



## *Carapa cedrotagua* (Cedreloideae, Meliaceae, Sapindales), a new species from surroundings of the Serranía de los Yariguíes in Eastern Andes of Colombia

YEISON LONDOÑO-ECHEVERRI<sup>1,2,3,5</sup>, ANA MARÍA TRUJILLO-LÓPEZ<sup>1,2,3,6</sup> & JAIDER JIMÉNEZ-MONTOYA<sup>1,4,7</sup>

<sup>1</sup>Herbario Universidad de Antioquia (HUA), Instituto de Biología, Facultad de Ciencias Exactas y Naturales, Universidad de Antioquia, A.A. 1226, Medellín, Colombia

<sup>2</sup>Grupo de Estudios Botánicos (GEOBOTA), Instituto de Biología, Facultad de Ciencias Exactas y Naturales, Universidad de Antioquia, A.A. 1226, Medellín, Colombia

<sup>3</sup>Herbario Gabriel Gutiérrez Villegas (MEDEL) y Semillero en estudios taxonómicos de plantas de Colombia, Facultad de Ciencias, Universidad Nacional de Colombia, A.A. 3840, Medellín, Colombia

<sup>4</sup>Fundación Jardín Botánico de Medellín, Herbario “Joaquín Antonio Uribe” (JAUM), Calle 73 No. 51D-14, Medellín, Colombia

<sup>5</sup>✉ [yondono@unal.edu.co](mailto:yondono@unal.edu.co); <https://orcid.org/0000-0001-5169-598X>

<sup>6</sup>✉ [amtrujillo@unal.edu.co](mailto:amtrujillo@unal.edu.co); <https://orcid.org/0000-0002-0898-1646>

<sup>7</sup>✉ [jaiderjimenez01@gmail.com](mailto:jaiderjimenez01@gmail.com); <https://orcid.org/0000-0003-3813-009X>

### Abstract

*Carapa cedrotagua*, a new species from the surroundings of Serranía de los Yariguíes, in the Eastern Andes of Colombia, is described and illustrated. Notes about its geographical distribution, phenology, uses, conservation status and taxonomic affinities are provided. The new species is similar to *C. alticola*, *C. guianensis*, and *C. pariensis*, but differs from these species mainly by its morphological combination of shorter petiolules 3.4–6(–7) mm long, leaflets secondary veins flat in the abaxial surface, stipitate and beaked fruits with valves bearing warty excrescences, and the spheroid or slightly compressed seeds with hilum 8.2–12.1 × 4.5–6.1 mm. *Carapa cedrotagua* is a common and economically important species in the area where it occurs, and it is commonly confused with *C. guianensis*.

**Key words:** andiroba, Biodiversity, endangered species, Swietenioideae, timber species

### Introduction

*Carapa* Aublet (1775: 32) is a monophyletic group (Kenfack 2008) of Meliaceae subfam. Cedreloideae, which has priority over Swietenioideae, see Thorne & Reveal (2007) (Styles 1981, Muellner *et al.* 2003, 2006, 2009, Kenfack 2008). The genus currently comprises 29 species distributed in the tropics of Africa and America (Kenfack 2011a, Palacios 2012, Fischer *et al.* 2021), and it can be recognized by its generally arboreal habit, leaflets with entire margin, calyx aestivation quincuncial or decussate, 8 or 10 stamens connate in a tube with anthers attached at the throat, annular and cushion-shaped nectary, ovary locules generally with (2–) 4, 6 or 8 ovules, and septifragal capsules with unwinged seeds (Styles 1981, Kenfack 2011a, 2011b, Mabberley 2011).

Several species of *Carapa* have both economic and cultural importance, due mainly to their timber and the oils present in the seeds (Kenfack 2011a), which has led to high exploitation of some of them, resulting in several species being currently considered under some category of extinction risk by the IUCN (2022).

Several studies conducted over the last decades improved the knowledge on the taxonomy, morphology, and systematics of *Carapa* (Gentry 1988, Forget *et al.* 2009, Kenfack 2008, 2011a, 2011b, 2011c, Kenfack & Pérez 2011, Fischer *et al.* 2021). Kenfack (2011a) provided the most recent taxonomic treatment for the genus, recognizing 27 species and making a remarkable change from the concept proposed in the monograph by Styles (1981), who recognized only two morphologically variable species.

In Colombia, four species are recognized by Kenfack (2011a) in the synopsis of the genus: *Carapa guianensis* Aublet (1775: 32), *C. nicaraguensis* A.C.P. de Candolle (1878: 717), *C. planadensis* Kenfack (2011a: 180) and *C. vasquezii* Kenfack (2011c: 7). In the “Catálogo de plantas y líquenes de Colombia”, six species of *Carapa* were recognized

(Bernal 2016a), but the reference collections of *C. alticola* Kenfack & Pérez (2011: 125) and *C. megistocarpa* Gentry & Dodson in Gentry (1988: 1434) are the type and paratype specimens of *C. planadensis*; and *C. longipetala* Kenfack in Kenfack & Pérez (2011: 125) is expected to occur in the country, but with no records yet confirmed. *Carapa procera* A.P. de Candolle (1824: 626) was considered with transatlantic distribution by Styles (1981), while Kenfack (2011a) indicated it as distributed only in Africa and that most of its previous records in America belong to *C. surinamensis* Miquel (1851: 75), which is not recorded in Colombia.

Recent botanical explorations focused on biological conservation actions in the Serranía de Los Yariguíes (Yariguíes Mountain Range), a nearly isolated mountain range from the Eastern Andes of Colombia, allowed the study of a species of *Carapa* that is well known by the communities in the region for both its economic and cultural importance. This species has morphological features that differ from other species of the genus in the neotropics and it is here formally described as a new species. The new species is illustrated, and comments on its geographic distribution, taxonomic affinities, phenology, and conservation status are also provided.

## Materials and methods

The taxonomy is based in Styles (1981), Kenfack (2011a, 2011b), and Mabberley (2011). Protologues, nomenclatural types and representative specimens of published names for the genus were revised from digital images through the Global Plants project (<http://plants.jstor.org>), Tropicos database (<http://tropicos.org>), virtual herbaria housing type specimens, and original publications. *Carapa* specimens housed at herbaria FMB, HUA, JAUM, and MEDEL were physically analyzed, together with the consultation of digital images at COL, NY, UDBC, UIS, and US (acronyms according to Thiers 2016).

Fieldwork was carried out in the municipality of Simacota, in Santander department, where the species was collected. Eight specimens of the new species were analyzed using a stereomicroscope for the morphological description. The flowers were described and illustrated from material preserved in 70% ethanol, rehydrated material, and photographs of fresh structures. The fruits were described and illustrated from dried material and photographs of fresh structures. Morphological terminology was mainly based in Kenfack (2011a), and the terminology for laminar structures and venation followed Ellis *et al.* (2009); for bases and apices, the angle was written first and followed by the shape (*e.g.*, acute and cuneate).

The composite digital plates were made using GIMP 2.10.32. The distribution map was made using Arcgis 10.5. The climate types follow Köppen-Geiger climate classification (Kottek *et al.* 2006). The conservation status was evaluated according to the criterion B of IUCN (2012) and assessed by the R package “ConR” (Dauby 2019). Erroneous data detected for the localities on the specimen labels were corrected and written in square brackets.

## Taxonomy

*Carapa cedrotagua* Londoño-Ech., A.M. Trujillo & Jiménez-Mont., *sp. nov.* (Figs. 1, 2, 3)

**Type:**—COLOMBIA. Santander [=Santander]. Mun. Simacota: vereda El Salto, predio Cachipay, entre las quebradas Rancho Larga, Tacuyala y Santa Rosa, inmediaciones del PNN Serranía de los Yariguíes, 1944 m, 6°28'30.68"N, 73°24'7.52"W, 24 March 2022 (fl & im fr), Y. Londoño *et al.* 1212 (Holotype: HUA!; isotype: FMB!).

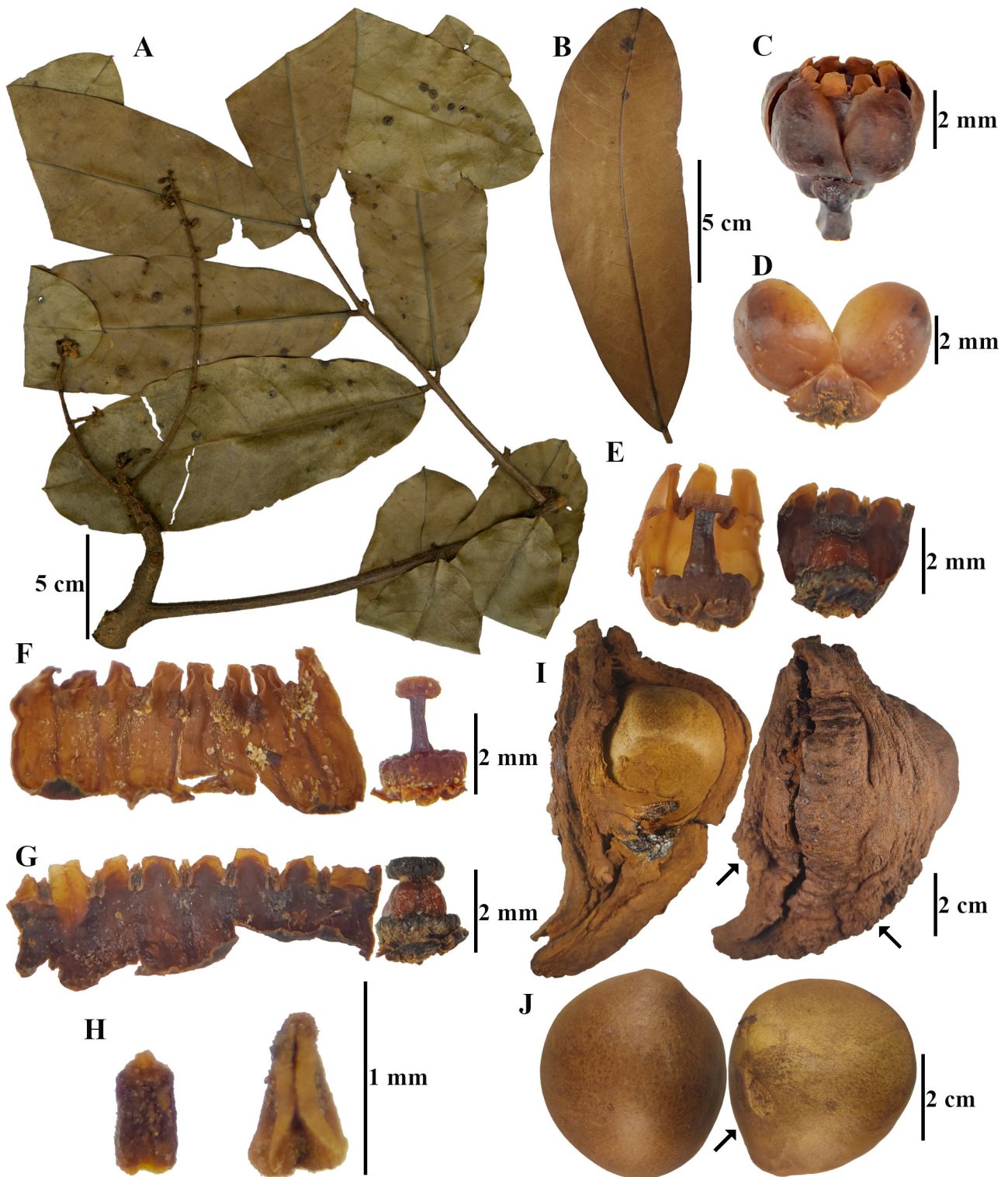
**Diagnosis:**—*Carapa cedrotagua* differs from *C. alticola* and *C. guianensis* by the following combination of morphological features: the often shorter petiolules 3.4–6(–7) mm long (vs. 8–17 mm long in *C. alticola*, 5–12 mm long in *C. guianensis*), the fruits with valve median ribs bearing warty excrescences (vs. median ribs lacking warty excrescences in both species), and the spheroid or slightly compressed seeds (vs. seeds angular with rounded edges in *C. alticola*, or strongly angular with sharpened edges in *C. guianensis*). Additionally, *C. cedrotagua* can be distinguished from *C. alticola* by its leaflet secondary veins flat (vs. raised) in the abaxial surface and its fruits 4.5–7.8 cm diam. when dry (vs. 10–15 cm diam.); from *C. guianensis* it also differs by pedicels 1.6–2.5(–3.5) mm long [vs. 0.2–1(–1.5) mm long], stipitate and beaked fruits (vs. fruits without stipe or beak), and its elliptic to ovate seed hilum, 8.2–12.1 × 4.5–6.1 mm (vs. linear, 15–33 × 0.3–1.7 mm).





