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Short Communication

Rediscovery of *Thismia caudata* after 129 years and synopsis of other achlorophyllous herbs from the Pico do Marumbi State Park and buffer zone in Piraquara, Paraná, Brazil

Román Carlos Ríos[1,2,4] & *Vinicyus Jorge Mordaski Visni da Cruz*[1,3]

Abstract

The Atlantic Forest is one of the world's biodiversity hotspots. The Pico do Marumbi State Park is home to an evergreen ombrophilous forest with areas of transition to the Araucaria moist forest. In spite of the high diversity of life forms in the area, there are few studies of understory herbaceous plants. The present study reports the rediscovery for Brazil and the first record for Paraná state of an extremely rare species of Thismiaceae, *Thismia caudata*. The only record so far has been for the Rio de Janeiro state. In February 2021, *T. caudata* was discovered with fruit and flower. We also present other records of achlorophyllous herbaceous species that were occasionally found near the rediscovered Thismiaceae. In total, eight species belonging to five families are reported with descriptions of the morphology and natural environment, as well as phenological aspects. These are *T. caudata*, *T. cordata*, and *T. panamensis* (Thismiaceae); *Langsdorffia hypogaea* (Balanophoraceae); *Voyria aphylla* (Gentianaceae); *Apteria aphylla* and *Gymnosiphon tenellus* (Burmanniaceae); *Triuris hyalina* (Triuridaceae). In addition, we present the very first photographs of *T. caudata.*

Key words: Atlantic Forest, holoparasite plant, mycoheterotrophic plant, Serra Marumbi.

Resumo

A floresta Atlântica costeira é um dos hotspot de biodiversidade no nível mundial. O Parque estadual Pico do Marumbi apresenta floresta ombrófila sempre verde com áreas de transição com a floresta com araucária. A alta diversidade de formas de vida na área apresenta poucos estudos das plantas herbáceas do sub-bosque. Este estudo reporta o redescobrimento para o Brasil e o primeiro registro para o estado do Paraná de uma espécie de Thismiaceae extremamente rara, *Thismia caudata*. O único registro até agora foi para o estado de Rio de Janeiro. Em fevereiro de 2021 *T. caudata* foi descoberta com fruto e flor. Também apresentamos outras espécies herbáceas aclorofiladas registradas e as vezes, acompanhantes da Thismiaceae redescoberta. No total oito espécies pertencentes a cinco famílias são reportadas com descrição da morfologia e do ambiente natural como de aspectos fenológicos. Essas foram: *T.caudata*, *T. cordata* e *T. panamensis* (Thismiaceae); *Langsdorffia hypogaea* (Balanophoraceae); *Voyria aphylla* (Gentianaceae); *Apteria aphylla* e *Gymnosiphon tenellus* (Burmanniaceae) e *Triuris hyalina* (Triuridaceae). Apresentamos as primeiríssimas fotografias de *T. caudata.*

Palavras-chave: Floresta Atlântica, planta holoparasita, planta micoheterotrofa, Serra Marumbi.

The Atlantic domain in Brazil comprises several forest formations over a wide geographical distribution, with the greatest species richness occurring in the evergreen rainforest, which contains 80% of endemic angiosperm species (BFG 2022). Some are extremely rare and have unique life forms, such as achlorophyllous plants. Non-photosynthetic plants are heterotrophic organisms

[1] Universidade Federal do Paraná, Depto. Ciências Florestais, Curitiba, PR, Brasil.
[2] ORCID: <https://orcid.org/0000-0001-6590-6944>.
[3] ORCID: <https://orcid.org/0000-0003-4055-9093>.
[4] Author for correspondence: rioselvas@gmail.com

that have evolved from green plants and developed unique nutrition mechanisms, either parasitizing roots or mycorrhizal fungi (Leake 1994; Nuraliev *et al*. 2019).

Mycoheterotrophic plants are generally small, with reduced stems, squamous leaves that are never green, and morphologically complex reproductive organs; they need an intermediary host to access carbon assimilated by green plants (Mercx 2013). Therefore, they are epiparasites of mycorrhizal fungi that obtain the sap from the roots of the green plants with which they associate (Mercx 2013). Their functional and ecological characteristics are still poorly understood (Tsukaya 2018).

