taxa.

Title, Running title, Addresses, Abstract [+ optional Abstract in second language] & Key Words

- Title is flush left, in upper and lower case letters.
- Below Title, author(s) name(s) are on one line, flush left, in upper and lower case letters. Author(s) name(s) are in the following order: First Name (complete spelling), Second Name (initial), Surname. Indicate by superscript number after author's name any current address. Addresses include Institution, Street, City, State, Postal Code, Country. Indicate with asterisk (*) the name of the correspondent author; indicate with asterisk, after the addresses, the email of the correspondent author.
- Abstract begins on new page, is flush left, in upper and lower case letters. Abstract must be one paragraph and not indented. Do not cite references or use abbreviations in the abstract. Abstract is intended for quick understanding of the article content and must include short but full reference to paper results. In the case of newly described taxa, diagnostic characters must be shortly stated. Optional abstract in a second language should follow in separate paragraph in same format.
- Key Words: give up to 6 keywords arranged alphabetically, preceding text as follows: Key Words: ... Keywords should reflect the main content of the manuscript, avoiding to repeat words already mentioned in the title.
- Spanish speaking authors are required to always include a second abstract in Spanish. No translation services are provided by the editorial staff.
- Below Key Words, Running title is on one line, flush left, in upper and lower case letters. The running title includes the author(s) surname(s) and a short title. The total number of characters must not exceed 50.

Text

- Begin on a new page.
- Main headings are flush left in upper- and lower-case letters and in boldface on a separate line. Secondary headings are flush left in upper and lower case letters and in italics, followed by a period, dash, and the paragraph text. Tertiary headings are flush left in upper and lower case letters and underlined, followed by a period, dash, and the paragraph text.
- All figures and tables must be cited in the text and must be cited consecutively in numerical order.
- Each reference cited in the text must be in the Literature Cited section, and vice versa.
- Cite literature in the text as follows:
 1. One author: Nobody (1991) or (Nobody 1991).
 2. Two authors: Nobody and Somebody (1991) or (Nobody & Somebody 1991).
 3. More than two authors:
The first time you cite it: Nobody, Somebody & Someother (1991) or (Nobody, Somebody & Someother 1991).
Subsequent citations: Nobody *et al.* (1991) or (Nobody *et al.* 1991).
 4. More than six authors: Nobody *et al.* (1991) or (Nobody *et al.* 1991).
 5. Manuscripts accepted for publication but not yet published: Nobody (in press) or (Nobody in press).
 6. Unpublished materials: S. Nobody (unpubl. data) or (S. Nobody pers. comm. Year).
 7. Within parentheses, use a comma to separate different citations (Nobody 1991, Somebody 1991). Citations should be listed in the order they appear in the reference list (alphabetically, then chronologically).
 8. Use a, b, c, and so forth, for two or more papers by same author(s) in one year (e.g., Nobody 1990a,b, Boom 1985b).
- Cite authors of all names at rank of genus and below where first used in text. Do not repeat author citations after the first name's use. Refer to Authors of Plant Names (Brummitt & Powell 1992) for correct abbreviations.
- Italicize all scientific names at the generic level or below.
- Spell out genus and species the first time used in a paragraph and abbreviate generic name by first initial thereafter in that paragraph. Do not abbreviate genus name at the beginning of a sentence.
- Use *Index Herbariorum* (*Regnum Veg.* Vol. 120. 1990; <http://www.nybg.org/bsci/ih/>) abbreviations to designate herbaria. It is not necessary to cite this publication.
- Do not use footnotes.
- Numbers. Write out one through nine, unless a measurement or in a description. Use comma with more than four digits (1000 but 10,000); 0.5 instead of .5; “%” instead of “percent.” Use 8.0–8.5 and not 8–8.5.
- Abbreviate units of measurements without a period, e.g., km, mm, ft, mi, and so forth; temperatures are as follows: 20°C.
- Write out other abbreviations the first time used in the text and abbreviate thereafter: “Trichome morphology was examined using scanning electron microscopy (SEM).”
- If keys are included, they should be dichotomous and indented. Couplets should be numbered, not lettered, and the numbers followed by periods. Authors of taxa are not included and species are not numbered in the key.
- Specimen citation should include: locality, latitude and longitude when available, elevation, collection date, collector (“*et al.*” when more than two), collector's number, and herbarium(a) of deposit (using abbreviations in *Index Herbariorum*). Countries are cited from north to south; political subdivisions are in alphabetical order within countries; collectors are in alphabetical order within subdivisions.
- Acknowledgments should be brief and to the point.
- Manuscripts dealing exclusively with new geographic records and range extensions of previously known taxa are not of primary interest for the journal. They will be nevertheless considered for publication in a special section of LANKESTERIANA under the collective heading of “New records and range extensions”, according to the availability of space and the phylogeographic significance of the proposed records. Regional extensions within-country are seldom considered for publication in the journal unless of particular relevance.