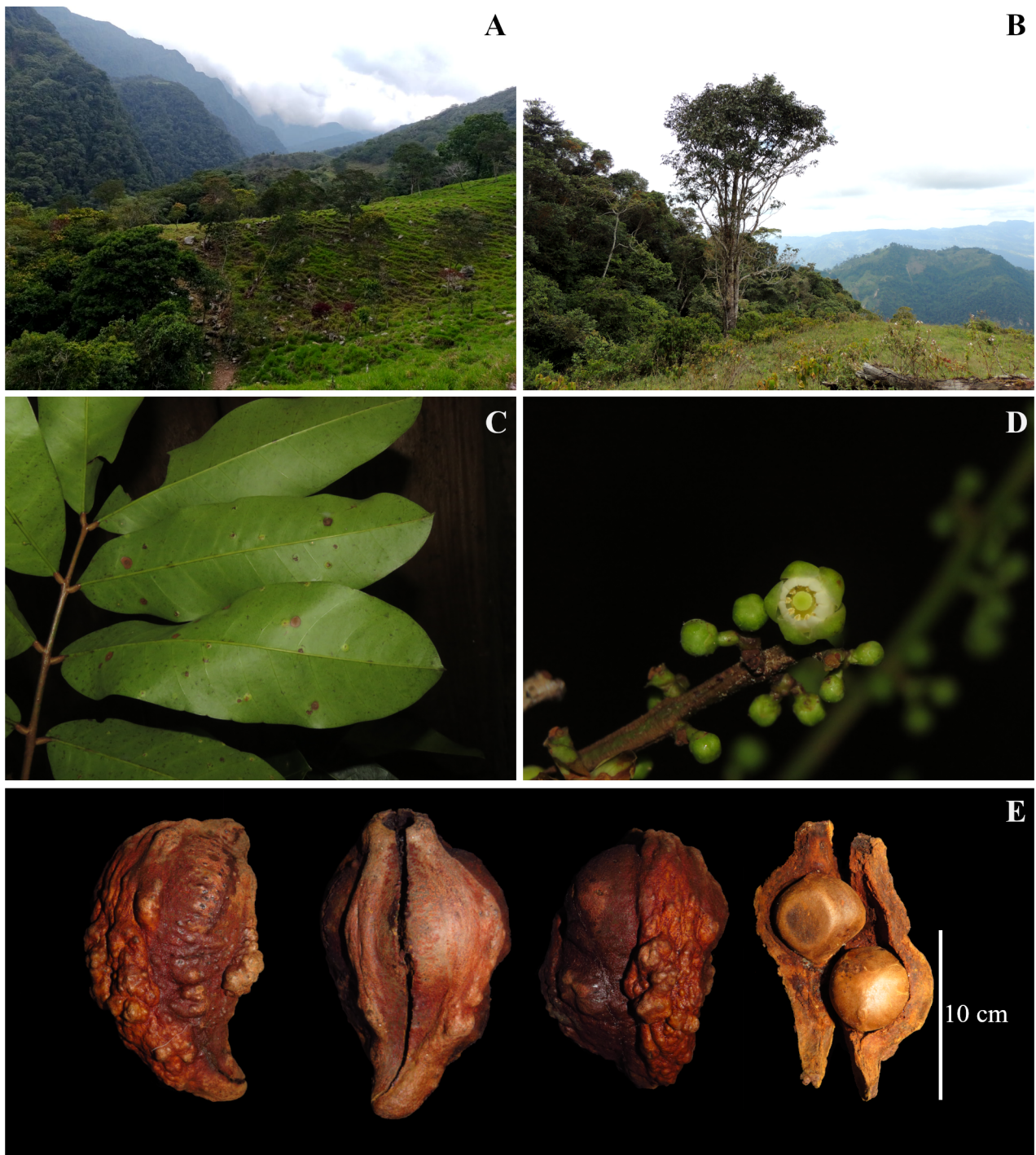
FIGURE 1. Holotype of *Carapa cedrotagua*.





**FIGURE 2.** Illustration of *Carapa cedrotagua*. **A.** Flowering branchlet. **B.** Terminal leaflet, abaxial surface. **C.** Flower 4-merous and staminate, lateral view. **D.** Calyx and corolla, one sepal and two petals removed, abaxial view. **E.** Comparison of androecium and gynoecium in staminate flower at left or pistillate flower at right. **F.** Androecium and gynoecium in staminate flower. **G.** Androecium and gynoecium in pistillate flower. **H.** Comparison of antherodes from pistillate flowers at left or anther from staminate flower at right. **I.** Fruit in dried specimen, longitudinal view inside showing seed at left, outer surface at right, arrows indicating warty excrescences. **J.** Seed, dorsal view at left, adaxial-lateral view showing hilum at right, arrow indicating the direction to see hilum. (A, from the isotype; B, from *Díaz-Rueda et al.* 2626; C, E—right, G, H—left, from *Díaz-Rueda et al.* 2476; D, E—left, F, H—right, from the holotype; I, J, from *Toledo 1*. Digital plate by Y. Londoño).





**FIGURE 3.** Live photographs of *Carapa cedrotagua*. **A.** Habitat. **B.** Habit and habitat. **C.** Leaflets abaxially. **D.** Flower 5-merous, upper view. **E.** Fruits and seeds, showing variation in both, the size and density of warty excrescences of fruit, and shape of seeds. (A, from type locality; B, unvouchered, from locality of Díaz-Rueda *et al.* 2609; C, D, from the holotype; E, from Toledo 1. Photographs A, C, D, by Y. Londoño; B, by Daniel Díaz-Rueda; E, by A.M. Trujillo. Composed photograph by Y. Londoño)

*Trees* 15–27 m tall, glabrous in buds and branchlets, very young leaves with sparse lepidote indumentum, early glabrescent. *Leaves* alternate, paripinnate, (8–) 10–12-foliolate (young plants with leaves sometimes imparipinnate, 3–5-foliolate), leaflets pairs opposite; petiole 9.3–19.5 cm long, swollen at base, slightly flattened adaxially, ridged longitudinally, with two nectaries located abaxially at base, each *ca.* 1 mm diam., orbicular; rachis 10–28.5 cm long, slightly flattened adaxially, ridged longitudinally, with one nectary located abaxially at the insertion of petiolules, *ca.* 2 × 0.5 mm, elliptic; petiolule 3.4–6 mm long (up to 7 mm long in vegetative branches), flat to canaliculate adaxially, corrugate, striate transversely; blades 6.6–33.1 × 3.3–9 cm, elliptic, oblong or narrowly oblanceolate, terminal ones

slightly falcate, with midvein curved towards leaf base; basally acute to obtuse, cuneate to rounded, insertion slightly oblique, apically obtuse, rounded (shortly acuminate in vegetative branches), mucronate *via* involute margin 1–5 mm long; glabrous in both surfaces, with numerous nectaries abaxially, irregularly arranged, each *ca.* 0.5 mm diam., orbicular, the margin entire; midvein raised abaxially, flat to slightly raised adaxially; secondary veins 8–16 in each side, eucamptodromous, flat abaxially (slightly raised in vegetative branches), flat to slightly raised adaxially, spacing irregular, intersecondary veins present, tertiary veins percurrent. *Inflorescences* thyrses, grouped in a terminal short-shoot, each of them in the axils of reduced scale-like leaves, axes glabrous; main axis (4.7–)9.1–20.3(–30.5) cm long (including peduncle 0.5–6.1 cm long), striate transversely, epidermis peeling off, bearing primary bracts 2–3 × 2–2.5 mm, broadly ovate; secondary axes 0.3–2.8 cm long, bearing secondary bracts 0.8–0.9 × 0.9–1.5 mm, broadly ovate; pedicel 1.6–2.5(–3.5) mm long, glabrous, bearing two bracteoles, each 0.9–1.2 × 0.8–1.2 mm, ovate; bracts and bracteoles, apically acute and straight, minutely puberulous abaxially, glabrous to minutely glandular-puberulous adaxially, persistent, the margin entire and ciliate-papillate. *Flowers* 4(–5)-merous, calyx aestivation decussate (quincuncial in 5-merous flowers); sepals 1.2–1.3 × 1.3–1.4 mm, ovate to orbicular, apically acute to obtuse, straight to rounded, minutely puberulous abaxially, glabrous to minutely glandular-puberulous adaxially, the margin entire and ciliate-papillate; corolla aestivation contorted, petals (4.3–)5–5.3(–6) × (3–)3.6–4 mm, orbicular, cucullate, apically obtuse and rounded, mainly glabrous, minutely glandular-puberulous in both surfaces apically, green-whitish (*in vivo*), with 1–4 nectaries abaxially, each *ca.* 0.1 mm diam., orbicular, inconspicuous and visible as lustrous dark dots, the margin entire and ciliate-papillate; androecium 8(–10)-merous, staminal tube 3–4.4 mm long, glabrous, white (*in vivo*), lobes 1–1.5 × 1–1.5 mm, ovate, apex truncate, involute at the lateral margins; disc 0.8–1 mm high, 2–2.8 mm diam., cushion-shaped, yellow (*in vivo*); *staminate flowers* with anthers 0.8 × 0.7–0.8 mm, orbicular to ovate, papillate dorsally, appendaged by connective extension apically; pistillode with ovary 1.2–1.6 mm high, 1.1–1.2 mm diam., narrowly ovoid, glabrous, style 1.2–1.5 mm high, 0.4–0.7 mm diam., glabrous, stigma 0.5 mm high, 1.1–1.4 mm diam., discoid, minutely papillate; *pistillate flowers* with antherodes *ca.* 0.5 × 0.4 mm, orbicular to oblong, papillate dorsally, appendaged by connective extension apically; ovary 1.7–2 mm high, 1.6–2 mm diam., broadly ovoid, glabrous, 4-locular, each 4-ovulate; style obsolete; stigma *ca.* 0.5 mm high, 1.2–1.7 mm diam., discoid, minutely papillate. *Fruits* septifragal capsules, up to 18 cm high and 12.5 cm diam. *in vivo*; 6.8–13.1 cm high and 4.5–7.8 cm diam. when dry, irregularly ellipsoid to spheroid, narrowing into a stipe at base, apically beaked, glabrous, brown at maturity, 4-valved, with numerous nectaries around the septae, each 0.5–1.2 mm diam., orbicular; valves with a median longitudinal rib bearing warty excrescences, variable in size and density, up to 1 cm high. *Seeds* 1–2 per valve, 3.9–5.3 cm diam., mainly spheroid or with 1–2 slight compressions by contact with other seeds, glabrous, testa smooth, hilum 8.2–12.1 × 4.5–6.1 mm, elliptic to ovate.

