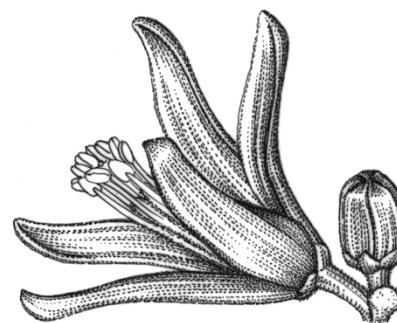


Marcelo Fernando Devecchi

Phylogeny and Systematics of  
*Simaba* Aubl.  
(Simaroubaceae)



São Paulo, 2017

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Orientador: José Rubens Pirani  
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*A todos que de uma forma outra estiveram presentes ao longo destes anos*



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## PHYLOGENY AND SYSTEMATICS OF *SIMABA* AUBL. (SIMAROUBACEAE)

### ABSTRACT

*Simaba*, as traditionally and currently circumscribed, is the largest genus in the Simaroubaceae and is mostly restricted to tropical South America with a few species extending northward into Central America. The genus encompasses a large morphological heterogeneity, expressed in the vegetative and reproductive morphology, and many of its species are narrow endemics, most of them poorly known. Our phylogenetic analyses based on DNA sequence data from two nuclear ribosomal spacer regions (ITS and ETS) and three plastid regions (*rps16* intron, and intergenic spacers *psbA-trnH* and *trnL-trnF*), including a comprehensive sampling of species of *Simaba* and closely related genera, show that *Simaba* as traditionally circumscribed is not monophyletic, with taxa segregated into two strongly supported but distinct clades. Also, we performed ancestral character reconstructions to identify morphological characters that could serve as synapomorphies for major clades. Based on the results of the phylogenetic analyses performed, a division of *Simaba* s.l. into two distinct genera is here proposed. The clade composed by species of *Simaba* sect. *Tenuiflorae* Engl., which includes the type species of *Simaba*, is here proposed to be recognized as *Simaba* sensu stricto, while the species of *Simaba* formerly included in *S.* sect. *Grandiflorae* Engl. and *S.* sect. *Floribundae* Engl. form a distinct lineage that will be recognized as members of another genus, *Homalolepis* Turcz., a taxon currently treated in synonymy of *Simaba*. As here circumscribed, *Simaba* s.s. comprises approximately 10 species distributed mostly in the Amazonian region, and *Homalolepis* comprises 28 species with mostly extra-Amazonian distribution, mainly in the cerrado and Atlantic forest domains. In addition to molecular data support, several morphological characters corroborate the recognition of the two clades as distinct lineages. We provide a synopsis of *Simaba* s.s., including an emended description of the genus, the description of four new species, complete nomenclature for each accepted species, including new lectotypifications. We also present a taxonomic treatment of *Homalolepis*, with a key for two sections and species, data on nomenclatural types, including new lectotypifications and one epitype, complete synonymy, full morphological descriptions, including two new species, etymology of species names, common names and uses, illustrations and photos of live specimens, as well as comments on phenology, taxonomy and nomenclature. Distribution maps are provided for each species, along with biogeographical and ecological comments.



