

A NEW TROPICAL SPECIES OF *APHYLLON* (OROBANCHACEAE: OROBANCHEAE)
FROM CHIAPAS, MEXICO
UNA NUEVA ESPECIE TROPICAL DE *APHYLLON* (OROBANCHACEAE: OROBANCHEAE)
DE CHIAPAS, MÉXICO

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Abstract

Background: *Aphyllon* is a genus of 25 root-holoparasitic species restricted to the Americas. It has a disjunct distribution, with 21 species distributed in North America and four in South America. *Aphyllon* is divided into two sections: *Aphyllon* and *Nothaphyllon*. All species of the genus have host-specificity, make it a study model in the evolution of holoparasitic plants. Recently, observations of a putative new species of *Aphyllon* were detected on iNaturalist.

Questions: Are the alluded iNaturalist observations of *Aphyllon* supported as a new species? What characters distinguish this taxon from the other species of *Aphyllon*?

Studied species: Taxa of *Aphyllon* section *Nothaphyllon*.

Study site and dates: Mexico; 2020–2023.

Methods: Specimens were collected, dissected, measured, photographed and preserved. Herbarium specimens and literature on *Aphyllon* were reviewed. Comparisons of the taxon with species of section *Nothaphyllon*'s were performed.

Results: A new species of the holoparasitic *Aphyllon* (Orobanchaceae) is described and illustrated. It is the second species of tropical humid vegetation in Mexico, an atypical environment for most of the genus, and it is the only species of the section with racemes with narrowed to nearly closed corolla mouths, and straight, non-revolute lobes of the lower lip.

Conclusions: The records in the citizen science platform have been useful to illustrate the morphology and color of the organisms, as well as to propose new species of *Aphyllon*. The photographs provide information not found in herbarium specimens due to oxidation and discoloration that occurs when drying Orobanchaceae plants.

Keywords: endemism, Chiapas, iNaturalist, Mexico, parasitic plant, taxonomy.

Resumen

Antecedentes: *Aphyllon* es un género de 25 especies holoparasitas de raíces restringidas a América. Posee distribución disyunta, con 21 especies distribuidas en Norteamérica y cuatro en Sudamérica. *Aphyllon* se divide en dos secciones: *Aphyllon* y *Nothaphyllon*. Las especies del género tienen especificidad de hospederos, convirtiéndolas en un modelo de estudio de la evolución de plantas holoparasitas. Recientemente, fueron encontradas observaciones en iNaturalist de una posible nueva especie de *Aphyllon*.

Preguntas: ¿Las observaciones de *Aphyllon* mencionadas de iNaturalist se sustentan como una especie nueva? ¿Qué caracteres permiten distinguirla de otras especies de *Aphyllon*?

Especies estudiadas: Taxones de *Aphyllon* sección *Nothaphyllon*.

Sitios y años de estudio: México; 2020-2023.

Métodos: Especímenes del taxón fueron colectados, disectados, medidos, fotografiados y preservados. Se revisaron ejemplares de herbarios y literatura de *Aphyllon* para su determinación y se realizaron comparaciones con especies de la sección *Nothaphyllon*.

Resultados: Se describe e ilustra una nueva especie holoparasita de *Aphyllon* (Orobanchaceae) siendo la única especie de la sección con racimos con bocas de corola estrechadas a casi cerradas y lóbulos del labio inferior rectos y no revolutos. Es la segunda especie de vegetación tropical húmeda en México, un tipo de vegetación atípico para el género.

Conclusiones: Los registros en ciencia ciudadana han resultado útiles para ilustrar la morfología y color de los organismos, así como proponer nuevas especies de *Aphyllon*. Las fotografías proporcionan información que se pierde en los especímenes de herbario por la oxidación y decoloración que se producen al secar las plantas de Orobanchaceae.

Palabras clave: endemismo, Chiapas, iNaturalist, México, planta parásita, taxonomía.