**Distribution and habitat:**—*Carapa cedrotagua* occurs in the Eastern Cordillera of the Colombian Andes in the department of Santander, principally around the Serranía de los Yariguíes mountain complex (see Moreno & Tinjacá 2018) (Fig. 4), in the municipalities of El Carmen de Chucurí, San Vicente de Chucurí, and Simacota, and with a single collection from El Socorro municipality in an adjacent place at the east of the Serranía. This species occurs in the Andean biogeographic region (*sensu* Bernal 2016b), under warm temperate climate (Cfb climate type), at elevations between 1160–1944 m.

The trees recorded in the Serranía de los Yariguíes grow in fragmented forests or as remnant trees in pastures for livestock—*i.e.*, as spontaneous vegetation—and sometimes likely as cultivated trees (D. Díaz-Rueda pers. comm.). The specimen from El Socorro comes from a tree grows in coffee plantation (J.G. Vélez *et al.* 6099).

**Phenology:**—Flowering in March to April and July, fruiting in February to March, May and July.

**Etymology:**—The epithet “*cedrotagua*” is the vernacular name used for the species by the communities in the area, probably because its wood resembles *Cedrela* Brown (1756: 158), whose species are commonly named as “cedro”, and its seeds resemble those of the ivory palm *Phytelephas* Ruiz & Pavón (1798: 299), commonly named as “tagua”. The use of this epithet is intended to generate connection between the scientific name and the community that use the vernacular name for this species, which is well known due to both economic and cultural importance for them.

**Uses:**—*Carapa cedrotagua* is specially used as a shady tree in coffee plantations and as a timber tree because of the good quality of its wood, which is widely used in the roof structure of houses, for making furniture, as stakes or wood posts and as wooden boards in the roof of “casas elbas” (an infrastructure for the drying of coffee grains; D. Díaz-Rueda pers. comm.).

**Preliminary conservation status:**—*Carapa cedrotagua* is known by four subpopulations with AOO=28 km<sup>2</sup> and EOO=790 km<sup>2</sup>, three of them in small forest patches (<50 km<sup>2</sup>) immersed in an agricultural-livestock matrix. From another perspective, three subpopulations are inside protected areas and one outside, which give place to two locations. Despite most of the subpopulations are found in protected areas, the “Endangered” EN category is here proposed



according to the criteria B: B1ab(iii)+2ab(iii), due to its small geographic distribution, the fact that all subpopulations are found less than 10 km from population centers, most of them under low quality of habitat, and the direct threat by commercial logging.