Imhof (2010) documents 438 identified mycoheterotrophic species, classified into 84 genera and 10 families. Of these, 51 species are eudicotyledons, and 387 are monocotyledons. These plants occur mainly in tropical regions. In Brazil, mycoheterotrophic species have been found from the families Orchidaceae, Burmanniaceae, Gentianaceae, Triuridaceae, and Thismiaceae (Flora do Brasil 2020, continuously updated).

Mycoheterotrophic species belonging to the family Thismiaceae are some of the most difficult to detect in the field. Some of these species are only represented by their type materials, such as *Thismia prataensis* Mancinelli, C.T. Blum & E.C. Smidt (2012: 879) (Marcinelli *et al*. 2012) in Paraná state and *T. caudata* Maas *et al*. (Maas H, Maas PJM, Benthem VJ, Snelders HCM & Rübsamen T 1986: 162) in Rio de Janeiro state. *Thismia* is the only genus of mycoheterotrophic plants recorded to date in Brazil, with 15 species documented, 10 of which are endemic (BFG 2022).

Most species in Brazil have incomplete descriptions with few records (Ferreira-da-Silva & Alvarenga Braga 2022). One of these is *T. caudata*, which until now has had a single record from Rio de Janeiro state, collected in 1892 by A. Glaziou; its type is currently deposited at the Museum of Natural History of Paris (Maas *et al*. 1986). In February 2021, this species was rediscovered in the Pico do Marumbi State Park, Paraná, 129 years after the collection of the type.

We report the second record of *T. caudata* in Brazil, rediscovered after 129 years, and the first from southern Brazil and Paraná. Complementary information on morphology and the first photographs of *T. caudata* are presented, in addition to a synopsis of other non-photosynthetic plants from fieldwork conducted in the forests of Pico do Marumbi State Park, Piraquara.

The Pico do Marumbi State Park is located in the municipalities of Piraquara, Quatro Barras, and Morretes, with a total area of 8,700 ha (ISA 2021). The study areas are all located in Piraquara municipality (Fig. 1), on the west side of the park. The study areas can be characterized as follows:

Area 1: Sanepar (25°29'41"S, 48°59'28"W). Transition forest between the rainy evergreen forest and the Araucaria moist forest, with no records of anthropogenic disturbance since 1907. Altitudes ranging between 1,000 and 1,100 m. Area 2: Salto Melança (25°29'51"S, 48°59'47"W). Transitional forests between rainy evergreen forest and Araucaria moist forest with an advanced stage of succession (over 50 years without anthropogenic intervention). Altitudes ranging between 930 and 990 m. Area 3: Torre Amarela and Morro do Canal (25°30'55"S, 48°59'20"W). Exclusively covered by rainy evergreen forests. Altitudes ranging between 1,000 and 1,050 m.

Data collection and analysis

Collections were carried out from 2019 to 2023, mainly during the rainy periods of summer. In Area 1, 3,500 m of trails were covered between 2021 and 2022, for a total of 80 hours of exploration and collection (Fig. 1). In Area 2, 5,900 m of trails were covered from 2019 to 2021, for a total of 192 hours of exploration and collection (Fig. 1). In Area 3, 3,000 m of trails were covered between 2020 and the present, for a total of 144 hours of exploration and collection (Fig. 1).

The specimens were identified using taxonomic keys, specialized literature (Maas & Rubsamen 1986; Maas & Ruyters 1986; Maas & Maas 2005; Melo *et al*. 2010; Melo & Alves 2013; Guilherme *et al*. 2016), and by comparison with herbarium collections from other institutions (MBM, UPCB, Thiers, continuously updated), as well as by consulting taxonomists.

The nomenclature of the families followed APG IV (2016); geographic distribution was considered according to GBIF (2021) for the Americas, and Govaerts (2019) and Flora do Brasil 2020 (continuously updated) for Brazil.

The collected and identified material was deposited in the herbaria of the Faculty of Forestry and Biological Sciences of the Federal University of Paraná (Universidade Federal do Paraná - UFPR) (EFC and UPCB, Thiers, continuously updated).