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Orobanchaceae is the largest family of parasitic plants, containing several nutritional stages (Westwood *et al.* 2010, Heide-Jørgensen 2013). Holoparasitism is the condition of parasitism where all nutrients are obtained from a host through specialized structures called haustoria (Kuijt 1969, Heide-Jørgensen 2013). It has been suggested that it appeared at least three independent times along the evolution of Orobanchaceae (McNeal *et al.* 2013, Fu *et al.* 2017, Mortimer *et al.* 2022). According to Stevens (2023), the updated diversity of the family consists of 104 genera with 2,309 species. Of these, 20 genera with more than 270 species are holoparasitic (Heide-Jørgensen 2013, Nickrent 2020). Current phylogenetic classification of the family contains eight clades, one of them being Orobancheae, which consists of exclusively holoparasitic species with 15 genera and ca. 230 species (Schneeweiss 2013, Nickrent 2020, Stevens 2023). *Orobanche* L. is the most diverse genus of this clade, in spite of the transference of some species to the resurrected American genus *Aphyllon* Mitch. (Schneider 2016). Phylogenetic studies suggested that *Aphyllon* species had a rapid diversification in the Pleistocene (Schneider & Moore 2017). Also, the species of *Aphyllon* developed host specificity to one or very few host species along its distribution (Schneider *et al.* 2016).

The current circumscription of *Aphyllon* includes two sections based on morphology. Section *Aphyllon* is defined by the absence of bracteoles subtending the calyx and pedicels longer than the flower; in contrast, section *Nothaphyllon* A. Gray possesses two bracteoles subtending the calyx and pedicels equal to or shorter than the flower (Schneider 2016). A taxonomic treatment of Mexican *Aphyllon* species is still needed. Only some of its species (still treated as *Orobanche*) have been addressed in regional treatments (Calderón de Rzedowski 1998, Alvarado-Cárdenas 2008). The species of the *A. cooperi* complex in Central and Northern Mexico were studied by Collins & Yatskievych (2015). The latest studies on the genus were the description of *A. castilloi* Franc.Gut., Cházaro & Espejo (Francisco-Gutiérrez *et al.* 2019) and the redescription of *A. franciscanum* (Achéy) A.C.Schneid., segregated from *A. fasciculatum* (Nutt.) Torr. & A. Gray as result of morphometric analyses (Schneider & Benton 2021).

The taxonomic determination of holoparasitic species is complicated due to the nature of the species, whose structures discolor during drying. Herbarium specimens are very similar morphologically and internal characters, which contribute to distinguish among taxa, often cannot be dissected and observed. Platforms and applications of citizen science for uploading photographs of living specimens like iNaturalist, can be useful data sources for taxonomic determination. Based on observations recorded in Chiapas and uploaded to iNaturalist, individuals belonging to the genus *Aphyllon* were detected. The observations did not correspond in morphology or distribution to any of the *Aphyllon* species extant in Southeastern Mexico. The subsequent collection of specimens and their detailed analysis corroborated that it is a new species for science. With this additional new species, *Aphyllon* now comprises 26 species, 22 of them distributed in North America and the remaining four in South America.

Here a new holoparasitic species discovered on iNaturalist is presented. The aims of this study were: 1) to describe and illustrate a new *Aphyllon* species and 2) compare it with the known species of the genus in Mexico.

Materials and methods

Taxonomic determination. Photographed plants of *Aphyllon* by user Jonapa on iNaturalist were first visually compared with other species of *Aphyllon* determined on the platform. As a first complete revision of the specimens of *Aphyllon* stored in ENCB, IBUG, MEXU, and XAL herbaria (all herbaria acronyms follow Thiers 2023) from 2017 to 2020 did not provide records of species in Chiapas, a second revision of herbarium online databases were performed. Due to absence of specimens from Chiapas in the herbaria examined, a botanical exploration was carried out to locate the plant at the coordinates published on iNaturalist. The collected specimens of *Aphyllon* were dissected to describe, measure, and photograph morphological characters and color before the plants darkened. Roots of host species are under phylogenetic determination; results of analyses will be published in the forthcoming checklist of Orobanchaceae of Mexico. Species determination was made comparing structures with characters of the taxa reported for Mexico by Francisco-Gutiérrez *et al.* (2019) and the taxa recently redefined by Schneider & Benton (2021). In this study, we followed the infrageneric classification proposed by Schneider (2016).