Literature Cited

- Use hanging indentation.
- Continue page number sequence.
- “In press” citations must have been accepted for publication; give the name of the journal (and volume number if known) or the publisher.
- Insert a space after each initial of an author’s name.
- Insert the year of the publication in parenthesis.
- Do not abbreviate journal names.
- Titles of books are written in lower case except the first word and proper nouns and as required in original language of titles.
- Italicize title of journal and book titles.
- Italicize scientific names in the title of articles.
- Cite literature as follows:
 1. One author: Nobody, A. B. (1991).
 2. Two authors: Nobody, A. B. & Somebody, C. D. (1991).
 3. More than two authors: Nobody, A. B., Somebody, C. D. & Someother, E. F. (1991).
 4. Book chapter: Nobody, A. B. (1991). The effect of light on growth. In: C. D. Somebody (Ed.), *Light and growth* (pp. 209–291). London: Light Press. – or – Nobody, A. B. (1991). The effect of light on growth. In: C. D. Somebody & E. F. Someother (Eds.), *Light and growth* (pp. 209–291). London: Light Press.
 5. Journal article: Nobody, A. B. (1991). The effect of light on growth. *Title of Journal*, 3(1), 15–20. doi: insert DOI when it is available.
 6. Manuscripts accepted for publication but not yet published: Nobody, A. B. (In press). Name of the journal or publisher. The name of the journal where the paper was accepted must be indicated, the volume number should be included if known.
- Please refer to the 6th Edition of APA Formatting and Style Guide for more examples of cited literature.

Tables

- Continue page number sequence.
- Each table must start on a separate page and must be double-spaced. Tables can be printed landscape or portrait. Do not reduce type size of tables. If necessary, continue table on additional pages.
- Portrait tables can be prepared to be printed 1- or 2-column width; plan accordingly.
- The title of the table should be flushed left, preceded on the same line by the word “Table” and an arabic numeral.
- Items on each row must be separated by a single tab.
- Superscripts referring to footnotes should be lowercase letters, not numbers.
- Footnotes should be placed as separate paragraphs at end of table.
- References cited in tables must be included in the Literature Cited.

Figure Legends

- Begin a new page; continue page number sequence.
- All figures (maps, photos, line illustrations) should be in a single sequence, consecutively numbered. Tables are in a separate, consecutively numbered sequence.
- Double-space the legends and group them according to figure arrangements. Do not use a separate page for each group.
- Number figures consecutively with arabic numerals.
- Type legends in paragraph format, e.g.: Figure 1. *Pleurothallis inedita*. A. Habitat. B. Flower. C. Flower dissection. D. Outer floral bract. E. Inner floral bract. F. Petal. G. Column, profile view (left) and 3/4 dorsal view (right). H. Pollinarium. (Drawn from the holotype). Illustration by Who Nobody. Figure 2. *Luisia inedita*. A. Habit. B. Fruit (*Somebody* 567, CR). Illustration by Who Nobody. Note that labels on figure (“A”) should be in upper case and match that on legend. Italicize collector’s name and number.

- The specimen(s) on which the illustrations are based must be noted.
- The author(s) of the illustration must be credited in the figure legend.
- Do not include non-alphanumeric symbols (lines, dots, stars, etc.) in legends; label them on the figure itself or refer to them by name in the legend.