## FILOGENIA E SISTEMÁTICA DE *SIMABA* AUBL. (SIMAROUBACEAE)

### RESUMO

*Simaba*, como tradicionalmente circunscrito, é o maior gênero de Simaroubaceae e é principalmente restrito à América do Sul tropical, com algumas espécies que se estendem para o norte na América Central. O gênero engloba uma grande heterogeneidade morfológica, expressa tanto na morfologia vegetativa quanto reprodutiva, e muitas de suas espécies são endêmicas, estreitamente distribuídas, muitas delas ainda pouco conhecidas. Nossas análises filogenéticas baseadas em dados de sequências de DNA de duas regiões espaçadoras ribossômicas nucleares (ITS e ETS) e três regiões plastidiais (*rps16* intron e espaçadores intergênicos *psbA-trnH* e *trnL-trnF*), incluindo uma amostragem abrangente de espécies de *Simaba* e gêneros proximamente relacionados, mostra que *Simaba* como tradicionalmente circunscrito não é monofilético, com os táxons segregados em dois clados fortemente sustentados e distintos. Também realizamos reconstruções de caracteres ancestrais para identificar caracteres morfológicos que poderiam servir como sinapomorfias para os principais clados. Com base nos resultados das análises filogenéticas realizadas, uma divisão de *Simaba* s.l. em dois gêneros distintos é aqui proposta. Propomos aqui que o clado composto pelas espécies de *Simaba* sect. *Tenuiflorae* Engl., que inclui a espécie-tipo de *Simaba*, seja reconhecido como *Simaba* sensu stricto, enquanto as espécies de *Simaba* anteriormente incluídas em *S.* sect. *Grandiflorae* Engl. e *S.* sect. *Floribundae* Engl. formam uma linhagem distinta que será reconhecida como um outro gênero, *Homalolepis* Turcz., um táxon atualmente tratado em sinonímia de *Simaba*. Como aqui circunscrito, *Simaba* s.s. compreende aproximadamente 10 espécies distribuídas majoritariamente na região Amazônica, e *Homalolepis* compreende 28 espécies com distribuição predominantemente extra-Amazônica, principalmente nos domínios do Cerrado e da Floresta Atlântica. Além da sustentação dada pelos dados moleculares, vários caracteres morfológicos corroboraram o reconhecimento desse dois clados como linhagens distintas. Apresentamos aqui uma sinopse de *Simaba* s.s., incluindo uma descrição emendada do gênero, a descrição de quatro novas espécies, nomenclatura completa de cada espécie aceita, incluindo novas lectotipificações. Apresentamos também uma revisão taxonômica de *Homalolepis*, com chave para duas seções e espécies, dados sobre tipos nomenclaturais, incluindo novas lectotipificações e designação de um epítipo, sinonímia completa, descrições morfológicas, incluindo descrição de duas espécies novas, etimologia de nomes de espécies, nomes comuns e usos, ilustrações e fotos de espécimes vivos, bem como comentários sobre fenologia, taxonomia e nomenclatura. São fornecidos mapas de distribuição de cada espécie, juntamente com comentários biogeográficos e ecológicos.



## GENERAL INTRODUCTION

Simaroubaceae are a small angiosperm family composed by approximately 109 species arranged in 22 genera (Clayton et al. 2007, 2009, 2011). The family is primarily pantropical, including tropical, subtropical and temperate elements, and probably originated in North America, dating from the early Tertiary (Clayton et al. 2009). The center of diversity (in number of species) is found in the Neotropical region with over 75 species grouped in eight genera. Simaroubaceae is monophyletic based on morphological and molecular analyses (Fernando et al. 1995, Gadek et al. 1996, Clayton et al. 2007, Muellner et al. 2007), and is most closely related to Meliaceae and Rutaceae within the Sapindales order (Gadek et al. 1996, Muellner-Riehl et al. 2016). Furthermore, the exclusive presence of the quassinooids is a chemical synapomorphy of the family.

*Simaba*, as traditionally and currently circumscribed, is the largest genus in the family, comprising approximately 23–25 species (Cavalcante 1983, Clayton 2011). The species are restricted mostly to tropical South America, but a few species extend northward into Central America, and many of its species are narrow endemics, most poorly known (Devecchi & Pirani 2015, Devecchi et al. 2016). The species shows a large morphological heterogeneity, expressed in characters of habit, leaves, flowers, and fruits, some are small to large trees up to 40 m tall, while others are highly branched shrubs or subshrubs with a thickened underground system. The leaves are pinnate with (sub)opposite leaflets, except for two species that bear unifoliolate leaves. The leaflets of most species are provided with a conspicuous apical gland, which seems to be a nectary. The flowers are bisexual or occasionally unisexual, grouped in terminal or subterminal thyrsoids or thyrses, obdiplostemonous with stamens bearing a basal, adaxial, laminar appendage. The fruits of *Simaba* are schizocarpic, comprising one to five drupaceous fruitlets, each with a single seed.

The genus was erected by Aublet (1775) with a single species, *S. guianensis*, from French Guiana. For approximately 70 years, only a few new species were described and the first taxonomic revision prepared for *Simaba* is that of Planchon (1846), in which he recognized eleven species, including a newly described one. Engler (1874), in his treatment of the family for *Flora Brasiliensis*, described six new species of *Simaba* and proposed an infrageneric classification for the genus, grouping the species in three sections based mainly on flower size and geographic distribution: *Simaba* sect. *Tenuiflorae* Engl., bearing the smallest flowers and restricted to the Amazonian region; *S. sect. Grandiflorae* Engl., comprising species with the largest flowers of the genus and found mostly outside Amazonian region; and *S. sect. Floribundae* Engl., with flowers of intermediate size and also largely extra-Amazonian. Boas (1913) used anatomical and floral morphology to suggest that species from the two extra-Amazonian sections should be united into a single section. Cronquist (1944a) accepted