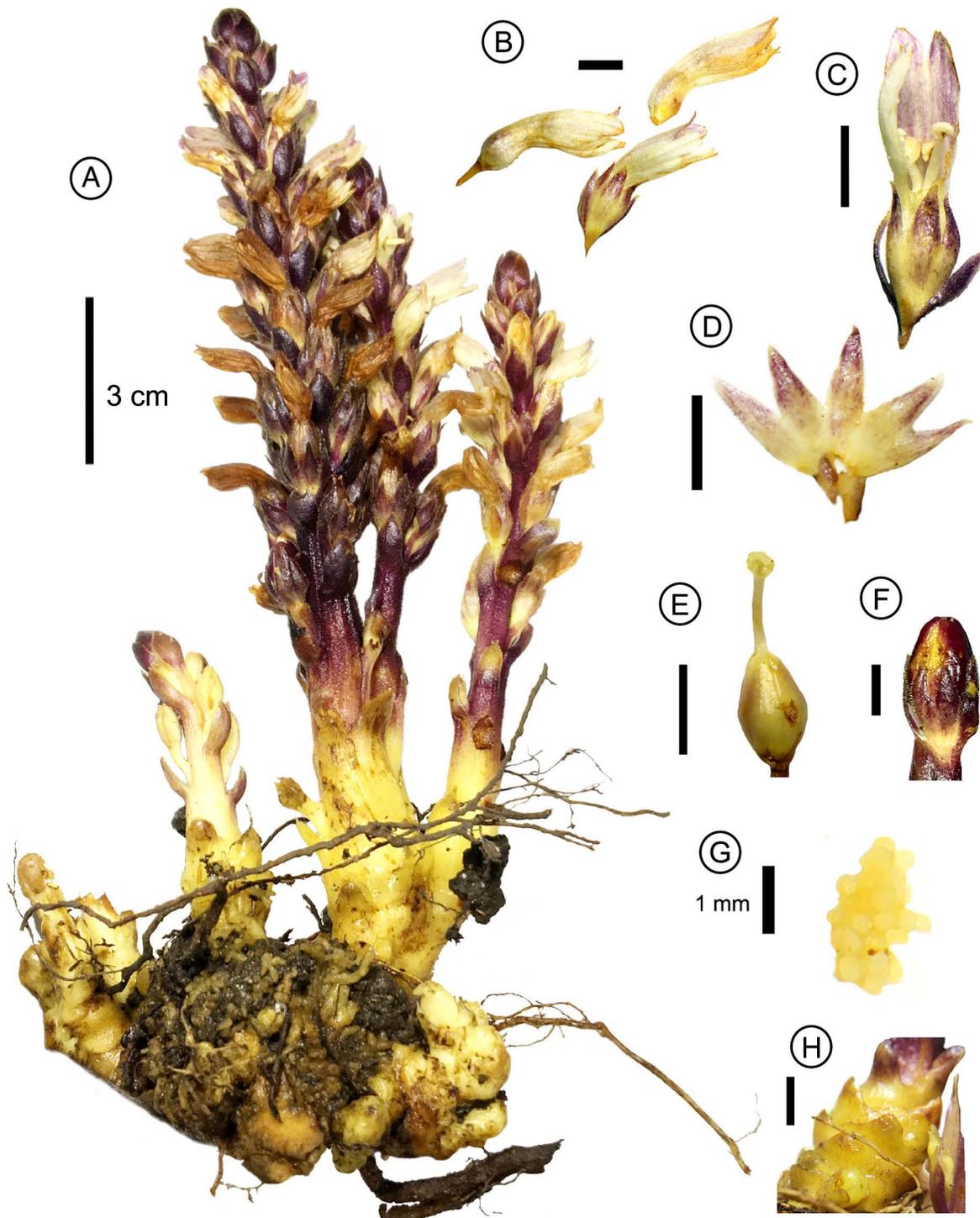


Figure 1. *Aphyllon chiapense* sp. nov. A) habit, B) corollas with divided lobes of lower lip, C) dissected flower, D) dissected calyx, E) ovary with discoid stigma, F) fruit, G) immature seeds, H) scales. Scale bars represent 5 mm, except for when indicated. All photographs taken by Antonio Francisco-Gutiérrez.