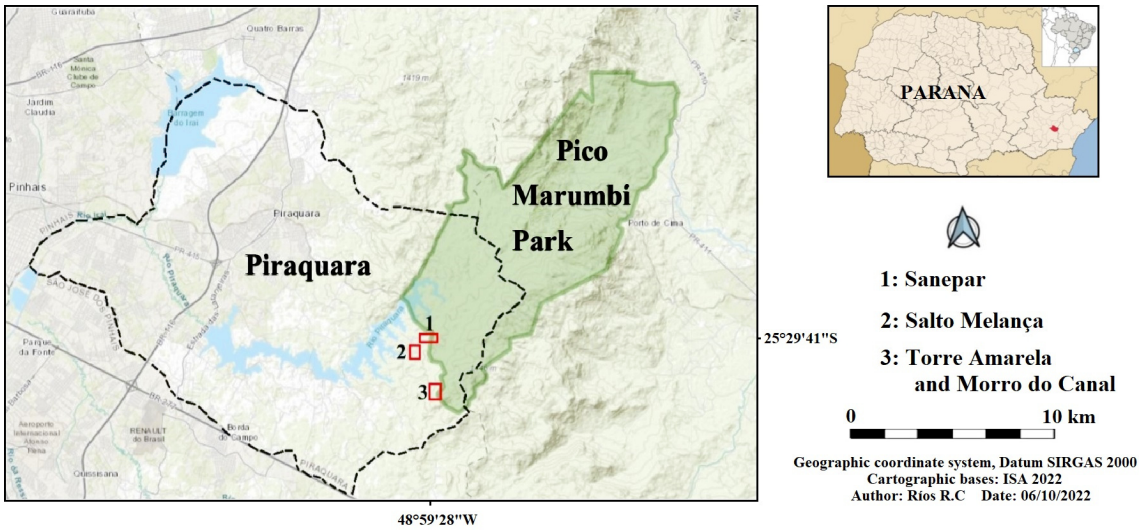

Figure 1 – Geographic distribution of achlorophyllous herbs from Pico Marumbi state park and buffer zone in Piraquara, Paraná, Brazil.

Eight species of achlorophyllous plants were found in the study areas: one holoparasite and seven mycoheterotrophic ones. The holoparasite species is *L. hypogaea*, widely distributed in the Neotropics. The mycoheterotrophic species found belong to the four families recorded in Brazil. These are Burmanniaceae (*A. aphylla* and *G. tenellus*), Gentianaceae (*V. aphylla*), Triuridaceae (*Triuris hyalina*), and Thismiaceae (*T. caudata*, *T. cordata*, and *T. panamensis*).

Identification key for the species of achlorophyllous herbs from Pico do Marumbi State Park and buffer zone in Piraquara, Paraná, Brazil

1. Root-holoparasitic life form; yellow tuberous rhizome ..... 3. *Langsdorffia hypogaea* (Balanophoraceae)
1'. Mycoheterotrophic life form; without yellow tuberous rhizome.
    2. Pentamerous, yellow to orange, solitary flower ..... 8. *Voyria aphylla* (Gentianaceae)
    2'. Trimerous solitary flower.
        3. Zygomorphic solitary flower.
            4. Annulus surrounded by a prominent star-shaped six-lobbed ornamentation ..... 5. *Thismia cordata* (Thismiaceae)
            4'. Annulus not surrounded by star-shaped ornamentation ..... 6. *Thismia panamensis* (Thismiaceae)
        3'. Actinomorphic flower.
            5. Apocarpic carpels, unisexual flowers, female capituliform inflorescence ..... 7. *Triuris hyalina* (Triuridaceae)
            5'. Syncarpic carpels, bisexual flowers without capituliform inflorescence.
                6. Flowers with miter and cylindrical roots..... 4. *Thismia caudata* (Thismiaceae)
                6'. Flowers without miter and cylindrical roots.
                    7. Purple stem and erect and bell-shaped flowers, yellow stigma ..... 1. *Apteria aphylla* (Burmanniaceae)
                    7'. White to light purplish stem; white and salverform flowers on cincinnus inflorescence; off-white stigma ... 2. *Gymnosiphon tenellus* (Burmanniaceae)