Engler's (1874, 1931) circumscription of *Simaba* and also adopted his sectional classification. By contrast, other authors have proposed alternative generic delimitations. Pierre (1896) proposed uniting *Simaba*, *Hannoia*, *Quassia* and *Odyendea* into a single genus. Nooteboom (1962a) agreed with Pierre, but concluded that the morphological differences among the genera of tribe Simaroubeae (*Simaba*, *Hannoia*, *Quassia*, *Simarouba*, *Odyendea*, *Pierreodendron*, *Samadera*) were insufficient to recognize any of them as distinct genera, and proposed merging them into a single, even more broadly circumscribed genus. In these latter treatments, both authors recognized their segregate genera, including *Simaba*, as sections in *Quassia* L. sensu lato. This broad circumscription of *Quassia*, however, was never embraced by most botanists, and in the Neotropics *Simaba*, *Simarouba*, and *Quassia* were maintained as distinct genera in regional floras and monographs (e.g. Porter 1973; Thomas 1985, 1990; Pirani 1987, 2015; Arrázola 1993; Thomas & Franceschinelli 2005; Devecchi & Pirani 2015, 2016; Devecchi et al. 2016), including the latest revision of *Simaba* (Cavalcante 1983). With the advent of molecular data, the broad circumscription of *Quassia* suggested by Nooteboom (1962a) was also refuted by the phylogenetic study of Simaroubaceae by Clayton et al. (2007, 2009), in which the sectional components of *Quassia* s.l. emerged as well supported and geographically distinct clades, most not closely related to one another. That analysis, based on four molecular markers, also found support for two of the three sections of *Simaba* proposed by Engler (1874). Further studies are necessary to achieve a better understanding of the phylogenetic relationships and sound generic limits within the family.

### Goals

The main goals of the present project is to study the systematics and evolution of *Simaba*, aiming to evaluate limits of the genus and of the infrageneric taxa already proposed, under a molecular phylogenetic approach, also seeking out for morphological characters that could serve as synapomorphies for major clades. Also, we aim to provide a taxonomic treatment of the species involved, based on extensive field work and herbarium survey.

### Structure of the thesis

The thesis is composed by this present general introduction, followed by five chapters, which are briefly described below, and some final general conclusions and two papers already published as attachments. All new names and new combinations of taxa here mentioned were or will be published in scientific journals, and consequently the present thesis should not be considered as the effective publication of any names.

Chapter One aims to evaluate the limits and evolution of the group through a phylogeny based on molecular data, focusing on *Simaba* and related genera, and also performing ancestral character reconstructions to identify morphological characters that could serve as synapomorphies for major clades. The manuscript have been submitted to *Molecular phylogenetics and evolution*, and is co-authored by William Wayt Thomas, Gregory M. Plunkett and José Rubens Pirani.

In Chapter Two a synopsis of *Simaba* s.s. is provided, with a new circumscription according to the findings of the phylogenetic analysis presented in chapter one. It will be submitted to publication co-authored by William Wayt Thomas and José Rubens Pirani only after completing a more detailed analysis of a complex species and of some others lacking suitable material.

Chapter Three comprises a detailed morphological survey that aims solve the problematic *Simaba ferruginea* species complex. The three clearly distinct groups that were recovered lead to a narrower definition of one species along with the reinstatement of another one which was traditionally treated under synonymy, and also allowed the description of a new species endemic of Guajira region in Colombia and Venezuela. The manuscript resulted have been submitted to *Systematic Botany* and is co-authored by William Wayt Thomas and José Rubens Pirani.

Chapter Four contains the description of two new dwarf species with restricted distribution in the Brazilian savanna (cerrado), both endangered according IUCN categories and criteria (2012). The manuscript resulted have been submitted to *Phytotaxa* and is co-authored by William Wayt Thomas and José Rubens Pirani.

Chapter Five provides a taxonomic revision of *Homalolepis* Turcz., a genus reestablished as a segregate from *Simaba* Aubl. as a consequence of the phylogenetic evidence presented in Chapter One. The treatment includes complete nomenclature for each accepted species, including new lectotypifications, identification key, morphological descriptions, illustrations of diagnostic characters, photos of live specimens and notes on taxonomy, geographic distribution and habitat of each species. This revision will be submitted to *Taxon*.