Species concept. We followed the concept of species cohesion (Templeton 1989) as an explanatory hypothesis for taxon recognition. The concept has a population genetics framework but does not disregard other cohesive factors to explain species recognition, such as expression of morphology (phenotypic variability constraints on individuals) and habitat distinctiveness (geographic distribution and ecological constraints). All these factors, together with the evolutionary processes, act for the differentiation of the tologenetic networks into two distinct lineages.

Distribution maps. Taxa from herbarium specimens, and observations of iNaturalist determined by specialists, were georeferenced. Photographs of iNaturalist with open license (CC-BY-NC) were used to illustrate the species. Maps were assembled in QGIS v. 2.18.15 (QGIS Development Team 2016) using the digital elevation model provided by Fick & Hijmans (2017).

Results

Aphyllon chiapense Franc.Gut. & L.O. Alvarado, sp. nov. (Figures 1, 2). *Type.* Mexico, Chiapas, Berriozábal: cerca de la orilla del río El Sabinal, al sur del Libramiento Sur, 16° 45' 15" N, 93° 17' 57" W, 934 m, 05 January 2023, A. Francisco-Gutiérrez, V. Pérez-Vázquez & M.E. Gutiérrez-Ramírez 285 (Holotype: MEXU; Isotypes: IBUG, XAL).

Diagnosis. *Aphyllon chiapense* belongs to *A.* sect. *Nothaphyllon* because of the presence of two bracteoles subtending the calyx, and pedicels shorter than the flowers; this species differs from the rest of the section by its mainly white corolla tube and narrowed to nearly closed corolla mouths, and straight and no revolute lobes of the lower lip.

Description. Achlorophyllous and holoparasitic plant. Thick subterranean tubercles, yellowish to greenish, 3-10 cm wide. Stems fleshy, 10-50 cm tall from above the ground, 4-15 mm wide, solitary or branched at base, glabrous at base to glandular-pubescent along the inflorescence, yellowish at base to dark purple along the inflorescence. Leaves reduced to scales, imbricate, triangular to broadly ovate, 4.7-12 × 3.7-10 mm, apex generally acute, margin entire, fleshy and coriaceous, waxy and glabrous on the surface. Inflorescence raceme occupying almost all the aerial part of the plant, flowers bracteate and pedicellate. Pedicels claviform, 3.6-13.9 × 1.7-3.1 mm, yellowish to purple, glandular-pubescent. Bracts sessile, elliptic to lanceolate, 7.8-10.6 × 2.2-4.4 mm, margin entire, apex obtuse. Bracteoles 2, linear to narrowly linear-lanceolate, 9-16.1 × 1.1-1.8 mm, margin entire, apex acute, externally glandular-pubescent, purple. Calyx campanulate, 7.2-12 × 4-6.5 mm, 5-lobed, lobes triangular, 3.2-5.3 × 1-3 mm, margin entire, apex acute, glandular-pubescent, yellowish with lobes purple. Corolla tubular, 18.4-21 × 2.7-5.7 mm, mainly white on the ventral surface, light purple on dorsal surface, constrained above the ovary and narrowed mouth, apparently closed, glandular-pubescent externally, palatal folds absent, glabrous, white. Upper lip 3.1-5.3 × 5.5 mm, 2-lobed, lobes 4-5.1 × 2.2-2.9 mm, ovate, margin entire, externally light purple, internally purple. Lower lip 3-lobed, lobes 3.2-5.1 × 1.3-2 mm, oblong to linear, straight and non-revolute, margin entire, apex bifid, each lobe 0.56-0.81 × 0.43-0.77 mm, white. Stamens filiform, 7.4-10.5 × 0.3-0.6 mm, glabrous, yellowish. Anthers 0.9-1.6 × 0.3-1.3 mm, glabrous or scarcely covered with simple hairs, base apiculate, included, yellowish, stalked glands on dorsal surface absent. Style 2.2-4.4 × 0.3-0.8 mm, glabrous, yellowish. Stigma laminar discoid ripply, 0.8-1.2 × 1.1-1.7 mm, yellowish. Ovary ovoid, 2.9-5.7 × 1.8-3.7 mm, glabrous, yellowish. Fruit a capsule ovoid to elliptical, 11-13.6 × 5.8-7.6 mm, glabrous, dark purple. Seeds (immature) numerous, irregularly ellipsoid, 0.32-0.35 mm in diameter, yellow, outer layer not distinguishable.