1. ***Apteria aphylla*** (Nuttall) Barnhart *ex* Small., Small, J.K., Flora of the Southeastern United States, 1: 309, 1903. Fig. 2a-c

Mycoheterotrophic herb, erect, with stems purple, unbranched, and flowers infundibuliform to bell-shaped. Ovary multiovulate, with three carpels, and stigma yellow, trifid. Fruit with multiple seeds, fruit pendular, capsule-shaped, with a persistent perianth.

Selected specimens: Piraquara, Salto Melança, Area 2, 1.V.2019, fl., *R.C. Ríos & V.M.J.V. Cruz 03* (EFC); Torre Amarela, Area 3, 5.XII.2020, fl., *R.C. Ríos & V.M.J.V. Cruz 10* (UPCB).

Widely distributed in the Neotropics from the southern USA to Argentina (BFG 2018; Maas *et al*. 2015). Widely distributed in Brazil, mainly in forests and seasonally flooded environments or very humid sites. Flowering and fruiting occur throughout the year.

In the present study, *A. aphylla* was observed co-occurring with other achlorophyllous plants (*V. aphylla*, *Triuris hyalina*, and *T. panamensis*).

Supplementary bibliography: Maas *et al*. (2015).

2. ***Gymnosiphon tenellus*** (Benth.) Urban, I., Symb. antill., 3(3): 438, 1903. Fig. 2d-f

Mycoheterotrophic herb, up to 10 cm high, white or off-white, or light purple, usually branched. Flower erect and salverform on a bifurcate cincinnus, with one to three flowers each. Flowers sessile to sub-sessile, with outer tepals trilobate and central lobe ovate-triangular. Stigma trifid, off-white (never yellow), without appendages. Fruit capsule-shaped, with a persistent floral tube.

Selected specimens: Piraquara, Torre Amarela, Area 3, 17.II.2020, fl., *R.C. Ríos & V.M.J.V. Cruz 06* (UPCB); Sanepar, Area 1, 1.III.2022, fl. and fr., *R.C. Ríos 40* (UPCB).

Distributed from Central America to Brazil in tropical forests. In Brazil, species of the genus are found in the Amazon region and the Atlantic Forest in Rio de Janeiro and Paraná.

Flowering and fruiting observed during the rainy season (October to February) in southern Brazil. *Gymnosiphon tenellus* specimens can be found in sympatry with other mycoheterotrophic species, such as *T. panamensis*, *Triuris hyalina*, and *V. aphylla*.

Supplementary bibliography: Maas *et al*. (2015); Souza *et al.* (2019).

3. ***Langsdorffia hypogaea*** Mart. In Eschwege j. Brazil. 2: 179, t.5 1818. Fig. 2g-h

Achlorophyllous herb, root parasites with haustoria, and rhizome roots yellow tuberous. Inflorescence unisexual with a female capituliform inflorescence and a male spadix inflorescence. Female flowers linear-prismatic, densely arranged but free from each other with yellowish coriaceous red tepals. Ovary without a cavity. Male flowers bracteates with pedicel. Fruit a small, one-seeded achene.

Selected specimens: Piraquara, Torre Amarela, Area 3, 4.IV.2021, fl., *R.C. Ríos 08* (UPCB).

Langsdorffia hypogaea can be distinguished from *L. heterotepala* due to the presence of a male capituliform inflorescence in the latter species (Cardoso 2020).

The geographical distribution of *L. hypogaea* extends from Mexico to Brazil, reaching different habitats like *campo rupestre* (rupestrian grassland), caatinga, and ombrophilous rainforest. Flowering occurs in the season of least rainfall in central-western and southern Brazil, coinciding with the scarcity of resources in the southern region of the country.

Flowering and fruiting occur from April to August, with some flowers in January. In the present study, *L. hypogaea* was also observed co-occurring with *G. tenellus*.

Supplementary bibliography: Cardoso (2020); Thorogood & Santos (2020).