Preparation and submission of illustrations

- Illustrations should be submitted digitally as TIF files (or, exceptionally, in any format that is Adobe Photoshop compatible). Do not submit original artworks. Illustrations in “native application” file formats (e.g., PageMaker, Quark, Excel, Word, WordPerfect, etc.) will not be accepted. Photographs should be scanned at a resolution of 600 dpi; line art, 600 to 1200 dpi. All digital illustrations must be complete, with letters, scale bars, and any other labeling; label figures by press-on letters or symbols or by other mechanical lettering process; labels produced on a typewriter, dot matrix, or inkjet are unacceptable. No modifications of incomplete illustrations or illustration enhancement are provided by the editorial staff.
- Parts of a plate are labeled A, B, C, etc. Letters will be black on a white or light background; white on dark background. They are not placed over a rectangular, contrasting background, but directly on the photograph or the drawing itself, without any frame. Letters will be in Helvetica, Arial, or other sans serif fonts.
- All original artwork from which digital illustrations are derived **MUST** be signed; unsigned digital illustrations will not be accepted. The artist must also be cited in the Acknowledgments.
- For all illustrations, color and black-and-white photographs, the electronic files print size should be as close as possible to final published size. Print size may be reduced without loss of quality, but small files cannot be altered to fit larger dimensions.
- The journal publishes black and white illustrations (pen and ink or computer-generated), color photographs and black-and-white photographs. Halftone images generated by electronic manipulation of original photographs are not allowed for publication, due to the difficulty of their typographic reproduction and their interpretation by the readers.
- Length of an illustration or plate as published is 8” (205 mm). Allow space in that 8” for the printed caption to appear below the figure. Two widths are possible as published: 1-column is 2.8” (71 mm); full page is 5.75” (146 mm). Final resolution of all the images cannot be less than 300 dpi.
- Do not combine photographs and line art.
- When preparing composite illustrations, do not include empty space between the components. Place numbers or letters on the illustration itself, not in the margins.
- Magnifications must be indicated by means of scale bars placed directly on the illustrations. Magnifications in the figure legend are not acceptable, and such figures will be returned to the author for scale bars.
- Maps should have a border, an indication of latitude and longitude, and should not have an undue amount of unused area. Distributions of several species with non-overlapping ranges can be placed on one map by using different symbols.
- Illustrations of a new species should clearly show the characteristics that distinguish it.

Conditions for publication

- Authors are not requested to pay page charges.
- In consideration of the publication of the article, authors grant to Jardín Botánico Lankester, Universidad de Costa Rica, all rights in the article.
- Authors warrant that their contribution is an original work not published elsewhere in whole or in part, except in abstract form, and that the article contains no matter which invades the right of privacy or which infringes any proprietary right.
- Authors will receive no royalty or other monetary compensation for the assignment set forth in this agreement.
- Jardín Botánico Lankester, Universidad de Costa Rica, in turn, grants to authors the royalty free right of republication in any book of which they are the authors or editors, subject to the express condition that lawful notice of claim of copyright be given.

What to submit

- A working version of the manuscript, including text and low resolution images (210 dpi JPEGs) must be submitted by e-mail to the Editors at: diego.bogarin@ucr.ac.cr, franco.pupulin@ucr.ac.cr, melissa.diaz_m@ucr.ac.cr, noelia.belfort@ucr.ac.cr and lankesteriana@ucr.ac.cr, pending the submission of a e-link for high-resolution images downloading (i.e., Dropbox or WeTransfer links). Submissions can also be made through a CD or DVD via regular mail (see address above).
- CD or DVD must be Macintosh and PC compatible, and must include two copies of manuscript and two copies of illustrations. Priority mail from abroad usually comes to Jardín Botánico Lankester, Universidad de Costa Rica, within 10 days since sent.
- Please double check in your computer the CD or DVD is readable.
- Include in the package a letter with any special instructions, any change of address during the next several months, any phone, fax, e-mail numbers for the corresponding author. Indicate which author of a multiauthored paper (if not the first) should receive the proofs.
- Immediately notify the Editor-in-chief (diego.bogarin@ucr.ac.cr), the Associate Editors (franco.pupulin@ucr.ac.cr, melissa.diaz_m@ucr.ac.cr) or the Technical Editor (noelia.belfort@ucr.ac.cr) by e-mail after sending your package.

When to submit

- The deadlines to receive manuscripts to be included in the three yearly issues of LANKESTERIANA (April, August and December) are January 1, May 1 and September 1, respectively. Pending the judgment of reviewers and the time to correspond with authors, the editorial staff of LANKESTERIANA is committed to reduce to a minimum the time for articles publication.

Submit to

- | | |
|---|---|
| <ul style="list-style-type: none"> • Diego Bogarín
<i>Editor-in-Chief</i>, LANKESTERIANA
Universidad de Costa Rica
Jardín Botánico Lankester
P.O. Box 302-7050 Cartago
Costa Rica
E-mail: diego.bogarin@ucr.ac.cr | <ul style="list-style-type: none"> • Melissa Díaz-Morales
<i>Associate Editor</i>, LANKESTERIANA
Universidad de Costa Rica
Jardín Botánico Lankester
P.O. Box 302-7050 Cartago
Costa Rica
E-mail: melissa.diaz_m@ucr.ac.cr |
| <ul style="list-style-type: none"> • Noelia Belfort Oconitrillo
<i>Technical Editor</i>, LANKESTERIANA
Universidad de Costa Rica
Jardín Botánico Lankester
P.O. Box 302-7050 Cartago
Costa Rica
E-mail: noelia.belfort@ucr.ac.cr | <ul style="list-style-type: none"> • Franco Pupulin
<i>Associate Editor</i>, LANKESTERIANA
Universidad de Costa Rica
Jardín Botánico Lankester
P.O. Box 302-7050 Cartago
Costa Rica
E-mail: franco.pupulin@ucr.ac.cr |

Questions about LANKESTERIANA should be addressed to lankesteriana@ucr.ac.cr.

LANKESTERIANA, the Scientific Journal of Jardín Botánico Lankester - Universidad de Costa Rica, is devoted to the publication of original contributions on orchidology, including orchid systematics, ecology, evolution, anatomy, physiology, history, etc., as well as reviews of books and conferences on these topics. Short communications and commentaries are also accepted, and should be titled as such. The official language of the journal is English (papers can be published with a summary in Spanish or other language), and works submitted in Spanish will be considered case by case. Manuscripts are evaluated critically by two or more external referees.

LANKESTERIANA is indexed by Clarivate' Biosis, Scielo, Scopus, Latindex, Scirus, and WZB, it is included in the databases of E-journals, Ebookbrowse, FAO Online Catalogues, CiteBank, Mendeley, WorldCat, Core Electronic Journals Library, and Biodiversity Heritage Library, and in the electronic resources of the Columbia University, the University of Florida, the University of Hamburg, and the Smithsonian Institution, among others.

LANKESTERIANA is published periodically in volumes, three times a year - in April, August and December - by the Jardín Botánico Lankester, Universidad de Costa Rica. POSTMASTER: Jardín Botánico Lankester, Universidad de Costa Rica, P.O. Box 302-7050 Cartago, Costa Rica, C.A.

EDITORIAL OFFICE: Jardín Botánico Lankester, Universidad de Costa Rica, P.O. Box 302-7050 Cartago, Costa Rica, C.A.

MANUSCRIPTS: Send to Editorial Office. INFORMATION FOR CONTRIBUTORS: Send a request to Editorial Office.

MEMBERSHIP OFFICE: Jardín Botánico Lankester, Universidad de Costa Rica, P.O. Box 302-7050 Cartago, Costa Rica, C.A.

SUBSCRIPTION RATES: \$50.00 per year. SUBSCRIPTION TERM: Calendar year only. Only INSTITUTIONAL SUBSCRIPTIONS are admissible. INDIVIDUAL SUBSCRIPTIONS will not be accepted.

REMITTANCES: All checks and money orders must be payable through a Costa Rican bank in U.S. dollars or colones.

Pay to: Jardín Botánico Lankester, FUNDACIÓN UCR. BACK ISSUES: Single issues are available for sale at \$ 20.00 (CR) and \$ 22.00 (elsewhere). Send inquiries to Membership Office.

CHANGES OF ADDRESS: Send mailing label or complete old address and new address to Membership Office.



LANKESTERIANA la revista científica del Jardín Botánico Lankester, Universidad de Costa Rica, se dedica a la publicación de contribuciones originales relativas a la orquideología, incluyendo la ecología, la evolución, la anatomía y la fisiología y la historia de las orquídeas, así como a revisiones de libros y conferencias en estos temas. Se aceptan, además, comunicaciones breves y comentarios, que serán titulados como tales. El idioma oficial de la revista es el inglés (los artículos pueden publicarse con resumen en español u otro idioma) y se considerarán para publicación trabajos presentados en español. Los manuscritos son evaluados críticamente por dos o más revisores externos.