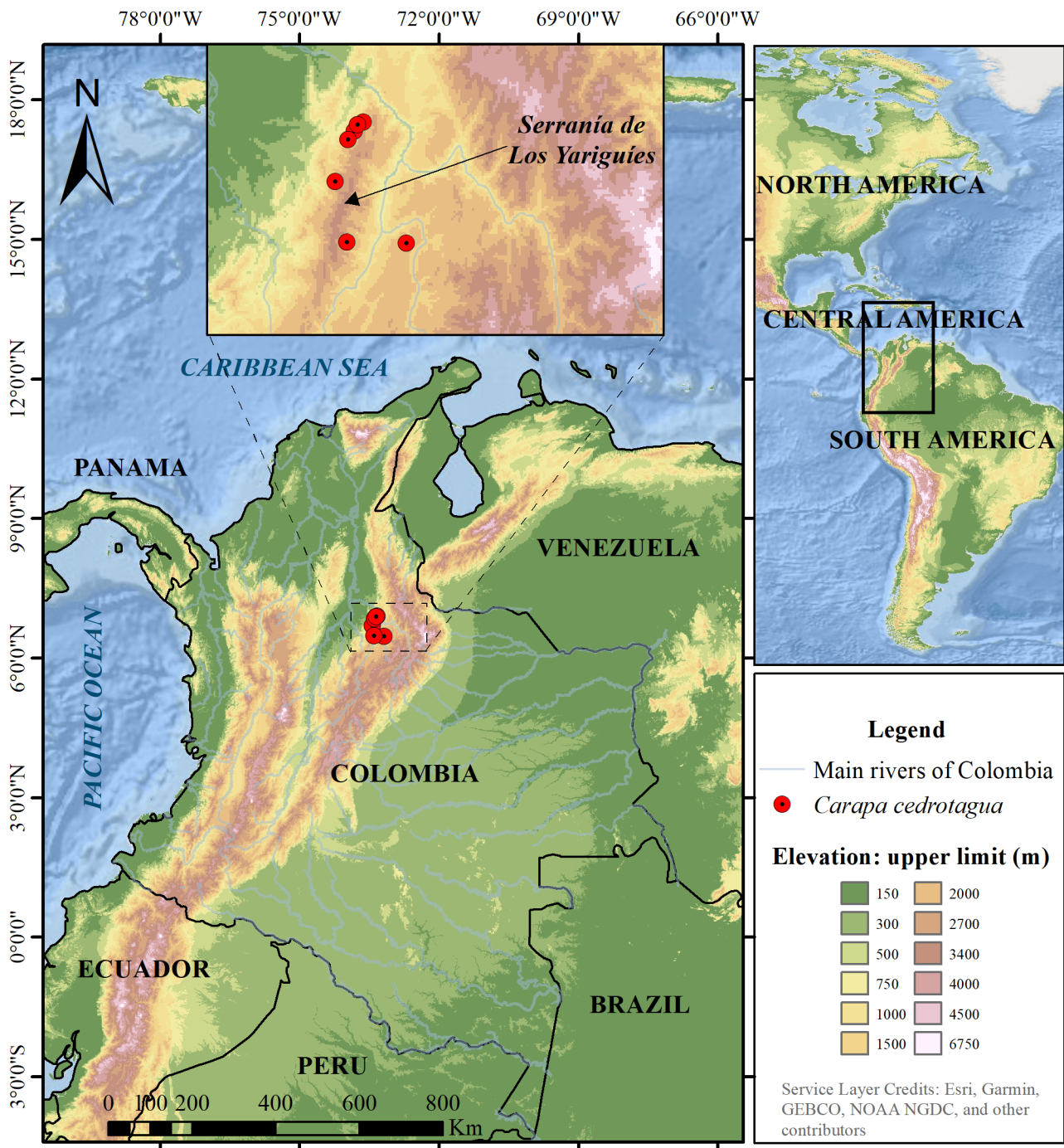


FIGURE 4. Geographical distribution of *Carapa cedrotagua*.

**Additional specimens examined:**—COLOMBIA. Santander. Mun. El Carmen de Chucurí: vereda La Bodega, finca Gustavo Gonzales, 1487 m, 6°41'27.6"N, 73°26'36.53"W, 24 February 2018 (fr), *F. Castaño et al.* 2060 [FMB!, UIS (digital image!)]. Mun. El Socorro: vereda El Bosque, finca La Meseta, 1700 m, 6°28'18.1"N, 73°11'13.7"W, 2 March 2004 (fr), *J.G. Vélez et al.* 6099 (FMB!, HUA!). Mun. San Vicente de Chucurí: vereda Chanchón Alto, finca Hato Nuevo, bosques abajo de la trocha del acueducto, zona norte de la serranía de Los Yariguíes, 1620 m, 6°54'9.7"N, 73°20'30.53"W, 2 April 2022 (bd & fl), *D. Díaz-Rueda et al.* 2476 (HUA!, UIS [n.v.]); vereda Mérida, finca San Cristóbal, filo de Morelia, zona norte de la serranía de Los Yariguíes, 1510 m, 6°52'19.52"N, 73°22'26.87"W, 20 July 2022 (fr), *D. Díaz-Rueda et al.* 2586 (HUA!, UIS [n.v.]); vereda Mérida (sector Varsovia), finca Varsovia, cultivos de lulo cercanos a la casa principal, zona norte de la serranía de Los Yariguíes, 1160 m, 6°50'31.16"N, 73°23'50.16"W, 27

July 2022 (fr), *D. Díaz-Rueda et al.* 2609 (HUA!, UIS [n.v.]); vereda Chanchón Bajo, escuela La Floresta, zona norte de la serranía de Los Yariguíes, 1210 m, 6°53'36.05"N, 73°21'46.86"W, 29 July 2022 (bd, fl & fr), *D. Díaz-Rueda et al.* 2626 (HUA!, UIS [n.v.]). Mun. Simacota: vereda El Salto, predio Cachipay, entre las quebradas Rancho Larga, Tacuyala y Santa Rosa, inmediaciones del PNN Serranía de los Yariguíes, 1944 m, 6°28'30.68"N, 73°24'7.52"W, 14 May 2022 (fr), *N.P. Toledo I* (HUA!).

**Notes:**—*Carapa cedrotagua* is very similar to *C. alticola* in their arboreal habit, absence of farinose indumentum (e.g., present in *C. nicaraguensis* and *C. vasquezii*), leaflets apically rounded, inflorescences poorly ramified, with basal secondaries axes less than 3 cm long, pedicels mainly up to 2.5 mm long (rarely up to 3.5 mm long in *C. cedrotagua*) and stipitate and beaked fruits, but the two species differ, as indicated in the diagnosis. Two additional vegetative features of *C. cedrotagua* can help to distinguish it from *C. alticola*: the insertion of the petiolules in blades is slightly oblique (vs. equally attached in both sides in *C. alticola*) and the terminal leaflets are commonly slightly falcate, with the midvein curved towards leaf base (vs. not falcate, midvein straight).