4. ***Thismia caudata*** Maas & H. Maas. Flora Neotropica Monogr. 42:162, 1986. Fig. 3a-g

Mycoheterotrophic herb, up to 15 cm high, white. Cylindrical and horizontal root. Stem terete with up to six ovate leaves. Flowers erect, floral tube obovoid, actinomorphic with circular throat. Tepals short, inserted in the floral tube, and the larger tepals inserted before the annulus, spatulated with revolting margins. Annulus, a ring of 12 erect lobes. Filament straight, inserted right below the throat. Connectives non-dilated, elliptical to circular anthers. Stigma trifid, deltoid, and wings with eyelashes. Fruit and seeds brown.

Selected specimens: Piraquara, Torre Amarela, Area 3, 15.II.2021, fl., *R.C. Ríos 11*; 25.XII.2021, fl., *R.C. Ríos 12* (EFC).

The species has a very restricted distribution: it has been reported in the Serra Alto Macahe in Nova Friburgo, Rio de Janeiro, and in the present study for

Figure 2 – a-c. *Apteria aphylla* – a. habitat and flower; b. habit and flower; c. gynoecium and androecium. d-f. *Gymnosiphon tenellus* – d. habit and habitat; e. ovules into ovary; f. tepals. g-h. *Langsdorffia hypogaea* – g. habitat and female flower; h. male flower. Scale bars: a, b, d. 10 mm; c, e. 2 mm; f. 1 mm; g. 15 mm; h. 5 mm. (Photos: a-h. Ríos CR, 2021).

Figure 3 – a-g. *Thismia caudata* – a-c. habit and flower; d. cilindrical roots; e. gynoecium and androecium; f. free tepals and mitre; g. fruit with seeds. Scale bars: a-c. 10 mm; d. 2.5 mm; e-g. 5 mm. (Photos: a-g. Ríos CR, 2022).

the Pico do Marumbi State Park. *Thismia caudata* was observed co-occurring with *T. cordata* and *T. panamensis*, *Triuris hyalina*, and *G. tenellus*. The environment where it was found is very humid, on stones with a thin litter layer. Flowering takes place from December to April.

Supplementary bibliography: Brade (1947).

5. *Thismia cordata* D.F. Silva & J.M.A. Braga. Phytotaxa, 571(1): 076, 2022. Fig. 4a-f

Mycoheterotrophic herb, tuberous with fibrous roots. Stem longitudinally bisulcate, unbranched, glabrous, white to orange. Flowers solitary, zygomorphic, perianth gibbous, orange, six-veined darkened. Outer perianth lobes ovate, base cordate. Annulus surrounded by six brownish spots and a prominent star-shaped ornamentation, aquamarine. Filaments narrowly triangular. Stamens pendulous, inserted below the annulus, connective dilated with four lobes, falcate. Ovary unilocular, multiovulate, placentation parietal. Fruit cup-shaped.

Selected specimens: Piraquara, Torre Amarela, Area 3, 10.I.2022, fl. and fr., *R.C. Ríos 13* (UPCB); Sanepar, Area 1, 8.IV.2023, fl. and fr., *R.C. Ríos 80* (EFC).

The species has a very restricted distribution: it has been reported only for the Pico do Marumbi State Park (Silva *et al*. 2022). *Thismia cordata* was observed co-occurring with *T. caudata*. The environment where it was found is very humid, on stones near streams. Flowering takes place from November to April.

6. *Thismia panamensis* (Standl.) Jonker, Monogr. Burmann.:234(1938). Fig. 5a-c

Mycoheterotrophic herb, up to 6 cm high, white, with white tuberous roots. Floral tube strongly zygomorphic with a horizontal throat, a whorl of six tepals with an inner whorl connate, and straight trichomes. Inferior ovary, tricarpellar, and unilocular. Trifid stigma and stylus short, cylindrical. Androecium comprised of six stamens and anthers bithecate. Fruit dehiscent, cup-shaped, with multiple fusiform seeds.

Selected specimens: Piraquara, Torre Amarela, Area 3, 16.III.2021, fl. and fr., *R.C. Ríos & V.M.J.V. Cruz 07* (UPCB); Sanepar, Area 1, 8.II.2022, fl., *R.C. Ríos 32* (UPCB).