Distribution and ecology. *Aphyllon chiapense* is only known from two locations from the municipalities of Berriozábal (collected specimens for this study) and Ocozocoautla (citizen science observations) in Northwestern Chiapas, Mexico. The species was found inhabiting tropical rainforest. The plants were found at elevations between 870 and 934 m, ranges obtained during the field work and iNaturalist observations. Species growing together with the new taxon are *Cedrela odorata* L., *Tabebuia rosea* (Bertol.) DC., *Aspidosperma megalocarpon* Müll. Arg., *Bursera simaruba* (L.)

A new species of *Aphyllon* from Chiapas

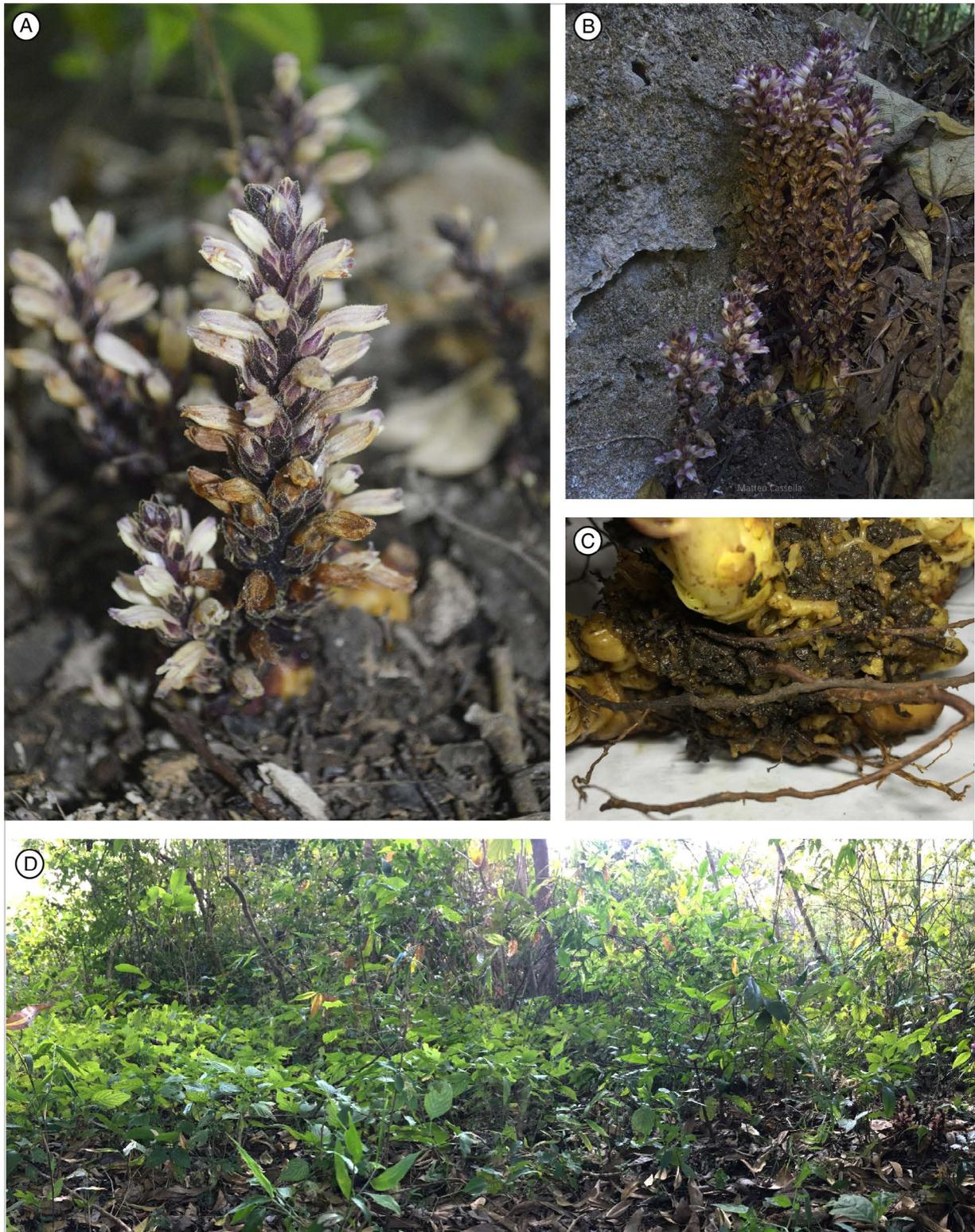


Figure 2. Field photographs of *Aphyllon chiapense*. A) mature plant, B) tallest known plants, C) host roots embedded in the tubercle of the parasite, D) panoramic view of the tropical rainforest where the new species grows (first from right). Credits: A, Victoria Pérez-Vázquez, B, Matteo Cassella (iNaturalist), C and D, Antonio Francisco-Gutiérrez.

Sarg., *Centrosema virginianum* (L.) Benth., *Ipomoea corymbosa* (L.) Roth ex Roem. & Schult., *Cirsium mexicanum* DC., *Senna nicaraguensis* (Benth.) H.S. Irwin & Barneby, *Dioscorea cyanisticta* Donn. Sm., and *Ampiphilium crucigerum* (L.) L.G. Lohmann. The tubercles were observed to be attached to two different kinds of roots which were followed, but their length exceeded one meter, making their tracking difficult. The first known citizen science observation of the species (available at <https://www.naturalista.mx/observations/10776255>) mentions to *Jatropha curcas* L. (Euphorbiaceae) as the possible host species, but it was not observed at the type locality. Molecular analyses are under development to identify the host species of multiple seedlings and trees attached to the *Aphyllon* haustoria.

Conservation status. *Aphyllon chiapense* is only known from two localities, one revealed from the iNaturalist platform (available at <https://www.naturalista.mx/observations/10776255>, <https://www.naturalista.mx/observations/145552685>, <https://www.naturalista.mx/observations/146226689>) and the other from the botanical exploration. The new species is potentially threatened by the habitat destruction due to the construction of housing in conserved areas of the municipality of Berriozábal, Chiapas. The other locality of the municipality of Ocozocoautla, reported in 2016 on iNaturalist, was visited without finding plants of the new species. The site is most similar to a tropical dry forest, considerably dryer than the locality of Berriozábal where specimens were collected. There is a lack of information related to more populations of the new taxon, so the data is considered insufficient (DD) to assess its conservation status (IUCN 2022).

Phenology. The known flowering season is from December to January. Fruits were collected in January.

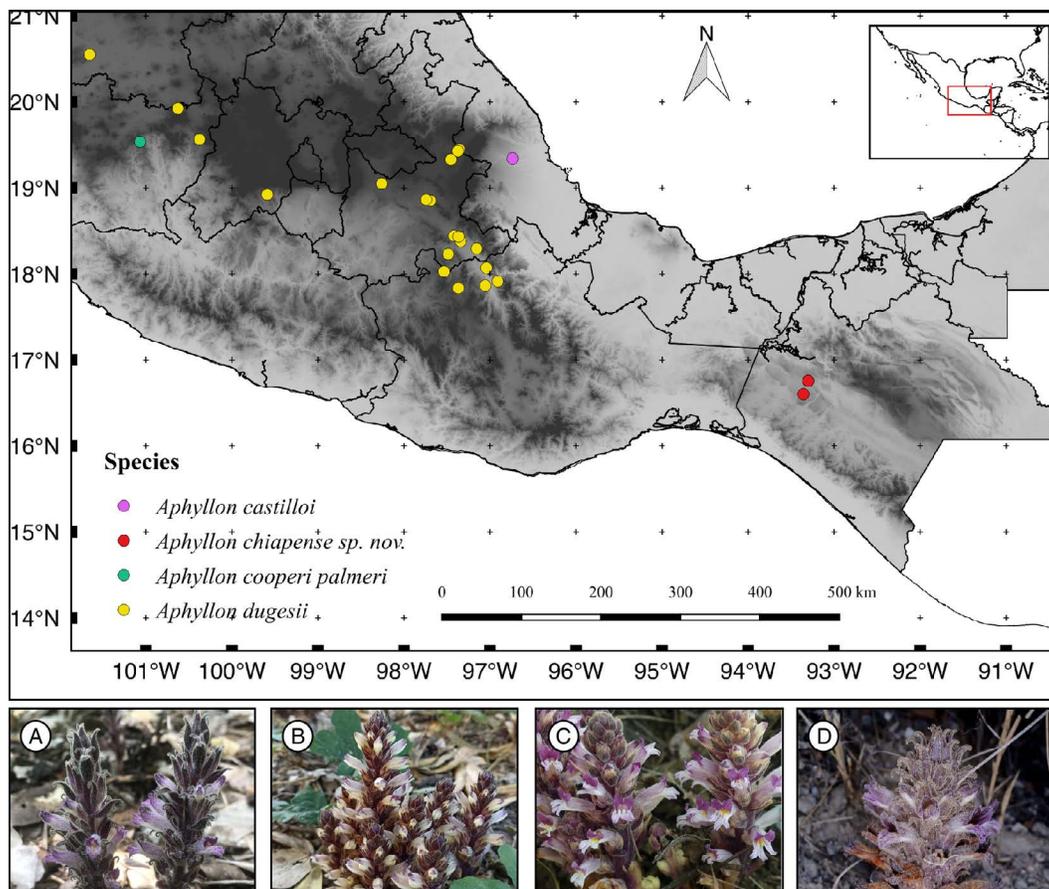


Figure 3. Distribution map of *Aphyllon* species in Southern Mexico: A) *A. castilloi*, B) *A. chiapense*, C) *A. cooperi* subsp. *palmeri*, D) *A. dugesii*. Credits of iNaturalist observers: Antonio Francisco-Gutiérrez (A), Rosa Isela Altúzar-González (B), Leon995 (C), Rocío Ramírez-Barrios (D).

Etymology. The epithet honors the state of Chiapas, Mexico, where the species was first observed, determined, and collected.

Taxonomic notes. The genus *Aphyllon* consists of holoparasitic plants whose morphology, distribution, and interaction with hosts require much work to understand. This contribution provides novelties in the first two aspects. Likewise, with this proposal of new species, *Aphyllon* now comprises 26 species, 22 of them distributed in North America and the remaining four in South America. Most of the *Aphyllon* taxa in Mexico belong to section *Nothaphyllon*: *A. tuberosum* (A. Gray) A. Gray, *A. californicum* subsp. *feudgei* (Munz) A.C. Schneid., *A. cooperi* A. Gray subsp. *cooperi*, *A. cooperi* subsp. *latilobum* (Munz) A.C. Schneid., *A. cooperi* subsp. *palmeri* (Munz) A.C. Schneid., *A. dugesii* S. Watson, *A. parishii* (Jeps.) A.C. Schneid. subsp. *parishii*, *A. parishii* subsp. *brachylobum* (Heckard) A.C. Schneid., and *A. castilloi*; whereas only one species belongs to section *Aphyllon*, *A. fasciculatum* (Nutt.) Torr. & A. Gray (Schneider 2016, Francisco-Gutiérrez *et al.* 2019).

Due to the morphological similarity of the herbarium specimens of the species found in Southern Mexico, we provide a photographic comparison and distribution map to differentiate the taxa inhabiting this area: *A. castilloi*, *A. cooperi* var. *palmeri*, *A. dugesii*, and the new species *A. chiapense* (Figure 3). All these species share similarity in having brown to purple and glandular trichomes on bracts and sepals. Also, the corollas have purple colors mainly on the lobes (Figure 3). The most similar species to *A. chiapense* based on morphology and type of vegetation is *A. castilloi*, another endemic species restricted to tropical rain forests. Diagnostic characters among these two species are presented in Table 1. The most evident feature of this new species with respect to the other species in the genus, is the corolla mouth nearly closed, with the lobes of the lower lip straight and non-revolute, and the absence of palatal

Table 1. Morphological comparison between *Aphyllon chiapense* sp. nov. and *A. castilloi*.

Characters	<i>Aphyllon chiapense</i>	<i>Aphyllon castilloi</i>
Tubercle width (cm)	3-10	1.5-4
Tubercle color	Yellowish to greenish	Whitish
Stem length (cm)	10-50	3.5-13
Stem indument	Glabrous at base to glandular-pubescent towards apex	Pubescent to densely pubescent towards apex
Corolla color	Mainly white on the ventral surface, light purple on dorsal surface, lobes light purple externally, purple internally	Purple or light purple, white at base and lobes purple.
Lower lobes shape and curvature	Oblong to linear, straight	Oblong to ovate, revolute
Palatal folds	Absent	Present
Stigma shape	Laminar discoid	Bilobed
Capsule length (cm)	1.1-1.36	0.7-1
Altitude (m)	870-934	530-600
Flowering	December-January	October-December
Habitat	Tropical rainforest	Semideciduous tropical rainforest
Geographic distribution	Chiapas, Mexico	Veracruz, Mexico
Source	This study	Francisco-Gutiérrez <i>et al.</i> 2019

folks, features distinguishable in photographs of living plants available on the citizen science platform iNaturalist and a previous illustrated article (Collins & Yatskievych 2015). These shared attributes among the individuals of the species described here and their differences with those of the taxa compared, fulfill the morphological cohesion (restrictions of phenotypic variability in individuals), proposed in our explanatory hypothesis.

The discovery of this new species is also relevant due to the fact that the genus *Aphyllon* was not reported in the state of Chiapas by Francisco-Gutiérrez *et al.* (2019). The most recent Mexican checklist of native species (Villaseñor 2016) reported the presence of *Aphyllon* in 23 states, but not in Chiapas. The online database of MEXU herbarium (<https://datosabiertos.unam.mx/biodiversidad/>) also does not record specimens from Chiapas. Additionally, this is the second known tropical species of *Aphyllon*. The first one, *Aphyllon castilloi*, was described from tropical semideciduous forest in central Veracruz, eastern Mexico, a rare type of vegetation for the genus, normally distributed in desertic areas (Francisco-Gutiérrez *et al.* 2019). However, *Aphyllon chiapense* inhabits zones with high trees (> 30 m) and high levels of humidity. Additionally, the potential host of *A. chiapense* must be a completely different species, since the vegetation composition is distinct from that of the other species of the genus in Mexico (Francisco-Gutiérrez *et al.* 2019). Molecular phylogenetics (Schneider *et al.* 2016) and morphological observations (Francisco-Gutiérrez *et al.* 2019, Schneider & Benton 2021) suggested host-specificity of the species of *Aphyllon*, a pattern observed in other holoparasites (Ortega-González *et al.* 2020). These contrasting environments in which *A. chiapense* and *A. castilloi* grow reflect the differences in habitat and environmental requirements of each of them (habitat distinctiveness) suggested in the cohesive species concept.

Discussion

iNaturalist platform information is increasingly being considered in biological studies, as it complements data present in biological collections and contributes to documenting biodiversity loss and conservation (Spear *et al.* 2017, Soteropoulos *et al.* 2021). Likewise, it has been relevant in the rediscovery of taxa and the discovery of new species (Egger & Velázquez-Sánchez 2018, Svoboda & Harris 2018, Alvarado-Cárdenas *et al.* 2020). In the case of the species of *Aphyllon*, observations of citizen science can be a useful tool to determine specimens collected or photographed, or as in this case, to identify undescribed taxa, and to have precise data to perform scientific collections and collaborations.

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