Additionally, two previously published papers dealing with two new species of *Simaba* that were described during the development of the current work are presented as attachments.

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**ATTACHMENTS:**  
**ONE.**



# A new species of *Simaba* sect. *Grandiflorae* (Simaroubaceae) from Jalapão region, Tocantins, Brazil

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## ABSTRACT

*Simaba tocantina*, a new species of Simaroubaceae, is described and illustrated. It belongs to *Simaba* sect. *Grandiflorae* since its flowers reach 21–25 mm long and its staminal appendages are covered by intertwined trichomes forming a pseudotube around the gynoecium. Its differences from the related species in the section are pointed out herein, including a key to the five species of the group. As other *cerrado* members in the genus, the new species is a shrub with a thickened underground system, from which a few aerial branches develop, as well as a long, erect, showy inflorescence. It is known only by a few records from the *cerrado* of the Jalapão State Park in Tocantins, Brazilian Central Plateau, and its conservation status is assessed.

## RESUMO

*Simaba tocantina*, uma nova espécie de Simaroubaceae, é descrita e ilustrada. Ela pertence a *Simaba* sect. *Grandiflorae*, uma vez que suas flores têm 21–25 mm de comprimento e seus apêndices estaminais são cobertos de tricomas entrelaçados formando um pseudotubo em torno do gineceu. Suas diferenças das espécies mais relacionadas na seção são discutidas, incluindo uma chave de identificação das cinco espécies deste grupo. Como ocorre em outros membros do gênero que habitam o cerrado, a nova espécie é um arbusto com um sistema subterrâneo espesso, a partir do qual poucos ramos aéreos se desenvolvem, bem como uma inflorescência longa, ereta e vistosa. A espécie é conhecida apenas de poucos registros da região de cerrados do Parque Estadual do Jalapão, no estado do Tocantins, no Planalto Central Brasileiro, e seu status de conservação é aqui acessado.

KEY WORDS – *cerrado*; endemism; Jalapão State Park; Sapindales; Taxonomy;

## INTRODUCTION

*Simaba* Aublet (1775: 400) is the largest genus in the Simaroubaceae, a mostly tropical family of Sapindales with 22 genera and ca. 109 species (Clayton 2011). *Simaba* is mostly restricted to tropical South America, with only one species, *S. cedron* Planchon (1846: 566), reaching Central America. While *S. monophylla* (Oliver) Cronquist (1944: 88) and *S. moretti* Feuillet (1983: 745) are endemic to the Guianas region, and *S. praecox* Hassler (1907: 723) is endemic to Paraguay, all remaining species are recorded to Brazil, which is the diversity center of the group. The genus encompasses an interesting array of morphological variation, related to its wide ecological and geographical distribution. Its species may be treelets to tall trees in the Amazon forests or in moist to seasonal areas along the Atlantic forest (from São Paulo State to Rio Grande do Norte states). On the other hand, several species are shrubs or subshrubs, commonly with a thick underground system, found on open formations like the *Cerrado* (Neotropical savanna) in Central Brazil and neighbor countries, or in the sandy, *restinga* vegetation on sedimentary plains along the coast of Brazil (e.g. Cavalcante 1983). The leaves in *Simaba* species are pinnate, seldom unifoliolate; the leaflets are opposite to subopposite, discolor, and often provided with an apical gland, which can be very conspicuous or not to the naked eye. The flowers are produced along terminal to subterminal inflorescences (thyrses), which may reach up to one meter long in some species. The flowers are bisexual, 5– (–6)–merous, with sepals connate, free petal and 10 stamens bearing a conspicuous, usually densely pilose, appendix along the proximal part of the filaments. The gynoecium lies on top of a short gynophore, and is formed by five uniovulate carpels, which are free from each other at the base and united along the styles. The fruit is schizocarpic and usually only one of its carpels develops as a drupaceous fruitlet, with a hardened endocarp and a fleshy mesocarp, bearing only one seed (Engler 1874; Cavalcante 1983; Clayton 2011).

Some species of *Simaba* are known from just a few records, and usually from restricted areas, as *S. floribunda* Saint-Hilaire (1823: 277), *S. salubris* Engler (1874: 219), *S. praecox* and *S. monophylla*. Some may have even become extinct, as is the case of *S. suaveolens* