

# A new species of *Solanum* sect. *Acanthophora* (Solanaceae) from Argentina and Brazil

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## Abstract

A new species of *Solanum* belonging to section *Acanthophora* (subgenus *Leptostemonum*) from Argentina and Brazil is described. *Solanum neei* Chiarini & L.A.Mentz, **sp. nov.** is found in clearings of semideciduous forests and in secondary formations, from the states of Paraná, Rio Grande do Sul and Santa Catarina in Brazil to the Misiones province in Argentina. It is morphologically similar to *S. incarceratum* Ruiz & Pav. from Peru, Bolivia and Western-Central Brazil, differing mainly by its pedunculate inflorescences. A key to related species is provided, as well a photograph of the holotype, a distribution map and illustration.

## Keywords

Acanthophora, Argentina, Atlantic Forest, Brazil, *Leptostemonum*, “spiny solanum”

## Introduction

The Solanaceae is a cosmopolitan family of considerable economic importance with its centre of diversification in South America (D’Arcy 1991, Hunziker 2001). It includes 92 genera and around 2300 species, *Solanum* L. being the largest genus with ca. 1400 species. Within this genus, a remarkable natural group is subgenus *Leptostemonum* (Dunal) Bitter (the so-called “spiny solanums”), which includes cultivated representatives such as *S. melongena* L. (eggplant), *S. quitoense* Lam. (naranjilla or lulo) and *S. sessiliflorum* Dunal (cocona or cubiu). Other species, including *S. elaeagnifolium* Cav.

(silverleaf nightshade), *S. sisymbriifolium* Lam. (sticky nightshade or wild tomato) and *S. carolinense* L. (horsenettle) are noxious weeds. Subgenus *Leptostemonum* includes section *Acanthophora* Dunal, whose members are characterized by the presence of simple hairs on the upper leaf surface (Levin et al. 2005, Nee 1991). This section is monophyletic (Levin et al. 2005) and comprises about 20 herbs or small shrubs adapted to disturbed areas and secondary open forests with its center of diversity in eastern Brazil. Some of its species are considered invasive weeds [e.g. *S. viarum* Dunal (“tropical soda apple”), naturalized in USA, Africa, and Asia (Bryson and Byrd 1994, Welman 2003), and *S. palinacanthum* Dunal (“pocote”, “joá bagudo”) which invades roadsides and crop fields in Argentina and Brazil (Mentz and Oliveira 2004, Nee 1991)]. Conversely, other species of sect. *Acanthophora* are cultivated as ornamentals (e.g. *S. mammosum* L., “apple of Sodom”, “cow’s udder” or “nipple fruit”; and *S. capsicoides* All., “cockroach berry”). Section *Acanthophora* is especially diverse with respect to the fruit, which can be a berry or a carcerulus (a fruit resembling the true berries, but with an aerial space between the seeds and the pericarp at maturity), small or relatively large (1.35–4 cm diam.), orange, red, yellow, or greenish yellow, and the seeds can be winged or not (Levin et al. 2005, Chiarini and Barboza 2009). This variability is also seen in microscopic structures, such as sclereids, layers of spongy tissue and crystals at the hypodermis, which are all related to different dispersal syndromes (Chiarini and Barboza 2009).

Nee (1979a) provided a taxonomic treatment of sect. *Acanthophora* in his doctoral thesis, that he subsequently revised slightly (Nee 1979b, 1991); in all of these he identified several probable undescribed new species known from just a few collections. Since that time, sufficient material has accumulated to formally describe one of these, and it is named in honor of Dr. Michael Nee to commemorate his work on the section.

## Taxonomic treatment

### *Solanum neei* Chiarini & L.A.Mentz, sp. nov.

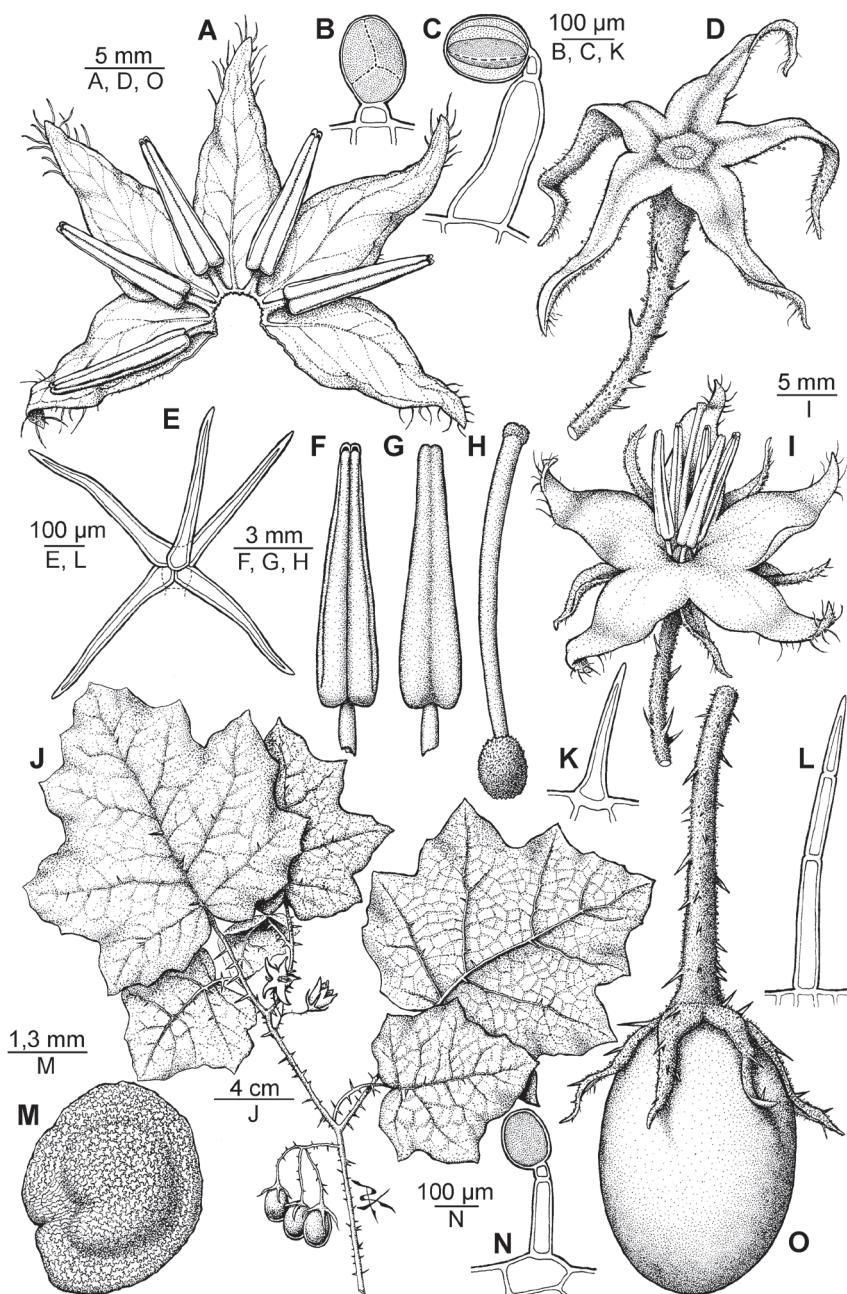
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[http://species-id.net/wiki/Solanum\\_neei](http://species-id.net/wiki/Solanum_neei)

Figs 1–4

**Diagnosis.** Differs from *Solanum incarceratum* Ruiz & Pav. by its inflorescences with unarmed or prickly peduncles 1.8–4 cm long (versus sessile inflorescences in *S. incarceratum*); also differs from *S. acerifolium* Dunal and *S. atropurpureum* Schrank by its unequal, linear calyx lobes (versus equal, triangular or deltoid calyx lobes in *S. acerifolium* and *S. atropurpureum*); the non-petaloid linear calyx lobes also distinguishes it from *S. anoacanthum* Sendtn., which has petaloid, elliptic-lanceolate calyx lobes.

**Type.** Argentina. Misiones: Dpt. Guaraní, Predio Guaraní, 26°54'59"S, 54°12'18"W, Tramo I, borde de selva, 16-X-2002, S.G. Tressens et al. 6749 (holotype: CORD [CORD00006750], isotype: CTES).



**Figure 1.** *Solanum neei*. **A** Inside view of spread open corolla **B** Glandular trichome of the ovary **C** Glandular trichome of the stem **D** Calyx **E** Stellate short-stalked trichome from the lower leaf surface **F–G** Ventral and dorsal view of the anther, respectively **H** Gynoecium **I** Flower **J** Branch with flowers and fruits **K** Unicellular trichome from the upper leaf surface **L** Multicellular uniseriate trichome from the upper leaf surface **M** Seed **N** Glandular trichome from the upper leaf surface **O** Fruit. **I** from *Tressens et al.* 6749; the rest from *Subils & Moscone* 4160. Drawn by P. Peralta.

**Description.** Shrub up to 1.7 m tall. Stems sparsely pubescent with glandular hairs (stalked or sessile) and 2–5 celled simple hairs, armed with straight (sometimes recurved), broad-based prickles to 5–10 mm long, and needlelike prickles, 1–2 mm long. Sympodial units di- or trifoliate. Leaves solitary or sometimes geminate, if geminate then one of the leaves about twice the size of the other; petioles 3–9 cm long, pubescent with glandular and simple trichomes and armed with acicular prickles to 1.2 cm; blades membranaceous, deltoid, 10–19 × 9–18 cm, with 2–3 pairs of shallow, broadly triangular teeth or lobes, the base truncate or cuneate to subcordate; upper surface with simple, spreading, 2–4-celled eglandular hairs and very short glandular hairs; lower surface moderately to sparsely pubescent with stellate, sessile or short-stalked trichomes, with (3) 4 (6) lateral rays and a central ray (midpoint) the same size or a little longer, and with glandular hairs and prickles on the midvein, the prickles 1–3 mm long, smaller than those of the petioles. Inflorescence extra-axillary, pedunculate, unbranched, scorpioid, (3) 5–25-flowered, with prickles to 2 mm long; peduncles up to 1.8–4 cm (2.5–5 cm in fruit) unarmed to prickly, with simple and glandular hairs; pedicels up to 3 cm, enlarged towards the apex, unarmed to prickly, with simple and glandular hairs. Flowers all perfect; calyx lobes unequal, elongate, linear-lanceolate to linear, equal to or somewhat shorter than the corolla lobes, 0.6–1.6 cm long and up to 1 mm wide (1.3–2.6 cm long in fruit), pubescent with glandular and simple hairs, sometimes also with some small prickles; corolla stellate, 2.2–2.5 cm in diameter, white, with simple hairs outside, inner surface glabrous, the lobes planar, lanceolate, 12–14 mm long × 4.5–6 mm wide; anthers attenuate, yellow, 8–9 mm long, opening by apical pores; ovary globose covered by small glandular trichomes; style whitish, 10–11 mm; stigma capitate or clavate, green. Fruits globose-ellipsoid, ca. 1.5 cm long × 1 cm wide, variegated when immature, yellow when ripe, subtended by the calyx lobes that are usually longer than the fruit (sometimes the same length or a little shorter). Seeds orbicular, compressed, winged, ± 3 mm diam. Chromosome number  $2n = 24$  (Acosta et al. 2005, sub nom. *Solanum* sp. 2).

**Distribution** (Fig. 4). Southern Brazil in the states of Paraná, Rio Grande do Sul and Santa Catarina, Brazil, and in Prov. Misiones, Argentina; 100–1000 m elevation. *Solanum neei* inhabits the Atlantic Forest region (Alto Paraná Atlantic forest, *Araucaria* humid forest and Serra do Mar coastal forest), in areas with 1200–2000 mm of annual precipitation.

**Ecology.** The new species is found in clearings of semideciduous primary forests and in secondary forest. Flowering specimens have been collected from September to April; fruiting specimens from October to April.

**Etymology.** The epithet honors Dr. Michael Nee, a specialist in Solanaceae at the Institute of Systematic Botany, New York Botanical Garden (USA). Nee's contributions to the knowledge of this family (and particularly of genus *Solanum*) are many and remarkable, and include his Ph.D. thesis on the taxonomy of section *Acanthophora*.

**Preliminary conservation status.** *Solanum neei* is a species of open and somewhat disturbed habitats (as are many 'spiny solanum' species) and seems to be fairly evenly distributed within its area (Fig. 4). The species has been regularly collected to date. Although not usually common where it occurs, it is not a species of immediate conser-





**Figure 2.** Fruiting branch of *Solanum neei* in Misiones, Argentina (Keller 3922, CTES).

vation concern. Applying the criteria of the IUCN (<http://www.iucn.org/>) suggests its conservation status should be 'Least Concern' (LC).

**Specimens examined.** ARGENTINA. Misiones: Dpt. San Javier, Cnia. Acaraguá, 29-IX-1946, *Bertoni* 3032 (LIL); Dpt. Gral. San Martín, El Alcázar, propiedad

Alto Paraná S.A., 23-IX-2000, *Keller 315* (CTES); Dpt. San Pedro, camino de tierra que une la RP 17 con la RN 14, a la altura de Piñalito Sur, 13-I-2007, *Keller 3922* (CTES); Dpt. Eldorado, ruta de Eldorado a B. de Irigoyen, a  $\pm$  45 km de Eldorado, 17-XI-1980, *Legname et al. 7525* (CTES, LIL); Dpt. Iguazú, urwald picada bei den Yguazu fällen, 13-IX-1915, *Osten & Rojas 8267* (G); Dpt. San Pedro, Ruta prov. 17, 80 km al E de Eldorado, 22-I-1973, *Schinini & Fernández 5978* (SI); Dpt. Iguazú, Ruta 12, rumbo a Bosetti, a  $\pm$  5 km del límite del PN, 29-V-1987, *Subils & Moscone 4160* (CORD); Dpt. Guaraní, Predio Guaraní, 26°54'59"S, 54°12'18"W, sendero CiFOR, 27-IV-1999, *Tressens et al. 6106* (CTES).

**BRAZIL. Paraná:** Larangeiras do Sul, Rio Iguaçu, Salto Osório, 18-IV-1970, *Hatschbach 24155* (MBM); Maringá, Horto Florestal, 29-I-1970, *Hatschbach 26187* (MBM). **Rio Grande do Sul:** Rodeio Bonito, rodovia para Planalto, 6-XII-1986, *Bassan & Benedetti 746* (HAS); São Francisco de Paula, Faz. Englert, I-1944, *Buck s.n.* (PACA 11621); Caxias do Sul, Morro do Biondi, 19-XI-1951, *Cordeiro s.n.* (ICN 896); Santo Ângelo, Granja Piratini, 24-XI-1973, *Hagelund 7473* (ICN) - XII-1941, *Leite 743* (NY) - São Salvador, 12-I-1941, *Leite 2189* (SP); Ijuí, Augusto Pestana, 27-IX-1953, *Pivetta 946* (PACA); São Francisco de Paula, Potreiro Novo, Tainhas, 23-II-1978, *Sehnem 15906* (PACA 72218); Veranópolis, 4° seção, 3-IV-1983, *Silveira 633* (HAS); Montenegro, Kappesberg, 16-XII-1935, *Rambo 2198* (PACA); Caxias do Sul (São Francisco de Paula) Vila Oliva, 6-I-1946, *Rambo 31113* (B, PACA, LIL 199948); Bom Jesus, Fazenda da Ronda perto Vacaria, 30-XII-1946, *Rambo 34640* (PACA); Cambará do Sul, perto S. Francisco de Paula, II-1948, *Rambo 36080* (PACA). **Santa Catarina:** Caçador, Rio do Bugre, 7-XII-1962, *Klein 3449* (HBR).

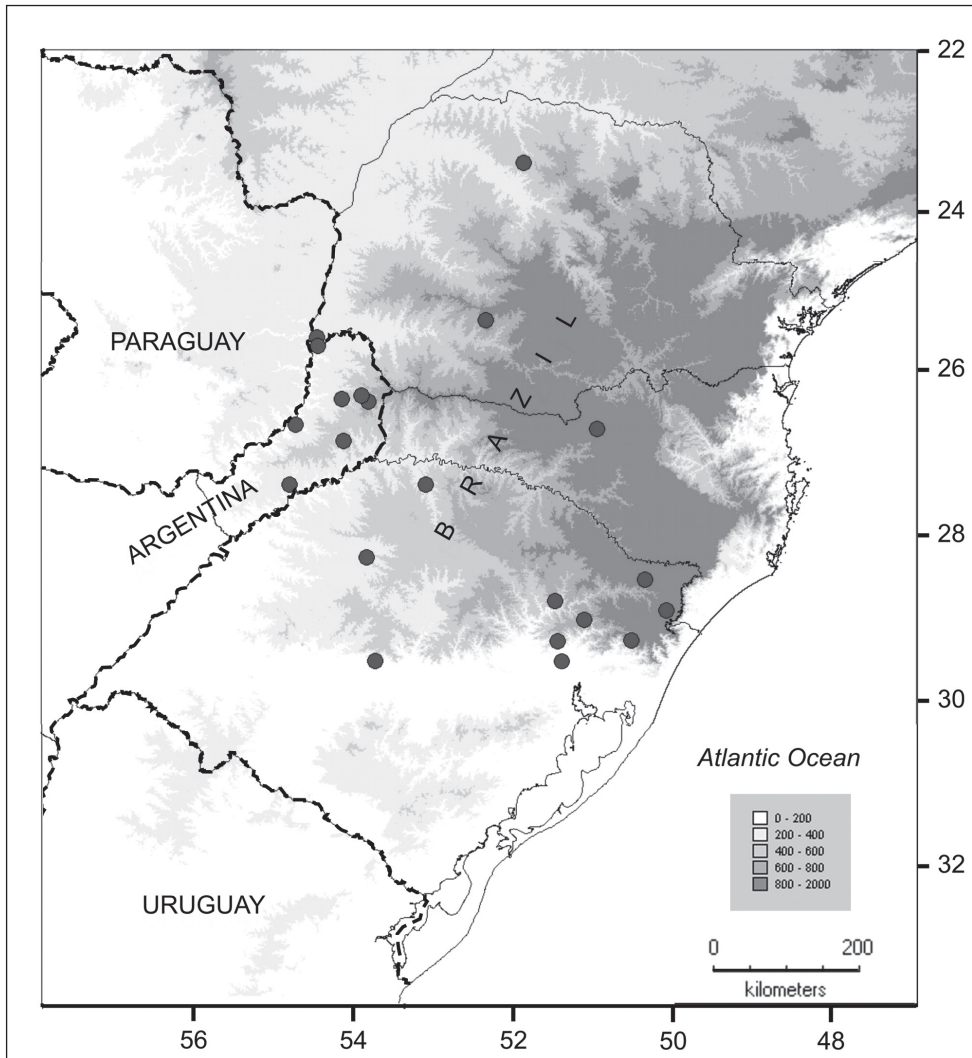
**Discussion.** This species is undoubtedly placed within sect. *Acanthophora* due to the lack of stellate hairs and the presence of simple hairs on the upper leaf surfaces. Because of its flattened and winged seeds, *S. neei* would be placed in the *Pterosperma* group of sect. *Acanthophora* in the taxonomic scheme of Nee (1979a; see Levin et al. 2005 for an explanation of Nee's subsectional groups). However, Levin et al. (2005) demonstrated that the groupings based on seed morphology are unnatural, although they did not sample all species of the section. Therefore, the phylogenetic position of *S. neei* within sect. *Acanthophora* is unknown.

Morphologically, *S. neei* resembles *S. incarceratum*, but the well developed peduncles of the inflorescences (Figs 1, 2) distinguish it from the latter, which has sessile or almost sessile inflorescences. Other characteristics that also help to distinguish these two species are the leaf shape (barely lobed in *S. incarceratum*), the fruit shape (globose in *S. incarceratum*) and the distribution range: *S. incarceratum* inhabits Peru, Bolivia and the states of Bahia, Goiás and Minas Gerais (Brazil), therefore it would overlap with *S. nee* only in a small area in the Brazilian state of Paraná. *Solanum anoacanthum* has also some resemblance to *S. neei*: both species have long calyx lobes that are equal to or longer than the corolla lobes and longer than half of the fruit, but in *S. anoacanthum* the lobes are wider and petaloid, whilst in the latter, they are linear-lanceolate to linear and not more than 1 mm wide.





**Figure 3.** Photograph of the holotype of *Solanum neei* (Tressens et al. 6749, CORD 00006750).



**Figure 4.** Distribution of *Solanum neei* in Argentina and Brazil.

Some species of sect. *Acanthophora* have derived breeding systems and are andromonoecious (with both long- and short-styled flowers in the same inflorescence, e.g., *S. capsicoides*), but the new species seems not to be andromonoecious, since all specimens studied had inflorescences with only long-styled flowers.

A specimen belonging to *Solanum neei* was placed by Nee (1991) under the name *Solanum species B*, and later Mentz and Oliveira (2004) described and illustrated it under '*Solanum* sp 1', but neither of these works validly publishes it as a new species.

Key to the species of section *Acanthophora* with flattened or winged seeds in Southern Brazil/Northern-Eastern Argentina (for all members of the section in the region see Mentz and Oliveira 2004)

- 1 Plants not andromonoecious, with all the flowers hermaphroditic; fruits smaller than 2 cm in diameter.....2
- Plants andromonoecious; fruits larger than 2 cm in diameter.....5
- 2 Calyx lobes equal to or longer than the corolla lobes and longer than half of the fruit, elliptic-lanceolate to linear.....3
- Calyx lobes markedly shorter than the corolla lobes and shorter than the half of the fruit, deltoid to narrowly triangular .....6
- 3 Calyx lobes not petaloid, linear-lanceolate to linear, up to 1 mm wide and 6–16 mm long.....4
- Calyx lobes petaloid, elliptic-lanceolate, ca. 2–4 mm wide and 14–20 mm long ..... *S. anoacanthum* Sendtn.
- 4 Penduncle of inflorescences very short or absent ..... *S. incarcerationum* Ruiz & Pav.
- Penduncle of inflorescences well developed, up to 1.8–4 cm long..... *Solanum neei* Chiarini & L.A.Mentz
- 5 Fruits yellow or greyish-green. Stems sprawling, pubescent with 1–3-celled simple eglandular hairs and some glandular hairs and armed with profuse acicular prickles ..... *S. platense* Dieckmann
- Fruits orange-red. Stems erect to prostrate, glabrous or pubescent with a few simple 4–6-celled eglandular hairs and armed with some acicular or recurved flattened prickles..... *S. capsicoides* All.
- 6 Leaves entire or with 3–5 triangular entire lobes ..... *S. acerifolium* Dunal
- Leaves clearly lobed or pinnatifid, the lobes sinuate or again lobed .....7
- 7 Upper leaf surfaces almost glabrous at maturity, with only some stellate hairs on the midvein; blades deeply lobed. Stem prickles reflexed. Calyx and corolla glabrous or with a few hairs. Berries orange, globose, 15–20 mm in diameter ..... *S. atropurpureum* Schrank
- Upper leaf surfaces with evident and persistent simple hairs; blades sinuate to lobed. Stem prickles straight. Calyx with bristle-like hairs up to 3 mm long; corolla hispid. Berries yellowish, ovoid, 11–15 mm in diameter..... *S. tenuispinum* Rusby

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# *Costus loangensis*, an exciting new species from Gabon, Africa

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## Abstract

A new species of spiral ginger (*Costus*: Costaceae) from Gabon, Africa is described. *Costus loangensis* H. Maas & Maas is found in the coastal region on white sand soils under a tropical rain forest canopy. It is morphologically distinct from all other African species of *Costus* but shows some similarities in floral form with the savanna-inhabiting *Costus spectabilis* (Fenzl) K. Schum. and similarities in vegetative form with *Costus ligularis* Baker. Only one population of the new species is documented. Photographs of the new species are included as is a preliminary phylogeny indicating its position within the African Costaceae.

## Keywords

Africa, Gabon, Costaceae, *Costus*, Zingiberales, spiral ginger

## Introduction

The plant family Costaceae is pantropical in distribution with its largest genus, *Costus* L., restricted in distribution to African and New World Tropics. Based on phylogenetic studies, the ancestral distribution of *Costus* is the African tropics and its current distribution is reflective of a long distance dispersal event from Africa to the neotropics (Specht et al. 2001). Estimates based on fossil calibrations indicate

that the Neotropical lineage diverged from the African *Costus* clade approximately 33 million years ago (Specht 2006b), while subsequent diversification of the neotropical *Costus* lineage based on rates of molecular evolution is estimated to have occurred within the past 4 million years (Kay et al. 2005), indicating a recent rapid radiation of the neotropical *Costus* lineage following colonization. There are currently ~80 species in the new world clade as compared with only ~25 species in the combined African lineages.

In all *Costus* species, the staminodial labellum, formed by the fusion of five petaloid organs in the stamen whorl, is predominantly responsible for the floral display. The ancestral *Costus* flower had a broad, open labellum; solid white or yellow in color; with no strong markings indicative of a specific pollination syndrome (Specht et al. 2001). Phylogenetic studies using molecular and morphological data (Specht 2006a) indicate a single evolutionary origin of the bee-pollinated floral form from the ancestral open floral morphology, resulting in a relatively diverse African clade (~7 species) all with a floral morphology indicative of bee pollination (e.g. *Costus afer* Ker Gawl., *Costus dubius* (Afzel.) K. Schum). The Neotropical *Costus* lineage is sister to this bee-pollinated African clade, and the earliest diverging species of the neotropical clade retain the ancestral bee-pollination syndrome (Specht 2006b; Kay et al. 2005). Within the neotropical *Costus*, bird pollination has evolved as many as 7 times, each associated with a radiation of a bird-pollinated lineage (Kay et al. 2005, Specht 2006a). It is hypothesized that this evolutionary toggle between bee and bird pollination and adaptation to hummingbird pollination (Kay et al. 2005) may have led to the rapid radiation of this lineage in the Neotropics subsequent to its divergence from the African ancestral populations (Specht 2006b). There are no known bird-pollinated species in Africa, with the possible exception of *Costus giganteus* Welw. ex Ridl. from São Tomé and Príncipe which bears red bracts and tubular yellow flowers that resemble those of Neotropical bird-pollinated species.

As part of a larger effort to monograph all African species of *Costus*, the authors recovered a photograph of a *Costus* flower published in a guide to the Loango National Park (Vande weghe 2007). This photo represented a plant that was not present in studied herbarium or living material and had not yet been described. An expedition to Gabon with a targeted trip to the Loango National Park (= Parc National de Loango) and the surrounding region revealed a single population of the unknown species, here described.

***Costus loangensis* H. Maas & Maas, sp. nov.**

urn:lsid:ipni.org:names:77123154-1

[http://species-id.net/wiki/Costus\\_loangensis](http://species-id.net/wiki/Costus_loangensis)

**Diagnosis.** *Costus loangensis* (Fig. 1) is a short-stemmed (about 0.5 m tall) plant with few (6–7) leaves and with completely yellow flowers. Stems and leaves are covered with



**Figure 1.** Photographs of *Costus loangensis* from the single known population. Photo credit: J.P. Vande weghe.

a dense indument of erect to half-appressed hairs. *Costus loangensis* differs from *Costus spectabilis* (Fenzl) K.Schum., another short-stemmed yellow-flowered species, by having a well developed aerial stem. *Costus spectabilis* inhabits savannas and has only 4

**Table 1.** Use of characters to differentiate *Costus loangensis* from other African species with similar morphological characters.

Species	Flower color	Stem height	Bract appendage
<i>Costus loangensis</i>	yellow	0.5m	No
<i>Costus spectabilis</i>	yellow	0m	No
<i>Costus ligularis</i>	pale pink to white	0.5m	No
<i>Costus gabonensis</i>	yellow	1.5m	Yes, red/brown reflexed

leaves that remain strongly pressed to the ground. *Costus loangensis* differs from *Costus ligularis* Baker, also a short-stemmed and indumented plant, by the colour of its flowers (*Costus ligularis* has a pale pink flower) and the length of the calyx (5–7 mm in *C. ligularis* v. 11–12 mm in *C. loangensis*) (Table 1).

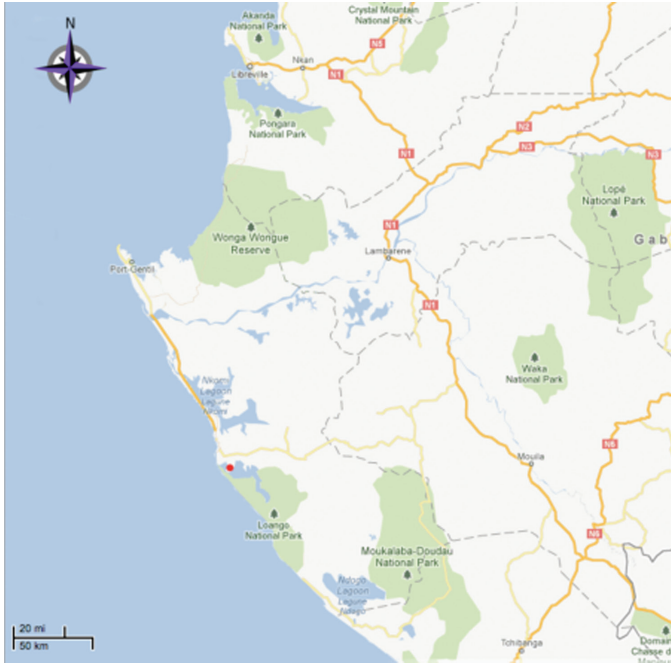
**Type.** P.J.M. Maas, F.J. Breteler, C.D. Specht, H. Maas-van de Kamer, R. Niangadouma 10184 (holotype WAG; isotypes K, LBV, MO, UC), Gabon, prov. Ogooué-Maritime: Parc National de Loango, between Lodge and Staff building, 1°54'43.3"S, 9°19'33.6"E, wet forest on white sand, along forest trail, at about sea level, 9 November 2011.

**Description.** Terrestrial herb, 0.5–0.6 m tall, stems dark brownish red. *Leaves:* dark olive-green, several (6–7) concentrated at the apex of the stem; sheaths dark red, 0.6–0.8 cm diam.; ligule green, 2-lobed, 15–18 mm long, membranous; petiole 5–6 mm long; sheaths sparsely to rather densely covered with erect to half-appressed hairs ca. 2 mm long, ligule and petiole densely to rather densely so; lamina narrowly elliptic to elliptic, 14–16 by 5–6 cm, densely to rather densely covered with erect to half-appressed hairs 1.5–2 mm long on both sides, zone along midrib sometimes reddish, base attenuate, apex acute. *Inflorescence:* 3–5-flowered, ovoid, 2 by 1–1.5 cm, terminating the leafy stem; outer side of bracts, bracteoles and calyx densely covered with appressed to half-appressed hairs ca. 0.2 mm long, ovary sparsely so. *Flower:* 1 per bract; bracts brown to reddish brown, chartaceous, narrowly ovate-triangular to ovate-triangular, 1.7–2 by 0.5–1 cm, callus 2.5–3 mm long; appendages absent; bracteole reddish, boat-shaped, 15–18 mm long, callus 1.5–2 mm long; calyx reddish to greenish, 11–12 mm long, lobes deltate, ca. 2 mm long, callus ca. 1 mm long; corolla yellow, 50–55 mm long, tube 20–25 mm long, lobes narrowly elliptic, 30–35 mm long, outer side rather densely covered with half-appressed hairs ca. 1 mm long particularly near the apex, together forming a hood over the throat opposite the labellum, apex with a callus-like thickening; labellum yellow, horizontally flattened with funnel-shaped base, broadly obovate when spread out, 30–40 by 40–50 mm, margin fimbriate (fimbriae 2–3 mm long); stamen yellow, 25–30 by 7–10 mm, apex reflexed, anther 5–7 mm long; ovary narrowly obovoid, ca. 6 mm long, stigma bilamellate, dorsal appendage 2-lobed. *Fruit* and *seeds* not seen.

**Distribution.** Gabon (Fig. 2). Only known from the type location.

**Habitat and ecology.** In wet forest, on white sand soil under rain forest canopy (Fig. 3). Elevation just above sea level. Flowering: November; fruiting: unknown.

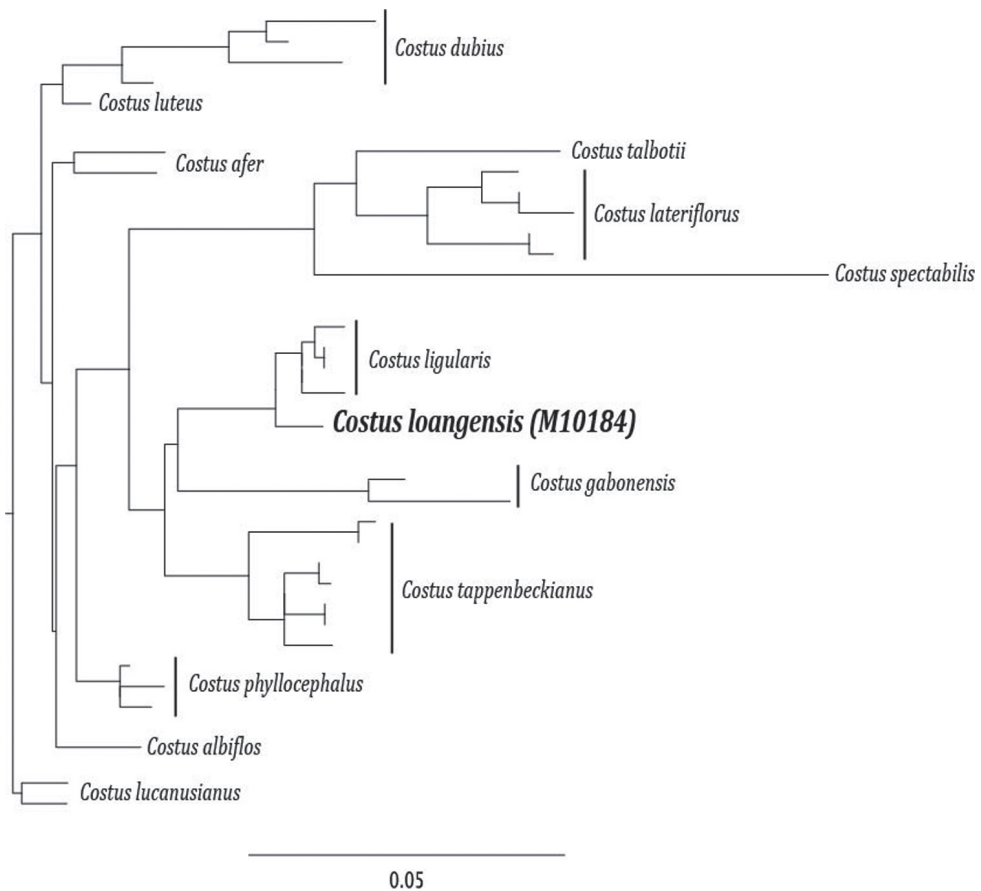




**Figure 2.** Map of locality for *Costus loangensis*. The red dot represents the type locality.



**Figure 3.** *Costus loangensis* habit and habitat, as being studied by co-author P.J.M. Maas. Photo credit: H. Maas-van de Kamer.



**Figure 4.** Phylogeny of African *Costus* species (Table 2) including newly described *Costus loangensis*. The phylogeny was constructed in PhyML (Guindon and Gascuel 2003) with aligned sequence data for two low copy nuclear markers [calmodulin (cam) intron (Johansen 2005) and rpb2 (Specht 2006a)] and nrDNA markers ITS and ETS. All nodes indicated have >50% bootstrap support.

**Phylogenetic relationship.** Based on a combined 4 molecular marker (CAM, ITS, ETS, rpb2) phylogenetic analysis with taxon sampling that included African species in the genus *Costus*, *Costus loangensis* H. Maas & Maas is found to be well supported as sister to a clade of *Costus ligularis* Baker specimens (Fig. 4). *Costus loangensis* fits within the general distribution range of *C. ligularis*, however no populations of *Costus ligularis* were found in sympatry. *Costus loangensis* is restricted in elevation to just above sea level, while *C. ligularis* is commonly found 0–600m above sea level throughout low-elevation rain forests in Cameroon and Gabon.

**Vernacular names.** Not recorded. This plant seems to go unnoticed by the local population and has no known uses.

**Etymology.** *Costus loangensis* is named after the place where it was photographed and now has been collected and documented for the first time: near the Loango Lodge, in “Parc Nacional de Loango” in Gabon.

**Table 2.** List of collections included in phylogeny to place *Costus loangensis* sp. nov.

<i>Costus</i>	<i>afer</i>	L87-0185
<i>Costus</i>	<i>afer</i>	M10205
<i>Costus</i>	<i>albiflos</i>	M10411
<i>Costus</i>	<i>dubius</i>	M10206
<i>Costus</i>	<i>dubius</i>	GH89-0918
<i>Costus</i>	<i>aureus</i>	M9302 (vouchered from Burger's Bush)
<i>Costus</i>	<i>lucanusianus</i>	M10000
<i>Costus</i>	<i>lucanusianus</i>	L87-0286
<i>Costus</i>	<i>ligularis</i>	M10329
<i>Costus</i>	<i>ligularis</i>	M10267
<i>Costus</i>	<i>ligularis</i>	BB 1998-0923003
<i>Costus</i>	<i>lateriflorus</i>	M9995
<i>Costus</i>	<i>lateriflorus</i>	M10331
<i>Costus</i>	<i>lateriflorus</i>	GH98-224
<i>Costus</i>	<i>spectabilis</i>	GH96-284
<i>Costus</i>	<i>gabonensis</i>	M10291
<i>Costus</i>	<i>gabonensis</i>	CS02-339
<i>Costus</i>	<i>tappenbeckianus</i>	M10226
<i>Costus</i>	<i>tappenbeckianus</i>	GH94-628
<i>Costus</i>	<i>talbotii</i>	BB 2003-0109009
<i>Costus</i>	<i>phyllocephalus</i>	M10389
<i>Costus</i>	<i>phyllocephalus</i>	L87-0057
<i>Costus</i>	<i>phyllocephalus</i>	BB 2001-0402004

L=Lyon Arboretum

M=Maas collection

CS=C. Specht collection

GH=Greenhouse at Smithsonian NMNH

BB=Burger's Bush

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Research and Exploration (grant #8994-11) for financial support for travel to Gabon and S. Salzman, T. Renner, S. Shen, and K. Yu for producing and analyzing the phylogenetic data presented in this paper.

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# Diatoms from Brazil: the taxa recorded by Christian Gottfried Ehrenberg

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## Abstract

The flora of diatoms from Brazil has been studied by several authors from the beginning of the 19<sup>th</sup> up to now. Some of the old lists and descriptions are unknown or have been ignored by Brazilian researchers and the situation of the names cited was not assessed. Here we compiled a list of 101 taxa of diatoms from Brazil registered by Christian Gottfried Ehrenberg during the 19<sup>th</sup> century. We checked the current nomenclatural status of those taxa and lectotypified species from Brazil described by this author. For this, we accessed the Ehrenberg collection in the Museum für Naturkunde, Berlin, Germany, where 11 samples from Brazil studied by Ehrenberg are housed and published in different papers. Using these samples, we found 101 taxa (specific and infraspecific) published by Ehrenberg from Brazil. Five species (*Eunotia bidens* Ehrenb., *E. depressa* Ehrenb., *E. elephas* Ehrenb., *Pinnularia microstauron* Ehrenb., and *Terpsinoe brasiliensis* Ehrenb.) were new descriptions and were lectotypified here. The other species cited for Brazil were described initially from other places. However, 23 names were invalid and one illegitimate.

## Keywords

Lectotypification, nomenclatural status, Ehrenberg collection, *Eunotia*, *Pinnularia*, *Terpsinoe*



## Introduction

The 19<sup>th</sup> century was very important regarding the description of the biodiversity of algae and protists. At the first half of that century, material from different parts around the world was analyzed by researchers from Europe and is today deposited in institutions on this continent. Christian Gottfried Ehrenberg was one of these early researchers (Lazarus and Jahn 1998). His collection comprises material from Africa, America, Europe, Asia and Oceania. However, the collection was mostly unavailable until 1990 (Lazarus and Jahn 1998). This inaccessibility and the absence of designated nomenclatural types of many taxa described by him, resulted in unclear taxonomic concepts of a number of these species.”

Brazil is among the regions from South America whose diatom flora was studied by Ehrenberg. Samples from the States of Amazonas, Rio de Janeiro, São Paulo, Minas Gerais and Santa Catharina were analyzed by Ehrenberg and the names of some species were published in five publications (Ehrenberg 1839, 1841, 1843, 1851, 1854). Several of the taxa names published by him are in apparent disuse, and the current nomenclature of many of them is not known. This is true for the entire list of Ehrenberg’s names. The validation of these names is guided by the ICZN (International Code of Zoological Nomenclature), as stated by Article 45.4 of the International Code of Botanical Nomenclature (ICBN) (McNeill et al. 2006), since diatoms were considered by Ehrenberg as polygastric animals.

Recently, Brazil is among the countries that have employed efforts to repatriate data of plants collected by foreign researchers during 18<sup>th</sup>, 19<sup>th</sup> and 20<sup>th</sup> centuries. Such efforts have resulted positively in the creation of virtual herbaria (Zappi et al. 2012) and in the cataloguing of the flora thus increasing lists of species recorded in all its territory (Forzza et al. 2012). Several European collections have diatom material from Brazil (e.g. Ehrenberg, Grunow, Hustedt, Tempère & Peragallo, Krasske) which is still mostly unexplored. Such collections are very important for taxonomic studies which are the base to the knowledge of the biodiversity and, consequently, to the knowledge of tropical aquatic systems. Thus, this is the first work that deals of repatriation of data about algae, specifically diatoms.

The aim of this study was to compile a list of taxa of diatoms from Brazil registered by Ehrenberg, to check the current nomenclatural status of those taxa, and to lectotypify specific and infraspecific taxa.

## Material and methods

The Ehrenberg Collection (i.e., preparations, drawings and publications) was accessed at BHUPM (Museum für Naturkunde, Leibniz-Institut für Biodiversität- und Evolutionsforschung an der Humboldt Universität zu Berlin), where it is deposited and recorded under the following numbers of cases (Kästen) and card folders (Bücher): K. 18 B. 3-5, K. 19 B. 9, K. 52 B. 12, K. 53 B. 10; Jahn and Kusber (2004) have transcribed this for the use in databases; the material thus includes the following micas-

trips: 180301-180316, 180401-180416, 180501-180516, 190901-190916, 521201-521216, 531001-531016. The data of the samples (i.e., original number of sample, locality, collector (leg.), date of sampling, study on which the analysis of such samples were published) are compiled in Table 1. The original number of sample is maintained by BHUPM as current control number.

To verify the nomenclature of some names, beside Ehrenberg's original publications, we consulted Index Nominum Algarum (2012), Algaebase (Guiry and Guiry 2012) and Algoterra (Jahn and Kusber 2012).

The occurrence of the taxa cited for Brazil but originally described from other places than Brazil is provided in this study by the number of original samples (Table 1), except the sample from Tefé Lake (Ega-See) for which the Sample Index did not provide the number of the original sample and which will be referred to as Tefé Lake.

## Results

### A brief history about the samples from Brazil

Ehrenberg never went to Brazil. However, he received samples from different important persons of the history of such country. The main was Carl Friedrich Philipp von Martius (1794–1868), a researcher of the Brazilian flora, who sent samples from Coari (Amazonas State) to Ehrenberg (1839, 1841, 1843). Karl Sigismund Kunth (1788–1850), Eduard Friedrich Poeppig (1788–1868), Édouard Louis Chavannes (1805–1861) were other naturalists that travelled though South America, including Brazil, and sent samples from Rio de Janeiro and Minas Gerais States, Amazonas State and São Paulo State, respectively (Ehrenberg 1843, 1854). On the other hand, the samples from Santa Catarina State were collected by Carl Pabst (1825–1863) who worked as a land surveyor in the old Dona Francisca Colonie (today Joinville city) and was an assistant of the botanist Franz Gustav Straube (1802–1853) (Straube 1992). However, these samples were sent to Ehrenberg by Carl Alfred Müller (1855–1907) (Ehrenberg 1854), a German bryologist.

Twelve samples from five States from Brazil were sent to Ehrenberg (Fig. 1), but only eleven were cited by him in his studies, and one sample was not catalogued in the Sample Index (i.e., Tefé Lake, vide Table 1). The samples were stored in powder boxes (Figs 2–4) or old medicine boxes (Fig. 5) and are kept in the Museum für Naturkunde in a very good state. As well as the other Ehrenberg samples, the preparations of material from Brazil were made using mica discs, embedded with Canada Balsam (Lazarus and Jahn 1998).

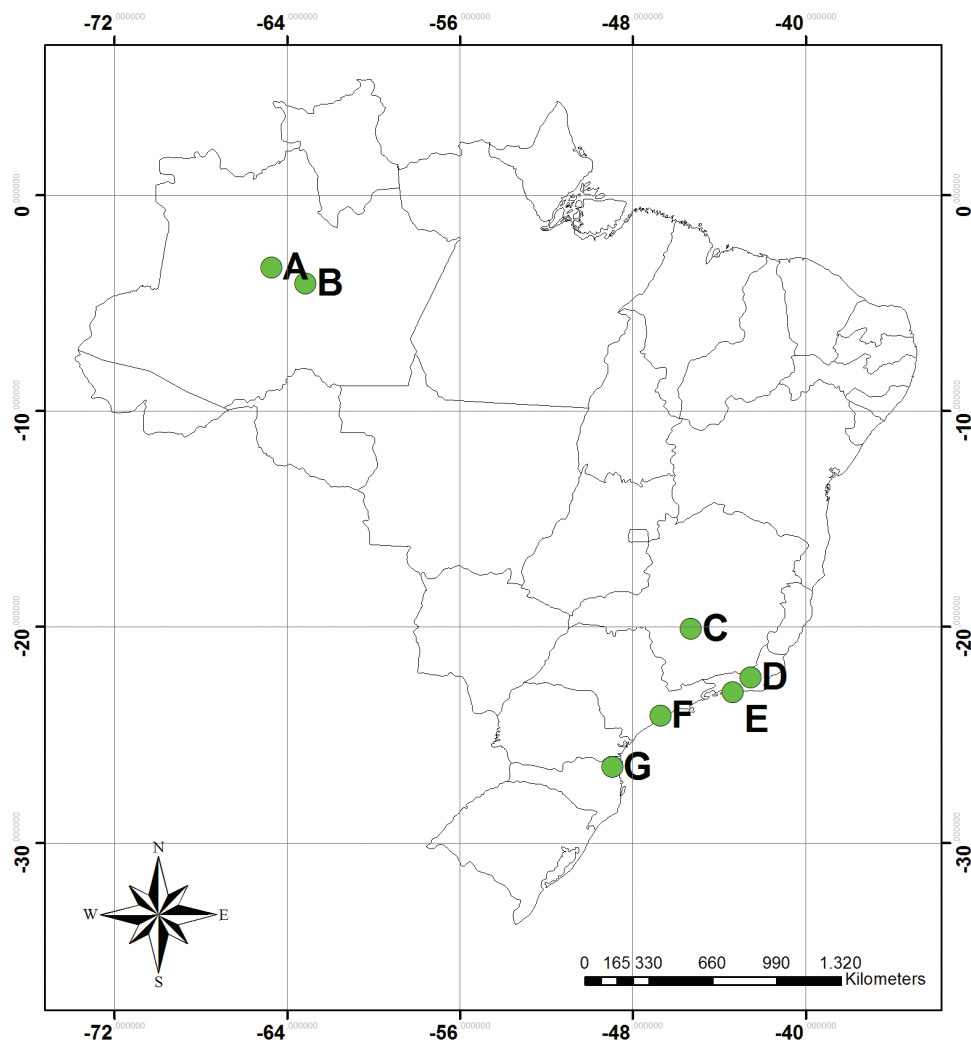
From these samples, we cataloged 101 taxa (specific and infraspecific) published by Ehrenberg from Brazil, of which five were new descriptions, 72 whose first descriptions were made from other places than Brazil, and 23 were invalid and one illegitimate name.

The list of all taxon names is given below, and the species described initially from Brazil are here lectotypified.

**Table 1.** Data about samples of diatoms from Brazil analyzed by Ehrenberg.

Original sample	Original name of the locality	Current name of the locality	Coordinates		Collector	Date of sampling	Micasatrips	Extra data of the samples	Reference
1085	Ega	Tefé, Amazonas State	3°20'29.87"S	64°43'33.39"W	Eduard Friedrich Poeppig	Between 1831 and 1832	180313-180316	Subaerial, moss <i>Hypnum acuminatum</i>	Ehrenberg (1854)
*	Ega-See	Tefé Lake, Tefé, Amazonas State	3°20'29.87"S	64°43'33.39"W	Eduard Friedrich Poeppig	Between 1831 and 1832	180416	Periphytic, under <i>Oscillaria</i> sp.	Ehrenberg (1854)
1104	Praya de Sernambatyba	Barra Beach, Rio de Janeiro, Rio de Janeiro	23°0'35.56"S	43°22'8.97"W	Karl Sigismund Kunth	Between 1829 and 1841	180501-180502	Root of <i>Eriocaulon moestum</i>	Ehrenberg (1843, 1854)
1105	Santo Antonio do Monte	Santo Antônio do Monte, Minas Gerais State	20°4'50.27"S	45°17'55.27"W	Karl Sigismund Kunth	Between 1829 and 1841	180503-180504	Humus attached to Gramineae	Ehrenberg (1843, 1854)
1106	São Paulo	São Paulo, coast	24°5'31.91"S	46°43'6.76"W	Édouard Louis Chavannes	1846*	180507-180508	Soil	Ehrenberg (1854)
1099	Rio Conigo in Rio de Janeiro A	Congo River, Nova Friburgo, Rio de Janeiro State	22°19'33.03"S	42°33'5.48"W	Hermann Encke	07th April 1850	180401-180406	Sediment	Ehrenberg (1851, 1854)
1100	Rio Conigo in Rio de Janeiro B	Congo River, Nova Friburgo, Rio de Janeiro State	22°19'33.03"S	42°33'5.48"W	Hermann Encke	07th April 1850	180407-180408	Sediment	Ehrenberg (1851, 1854)
1101	Insel St. Catharina, Rio de Lauro	Santa Catarina	26°28'24.01"S	48°57'9.32"W	Carl Pabst	1850	180409-180410	Subaerial, moss <i>Hypnum</i> sp	Ehrenberg (1854)
1102	Insel St. Catharina, Rio Concescao	Santa Catarina	26°28'24.01"S	48°57'9.32"W	Carl Pabst	1850	180411-180412	Subaerial, moss <i>Hypnum laxense</i>	Ehrenberg (1854)
1103	Insel St. Catharina, Barre des Itajahi	Santa Catharina	26°28'24.01"S	48°57'9.32"W	Carl Pabst	November and December 1846	180413	Subaerial, moss <i>Sphagnum pulchricoma</i>	Ehrenberg (1854)
1087	Sumpfboden, Amazonas, Coari	Coari, Amazonas State	4°5'13.84"S	63°8'40.87"W	Carl Friedrich Philipp von Martius		180301-180308		Ehrenberg (1839, 1841, 1843)

\* The Sample Index did not provide the number of the respective sample



**Figure 1.** Localities of the samples from Brazil studied by Ehrenberg (1841, 1843, 1851, 1854); **A** Ega (Tefê), Amazonas **B** Coari, Amazonas **C** Santo Antônio do Monte, Minas Gerais **D** Rio Conigo (Cônego River), Nova Friburgo, Rio de Janeiro **E** Praya de Sernambatyba (Barra Beach), Rio de Janeiro **F** São Paulo **G** Santa Catarina.

Types of valid and legitimate names (available proposals) firstly described from Brazil

*Eunotia bidens* Ehrenb., Abh. K. Akad. Wiss. Berlin, Physik. Kl., 1841: 413, 1843.

[http://species-id.net/wiki/Eunotia\\_bidens](http://species-id.net/wiki/Eunotia_bidens)

Figs 6–7

**Lectotype (designated here).** Specimen in preparation 180404b, marked with yellow (g) ring, from sample 1099 “Rio Conigo in Rio de Janeiro”, Ehrenberg Collection, in BHUPM (Museum für Naturkunde) (Fig. 6).

**Locality of the lectotype.** Rio Conigo [Cônego River], Nova Friburgo, Rio de Janeiro, Brazil.

**Locality of the syntypes.** New-York, Andower “Conn.” (Connecticut)

**Original description.** “*striata, ventre plano, dorso convexo medio exciso (bidentato), apicibus dilatatis truncatis.* = *E. diodon apicibus truncatis.*”

Ehrenberg (1843, p. 373) cited the original locality as Brazil and USA (New York and Andower, Connecticut). In the material from New York (preparations 250401–250408, 260101–260112 and 260301–260308) we did not find any reference to *E. bidens*, even under the name *Himantidium* that Ehrenberg (1843) related to the taxon on page 373. On the other hand, in the material from Andower (preparations 260201–260208) we found a reference to *E. bidens* in the preparation 260205d, marked with a blue ring, but it was not in a good condition to be photographed. Therefore, we chose the material from Brazil as lectotype.

***Eunotia depressa* Ehrenb., Abh. K. Akad. Wiss. Berlin, Physik. Kl., 1841: 413, Tafel I, Fig IV: 6b, Tafel IV, Fig I: 12, 1843**

[http://species-id.net/wiki/Eunotia\\_depressa](http://species-id.net/wiki/Eunotia_depressa)

Fig 8–9

**Lectotype (designated here).** Specimen in preparation 180403a, marked with yellow (g) ring, from sample 1099, “Rio Conigo in Rio de Janeiro”, Ehrenberg Collection, in BHUPM (Museum für Naturkunde) (Fig 8).

**Locality of the lectotype.** Rio Conigo [Cônego River], Nova Friburgo, Rio de Janeiro, Brazil.

**Locality of the other syntype.** “New York?”

**Original description.** “*striata, anguste linearis, ventre plano aut leviter concavo, dorso depresso plano, prope apices rotundatos subito attenuato.*”

Ehrenberg (1843, p. 373) defined that *E. depressa* occurred in Brazil and possibly in USA (New York). We verified the preparations from New York (K: 25, B: 4; K: 26, B: 1, 3) but did not find any citation of *E. depressa*. Therefore, we defined the lectotype from the material from Brazil.

***Eunotia elephas* Ehrenb., Abh. K. Akad. Wiss. Berlin, Physik. Kl., 1841: 414, Tafel I, Fig IV: 5, 1843.**

[http://species-id.net/wiki/Eunotia\\_elephas](http://species-id.net/wiki/Eunotia_elephas)

Figs 10–12

**Lectotype (designated here).** Specimen in preparation 180502e, marked with red (r) ring, from sample 1104 “Praya Senambatyba, Rio de Janeiro”, Ehrenberg Collection, BHUPM (Museum für Naturkunde) (Fig 11).

**Locality of the lectotype.** “Praya de Sernambatyba”, Rio de Janeiro, Brazil.

**Original description.** “*striata, latissima, curva, apicibus late rotundatis, dorso, tridentato.*”





**Figure 2–5.** General storage of samples from Brazil in Ehrenberg Collection, Museum für Naturkunde  
**2–4** Gunpowder boxes **2–3** Lateral view **4** View from the top **5** Medicine box

*Pinnularia microstauron* (Ehrenb.) Cleve, *Acta Soc. Fauna Fl. Fenn.* 8(2): p. 28. 1891

[http://species-id.net/wiki/Pinnularia\\_microstauron](http://species-id.net/wiki/Pinnularia_microstauron)

Fig. 13

Basionym: *Stauroptera microstauron* Ehrenb., *Abh. K. Akad. Berlin, Phys. Kl.* 1841: 423, Tafel I, Fig IV: 1, Tafel IV, Fig II: 2, 1843.

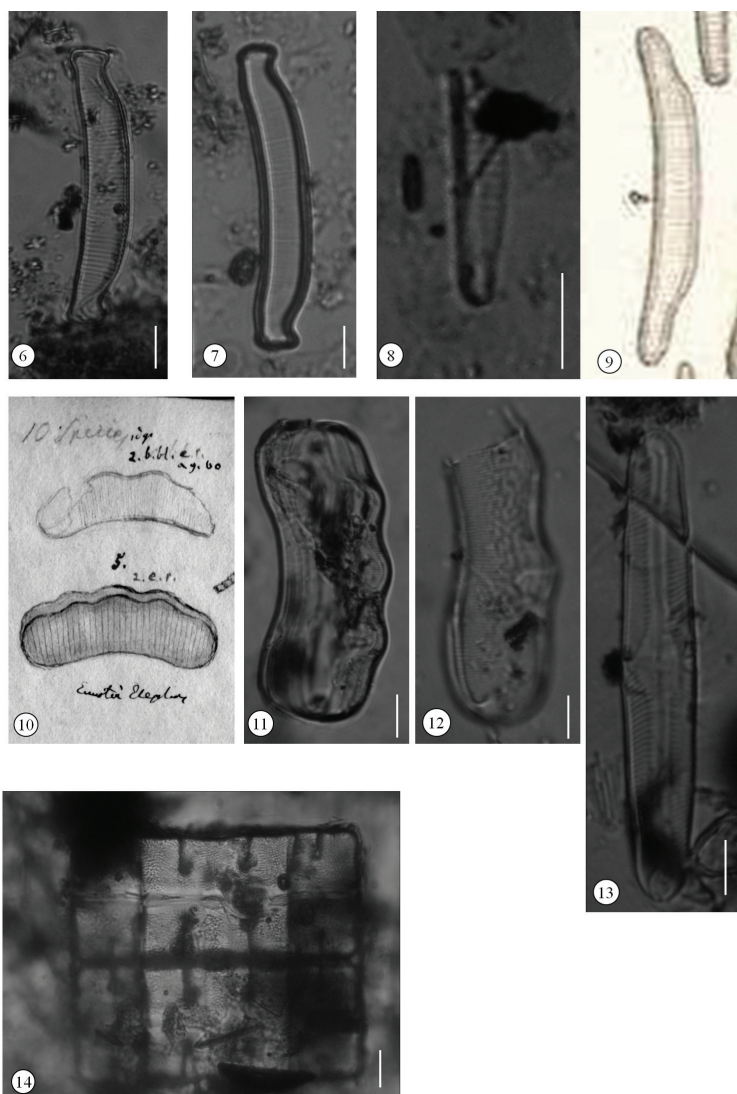
**Lectotype (designated here).** Specimen in preparation 180502d, marked with red (r) ring, from sample 1104, “Praya de Sernambatyba, Rio de Janeiro”, Ehrenberg Collection, in BHUPM (Museum für Naturkunde) (Fig. 13).

**Locality of the lectotype.** “Praya de Sernambatyba”, Rio de Janeiro, Brazil.

**Locality of the syntype.** Labrador.

**Original description.** “*testula styloformis a ventre linearis, lateribus rectis, apicibus arcte constrictis late rotundatis.*”

Krammer (1992, pl. 32, fig. 10) [reproduction of Ehrenberg’s published figure (1843, Tafel I, Fig. IV:1)] defined an “iconotype” for *P. microstauron*. Since we found the specimen used by Ehrenberg to describe the species, we designated it here as lectotype of the species. *S. microstauron* was described for two samples from Brazil and Canada (Labrador) (Ehrenberg 1843, p. 387). However, we did not find any mentioning of *S. microstauron* in the legends of the mica from Labrador (250509 to 250516). Therefore, we defined the lectotype from the material from Brazil.



**Figures 6–14.** Diatoms from Brazil published by Christian Gottfried Ehrenberg **6–7** *Eunotia bidens* Ehrenb **6** Lectotype, preparation 180404b, marked with yellow (g) ring, from sample 1099 “Rio Conigo in Rio de Janeiro”, Ehrenberg Collection, in BHUPM (Museum für Naturkunde) **7** Another specimen of *E. bidens* found in preparation 180405a, marked with yellow (g) ring **8–9** *Eunotia depressa* Ehrenb **8** Lectotype, preparation 180403a, marked with yellow (g) ring, from sample 1099, “Rio Conigo in Rio de Janeiro”, Ehrenberg Collection, in BHUPM **9** *E. depressa* provided by Ehrenberg (1843, Tafel I, Fig IV: 6b) **10–12** *Eunotia elephas* Ehrenb **10** Part of Ehrenberg’s drawing sheet No. 2050 from “Praya de Sernambatyba” (Barra Beach) **11** Lectotypus, preparation 180502e, marked with red (r) ring, from sample 1104 “Praya Senambatyba, Rio de Janeiro”, Ehrenberg Collection, BHUPM **12** Another specimen of *E. elephas* found in preparation 180502e, marked with red (r) **13** *Pinnularia microstauron* (Ehrenb.) Cleve, lectotype, preparation 180502d, marked with red (r) ring, from sample 1104, “Praya de Sernambatyba, Rio de Janeiro”, Ehrenberg Collection, in BHUPM **14** *Terpsinoe brasiliensis* Ehrenb., lectotype, preparation 180411a, marked with blue (bl) ring, from sample 1102, “Rio Consescao der Insel St. Catharina”, in BHUPM; Scale bars: 10 µm

***Terpsinoe brasiliensis* Ehrenb., Mikrogeologie, 310, 311, 1854.**

[http://species-id.net/wiki/Terpsinoe\\_brasiliensis](http://species-id.net/wiki/Terpsinoe_brasiliensis)

Fig. 14

**Lectotype (designated here).** Specimen in preparation 180411a, marked with blue (bl) ring, from sample 1102, “Rio Consescao der Insel St. Catharina”, in BHUPM (Museum für Naturkunde) (Fig. 14).

**Locality of the lectotype.** “Rio de Concescao, Insula St. Catharina, Brasilien”.

**Original diagnosis.** “mit sehr kleinen Notenzeichen”.

*T. brasiliensis* was published the first time by Ehrenberg in his book *Mikrogeologie* (1854). Several taxa of diatom published by Ehrenberg in this work are considered unavailable (invalid) according the Article 12 of ICZN (Ride et al. 1999) due to absence of a description, definition and indication of any illustration. This is not the case for *T. brasiliensis* and, maybe, could be the only case, in which Ehrenberg provided the following description “...und *Terpsinoë brasiliensis*, mit sehr kleinen Notenzeichen...” [and *Terpsinoe brasiliensis*, with very short musical notes]. This short description is considered to be enough by us, as well as several other descriptions published long ago by other authors (e.g., Agardh 1827).

### First descriptions from other localities than Brazil

We provide a list of taxa cited by Ehrenberg as occurring in Brazil. This list is names based and has not been checked with respect to current taxonomy. Authors of combinations have been checked.

***Amphitetras antediluviana*** Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1839: 142, 1840. [cited by Ehrenberg (1854), sample 1102]

***Amphora gracilis*** Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 410, 1843. [cited by Ehrenberg (1854), sample 1106]

***Amphora libyca*** Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1840: 205, 1840. [cited by Ehrenberg (1854), 1085, Tefé Lake, samples 1099, 1102]

***Bacillaria australis*** Ehrenb., Mikrogeologie, Atlas 8, Tafel XXXV-A, Fig II: 3, 1854. [cited by Ehrenberg (1854), sample 1085]

***Cocconeis lineata*** Ehrenb., Mikrogeologie, Atlas 8, Tafel XXXIX, Fig III: 11, 1854. [cited by Ehrenberg (1851), samples 1099, 1100]

***Cocconeis placentula*** Ehrenb., Infusionsthierchen, 194, 1838. [cited by Ehrenberg (1851, 1854), samples 1099]

***Cocconeis striata*** Ehrenb., Abh. Königl. Akad. Berlin, 1841: 370, Tafel III, Fig I: 30, 1843. [cited by Ehrenberg (1854), samples 1101, 1102].

***Cocconema gracile*** Ehrenb. Abh. Königl. Akad. Wiss. Berlin, 1841: 412, 1843. [cited by Ehrenberg (1851, 1854), sample 1099]

***Discoplea comta*** Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1844: 267. 1844. (nom. gen. inval.) [cited by Ehrenberg (1854), sample 1102]

- Eunotia amphioxys* Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 413, 1843. [cited by Ehrenberg (1851, 1854), samples 1099, 1102, 1106]
- Eunotia camelus* Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 413, 1843. [cited by Ehrenberg (1854), samples 1085, 1105]
- Eunotia diodon* Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1837: 45, 1837. [cited by Ehrenberg (1851, 1854), samples 1099]
- Eunotia monodon* Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 414, 1843. [cited by Ehrenberg (1854), samples 1102]
- Eunotia parallela* Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 414, 1843. [cited by Ehrenberg (1854), sample 1102]
- Eunotia pileus* Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 414, 1843. [cited by Ehrenberg (1854), sample 1085]
- Eunotia praeupta* Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 414, 1843. [cited by Ehrenberg, (1854), Tefé Lake]
- Eunotia quaternaria* Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 414, 1843. [cited by Ehrenberg (1854), sample 1105]
- Eunotia nonaria* Ehrenb. ex Rabenh., Fl. Eur. Alg., I, 71, 1864. [name already cited by Ehrenberg (1851), sample 1099]
- Eunotia octonaria* Ehrenb. ex Rabenh., Fl. Eur. Alg., I, 71, 1864. [name already cited by Ehrenberg (1851), sample 1099]
- Eunotia quinararia* Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 414, 1843. [cited by Ehrenberg (1854), sample 1099]
- Eunotia senaria* Ehrenb. ex Rabenh., Fl. Eur. Alg., I, 71, 1864. [name already cited by Ehrenberg (1851, 1854), sample 1099]
- Eunotia sphaerula* Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1870: 55, 1870. [name already cited by Ehrenberg (1854), Tefé Lake, sample 1102]
- Eunotia tetraodon* Ehrenb., Infusionsthierchen, 192, 1838. [cited by Ehrenberg (1854), sample 1085]
- Eunotia tridentula* Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 414, 1843. [cited by Ehrenberg (1841, 1854), sample 1099]
- Eunotia turgida* (Ehrenb.) Ehrenb., Infusionsthierchen, 190, 1838. [cited by Ehrenberg (1843), sample 1087]
- Fragilaria acuta* Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1840: 210, 1840. [cited by Ehrenberg (1854), samples 1099, 1102]
- Fragilaria entomon* Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 415, 1843. [cited by Ehrenberg (1854), sample 1102]
- Gallionella crenata* Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1847: 273, Tafel I Figs I: 8,9; Tafel I Figs II: 4,5; Tafel II Fig I: 12; Tafel II Figs II: 4,5; Tafel II Fig III: 3; Tafel III Fig I: 6; Tafel III Figs II: 9-11; Tafel IV Figs A: 8,9; Tafel IV, Tafel Figs B: 3-5; Tafel V Figs I: 5,6; Tafel VI Figs II: 4,6; 1849. [cited by Ehrenberg (1851, 1854), samples 1099, 1100]
- Gallionella distans* Ehrenb., Infusionsthierchen, 190, 1838. [cited by Ehrenberg (1841, 1843, 1854), samples 1087?, 1104, 1105]



- Gallionella granulata*** Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 415, 1843.  
[cited by Ehrenberg (1843, 1854), sample 1087?]
- Gallionella procera*** Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1847: 270, 273, 279, 285, 287, 293, 299, 303, 317, 319, 396, 399, 442, 443, 445, 447, 448, 449, 450, 451, 452, 453, 455, 456, 458, Tafel I Figs I: 6, 7; Tafel I Figs II: 3; Tafel II Figs I: 6, 7; Tafel II Figs II: 2, 3; Tafel II Fig III: 2; Tafel III Figs I: 3, 4; Tafel III Figs II: 4, 5; Tafel IV Figs A: 4, 5; Tafel IV Fig B: 2; Tafel V Fig I: 3; Tafel V Fig II: 4; Tafel VI Fig II: 1. 1849. [cited by Ehrenberg (1854), Tefé Lake, sample 1085]
- Gallionella sulcata*** Ehrenb., Infusionsthierchen, 170, 1838. [cited by Ehrenberg (1854), sample 1102]
- Gallionella varians*** (C.Agardh) Ehrenb., Infusionsthierchen, 167, 1838. [cited by Ehrenberg (1851), sample 1099?]
- Gomphonema clavatum*** Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1831: 88, 1832. [cited by Ehrenberg (1854), sample 1102]
- Gomphonema gracile*** Ehrenb., Infusionsthierchen, 217, 1838. [cited by Ehrenberg (1851, 1854), samples 1099, 1100; 1102]
- Gomphonema longiceps*** Ehrenb. ex Ralfs, in Pritchard, Hist. Inf., ed. 4, 890, 1861. [name already cited by Ehrenberg (1854), sample 1085]
- Himantidium arcus*** (Ehrenb.) Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1839: 127, 1839. [cited by Ehrenberg (1839, 1841, 1843, 1851, 1854), samples 1087, 1099, 1102, 1103, 1104, 1105]
- Himantidium gracile*** Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 417, 1843. [cited by Ehrenberg (1854), samples 1099, 1101, 1102]
- Himantidium monodon*** Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 417, 1843. [cited by Ehrenberg (1851, 1854), sample 1099]
- Himantidium papilio*** Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 417, 1843. [cited by Ehrenberg (1854), sample 1085]
- Navicula amphioxys*** Ehrenb. Abh. Königl. Akad. Wiss. Berlin, 1841: 417, 1843. [cited by Ehrenberg (1841, 1843, 1854), samples 1087, 1102, 1104]
- Navicula amphispheonia*** Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 417, 1843. [cited by Ehrenberg (1854), 1085, Tefé Lake, samples 1102, 1104, 1106]
- Navicula bacillum*** Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1838: 130. 1839. [cited by Ehrenberg (1851, 1854), 1099, samples 1101, 1102]
- Navicula gracilis*** Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1831: 79, 1832. [cited by Ehrenberg (1854), sample from Tefé Lake, without number]
- Navicula sigma*** Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1833: 259, 1834. [cited by Ehrenberg (1854), sample 1102]
- Navicula silicula*** Ehrenb. Abh. Königl. Akad. Wiss. Berlin, 1841: 419, 1843. [cited by Ehrenberg (1854), sample from Tefé Lake, without number]
- Navicula viridis*** (Nitzsch) Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1831: 81, 1832. [cited by Ehrenberg (1841), sample 1088]
- Pinnularia amphirrхина*** Ehrenb., Mikrogeologie, Atlas 17, Tafel XV-A, Fig 20, 1854. [cited by Ehrenberg (1854), sample 1102]

- Pinnularia borealis* Ehrenb. Abh. Königl. Akad. Wiss. Berlin, 1841: 420, 1843. [cited by Ehrenberg (1851, 1854), samples 1099, 1102]
- Pinnularia capitata* (Ehrenb.) Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1848: 18, 1848. [cited by Ehrenberg (1854), samples 1085, 1102]
- Pinnularia decurrens* Ehrenb. Abh. Königl. Akad. Wiss. Berlin, 1841: 420, 1843. [cited by Ehrenberg (1851, 1854), samples 1085, 1099, 1102]
- Pinnularia dicephala* (Ehrenb.) Ehrenb. Abh. Königl. Akad. Wiss. Berlin, 1841: 420, 1843. [cited by Ehrenberg (1843, 1854), samples 1102, 1104]
- Pinnularia gastrum* Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 421, 1843. [cited by Ehrenberg (1854), samples 1099?, 1102?]
- Pinnularia gibba* (Ehrenb.) Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 315, 1843. [cited by Ehrenberg (1854), sample 1102?]
- Pinnularia lanceolata* (Ehrenb.) Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 315, 1843. [cited by Ehrenberg (1854), sample 1102]
- Pinnularia macilenta* Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 421, 1843. [cited by Ehrenberg (1854), samples 1102, 1104]
- Pinnularia nobilis* (Ehrenb.) Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1845: 61, 1845. [cited by Ehrenberg (1843, 1854), sample 1104]
- Pinnularia tabellaria* Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 422, 1843. [cited by Ehrenberg (1851, 1854), sample 1099?]
- Pinnularia vespa* Ehrenb., Mikrogeologie, pl. XXXIII, Fig V: 9, 1854. [name already cited by Ehrenberg (1851, 1854), sample 1099]
- Pinnularia viridis* (Nitzsch) Ehrenb., Abh. Königl. Akad. Wiss. Berlin, 1841: 315, 1843. [cited by Ehrenberg (1843, 1851, 1854), samples 1099, 1100, 1102, 1104, 1105, 1106]
- Stauroneis gracilis* Ehrenb., Abh. Königl. Akad. Berlin, 1841: 423, 1843. [cited by Ehrenberg (1854), sample 1099]
- Stauroneis phoenicenteron* (Nitzsch) Ehrenb., Abh. Königl. Akad. Berlin, 1841: 311, 1843. [cited by Ehrenberg (1851, 1854), sample 1099]
- Stauroneis semen* Ehrenb. ex Ralfs in Pritchard, His. Inf., ed. 4, 912, 1854. [cited by Ehrenberg (1851, 1854), samples 1099; 1101; from Tefé Lake?, without number]
- Stauroptera isostauron* Ehrenb., Abh. Königl. Akad. Berlin, 1841: 423, 1843. [cited by Ehrenberg (1854), sample 1103?]
- Surirella bifrons* Ehrenb., Abh. Königl. Akad. Berlin, 1833: 259, 1834. [cited by Ehrenberg (1854), sample 1102]
- Surirella constricta* Ehrenb. ex Ralfs in Pritchard, Hist. Inf., ed. 4, 794, 1854. [cited by Ehrenberg (1854), samples 1102, 1103]
- Surirella euglypta* Ehrenb., Abh. Königl. Akad. Berlin, 1841: 424, 1843. [cited by Ehrenberg (1851, 1854), samples 1099, 1102]
- Surirella oblonga* Ehrenb. ex Ralfs in Pritchard, His. Inf., ed. 4, 795, 1854. [cited by Ehrenberg (1841, 1843, 1854), samples 1088, 1105]
- Synedra acuta* Ehrenb. ex Ralfs in Pritchard, His. Inf., ed. 4, 788, 1854. [cited by Ehrenberg (1854), sample 1099]



*Synedra lunaris* Ehrenb., Abh. Königl. Akad. Berlin, 1831: 87, 1832. [cited by Ehrenberg (1854), sample from Tefé Lake?, without number]

*Synedra ulna* (Nitzsch) Ehrenb., Abh. Königl. Akad. Berlin, 1831: 87, 1832. [cited by Ehrenberg (1841, 1843, 1851, 1854), samples 1087, 1099, 1100?, 1104, 1105, 1106?, from Tefé Lake?, without number]

*Terpsinoe musica* Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1843: 425, 1843. [cited by Ehrenberg (1854), sample 1102]

### Invalid names (unavailable proposals) or illegitimate names

As introduced before, Ehrenberg considered diatoms as “*animal poligastrica*” in all his publications. According to Article 45.4 of the ICBN, the validity of names of organisms originally not treated as plants, algae or fungi must be governed by the respective code (McNeill et al. 2006). Thus, the validity of names of diatoms published by Ehrenberg is ruled by the ICZN (Ride et al. 1999).

Article 12.1 of ICZN states that “to be available [valid], every new name published before 1931 must satisfy the provisions of Article 11 and must be accompanied by a description or a definition of the taxon that it denotes, or by an indication” (Ride et al. 1999). Subsequently, one of the meanings of the term “indication” and highlighted by us is the Article 12.2.7: “the proposal of a new genus-group name or of a new species-group name in association with an illustration of the taxon being named, or with a bibliographic reference to such an illustration”. Such conditions are not fulfilled by some names published by Christian Ehrenberg.

The names of diatoms listed below are those cited specifically by Ehrenberg (1841, 1843, 1851, 1854) from Brazilian samples and were considered by us as unavailable (invalid) (for cross code terms see David et al. 2012) because they do not fulfill Article 12 of the ICZN (Ride et al. 1999). On the other hand, in the case of *Navicula obtusa* Ehrenb. the name is available (valid), but illegitimate because it is a later homonym.

*Achnanthes brasiliensis* Ehrenb., Mikrogeologie, 310, 311 1854. (nom. inval.)

*Achnanthes incrassata* Ehrenb., Mikrogeologie, 310, 311, 1854. (nom. inval.)

*Achnanthes ventricosa* Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1848: 479, 1848. (nom. inval.)

*Cocconeis glans* Ehrenb., Mikrogeologie, 311, 1854. (nom. inval.)

*Cocconeis lineata* var. *brasiliensis* Ehrenb., Mikrogeologie, 309, 310, 311, 1854. (nom. inval.)

*Cocconeis lirata* Ehrenb., Mikrogeologie, 311, 1854. (nom. inval.)

*Eunotia amphioxys* var. *rostrata* Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1851: 228, 1851. (nom. inval.)

*Eunotia carinata* Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1851: 477, 1851. (nom. inval.)

- Eunotia denaria* Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1851: 477, 1851 (nom. inval.)
- Eunotia edulis* Ehrenb., Mikrogeologie, 315–650, 1854. (nom. inval.)
- Eunotia paradoxa* Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1843: 139, 1843. (nom. inval.) *non Eunotia paradoxa* Berg., Bot. Not. 1939: 433, 1939.
- Eunotia triglyphis* Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1851: 228, 1851. (nom. inval.)
- Fragilaria australis* Ehrenb., Mikrogeologie, 308, 311, 1854. (nom. inval.)
- Gallionella tenerrima* Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1842: 272, 1842. (nom. inval.)
- Navicula catharinae* Ehrenb., Mikrogeologie, 310, 311, 1854. (nom. inval.)
- Navicula microstauron* Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1841: 203, 1841. (nom. inval.)
- Navicula obtusa* Ehrenb., Abh. Königl. Akad. Berlin, , 1841: 419, 1843. (nom. illeg.) *non Navicula obtusa* Bory, Encycl. Méth., Hist. Nat. Zooph., 563, 1827. *nec Navicula obtusa* (Lagerst.) Hust., Süßw.-Diat. Deutschl., 36. 1909 (nom. illeg.)
- Pinnularia catharinae* Ehrenb., Mikrogeologie, 311, 1854. (nom. inval.)
- Pinnularia decora* Ehrenb., Mikrogeologie, 311, 1854. (nom. inval.)
- Pinnularia digitus* Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1845: 61, 1845. (nom. inval.)
- Pinnularia formica* Ehrenb., Mikrogeologie, 311, 1854. (nom. inval.) *non Pinnularia formica* (Ehrenb.) R.M.Patrick, Monogr. Acad. Nat. Sc. Philad., 13, 627, 1966.
- Raphoneis laevigata* Ehrenb., Mikrogeologie, 310, 311, 1854. (nom. inval.)
- Stauroptera brasiliensis* Ehrenb., Mikrogeologie, 311, 1854. (nom. inval.)
- Surirella ovata* Ehrenb., Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin, 1844: 341, 1844. (nom. inval.)

## Discussion

Biological collections represent a set of organism that lived in some locality during some time. Thus, historical collections are a portrait of the biodiversity of some place that can never be faithfully restudied. This is due to natural or anthropogenic factors responsible for changes of biological diversity of an environment in short, medium or long terms, (Jackson and Sax 2009). Therefore, historical collections of species are indispensable sources to study the biodiversity on earth (Shaffer et al. 1998).

Besides their scientific importance, such collections also perform a fundamental cultural role regarding the region in which the material was collected and for the development of science along the centuries. Through Ehrenberg's studies, for instance, it can be inferred which pathway some botanists such as Carl Friedrich Philipp von Martius, Karl Sigismund Kunth, Eduard Friedrich Poeppig, Édouard Louis Chavannes, and other personalities such as the Carl Pabst or Hermann Encke, took when traveling Brazil in the 19<sup>th</sup> century.

The cultural and scientific importance of the Brazilian samples studied by Ehrenberg can be found in its historical context. At the beginning of the 19<sup>th</sup> century, many regions in Brazil were occupied by natives whose social organization was different of other native people from South America. In 1818, Prince Regent D. Joao VI of Portugal started an immigration policy that resulted in the arrival of 1,458 Swiss immigrants between 1819 and 1820. These immigrants established themselves on the Cantagalo Farm and this settlement was known as Nova Friburgo. In 1824, Nova Friburgo received about 450 new people, this time German immigrants. Thus, it can be estimated that approximately 1,900 people lived in this region. In 1907, the Instituto Brasileiro de Geografia e Estatística already estimated about 19,185 inhabitants and in 2011 there were estimates of 182,748 inhabitants (IBGE 1912, 2011). In between, in 1850, Hermann Encke sent two samples to Ehrenberg.

Although we have no accurate estimates of the population from Nova Friburgo in 1850, it is clear that the impact on biodiversity generated by less than 19,185 inhabitants (in 1907) is lower than the impact of the current 182,748 inhabitants. This example can be translated to the other samples collected in Brazil until the first half of the 19<sup>th</sup> century. Even if it refers to only few places, these materials may be the most accurate examples of the biodiversity of Brazilian diatoms. Moreover, historical samples like those can help to understand anthropogenic effects on the biodiversity of diatoms in tropical and subtropical regions.

The list of Brazilian diatoms published in Ehrenberg's studies allowed also to discuss the taxonomy and nomenclature of some diatoms described in the 19<sup>th</sup> century. Although the taxonomy of the diatoms published by Ehrenberg are ruled by the ICZN, the conditions required for a taxon to be considered available (valid) are practically the same as those of the ICBN, that is, a description, a definition (differential diagnosis) or an indication (which can be a published illustration) are needed. This last issue justifies, for instance, to ensure the availability of species such as *Bacillaria australis*, *Gallionella crenata*, *G. procera*, *Pinnularia amphirrhina* and *P. vespa* which have no diagnosis, but indications to an illustration was provided.

Some unavailable names cited by Ehrenberg continued to be ruled by the ICZN which were available by him in later studies. This happened to *Eunotia sphaerula* and *Pinnularia vespa* which were cited by Ehrenberg (1854) and Ehrenberg (1851), respectively, but were made available by Ehrenberg (1870) and Ehrenberg (1854), respectively. Other species cited by Ehrenberg from Brazilian samples became ruled by the ICBN when validated by authors who treated diatoms as algae. This was the case with *E. nonaria*, *E. octonaria* and *E. senaria*, validated by Rabenhorst (1864), and *G. longiceps* validated by Ralfs (Pritchard 1861). Internal evidences enabled us to identify the author of the taxa by "Ehrenb. ex", linking them to the types from the Ehrenberg material.

Similarly, *Navicula obtusa* Ehrenb. (non *Navicula obtusa* Bory), the only illegitimate name among the 101 names published by Ehrenberg from Brazilian samples, was legitimated by Rabenhorst (1864, p. 197) with the new name *Navicula appendiculata* f. *obtusa*. This taxon was associated to "Ehrenb. (Verb. p. 131)". The term "Verb." mentioned by Rabenhorst (1864) referred to the paper *Verbreitung und Einfluss des*

*mikroskopischen Lebens in Süd- und Nord-Amerika*, published by Ehrenberg (1843). The paper that we had access has 154 pages, between the page 291 to 445 and, therefore, Rabenhorst (1864) referred to a page that does not exist on the paper that we analyzed, but maybe refers to a reprint version that we had not access. A similar fact is seen with *Eunotia bidens* Ehrenb. and *Gomphonema cygnus* Ehrenb. which were cited by Rabenhorst (1864, p. 74 and 286, respectively) and related to “Ehrenb. (Verb. p. 125 ...)” and “Ehrenb. (Verb. p. 128 ...)”. The difference between the pages cited by Rabenhorst (1864) and the correct page on Ehrenberg (1843) in both cases is 288 pages. Therefore, we can tell that Rabenhorst (1864) associated *Navicula appendiculata* f. *obtusa* with *Navicula obtusa* in Ehrenberg (1843, p. 419), the only taxa with the epithet *obtusa* on the page 419, even though he had not mentioned clearly *N. obtusa*.

According to the ICBN, an epithet of a latter homonym can be used in a different combination and on a different rank, if the epithet is available at this rank (Article 58.1, McNeill et al. 2006). In this case, the name is treated as new. Thus, the authorship published by Rabenhorst (1864) should be *N. appendiculata* f. *obtusa* Rabenh. and not *N. appendiculata* f. *obtusa* (Ehrenb.) Rabenh., which is in agreement with the Example 1 of the Article 58.1 of the ICBN (McNeill et al. 2006).

Another nomenclatural issue is about valid descriptions or definitions, which we have considered to define valid publication of some diatoms published by Ehrenberg. Some taxa published in the 19<sup>th</sup> century showed very short descriptions or diagnoses. This led us to consider the expression “...und Terpsinoë brasiliensis, mit sehr kleinen Notenzeichen...” provided by Ehrenberg (1854) as definition (differential diagnosis) of *T. brasiliensis* in relation to *T. musica*.

On the other hand, species such as *Navicula gracilis*, cited by Ehrenberg (1854) for Tefé Lake, and other species such as *Gomphonema discolor*, *Navicula fusiformis*, *N. gibba*, *N. turgida*, and *N. uncinata*, which were not cited for Brazil, showed one particularity. They were defined initially by Ehrenberg (1832a) by only a range of measures of specimens from different localities and can thus not be considered a valid description. According to the ICZN, description is “a statement in words” (Ride et al., 1999) and, therefore, only measurements do not constitute a description of some taxon. Thereby, *N. gracilis* as well as *Gomphonema discolor*, *Navicula fusiformis*, *N. gibba*, *N. turgida* and *N. uncinata* have to be considered available (valid) only according to Ehrenberg (1832b), when they were provided with a valid description. This implies that the attribution of the author of *N. gracilis* to Ehrenberg (1832a), as found in Algaebase (Guiry & Guiry, 2012) is not correct and should be changed to Ehrenberg (1832b).

Despite similarities among the ICZN and ICBN of a valid name, one difference must be highlighted: the independence of the validity of the name of the genus and the name of the species. In the ICZN, a species name is available even if the genus name is not available (Article 11.9.3.1, Ride et al. 1999) while according to the ICBN this condition is not allowed (Article 43.1, McNeill et al. 2006). This refers to *Discoplea comta* (Silva 2003), a name cited for Brazil. However, we notice problems about the original sense of this species and its concept (Silva 2003, Kusber and Jahn 2009).

Nagumo (2003) also noticed a similar condition concerning *Amphora libyca* when carrying out lectotypification of this species. Thus, the two cases showed that the names listed by Ehrenberg for Brazil do not necessarily correspond to the current concept of the taxa and highlight the need for future studies that reinvestigate the preparations and/or samples from Brazil and compare the types with the names cited according to Ehrenberg's concept.

Even considering these limitations, it is noteworthy that only about 43% of the valid names recorded by Ehrenberg (1839, 1841, 1843, 1851, 1854) and compiled here were reported for Brazil by other researches. The other 57% include taxa of *Eunotia*, *Pinnularia* and other genera that even under their synonyms were not recorded for Brazil, which corresponds to 44 names. The 77 diatom names cited by Ehrenberg (1839, 1841, 1843, 1851, 1854) make him the most important diatomologist of Brazilian diatoms in the first half of the 19<sup>th</sup> century.

## Conclusion

We catalogued 101 taxa recorded by Christian Gottfried Ehrenberg in a set of five studies, among which 77 are available (valid) names, 24 names are unavailable (invalid) and one is illegitimate. The reason why these 24 names are considered as invalid is the absence of a description or a definition (differential diagnosis) or the indication of an illustration. Among the 77 valid names, five were originally described for Brazil and are here lectotypified. Only 34 taxa of this list had been recorded until now by other studies than Ehrenberg's. The other 57% of the valid taxa can be treated as first citation of the name for the Brazilian diatom flora.

In the future, studies should be conducted to characterize all specimens of Brazilian diatoms described by Ehrenberg. This could be carried out through the sampling and analysis of recent material from the original locality of the lectotype.

With this compilation, we can go back to the Ehrenberg collection to compare Ehrenberg's identification as well as the current and the original concept of the species of diatoms from Brazil recorded by him. For this, studies with new preparations from his original samples will be necessary. Finally, it will be possible to carry out new studies comparing the old and recent diatom flora and associate the likely changes with the historical variables. This could provide tools to understand changing mechanisms of the biodiversity of diatoms in tropical and subtropical habitats.

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# *Symphysodontella madhusoodananii* (Pterobryaceae, Moss) a new species from the Western Ghats of India

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## Abstract

*Symphysodontella madhusoodananii* Manju & Rajesh, **sp. nov.** an epiphytic pendant moss, with flagellate branches and long acuminate leaves with two short costa is described and illustrated from the tropical wet evergreen forests of the Western Ghats of India.

## Keywords

*Symphysodontella madhusoodananii*, Pterobryaceae, Moss, Western Ghats, New Amarambalam, Kerala, India

## Introduction

*Symphysodontella* Fleischer is a genus of nine species known so far from India, Sri Lanka, Myanmar, Thailand, Malaysia, Vietnam, Indonesia, Papua New Guinea, New Caledonia, Borneo and the Philippines. Magill (1980) examined this genus carefully and defined it in detail by shifting the odd members to other genera such as *Myurium* and *Pterobryopsis*. The genus is characterised by long stem, creeping on bark, usually dendroid by pinnate or bipinnate branching or long drooping, sometimes with flagelliform branches; leaves ovate-lanceolate, acuminate, concave, with short, single or double costa, leaf cells elongate-smooth. The alar is usually not differentiated, however in some species it is coloured and with porose walls. The capsule is immersed or exserted, with small, cucullate, naked, calyptra. The spores are large and papillose.

Four taxa, viz., *Symphysodontella borii* Dixon, *S. pilifolia* Dixon, *S. subulata* Broth. and *S. tortifolia* Dixon were reported from the North-eastern India (Gangulee 1972). Of these *S. borii* Dixon was moved to *Myurium* as *M. borii* (Dixon) Magill, and *S. pilifolia* Dixon to *Pterobryopsis* as *P. pilifolia* (Dixon) Magill. Another related taxon, *Symphysodon involutus* (Thwaites & Mitt.) Broth. was transferred to *Symphysodontella* as *S. involuta* (Thwaites & Mitt.) M.Fleischer (Magill 1980). Thus in India three valid species, viz., *Symphysodontella subulata* Broth., *S. tortifolia* and *Symphysodon involutus* (Thwaites & Mitt.) Broth., were known to occur. Among these, *S. involuta* (Thwaites & Mitt.) M.Fleischer extends upto Southern India also (Manju et al. 2008, Daniels 2010).

During our recent exploration in the *Shola* forests (Southern montane wet temperate forests) of New Amarambalam Reserve Forest in the Malappuram District of Kerala, we collected an interesting species of *Symphysodontella*, which showed distinguishing characteristics from the other known species. We here describe this entity as a new species and provide a table of comparison with the other known species to India as well as a key.

## Taxonomic treatment

### *Symphysodontella madhusoodananii* Manju & Rajesh, sp. nov.

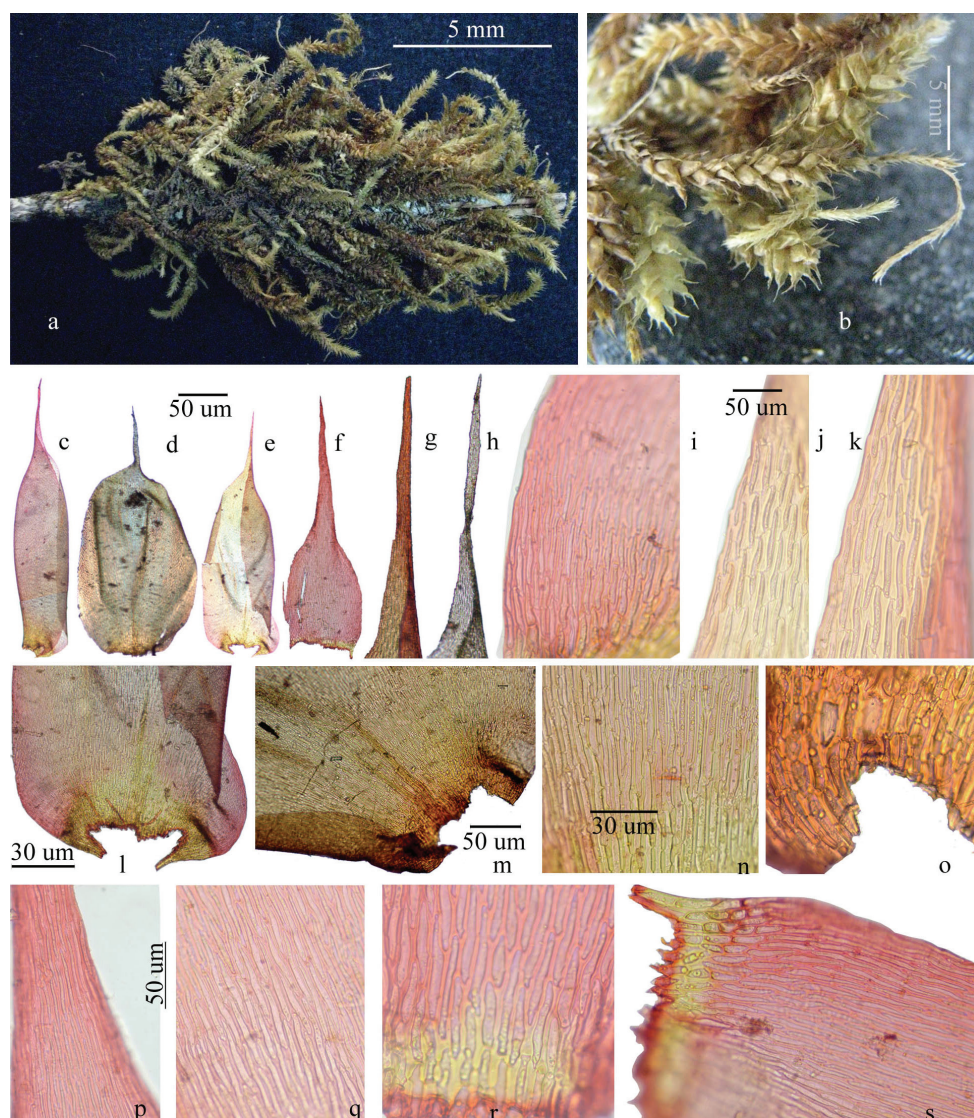
[http://species-id.net/wiki/Symphysodontella\\_madhusoodananii](http://species-id.net/wiki/Symphysodontella_madhusoodananii)

**Diagnosis.** *Symphysodontella madhusoodananii* is characterised by very short, double costate, oblong-lanceolate, long acuminate leaves. It shows some similarities to *S. tortifolia* Dixon in its long acuminate, complanate plicate leaves and some leaves being tortuose at tip. However, it differs in its oblong-lanceolate leaves, two distinct short costa in both main and secondary branch leaves and the leaves on main shoot and secondary branches being similar. It also differs having long drooping primary branches, short secondary branches and presence of copious flagelliform branches. *S. madhusoodananii* also shows some similarity with *S. subulata* Broth. in its two short-costate, ovate-lanceolate leaves, elongate-linear porose cells and yellowish brown stem attachment cells. However, it differs in cells being highly porose in its lateral wall and in the middle layer, the pores being rounded.

**Type. INDIA.** Kerala, Malappuram district, Nilambur, New Amarambalam Reserve Forest (bordering Mukurti National Park of Tamil Nadu), epiphytic on trees of shola forest, 1200 m alt., K.P.Rajesh 106933 (Holotype: CALI! Isotypes: BM!, CAL!, CALI!, MBGS!, ZGC!).

**Description.** Main stem long, creeping on bark, 3–5 cm long, scale leaves present, branches yellowish green to brownish, primary branch 5–7 cm long, secondary branches up to 2 cm long, mostly with flagelliform branches, flagella 2.5 cm long, erect to drooping, leaves oblong-lanceolate, lax erect-spreading,  $2.5 \times 0.9$  mm, leaves on main shoot lax, ovate, long acuminate, acumen 0.9 mm long, two very short distinct costa at base, leaves on main shoot and secondary branches dense, patent to squarrose,





**Figure 1.** *Symphysodontella madhusoodananii*, **a-b** habit **c-e** leaf at main stem **f** leaf at flagella **g-h** leaf tip **i** basal marginal cells **j-k** leaf margin at tip **l-m** leaf insertion cells **n** leaf middle cells **o** basal cells enlarged **p** leaf tip cells **q** leaf middle cells **r-s** leaf basal cells.

complanate, plicate, tip tortuose in some leaves, long apiculate, margin denticulate at tip, recurved below, cells at acumen elongate linear, up to 50 µm long, thick walled above, middle cells 60–70 µm × 20–25 µm, less thick but with porose walls below, 35–45 µm × 28–35 µm, costa and cells at stem attachment yellowish brown, alar cells not prominently differentiated in size but with deep brown, rectangular porose cells, 40–45 × 25–35 µm, porose in some cells, leaf insertion to the stem is U shaped; cells at flagella almost same size and shape; sporophyte not seen (Figure 1 a–s).

**Distribution.** It is distributed in the shola forests (Southern montane wet temperate forests) of New Amarambalam of Kerala and Mukuruty National Park of Tamil Nadu in the Western Ghats of India.

**Ecology.** It was found growing as epiphytic on branches of trees of shola forest.

**Etymology.** It is named in honour of Professor (Dr.) P.V. Madhusoodanan, for his meritorious contribution towards botany, especially on lower groups of plants of Southern India. He retired recently from the Department of Botany of University of Calicut, and now continues his research as an Emeritus Scientist in the Malabar Botanical Garden (MBG), Kozhikode. It is he who inspired the present authors to undertake studies on the bryophytes and pteridophytes.

## Discussion

*Symphysodontella madhusoodananii* is similar to *S. tortifolia* in its long acuminate, complanate plicate leaves and some leaves being tortuose at tip. It differs from *S. tortifolia* in its oblong-lanceolate leaves, two distinct, short costa in both main and secondary branch leaves and the leaves on main shoot and secondary branches being similar. In *S. tortifolia* the costa in the secondary branch leaf is single, reaching a little more than half the length. The secondary branches are dendroid by bi-pinnate branching with branching in different planes in *S. tortifolia*, and lacks flagelliform branches. However, in *S. madhusoodananii* the primary branches are long drooping, secondary branches short and flagelliform branches are frequent.

*S. madhusoodananii* also shows some similarity with *S. subulata* Broth. in its two short costa and ovate-lanceolate leaves. However, in *S. madhusoodananii* the cells are highly porose in its lateral wall and in the middle layer the pores are rounded. It is also having hanging secondary branches and copiously flagellate. The costa and cells at stem attachment is yellowish brown, alar cells not prominently differentiated but with deep brown, rectangular porose cells and the leaf insertion is U-shaped. Gangulee (1972) commented that the Indian population of *S. subulata* Broth. scarcely shows any flagellate branch. However, such branches are reported from the Philippine populations, but with having single costa. The present species is characterised by the leaves being oblong-lanceolate, and with very short and double costa (Table 1). A key to the Indian species of *Symphysodontella* is also given for easy identification.

**Conservation status.** The species was found growing on the trees of shola forests (Southern montane wet temperate forests) of New Amarambalam of Kerala, and the adjoining areas of Mukuruty National Park of Tamil Nadu. Located in the Nilgiri Biosphere Reserve, the New Amarambalam Reserved Forests with an area of more than 260 km<sup>2</sup>, is one of the most notable areas in the Western Ghats of Northern Kerala for its unique assemblage of floristic elements. The rare blending of many interesting floral elements makes this area as one among the most potential area to be considered for long term conservation. The unique geographic location and the rugged terrain with folds of hills and deep valleys, as a natural westward extension of the Nilgiri hills make

**Table 1.** Comparison of the morphological features of *Symphysodontella* species in India.

Characters	<i>S. madhusoodananii</i>	<i>S. subulata</i>	<i>S. tortifolia</i>	<i>S. involuta</i>
<b>Branching</b>				
Primary branches	long drooping	elongate	short	short
Secondary branches	short	hanging	dendroid	long, drooping
Flagelliform branches	frequent	frequent	absent	absent
<b>Leaves</b>				
Shape	Oblong lanceolate, long acuminate, complanate plicate	Ovate-lanceolate, acumen short	Ovate, long acuminate, complanate plicate	Lanceolate, not plicate
Apices	some leaves tortuose at tip	leaf tip not tortuose	some leaves tortuose at tip	Tip involutus; not tortuose at tip
Costa	Two short, distinct in both main and secondary branches	Very short two costa, not distinct	Single, reaching a little more than half the length in the secondary branch leaves	Single, reaching the middle of leaf, distinct in main and secondary branches
<b>Cells</b>				
Shape	elongate linear	elongate linear	elongate	elongate
wall	highly porose in its lateral wall and in the middle layer, pores rounded	thick walled, porose, rounded	slightly thick walled above, weekly porose above and less thick but porose walls below	Thin walled above and middle, thick porose
alar cells	not prominently differentiated in size but with brown cells, rectangular porose cells	differentiated with deep brown, rectangular porose cells	Tinted, less thick cells, rectangular	thick porose walls, tinted, rectangular

this landscape dotted with all major vegetation types of Southern India in a short span itself. The proposed plan for designating the New Amarambalam forests of Kerala as a Wildlife Sanctuary has not been materialised yet. The area with its unique geographical location, which changes along a sharp altitudinal gradient and thus offering a good array of natural habitats, forming the rare blend of species assemblages, is no doubt, an ideal landscape to be conserved. This also ensures the long term protection of many species and their populations, in a unique landscape with the continuum of the Nilgiri hills to the Silent Valley and adjacent areas. At present the species is known only from a small area, and with the majority lies in the non-protected part. Its conservation status could be improved by bringing these areas of Kerala state under protection.

**Specimens examined:** INDIA. Kerala, Malappuram district, Nilambur, New Amarambalam forest (bordering the Mukurthi National Park of Tamil Nadu), epiphytic on trees of shola forest, 1200 m alt., *K.P. Rajesh* 106933 (BM!, CAL!, CALI!, MBGS!, ZGC!); New Amarambalam Reserve Forest, 1200 m alt., *K.P. Rajesh* 111862 (CALI!, MBGS!, ZGC!); INDIA. Tamil Nadu, Pandiyar Estate (near Mukurthi National Park), 1300 m alt., on branches of trees of shola forest, *K.P. Rajesh* 111852 (CALI!, MBGS!, ZGC!), Mukurthi National Park, 1400 malt., on branches of trees of shola forest, *K.P. Rajesh* 109001 (CALI!, MBGS!, ZGC!).

### Key to the species of *Symphysodontella* in India

- 1a      Leaves complanate plicate, acumen long, 1 mm ..... **2**
- 1b      Leaves not plicate, acumen very short, 0.2–0.6 mm ..... **3**
- 2a      Costa in the primary and secondary branch leaves single, reaching a little more than half the length; flagelliform branches absent ..... *S. tortifolia*
- 2b      Costa in the primary and secondary branch leaves double, short, restricted to alar region; flagelliform branches frequent ..... *S. madhusoodananii*
- 3a      Plants smaller, 4 cm long; leaf tip narrow subulate..... *S. subulata*
- 3b      Plants robust, 8–10 cm long; leaf tip involutus ..... *S. involuta*

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# *Melothria domingensis* (Cucurbitaceae), an endangered Caribbean endemic, is a *Cayaponia*

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## Abstract

The Neotropical genus *Melothria* (Benincaseae, Cucurbitaceae) is a small group of yellow- or white-flowered climbers with small to medium-sized fruits. In 1899, Alfred Cogniaux described a species from montane rainforest in Haiti as *Melothria domingensis*, presumably based on the overall similarity in habit, leaf shape, and fruit morphology of his incomplete herbarium material to other Central American *Melothria* species. *Melothria domingensis* is still rare in European and American herbaria and the species has never been studied in detail. We here present molecular and morphological analyses, which show that the species is misplaced in *Melothria* and instead belongs in the distantly related tribe Cucurbiteae in the genus *Cayaponia*. We illustrate the species, provide the formal transfer and an extended description, and discuss the phylogenetic, biogeographic and ecological implications, including the finding that most likely bee- and not bat-pollination is ancestral in *Cayaponia*.

## Keywords

Cogniaux, Flora of Hispaniola, *Melothria domingensis*, pollinator shifts

## Introduction

The genus *Melothria* L. (including *Melancium* Naudin, *Cucumeropsis* Naudin, and *Posadaea* Cogn.) includes 12–15 species, confined to arid plains, clearings and forest margins, grass- or woodlands from the southern United States through Central and South America down to northern Argentina (Schaefer and Renner 2011 a, b). One species, *Melothria sphaerocarpa* (Cogn.) H.Schaefer & S.S.Renner, is also found in tropi-



cal West Africa, where it might have arrived only recently through human-mediated transport (Schaefer and Renner 2010); and another species, *Melothria pendula* L., is locally invasive in tropical Asia (De Wilde and Duyfjes 2010). *Melothria* species are monoecious, small to medium-sized, herbaceous climbers with usually simple leaves, small yellow or white flowers, and the fruit a smooth, and often fleshy berry to 20 cm in *M. sphaerocarpa*. Each fruit contains numerous, strongly compressed seeds; and the testa tends to be smooth, white, and often covered by long appressed hairs (Schaefer and Renner 2011b).

In 1899, Alfred Cogniaux described a new species of *Melothria* based on herbarium material from the Caribbean island of Hispaniola (Haiti and the Dominican Republic), which he had received from the Krug and Urban collection (Urban 1899). The type material (*L. Picarda* 1503, BR) contains complete leaves and fruit plus seeds but no fully developed flowers. While the overall habit, leaf shape and fruit type are quite similar to Central American species of *Melothria*, the ovoid seeds would be unique in that genus and are very similar to another, very distantly related genus: *Cayaponia* Silva Manso in the tribe Cucurbitae. And indeed, the Brazilian *Cayaponia* expert Vera Gomes-Klein annotated a specimen of *Melothria domingensis* Cogn. in the Berlin Herbarium (*E. L. Ekman* 1319, B) as “*Cayaponia* sp.” in July 1992; and two collections at New York Botanical Garden (*P. Acevedo-Rodriguez et al.* 13011 and 13274, NY) had originally been identified as *Cayaponia racemosa* (Mill.) Cogn. by M. T. Strong in 2010. The aim of our study here is to test this hypothesis using molecular and morphological data and to find out whether *Melothria domingensis* is indeed a misplaced *Cayaponia* or alternatively represents a unique type of seed morphology in *Melothria*.

## Materials and method

**Molecular analyses.** Total genomic DNA was isolated from leaf samples of four herbarium specimens of *Melothria domingensis* (all collected in the Dominican Republic, Table 1) using a commercial plant DNA extraction kit (NucleoSpin, MACHEREY-NAGEL, Düren, Germany), and following the manufacturer’s manual. Polymerase chain reactions (PCR) following standard procedures were used to amplify the entire nuclear ribosomal ITS region plus the following five chloroplast regions: *rbcL* gene, *trnL* intron, and the three intergenic spacer regions *trnL-trnF*, *rpl20-rps12*, and *trnH-psbA*. PCR protocols and primers are given in Kocyan et al. (2007) and Schaefer et al. (2009). In addition, we used the primer pair *trnH* (5'- CGC GCA TGG TGG ATT CAC AAA TC) and *psbA* (5'- GTT ATG CAT GAA CGT AAT GCT C) designed by Sang et al. (1997) with an annealing temperature of 48°C to amplify the *trnH-psbA* spacer region. Crude PCR products were sent to Functional Biosciences, Inc. (Madison, WI, USA) for ExoSap cleaning and Sanger sequencing with the same primers used for PCR reactions. Seventeen sequences were newly generated for *Melothria domingensis* plus eleven ITS sequences for selected species of the genera *Abobra* Naudin, *Calycophyllum* H. Karst & Triana, *Cionosicyos* Griseb., *Schizocarpum* Schrad., and *Tecunumania* Standl. & Steyerl., all of the tribe Cucurbitae, to obtain a more

**Table 1.** Taxa, Genbank accession numbers, and voucher information.

Taxon	Geographic origin	Specimen voucher	rbcl	trnL	trnL-trnF	rpl20-rps12	trnH-psbA	ITS1-5.8S-ITS2
<i>Abobra tenuifolia</i>	Argentina, Entre Rios	<i>T.M.Pedersen 10287</i> (GH)	--	--	--	--	--	JX505456
<i>Calycophyllum ueberbaueri</i>	Peru, Cuzco	collector unknown (GH)	--	--	--	--	--	JX505457
<i>Cayaponia domingensis</i>	Hispaniola, Dominican Republic	<i>G.J.Gastony et al. 640</i> (GH)	--	JX505449	JX505445	JX505453	JX505473	JX505465
<i>Cayaponia domingensis</i>	Hispaniola, Dominican Republic	<i>P.Acevedo-Rodriguez et al. 13274</i> (GH)	JX505455	JX505451	JX505447	JX505452	JX505471	JX505464
<i>Cayaponia domingensis</i>	Hispaniola, Dominican Republic	<i>A.H.Liogier 12563</i> (GH)	--	--	--	JX505454	JX505472	JX505466
<i>Cayaponia domingensis</i>	Hispaniola, Dominican Republic	<i>A.H.Liogier 12908</i> (GH)	--	JX505450	JX505446	--	--	JX505467
<i>Cayaponia (Selysia) prunifera</i>	Suriname	<i>Lindemann et al. 398</i> (NY)	--	--	--	--	--	JX505458
<i>Cionosicy exsiccus</i>	Mexico	<i>E.Cabrera 15257</i> (GH)	--	JX505448	JX505444	--	--	JX505459
<i>Cionosicy exsiccus</i>	Mexico	<i>G.F.Gaumer 888</i> (GH)	--	--	--	--	--	JX505460
<i>Cionosicy macranthus</i>	Honduras	<i>A.Molina 3838</i> (GH)	--	--	--	--	--	JX505461
<i>Cionosicy macranthus</i>	Mexico	<i>D.M.Kearns 321</i> (GH)	--	--	--	--	--	JX505462
<i>Cionosicy pomiformis</i>	Jamaica	<i>R.A.Howard &amp; G.R.Proctor 14941</i> (GH)	--	--	--	--	--	JX505463
<i>Tecunumania quetzalteca</i>	Costa Rica	<i>R.W.Lent 2311</i> (GH)	--	--	--	--	--	JX505470
<i>Schizocarpum palmeri</i>	Mexico, Rio Mayo	<i>H.S.Gentry 1032</i> (GH)	--	--	--	--	--	JX505468
<i>Schizocarpum reflexum</i>	Mexico, Michoacán	<i>M.Porter 1377</i> (GH)	--	--	--	--	--	JX505469

balanced sampling in our ITS matrix (for GenBank accession numbers and vouchers see table 1). Raw sequences were edited with Sequencher 4.9 (Gene Codes, Ann Arbor, Michigan, USA) and aligned by eye, using MacClade 4.08 (Maddison and Maddison 2003). We then added to those alignments sequences for all *Cayaponia* species available on Genbank (mainly from Kocyan et al. (2007), Schaefer et al. (2009), and Duchén and Renner (2010)) plus a set of Cucurbitaceae species representing all genera of the tribe Cucurbitae, three representatives of *Melothria* and representatives of the genera containing Caribbean species based on Schaefer et al. (2008). Bayesian and maximum likelihood analyses were performed with a final dataset of 67 accessions representing 60 species. Data matrix and trees have been deposited in TreeBASE (<http://www.treebase.org/>) study number S13322.

Maximum likelihood (ML) analyses and non-parametric bootstrap searches (BS) with the fast-bootstrap algorithm were performed using RAXML-VI-HPC v. XX (Stamatakis et al. 2008). RAXML searches relied on the GTR + G + I model and model parameters were estimated over the duration of specified runs. Bayesian inference also used the GTR + G model (with the default four rate categories) and relied on MrBayes v. 3.2.1 x64 (Ronquist and Huelsenbeck 2003). We analyzed the combined dataset with two partitions (plastid and nuclear ITS), allowing partition models to vary by unlinking gamma shapes, transition matrices, and proportions of invariable sites. Markov chain Monte Carlo (MCMC) runs started from independent random trees, were repeated twice, and extended for ten million generations, with trees sampled every 1000th generation. Convergence was assessed using Tracer 1.5 (Rambaut and Drummond 2003). Trees saved prior to convergence were discarded as burn-in (2000 trees), and a consensus tree was built from the remaining trees.

**Morphological analyses.** We studied *Melothria domingensis* specimens from the following herbaria: BR, GH, NY, U, and US. For comparison, both authors also studied a large number of *Cayaponia* and other Neotropical Cucurbitaceae specimens from all major European and American herbaria over the past decade. All measurements given in the text are from dry herbarium specimens.

**Analysis of pollination syndrome evolution and biogeography.** We used the same approach as described in Duchén and Renner (2010), namely ancestral character state reconstruction under maximum likelihood in Mesquite v. 2.72 (Maddison and Maddison 2009) based on the Markov k-state one-parameter model. We added *Melothria domingensis* to the matrix of that previous study with the character states “bee pollination” (based on flower morphology) and “rainforest habitat” (based on herbarium label information).

## Results

### Molecular analyses

Analyses of the nuclear ITS data matrix (55 accessions, 984 aligned nucleotides) and the individual and combined plastid matrices (67 accessions, 4831 aligned nucleotides)

produced congruent phylogeny estimates (Fig. 2, Fig. 3; phylogenies for individual plastid marker not shown), with all areas of discordance being restricted to branches with low support (i.e., BS <60% and Bayesian posterior probability (PP) <0.9). We therefore combined the ITS and plastid matrices into a single matrix (68 accessions, 60 species, 5673 aligned nucleotides) and in the following focus in our discussion on the phylogeny estimate built using this largest matrix (Fig. 4): the different accessions of *Melothria domingensis* are almost identical in their sequences and group together with high support (100% BS, 1.0 PP, Fig. 4). They are deeply nested in *Cayaponia*, which is monophyletic after inclusion of *Selysia* Cogn. as already suggested by Duchén and Renner 2010 (100% BS, 1.0 PP, Fig. 4). Sister group to *Cayaponia* is the monotypic *Abobra* (79% BS, 1.0 PP, Fig. 4) and the two together are sister to the *Schizocarpum* clade (100% BS, but <0.9 PP, Fig. 4). Within *Cayaponia*, *Melothria domingensis* is placed in a grade with the North American *C. quinqueloba* (Raf.) Shinnery (syn. *C. grandifolia* Torrey & A. Gray) and a large unresolved group including *C. podantha* Cogn., *C. americana* Cogn., *C. africana* (Hook.f.) Exell and several other Central and South American species. In contrast the three other *Melothria* species included in our matrix form a highly supported clade (100% BS, 1.0 PP, Fig. 4) and are sister to *Cucumis melo* L. (98% BS, 1.0 PP, Fig. 4).

## Morphological comparison

Comparison of seed, floral, fruit, and vegetative characters of *Melothria domingensis* with all available *Cayaponia*, *Cionosicy*s, and *Melothria* material reveals that seed number, size and shape are most similar to *Cayaponia* and not to *Melothria* or *Cionosicy*s. Mottled fruits like those of *Melothria domingensis* also occur in *Cionosicy*s, but all currently known species of *Cionosicy*s have much larger fruits and are many-seeded. In *Melothria*, fruits can be small and striped or mottled but all currently known species of that genus have many-seeded fruits with strongly compressed seeds. Only in *Cayaponia* do we find small fruits with few, tumid seeds.

Within *Cayaponia*, the relatively small leaves and few-flowered fascicles of *Melothria domingensis* are most similar to *Cayaponia quinqueloba*, an endemic from the southeastern United States. The fruits of *C. quinqueloba*, however, have the typical coriaceous or chartaceous exocarp of many other *Cayaponia* species, and not the distinctive spots of *Melothria domingensis* fruits. Another *Cayaponia* species with mottled fruits is *Cayaponia tibiricae* (Naudin) Cogn. (syn. *C. martiana* (Cogn.) Cogn.) of eastern Brazil, but its inflorescence is branched like that of *C. racemosa* (Mill.) Cogn. and a few others.

## New combination and extended description

Since molecular and morphological analyses agree that *Melothria domingensis* should be placed in the genus *Cayaponia*, we here provide the necessary new combination followed by an extended description:

***Cayaponia domingensis* (Cogn.) H.Schaefer & M.Nee, comb. nov.**

urn:lsid:ipni.org:names:77123716-1

[http://species-id.net/wiki/Cayaponia\\_domingensis](http://species-id.net/wiki/Cayaponia_domingensis)

basionym: *Melothria domingensis* Cogn. in Urb., Symb. Ant. 1: 451. 1899. TYPE:

Haïti: Ouest: prope Port-au-Prince in montibus Furcy del Tête, bois de pin [west Haiti, near Port-au-Prince, Furcy del Tête mountain, pine forest], 1800 m. Nov 1896, L. Picarda 1503, BR.

**Description.** Monoecious climber with 3–4 m long, slender, grooved stems (Fig. 1A); leaves triangulate-cordate, often deeply 3(-5)-lobed, shortly tomentose on both sides, glabrescent above, margin finely dentate; petioles 10–20 mm, striate; tendrils simple. Flowers probably diurnal (based on herbarium specimens with open flowers), solitary or in few-flowered fascicles in the leaf axils (Fig. 1B), the staminate and pistillate coxillary, shortly pedicellate; corolla pale yellow, inner petal surface white; calyx glabrous, broadly campanulate; stamens inserted near the base of the tube; filaments distinct, two anthers 2-thecous, one 1-thecous; ovary globose, glabrous; style erect, linear, inserted on a basal nectary; stigmas 3, dilated, reflexed; staminodes 3, minute; fruit globose, glabrous, 10–20 mm diam., with thin, leathery wall, dark green turning orange with greenish white mottling; fruiting pedicels 10–30 mm long (Fig. 1C); seeds 6, broadly ovoid, 5 × 4 × 2.5 mm; testa light brown, smooth (Fig. 1D).

**Phenology.** Flowering and fruiting specimens have been collected in April, June, August and September.

**Distribution.** Endemic to the Greater Antilles, island of Hispaniola, and perhaps Puerto Rico (one record from Ponce, Toro Negro Commonwealth Forest, between Cerro Maravillas and Monte Jayuya, along road off highway 143, 1190–1200 m, 26 Feb 1993, Breckon *et al.* 4427, NY, specimen not seen).

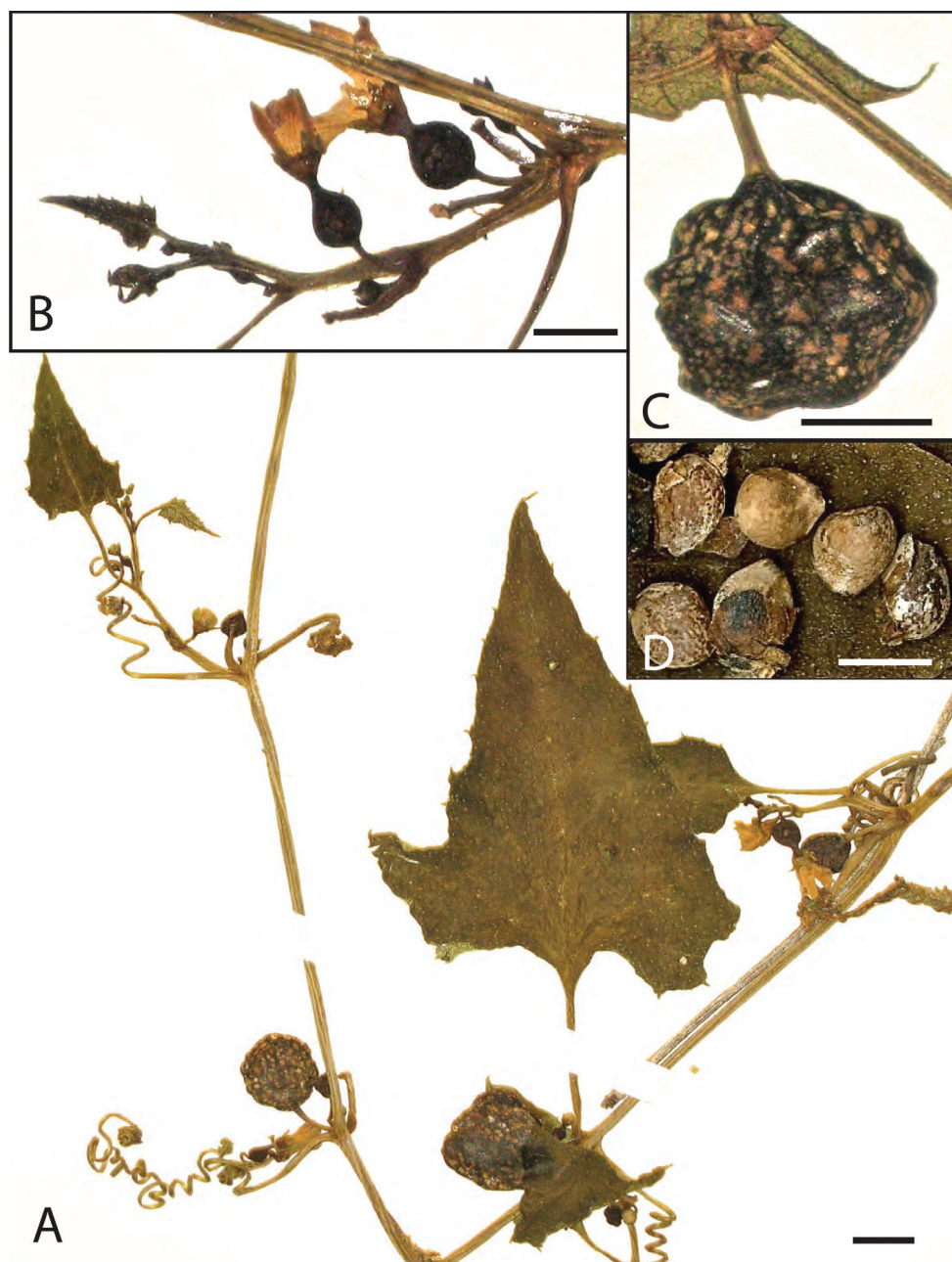
**Habitat.** According to specimen label information, the species occurs in rainforest, thickets and disturbed areas of cloud forest 1200–2200 m a.s.l., on limestone rocks with *Ardisia* Gaertn., *Brunellia* Ruiz & Pav., *Buddleja* L., *Cestrum* L., *Coccoloba* P.Browne, *Cordia* L., *Daphnopsis* Mart., *Garrya* Douglas ex Lindl., *Heterotrichum* M.Bieb., *Lobelia* L., *Meliosma* Blume, *Miconia* Ruiz & Pav., *Myrsine* L., *Palicourea* Aubl., *Persea* Mill., *Ocotea* Aubl., *Trema* Lour., *Turpinia* Raf., and *Weinmannia* L.

**Conservation status.** Listed as in danger of extinction (“peligro de extinción”) on an informal webpage for the flora and fauna of Hispaniola (Marcano 2009). The available information on distribution, population size, and threats does not seem sufficient for a formal classification following IUCN red list criteria.

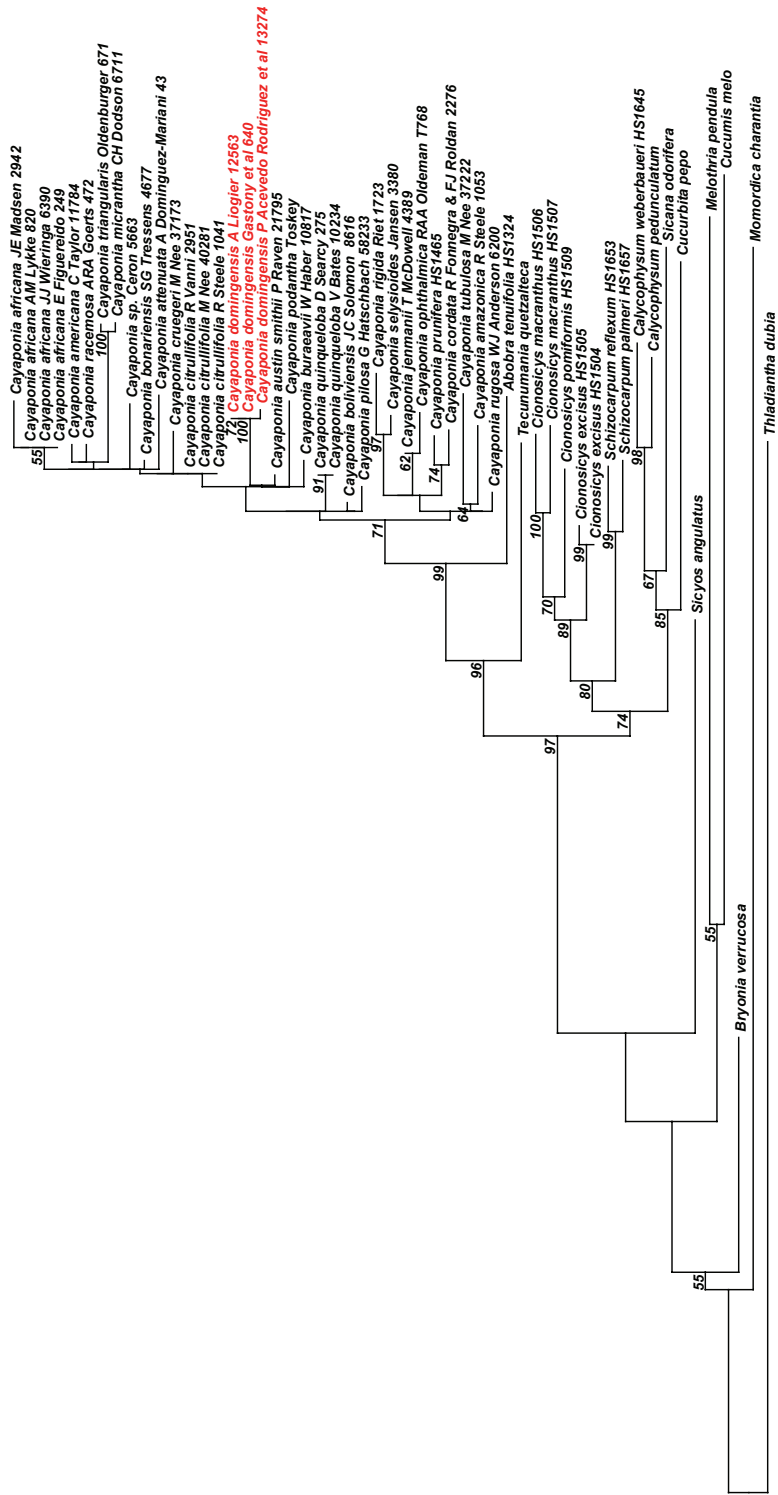
**Local names.** Mirliton blanc, Mirliton marron, Mirliton sauvage (Barker and Dardeau 1930; Liogier 1986).

**Specimens examined.** Dominican Republic. Baoruco: Sierra de Neiba, Sabana del Silencio, 18°39'07"N, 71°33'26"W, 2201 m, 19 Jun 2003 (fl., fr.), P.Acevedo-Rodríguez *et al.* 13011 (NY); Elías Peña: Sierra de Neiba, near La Doscientos, Hondo Valle, 1750–

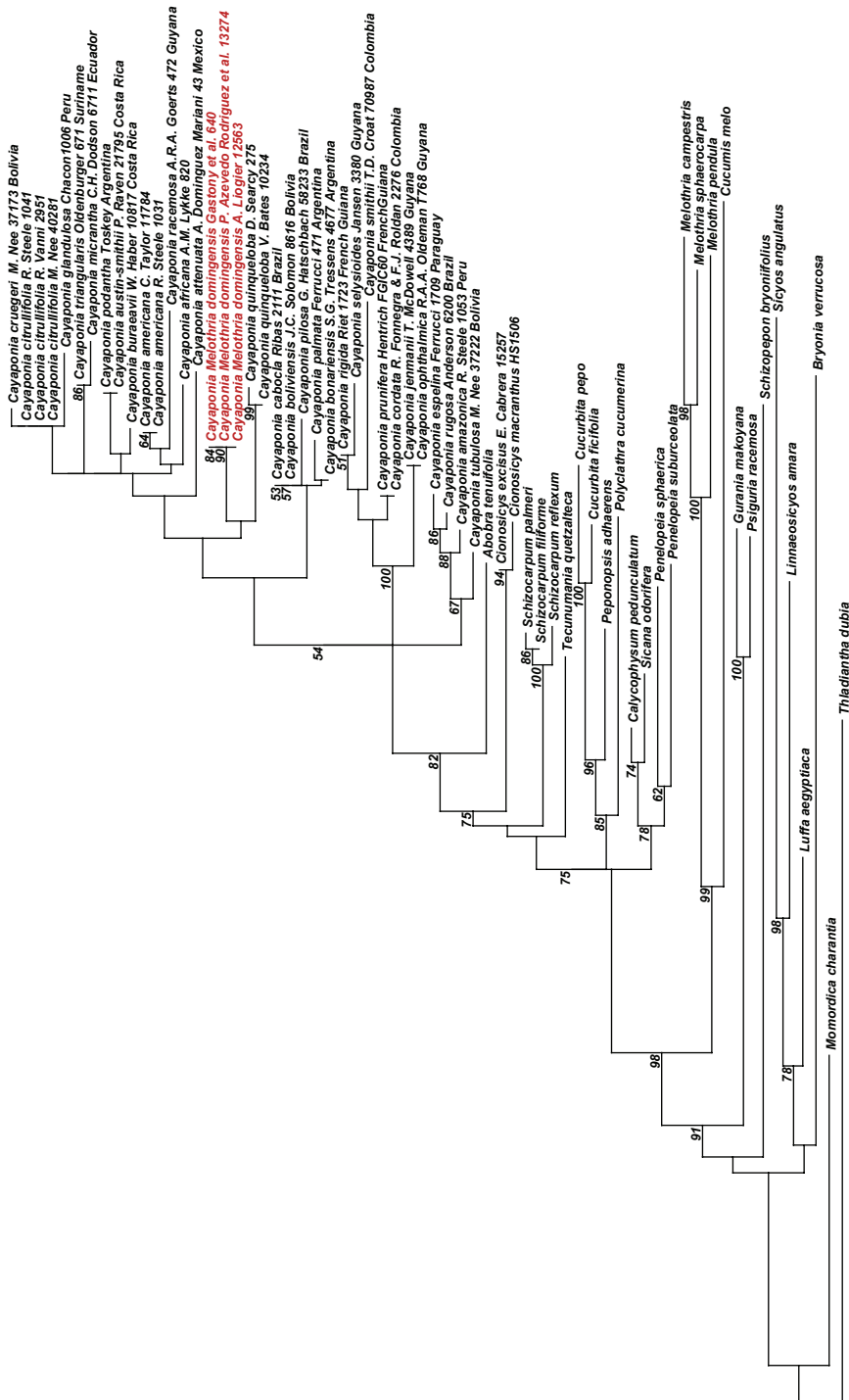




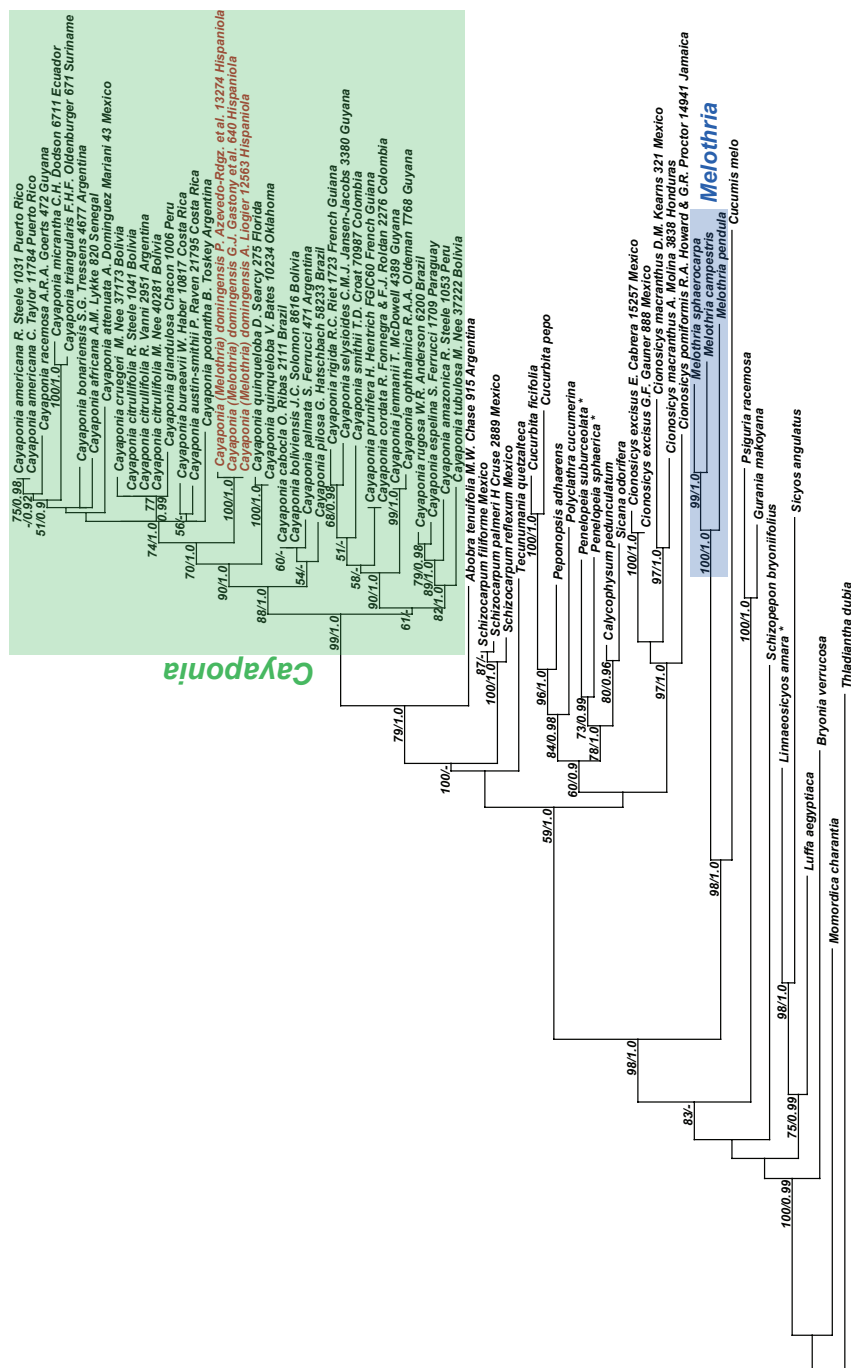
**Figure 1.** *Cayaponia domingensis* (Cogn.) H. Schaefer & M. Nee **A** habitus with leaves, tendrils, staminate and pistillate flowers, and young fruits **B** pistillate flowers **C** fruit **D** seeds; scale bar: 5 mm. Photographs of A.H.Liogier 12563 (GH) by H. Schaefer.



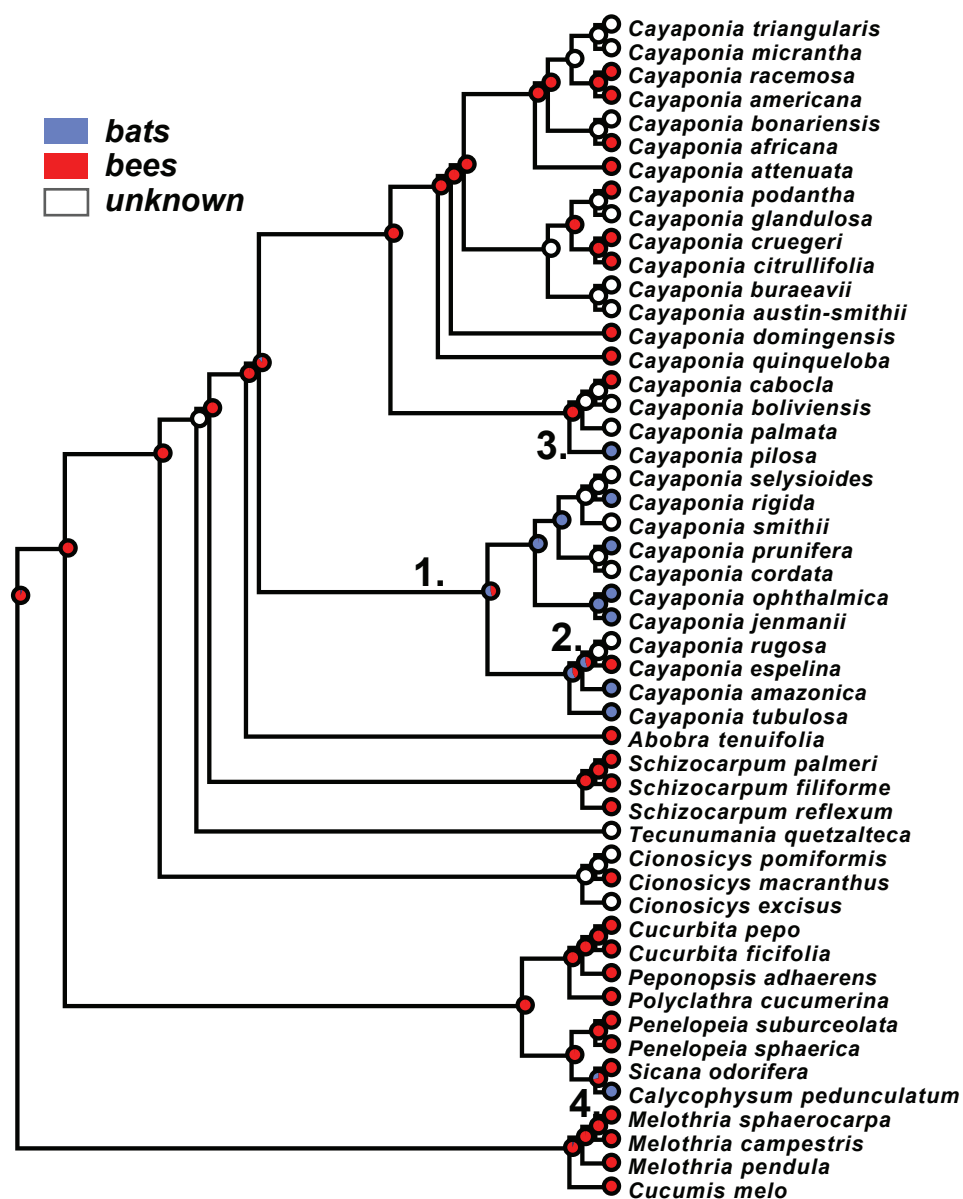
**Figure 2.** Best Maximum likelihood tree for *Cayaponia* and relatives based on the nuclear ribosomal ITS region (55 accessions, 984 aligned nucleotides). Likelihood bootstrap values ~ 60% is indicated above branches.



**Figure 3.** Best Maximum likelihood tree for *Cayaponia* and relatives based on six combined chloroplast loci: *rbcL* gene, *trnL* intron, *trnL-F* spacer, *rpl20-rps12* spacer, and *trnH-psbA* spacer (64 accessions, 4831 aligned nucleotides). Likelihood bootstrap support ~ 60% is indicated above branches.



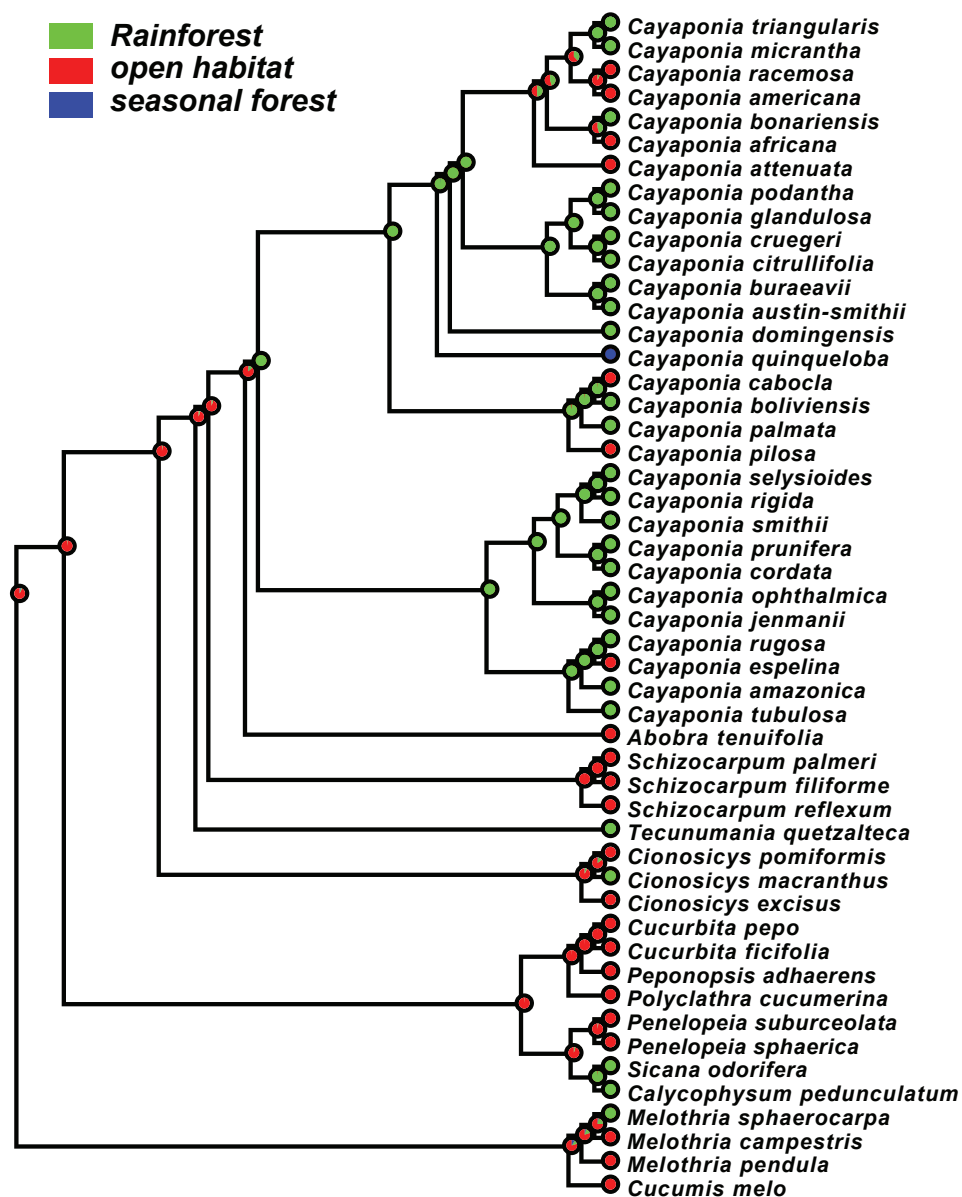
**Figure 4.** Best Maximum likelihood tree for *Cayaponia* and relatives based on 973 nucleotides from TTS plus combined chloroplast loci (67 accessions, 5673 aligned nucleotides). Likelihood bootstrap support ~ 60% and Bayesian posterior probabilities ~ 0.9 are indicated at the nodes.



**Figure 5.** Maximum likelihood reconstruction of ancestral pollination syndromes: bat pollination – blue; bee pollination – red; unknown – white; inferred pollinator shifts numbered 1–4.

1850 m, 5–7 Sep 1968, A.Liogier 12501 (NY, US); Sierra de Neiba, near La Doscien-  
tos, S of Hondo Valle, 1750–1850 m, 5–7 Sep 1968, A.Liogier 12563 (GH, NY). In-  
dependencia: Sierra de Neiba, between Ángel Félix and Aniceto Martínez, 18°41'37"N,  
71°46'56"W, 1867 m, 24 Jun 2003 (fl., fr.), P.Acevedo-Rodríguez et al. 13274 (GH,  
NY); Sierra de Neiba, along the Carretera Internacional near the crest of the range,





**Figure 6.** Maximum likelihood reconstruction of ancestral habitat type: rainforest - green; open habitat (including cerrado, savanna, bushland) - red; seasonal forest - blue.

along the Haitian border, vic. the San Rafael and Independencia border, 18°39'00"N, 071°37'48"W, 1700–2000 m, 9 Aug 1967, G.J.Gastony, G.C.Jones & D.H.Norris 640 (GH, NY, US); near Sapotén, above El Aguacate, Duvergé, 1500–1700 m, 4–5 Jan 1972, A.Liogier 18359 (F, NY); Sapotén, El Aguacate, Duvergé, 1300 m, 25 Jun 1977, A.Liogier & Liogier 27009 (NY); Sierra de Neiba, 30 km above Sabana Real on road

paralleling the Haïtian border, 18°40'00"N, 71°46'00"W, 1845 m, 18 Apr 2003 (fl., fr.), M.Nee & J.C.Montero Castro 52304 (MO, NY). La Vega: near La Ciénaga, N of Constanza, 1700 m, 16 May 1959, Jiménez 4010 (US); La Nevera, from Valle Nuevo to San José de Ocoa, 2100 m, 18 Oct 1968, A.Liogier 13134 (NY); cabezadas de Ciénaga de la Culata, Constanza, 1650 m, 16 Oct 1968, A.Liogier 13072 (NY); Loma Redonda, Ciénaga de la Culata, Constanza, 1600–1950 m, 23 Sept 1969, A.Liogier 16015 (NY, US). Pederales: Sierra de Bahoruco, sección Los Arroyos, 18°25'54"N, 71°74'45"W, 1500 m, 10 Jul 2007 (fl., fr.), T.Clase, L.Raz, D.Castillo, L.Reinosa & E.Soto. 4539 (MO); above Los Arroyos, along the International Highway from Pedernales to Duvargé, 1500–1600 m, 8 Nov 1969, A.Liogier 16775 (NY, US). Peravia [now San José de Ocoa]: 33.9 mi. N of the Parque Central de San José de Ocoa on the road to Constanza, 1800 m, 7 Jul 1982, T.A.Zanoni, M.M.Mejía & J.D.Pimentel B. 21376 (MO, NY, U). San José de Ocoa: La Horma Arriba, 1800–2000 m, 1 May 1972, A.Liogier 18595 (F, NY); La Nevera, 2100 m, 22–23 Oct 1976, A.Liogier & Liogier 25690 (NY). Santiago: upper Río Bao valley, at the base of La Pelona, 1700 m, 1–7, A.Liogier 12908 (NY). Haïti. Ouest: Fourcey, Massif de la Selle, ca. 1750 m, 5 Aug. 1924 (fl., fr.), E.L.Ekman 1319 (B, S, US). Massif de la Selle; Parc National Morne la Visite; Morne d'Enfer, eastern slopes and ridge, 1850–1880 m, 14 May 1984, W.S.Judd 4669 (FLAS).

### Pollination syndrome evolution

Our re-analysis of the evolution of pollination syndromes in *Cayaponia* reveals that bee pollination is most likely the ancestral state for the clade (Fig. 5) followed by one shift to bat pollination along the stem of the *C. tubulosa* Cogn.-*C. prunifera* (Poepp. & Endl.) P.Duchen & S.S.Renner clade and one reversal to bee pollination within the same clade (*C. espelina* (Silva Manso) Cogn.). A third shift is inferred for *C. pilosa* Cogn., which is bat pollinated but nested in a bee pollinated clade (Fig. 5).

### Ancestral habitat reconstruction

We find that the ancestral habitat of the *Cayaponia* lineage was most likely rainforest, which is in agreement with most extant species still being confined to some type of rainforest habitat (Fig. 6). Only few species, including *C. espelina*, *C. pilosa*, and some members of the clade containing *C. attenuata* (Hook. & Arn.) Cogn. shifted to more open habitats (Fig. 6).

### Discussion

Molecular and morphological evidence both show that *Melothria domingensis* is best placed in the *Cayaponia* clade and probably close to the North American *C. quinque-*

*loba*. However, due to the poor resolution in parts of our *Cayaponia* phylogeny, we are unable to identify exact sister group relationships. Better taxon sampling and additional variable DNA markers are needed to solve this question.

The newly identified *Cayaponia* species from Hispaniola is a rain- or cloud forest inhabitant with small, probably diurnal flowers on short pedicels that match all characters for bee-pollination in *Cayaponia* discussed in Duchén and Renner (2010). It therefore does not fit to the pattern of pollinator shifts from bat- to bee-pollination as an adaptation to open savanna habitats hypothesized for *Cayaponia* by Duchén and Renner (2010) based on an analysis including 19 of the c. 60 species of *Cayaponia*. And indeed, our re-analysis of the pollination syndrome evolution in *Cayaponia* also questions the finding that bat pollination might be the ancestral condition in the clade. We find that based on the extended sampling, the most likely ancestral condition is bee pollination but with still 70% of the currently known *Cayaponia* species remaining to be sequenced, this pattern can easily change in the near future. We can confirm, however, at least one inferred shift from bat- to bee-pollination in *C. espelina*, which would be one of very few transitions in that direction (Duchén and Renner 2010; Van der Niet and Johnson 2012). Fieldwork on pollinators of *C. espelina*, a common species of the Brazilian Cerrado, would be needed to elucidate this interesting case further.

*Cayaponia domingensis* is one of only few species in the genus and in the entire family Cucurbitaceae that occur above 2000 m a.s.l. (the highest collections known are from 2100 m a.s.l., *Liogier & Liogier* 25690 (NY), *A. Liogier* 13134 (NY) and 2201 m a.s.l., *P. Acevedo-Rodríguez et al.* 13011 (NY)). The mechanisms that allow this species to thrive at those altitudes are unknown but might be interesting to study. Most Cucurbitaceae are highly frost-sensitive and survive cold periods only as seeds (e.g. North American *Sicyos angulatus* L.), rootstocks (e.g. Central European *Bryonia dioica* Jacq.), or tubers (e.g. *Thladiantha dubia* Bunge). The only perennial Cucurbitaceae that thrive at even higher altitudes are some Himalayan *Thladiantha* species that reach up to 3500 m a.s.l.

The mottled fruits characteristic for *Cayaponia domingensis* are very rare in the genus and might have evolved as an adaptation to a specialised seed dispersal agent on the island. Unfortunately, we lack field observations on dispersal agents and judging from fruit and seed size, a wide range of animals, including birds, lizards, and small mammals might be involved.

Recent transoceanic dispersal has been inferred for the ancestors of *Cayaponia africana* s.l. (Schaefer et al. 2009; Duchén and Renner 2010). While Duchén and Renner (2010) hypothesized a stepping-stone route via the Brazilian island Fernando de Noronha, our findings suggest that long-distance dispersal out of the Caribbean might be another option.

Our results highlight that even after two decades of Molecular Systematics, we still need more sequencing combined with morphological analyses to sort out taxonomic problems in Cucurbitaceae and other understudied families. We can now be confident about the phylogenetic position of this enigmatic Caribbean endemic. This is, however, only a first step and we now plan to do fieldwork on Hispaniola to obtain accurate

distribution data, find out more about the ecology of this species, identify the threats to the remaining populations and ultimately develop a management plan to guarantee the survival of this unique endemic.

## Acknowledgements

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# *Codonoboea personatiflora* (Gesneriaceae), a new species from Peninsular Malaysia

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## Abstract

*Codonoboea personatiflora* Kiew & Y.Y.Sam, **sp. nov.**, is described from lowland forest in the foothills in Terengganu, Peninsular Malaysia. It is unique in the genus in its personate flower. Its conservation status falls within the IUCN Endangered category.

## Keywords

*Codonoboea personatiflora*, Gesneriaceae, new species, Terengganu, Peninsular Malaysia, personate flower

## Introduction

This striking new species has attracted attention for a number of years for its tall bushy habit and glossy young leaves conspicuously reddish towards the base and bright yellowish green towards the apex. However, it was only when it was cultivated in the nursery of the Forest Research Institute Malaysia in Kuala Lumpur that flowering material could be obtained and the species described. It belongs to *Codonoboea*, a genus of about 120 species that is an important component of the herb layer in rain forest in W Maleisia extending as far north as Southern Thailand and as far south as Sulawesi (Kiew and Lim 2011). Its centre of distribution with 79 species is Peninsular Malaysia where it is found in abundance and diversity (Kiew 2009). Recent molecular phylogenetic analyses (Weber et al. 2011) have confirmed that *Codonoboea* is monophyletic and is a genus distinct from *Didymocarpus* (Weber and Burtt 1983), *Henckelia* and *Loxocarpus* (Weber and Burtt 1998). It is unique among *Codonoboea* species in its personate (closed) flower.

## Taxonomy

### *Codonoboea personatiflora* Kiew & Y.Y.Sam, sp. nov.

urn:lsid:ipni.org:names:77123717-1

[http://species-id.net/wiki/Codonoboea\\_personatiflora](http://species-id.net/wiki/Codonoboea_personatiflora)

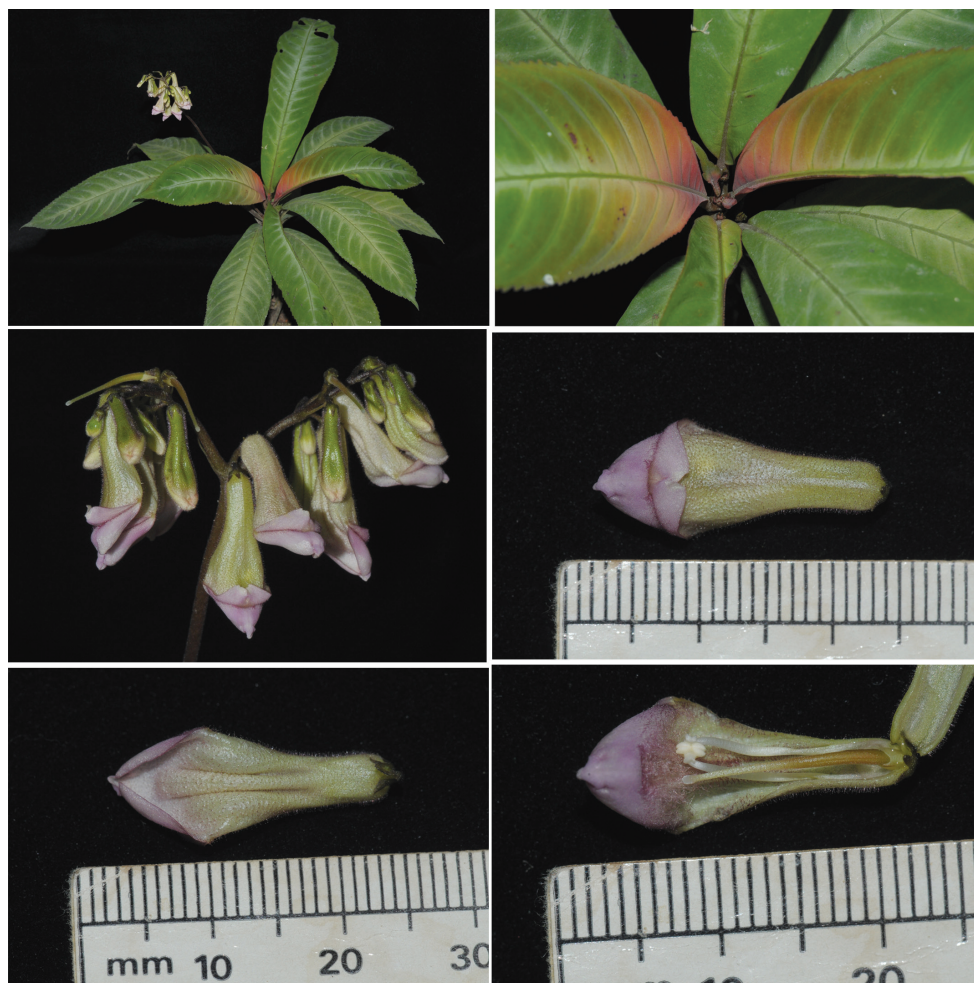
Figure 1, Map 1

**Diagnosis.** Different from all other species of *Codonoboea* Ridl. in its personate flower where the lower lip is directed upwards and completely closes the mouth of the corolla tube.

**Type. Peninsular Malaysia.** Terengganu: Kemaman, Sungai Nipah, Bukit Kajang, 4°20'N, 103°07'E, 22 Nov 1935, E.J.H. Corner SFN 30540 (holotype: SING!; isotypes: K!, L, E, SAR!).

Robust, erect, unbranched herb. **Stem** woody to 65 cm tall, flowering at ca 15 cm tall, bare stem below the leaves 4–9 mm diam. **Leaves** opposite, pairs equal, spaced 8–17 mm apart, glossy when young, reddish towards the base and bright yellowish green toward apex, older leaves uniformly dull greyish green above; petioles 1.3–3 cm long, slightly grooved above, minutely pubescent; lamina oblanceolate, thinly leathery, 15–34 × 4–8 cm, lateral veins whitish or yellowish green, sometimes with a silvery band along the midrib, paler beneath, base narrowed then slightly rounded, margin serrate in the upper half, teeth ca 1 mm long, apex narrowly acuminate, acumens to 1–2.5(–4) cm long; midrib and veins impressed above, prominent beneath in life, lateral veins 9–20 pairs, ferrugineous beneath.

**Inflorescence** a pair-flowered dichasial cyme with up to 5<sup>th</sup> order branching, erect from the upper leaf axils, 12–34 cm long, peduncle purple or reddish brown, 7.5–29 cm long, bracts green, linear, 2–10 × ca 0.5 mm, pedicels 2–5 mm long. Inflorescence, pedicel and calyx with minute, dense, non-glandular pubescence. **Flowers** pendent, to 20 mm long, almost hanging vertically down, buds green or only at the base; calyx brownish purple or green, ca 1.5–2 × 0.75 mm long, 5-lobed divided almost to the base, apex acute; corolla pale cream with pale pink lobes, personate, densely glandular pubescent outside, tube 9–13 × 3–5 mm, lower half of tube cylindric, the upper half gradually dilating to ca twice the width of the basal half, mouth 6–9 mm diam., upper lip erect, glabrous, ca 7 mm long with 2 strongly reflexed lobes, each ca 2.5 × 2.5 mm with a raised patch of long glandular hairs between lobes, lower lip positioned upwards and appressed against the upper lip closing the corolla mouth, 8–10 × 6.5–9 mm long, the 3 rounded, glabrous lobes reflexed to cucullate, raised and forming a rim, lateral lobes ca 2 × 2 mm, central lobe ca 3 × 2.5 mm, throat with dense patch of deep pink unbranched long multiseriate glandular hairs, nectar guides 2, strongly raised, concolorous with the tube; stamens 2, joined 4–5 mm from corolla base, filaments white, slightly bowed inwards, 7–13 mm long with 2 blunt horns at the attachment to the anther, anthers purple or pale cream, ca 2 × 0.75 mm, cohering face-to-face, staminodes 2, slender ca 3 mm long, hooked at apex; nectary cylindric, margin unequally lobed, upper lobes 2–3 mm long, lower lobes 2–3.5 mm long; ovary and style slender, with



**Figure 1.** *Codonoboea personatiflora* Kiew & Y.Y.Sam. **A** habit **B** coloured young leaves **C** pair-flowered cy-mose inflorescences **D** flower (top view) **E** flower (from below) **F** longitudinal section with upper lip removed.

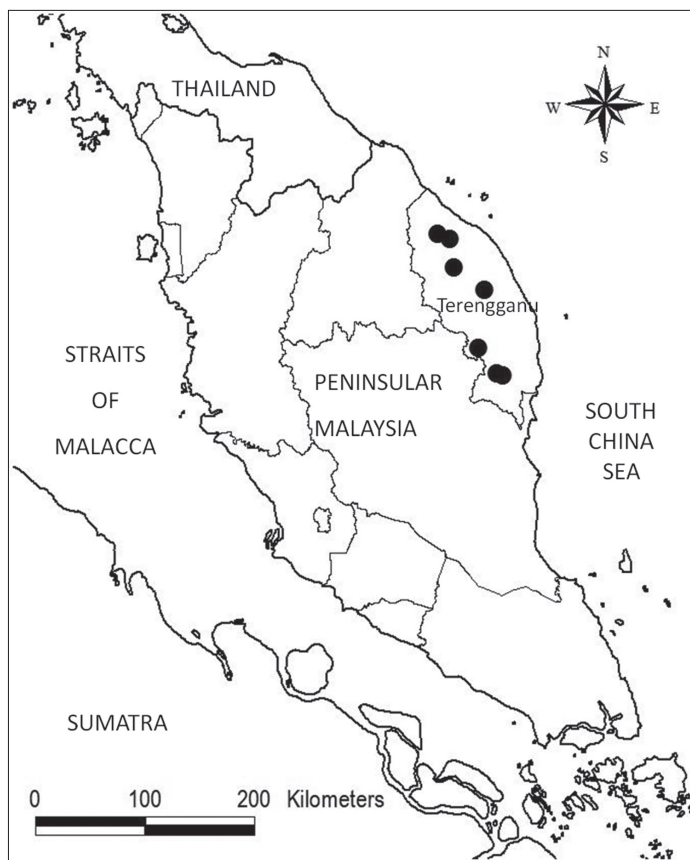
dense brownish glandular hairs, ovary white,  $5\text{--}8 \times 0.75\text{--}1$  mm long, style purple-brown,  $5\text{--}6$  mm long, stigma globose, almost  $0.5$  mm diam. The anthers and stigma are positioned at the same level just below the upper lip. **Fruits** slender, cylindric,  $22\text{--}45 \times 1\text{--}1.5$  mm, dehiscing along the upper suture.

**Distribution.** Peninsular Malaysia, endemic in the state of Terengganu.

**Ecology.** In primary or logged-over lowland mixed dipterocarp forest at low altitudes (below  $100$  m), on shaded hillsides or slopes, often above streams.

**Etymology.** Named for its personate (closed) flower that is unique for the genus.

**Conservation status.** EN B2a,b(ii,iii). Following the IUCN Criteria and Categories (IUCN 2001; Chua 2010), this species falls within the Endangered Category because it is known from five localities, has in total an area of occupancy of  $28$  sq km. In addition, it is nowhere found within Peninsular Malaysia's network of Totally Protect-



**Map I.** Distribution of *Codonoboea personatiflora* in Peninsular Malaysia.

ed Areas and it grows at low altitudes in lowland forest, a habitat that is threatened by or already has been logged or is threatened by forest clearance for oil palm plantations.

**Other specimens examined. Peninsular Malaysia.** Terengganu: Dungun, Jengai Forest Reserve, Compartment 71, 15 Mar 1998, Anon. s.n. (SING!), Compartment 52, 65 m alt., 4°32.76'N, 102°58.34'E, 17 Oct 2002, Y.Y.Sam FRI 47153 (KEP!, SAN!); Hulu Terengganu, Ulu Telemong Forest Reserve, 5°12'N, 102°46'E, 25 Jul 2006, R.Kiew RK 5339 (KEP!, K!, SAR!); Hulu Terengganu, Ladang Ternakan TER-SAT, 62 m alt., 5°01.07'N, 103°01.17'E, 31 Oct 2009, M.Kamarul-Hisham FRI 67168 (KEP! SING!); Kemaman, Sungai Nipah Forest Reserve, Jeram Tanduk, 81 m alt., 4°18.93'N, 103°10.42'E, Y.Y.Sam FRI 47197 (KEP! SING!); probably from Kemaman, Sungai Nipah, collector unknown, flowered in Forest Research Institute Malaysia Nursery on 9 Apr 2012, FRI 75314 (KEP!); Setiu, Ulu Setiu Forest Reserve, 5°26'N, 102°44'E, 7 Mar 2002, Y.Y.Sam FRI 44395 (KEP!), flowered in Forest Research Institute Malaysia Nursery on 9 Sept 2003, Y.Y.Sam FRI 44483 (KEP!).

**Discussion.** This new species belongs to *Codonoboea* sect. *Didymanthus* in its erect habit, petiolate leaves in distant pairs, cymose inflorescences with a long peduncle and

inconspicuous bracts, and medium-sized (to 2 cm long) flowers (Ridley 1923). However, it differs from the other species in this section, and indeed from all other known *Codonoboea* species, in its personate flower. The special feature of this flower is the lower lip where the recurved lobes form a rim that is pressed upwards against the upper lip and so closes the corolla mouth, unlike the usual open funnel- or trumpet-shaped or campanulate corolla of *Codonoboea* species. In addition, the aperture is filled by the long hairs, a feature not seen in other *Codonoboea* species. The lower lip appears to be hinged because it is readily bends downward when pressure is applied so opening up the mouth of the corolla tube.

The majority of *Codonoboea* species are nectar flowers (the cylindrical nectary surrounding the base of the ovary supplies nectar as the reward for the pollinator) with a narrow tubular flower that is strongly dilated to produce an open funnel- or trumpet-shaped flower, often with the lower lobes projecting and forming a landing platform for the insect pollinator. Usually there are yellow or orange nectar guides on the floor of the tube. The flower is therefore open to any insect small enough to enter the tube. Although there are very few observations on pollination in this genus, bumblebees (*Bombus* sp.) have been observed visiting two species, *C. hispida* (Ridl.) Kiew and *C. robinsonii* (Ridl.) Kiew, both belonging to *Codonoboea* sect. *Didymanthus* (Kiew 2009) and it is likely, based on floral morphology, that bees are the pollinators of most of these *Codonoboea* species. The other type of flower seen in the genus is the smaller, short-tubed, often campanulate pollen flower where the anthers are large and conspicuous in the mouth of the corolla. These flowers either have very small nectaries or none at all and pollen is offered as the reward.

This new species is obviously a nectar flower but is unique in *Codonoboea* in that the upper and lower lips fit closely together so that the mouth is closed and in addition there is a tangle of long hairs just inside the mouth that might prevent small insects from squeezing between the lips. This personate flower closely resembles that of the ornamental snapdragon, *Antirrhinum majus* L. (Scrophulariaceae) that is pollinated by bumblebees that on landing on the flower are sufficiently heavy to depress and open the lower lip.

There are only two other examples of this type of personate flower in Malaysian Gesneriaceae, namely in *Didymocarpus antirrhinoides* A.Weber (Weber and Burt 1983) that has a flower of similar size (15–23 mm long) and *Rhynchosolossus medusothrix* B.L.Burt (Burt 1962) with a corolla tube 10–25 mm long that in addition has ‘medusoid’ hairs in the throat. However, for none of these personate flowers is the pollinator known.

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