LANKESTERIANA está indizada por Biosis de Clarivate, Scielo, Scopus, Latindex, Scirus y WZB, está incluida en las bases de datos de E-journals, Ebookbrowse, FAO Online Catalogues, CiteBank, Mendeley, WorldCat, Core Electronic Journals Library y Biodiversity Heritage Library, así como en los recursos electrónicos de la Universidad de Columbia, la Universidad de Florida, la Universidad de Hamburgo y la Institución Smithsonian, entre otros.

LANKESTERIANA se publica periódicamente en volúmenes, tres veces por año - en abril, agosto y diciembre - por el Jardín Botánico Lankester, Universidad de Costa Rica. DIRECCIÓN POSTAL: Jardín Botánico Lankester, Universidad de Costa Rica, Apdo. 302-7050 Cartago, Costa Rica, C.A.

OFICINA EDITORIAL: Jardín Botánico Lankester, Universidad de Costa Rica, Apdo. Box 302-7050 Cartago, Costa Rica, C.A.

MANUSCRITOS: Enviar a la Oficina Editorial. INFORMACIÓN PARA CONTRIBUIDORES Y CONTRIBUIDORAS: Enviar pedidos a la Oficina Editorial.

OFICINA DE MEMBRESÍA: Jardín Botánico Lankester, Universidad de Costa Rica, Apdo. 302-7050 Cartago, Costa Rica, C.A.

COSTO DE SUSCRIPCIÓN: \$50.00 por año. TÉRMINOS DE SUSCRIPCIÓN: exclusivamente año de calendario. Se aceptan exclusivamente SUSCRIPCIONES INSTITUCIONALES. Las SUSCRIPCIONES INDIVIDUALES no podrán ser procesadas.

PAGOS: Todos los cheques y los órdenes de pago deberán ser pagables a través de un banco de Costa Rica, en dólares estadounidenses o en colones. Emitir los pagos a: Jardín Botánico Lankester, FUNDACIÓN UCR.

EDICIONES ANTERIORES: Los fascículos individuales disponibles para la venta tiene un precio de \$ 20.00 (Costa Rica) y \$ 22.00 (afuera). Enviar los pedidos a la Oficina de Membresía.

CAMBIOS DE DIRECCIÓN: Remitir la etiqueta de envío, o alternativamente la vieja dirección completa, y la nueva dirección a la Oficina de Membresía.

Amended description of the Sumatran endemic *Dendrobium bandii* (Orchidaceae) with notes on its conservation status and ecology
MARK ARCEBAL K. NAIVE, YUDA REHATA YUDISTIRA, MALCOLM VICTORIANO and PAUL ORMEROD 1

A new *Pseudolepanthes* (Pleurothallidinae: Orchidaceae) from Northwest Ecuador
MARCO F. MONTEROS, LUIS E. BAQUERO and SEBASTIÁN VIEIRA-URIBE 5

First record of a wild population of *Laelia dawsonii* f. *dawsonii* (Orchidaceae) for the state of Jalisco, Mexico
MIGUEL J. CHÁZARO-BASÁÑEZ, ALEXANDER JIMÉNEZ-VÁZQUEZ and EDUARDO A. PÉREZ-GARCÍA 11

Comparative floral surface micromorphology helps to discriminate between species of *Paphiopedilum* (Orchidaceae: Cyripedioideae) from Peninsular Malaysia
EDWARD E. BESI, LAM S. JIA, MUSKHAZLI MUSTAFA, CHRISTINA S.Y. YONG and RUSEA GO 17

Two new species of *Octomeria* (Pleurothallidinae) from Cordillera Del Cóndor, Zamora Chinchipe, Ecuador
LEISBERTH VÉLEZ-ABARCA, MARCO M. JIMÉNEZ and LUIS E. BAQUERO 33

A new species of *Eurystyles* (Orchidaceae) is exposed by a fierce hurricane in Puerto Rico
JAMES D. ACKERMAN and LUIS ORTIZ JORDAN 45

Books 51

Author instructions 55