*Carapa cedrotagua* has been confused and cultivated under the identity of *C. guianensis* (e.g., Moreno & Tinjacá 2018, Céspedes-Prada *et al.* 2020), from which the new species is recognizable by the morphological features indicated in the diagnosis. Kenfack (2011a) also recorded *C. guianensis* from Colombia, however, noting that the elevation range for this species is between 0–500 m. Species of *Carapa* in Colombia mainly inhabit moist habitats at low elevations, and only *C. cedrotagua* and *C. planadensis* reach medium-high elevations up to 1950 m at the eastern or western Andes, respectively.

Additionally, *Carapa cedrotagua* is similar to *C. pariensis* Kenfack (2011a: 194) in their beaked fruits with valve median ribs bearing warty excrescences, spheroid seeds, and the pedicels length, 1.6–2.5(–3.5) mm long in *C. cedrotagua* (2–3.5 mm long in *C. pariensis*). However, *C. cedrotagua* can be recognized from the latter by the larger habit 15–27 m tall [vs. 4–12(–15) m tall], the shorter petiolules 3.4–6(–7) mm long (vs. 10–17 mm long), the leaflet blades often smaller 6.6–33.1 × 3.3–9 cm [vs. 15–30(–40) × 6–14 cm], apically rounded (vs. straight to acuminate), the leaflet secondary veins flat abaxially (vs. raised) and the larger seed hilum 8.2–12.1 × 4.5–6.1 mm [vs. 2–4.5(–8.6) × 1–2(–4) mm]. Kenfack (2011a) indicate a height up to 12 m tall for *C. pariensis* in the key and description, however, in the same publication the diagnosis indicates 15 m tall, which agrees with the cited specimen, *J.A. Steyermark & G. Agostini 91357* (US).

The specimen *J.G. Vélez et al.* 6099 is the only record of the new species outside the Serranía de los Yariguíes and its label indicate that the tree occurs in a coffee plantation, being very likely that this was gathered from a cultivated individual, according to the reported uses for *C. cedrotagua*. Despite the Serranía is the unique known natural area of distribution of the new species, it is possible that it may also occur in neighbor areas.

## Acknowledgments

We thank the staff of all herbaria consulted for allowing access to their collections; David Kenfack for his review of the manuscript and helpful suggestions for improving it; Daniel Díaz-Rueda for keeping in mind this new species and looking for it in herbaria and in the field, for sharing the collections and photographs with us and for providing information about vernacular names and uses; Jhon A. Sánchez for sending specimens from FMB. The authors especially thank the Herbario Universidad de Antioquia (HUA) and its staff for the support provided over the years. The fieldwork was carried out in the floristic characterization for the G51 agreement among Ecohábitats Foundation, WWF Colombia and PNN of Colombia.

## References

- Aublet, J.B.C.F. (1775) Plantes de la Guiane Française, dont on n'a pu se procurer des es complets. In: Aublet, J.B.C.F. (Ed.) *Histoire des Plantes de la Guiane Française 2*. Pierre-Francois Didot jeune, London & Paris, supplement pp. 1–160.
- Bernal, R. (2016a) *Carapa*. In: Bernal, R., Gradstein, S.R. & Celis, M. (Eds.) *Catálogo de plantas y líquenes de Colombia*. Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Bogotá, pp. 1664–1665.
- Bernal, R. (2016b) Geografía de Colombia. In: Bernal, R., Gradstein, S.R. & Celis, M. (Eds.) *Catálogo de plantas y líquenes de Colombia*. Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Bogotá, pp. 19–32.
- Brown, P. (1756) *The Civil and Natural History of Jamaica*, in Three Parts. Printed for the author, London, 503 pp.



- Candolle, A.C.P. (1878) Meliacées. In: Candolle, A.L.P.P. de & Candolle, A.C.P. de (Eds.) *Monographiae phanerogamarum prodromi nunc continuation nunc revisio, Vol. 1*. G. Masson, Paris, pp. 399–758.
- Candolle, A.P. de (1824) *Prodromus Systematis Naturalis Regni Vegetabilis, Vol 1*. Treuttel & Würtz, Paris, 745 pp.
- Céspedes-Prada, C., Solano-Gutiérrez, C., Duarte-Sánchez, I. & Cogollo-Calderón, A.M. (2020) *Restauración ecológica de la zona Norte del Parque Nacional Natural Serranía de los Yariguíes*. Unión Temporal Jaguar Corredor Norandino y Parques Nacionales Naturales de Colombia. Bogotá, 130 pp.
- Dauby, G. (2019) *ConR: Computation of Parameters Used in Preliminary Assessment Conservation Status*. R package version 1.2.4. Available from: <https://CRAN.R-project.org/package=ConR> (accessed 10 July 2020)
- Ellis, B., Daly, D.C., Hickey, L.J., Johnson, K.R., Mitchell, J.D., Wilf, P. & Wing, S.L. (2009) *Manual of Leaf Architecture. 1st ed.* Cornell University Press, Ithaca, New York, 190 pp.  
<https://doi.org/10.1079/9781845935849.0000>
- Fischer, E., Killmann, D., Leh, B. & Janssens, S.B. (2021) *Carapa wohllebenii* (Meliaceae), a new tree species from montane forests in the Democratic Republic of Congo, Rwanda, and Burundi. *Phytotaxa* 511 (1): 20–36.  
<https://doi.org/10.11646/phytotaxa.511.1.2>
- Forget, P.-M., Poncy, O., Thomas, R.S., Hammond, D.S. & Kenfack, D. (2009) A new species of *Carapa* (Meliaceae) from Central Guyana. *Brittonia* 61: 366–374.  
<https://doi.org/10.1007/s12228-009-9090-z>
- Gentry, A.H. (1988) New species and a new combination for plants from trans-andean South America. *Annals of the Missouri Botanical Garden* 75: 1429–1439.  
<https://doi.org/10.2307/2399294>
- IUCN. (2012) *IUCN Red List Categories and Criteria: Version 3.1*. Second edition. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, England, 32 pp.
- IUCN. (2022) The IUCN Red List of Threatened Species. Version 2022-1. [<https://www.iucnredlist.org>]
- Kenfack, D. (2008) Systematics and evolution of *Carapa* (Meliaceae—Swietenioideae). Ph.D. Thesis, University of Missouri, St. Louis. 237 pp.
- Kenfack, D. (2011a) A synoptic revision of *Carapa* (Meliaceae). *Harvard Papers in Botany* 16: 171–231.  
<https://doi.org/10.3100/0.25.016.0201>
- Kenfack, D. (2011b) Resurrection in *Carapa* (Meliaceae): a reassessment of morphological variation and species boundaries using multivariate methods in a phylogenetic context. *Botanical Journal of the Linnean Society* 165: 186–221.  
<https://doi.org/10.1111/j.1095-8339.2010.01104.x>
- Kenfack, D. (2011c) *Carapa vasquezii* (Meliaceae), a new species from western Amazonia. *Brittonia* 63: 7–10.  
<https://doi.org/10.1007/s12228-010-9163-z>
- Kenfack, D. & Pérez, Á.J. (2011) Two new species of *Carapa* (Meliaceae) from Western Ecuador. *Systematic Botany* 36: 124–128.  
<https://doi.org/10.1600/036364411X553207>
- Kottek, M., Grieser, J., Beck, C., Rudolf, B. & Rubel, F. (2006) World map of the Köppen Geiger climate classification updated. *Meteorologische Zeitschrift* 15: 259–263.  
<https://doi.org/10.1127/0941-2948/2006/0130>
- Mabberley, D.J. (2011) Meliaceae. In: Kubitzki, K. (Ed.) *The Families and Genera of Vascular Plants X. Flowering Plants: Eudicots, Sapindales, Cucurbitales, Myrtaceae*. Springer, Berlin, pp. 185–211.  
[https://doi.org/10.1007/978-3-642-14397-7\\_13](https://doi.org/10.1007/978-3-642-14397-7_13)
- Miquel, F.A.W. (1851) *Stirpes Surinamensis Selectae. Natuurkundige Verhandelingen van de Hollandsche Maatschappij der Wetenschappen te Haarlem* 7 (2): 1–234, supplement [1]–165.
- Moreno, H. & Tinjacá, Z. (2018) *Plan de Manejo del Parque Nacional Natural Serranía de los Yariguíes 2018-2023*. Territorial Andes Nororientales, Parques Nacionales Naturales de Colombia, Simacota, 152 pp.
- Muellner, A.N., Pennington, T.D. & Chase M.W. (2009) Molecular phylogenetics of Neotropical Cedreleae (mahogany family, Meliaceae) based on nuclear and plastid DNA sequences reveal multiple origins of “*Cedrela odorata*”. *Molecular Phylogenetics and Evolution* 52: 461–469.  
<https://doi.org/10.1016/j.ympev.2009.03.025>
- Muellner, A.N., Samuel, R., Johnson, S.A., Cheek, M., Pennington, T.D. & Chase M.W. (2003) Molecular phylogenetics of Meliaceae (Sapindales) based on nuclear and plastid DNA sequences. *American Journal of Botany* 90: 471–480.  
<https://doi.org/10.3732/ajb.90.3.471>
- Muellner A.N., Savolainen, V., Samuel, R. & Chase M.W. (2006) The mahogany family “out-of-Africa”: divergence time estimation, global biogeographic patterns inferred from plastid rbcL DNA sequences, extant, and fossil distribution of diversity. *Molecular Phylogenetics and Evolution* 40: 236–250.

<https://doi.org/10.1016/j.ympcv.2006.03.001>

Palacios, W. (2012) Cuatro especies nuevas de árboles del Ecuador. *Caldasia* 34: 75–85.

Ruiz, H. & Pavón, J. (1798) *Systema vegetabilium Florae Peruvianaee et Chilensis, characteres prodromi genericos differentiales, specierum omnium differentias, durationem, loca natalia, tempus florendi, nomina vernacula, vires et usus nonnullis illustrationibus interspersis complectens*. Typis Gabrielis de Sancha, Madrid, 456 pp.

<https://doi.org/10.5962/bhl.title.887>

Styles, B. (1981) Swietenioideae. In: Pennington, T.D., Styles, B.T. & Taylor, D.A.H. (Eds.) *Flora Neotropica Monograph No 28: Meliaceae*. The New York Botanical Garden, New York, pp. 359–418.

Thiers, B. (2016 onward) Index herbariorum: a global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium. The New York Botanical Garden, Bronx, New York. Available from: <http://sweetgum.nybg.org/science/ih/> (accessed 2 March 2022)

Thorne, R.F. & Reveal, J.L. (2007) An updated classification of the class Magnoliopsida (“Angiospermae”). *The Botanical Review* 73: 67–181.

[https://doi.org/10.1663/0006-8101\(2007\)73\[67:AUCOTC\]2.0.CO;2](https://doi.org/10.1663/0006-8101(2007)73[67:AUCOTC]2.0.CO;2)