The species is distributed from Panama and Costa Rica to southern Brazil (Guilherme *et al*. 2016; Souza 2021). It is very difficult to detect in the field due to its ombrophilous habits under thick plant litter. Flowering and fruiting were observed from January to March in Piraquara. Detected in sympatry with *Triuris hyalina* and *G. tenellus*.

Supplementary bibliography: Merckx & Smets (2014); Marcinelli *et al*. (2012).

7. *Triuris hyalina* Miers, J., Trans. Linn Exclusion London, 19: 79, 1845. Fig. 5d-f

Mycoheterotrophic herb up to 10 cm high, hyaline stem without leaves, roots glabrous to sparsely hairy. Plant dioecious, unisexual flowers. Tepals three, triangular to deltate. Apex with a tail-like appendage. Female inflorescence capitulum-like and fruit achene, with rough epicarp. Androphore deltoid to broadly ovoid. Seeds globose to ellipsoidal.

Selected specimens: Piraquara, Salto Melança, Area 2, 1.V.2019, fl. and fr., *R.C. Ríos & V.M.J.V. Cruz 01* (EFC); Torre Amarela, Area 3, 21.III.2021, fl. and fr., *R.C. Ríos & V.M.J.V. Cruz 09* (UPCB); Sanepar, Area 1, 8.IV.2023, fl. and fr., *R.C. Ríos 83* (EFC).

Disjointly distributed from Mexico to Brazil. Restricted to very humid forest environments with thick plant litter. Flowering was observed from December to April; specimens can be found co-occurring with *T. panamensis*, *A. aphylla*, and *G. tenellus*.

Supplementary bibliography: Maas & Maas (2010); GBIF (2021); Ríos & Cruz (2021).

8. *Voyria aphylla* (Jacq.) Pers., Syn.pl. 1: 284. 1805. Fig. 5g-i

Mycoheterotrophic herb yellow, up to 20 cm high, with opposite scale-like leaves connate in their lower half. Flowers erect, solitary, gamopetalous, pentamerous, with calyx campanulate to cylindric, lobes triangular to broadly triangular. Corolla salverform, yellow to orange, tube cylindrical, lobes narrowly ovate to narrowly obovate. Fruit dehiscent, capsule-shaped; seeds many, fusiform.

Selected specimens: Piraquara, Salto Melança, Area 2, 1.V.2019, fl. and fr., *R.C. Ríos & V.M.J.V. Cruz 2* (EFC); Sanepar, Area 1, 1.X.2022, fl. and fr., *R.C. Ríos 66* (UPCB).

Widely distributed in the Neotropics from Mexico to Brazil (Maas & Ruytes 1986) and recently recorded in Argentina (Gatti & Keller 2019). Disjoint distribution between the Amazon region and the Atlantic Forest in Brazil (Silva *et al*. 2020). Flowering observed throughout the year; *Voyria aphylla* has been found co-occurring with other mycoheterotrophic species, such as *A. aphylla* and *Triuris hyalina*. In the present study, the species was observed in well-drained, clayey soil with sun exposure.

Supplementary bibliography: Silva *et al*. (2020).

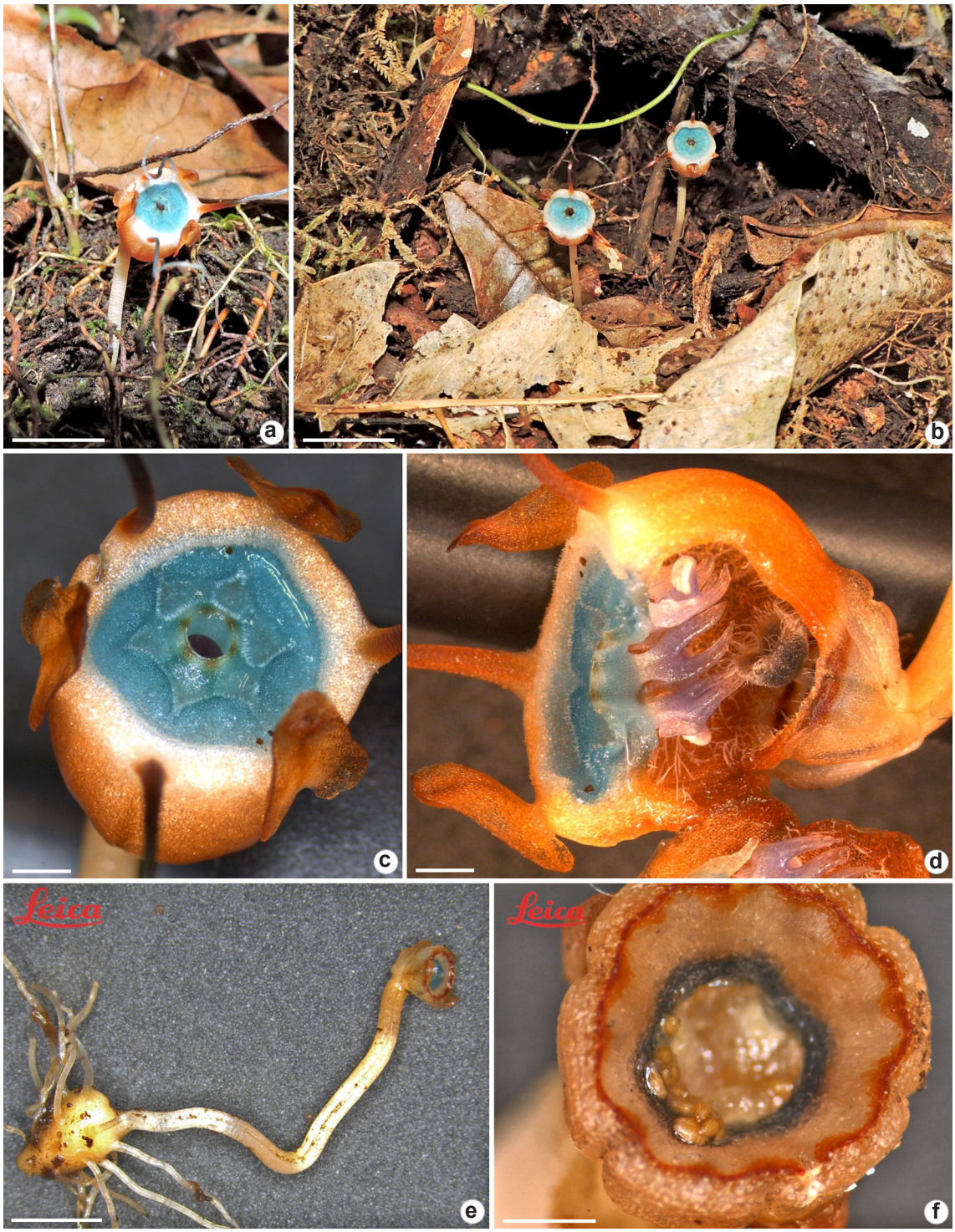

Figure 4 – a-f. *Thismia cordata* – a-b. habit and flower; c. annulus surrounded by star-shaped ornamentation; d. gynoecium and androecium; e. tuberose root with stem and fruit; f. cup shaped fruit with seeds. Scale bars: a, e. 1 cm; b. 2 cm; c, d, f. 1 mm. (Photos: a-f. Ríos CR, 2022).

Figure 5 – a-c. *Thismia panamensis* – a. tuber with two stems; b. trifid stigma with trichomes; c. habitat and flower; d-f. *Triuris hyalina* – d. hyaline stem with receptacle, tepals and ripe achenes ready for dispersion; e. habit and female flowers; f. female flower with apocarpous gynoecium. g-i. *Voyria aphylla* – g. habitat and flower; h. persistent corolla; i. capsule and seeds. Scale bars: a, d, f, i. 2 mm; b, c. 1 mm; e. 20 mm; g. 3 mm; h. 10 mm. (Photos: a-i. Ríos CR, 2021).

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Data availability statement

In accordance with Open Science communication practices, the authors inform that all data are available within the manuscript.

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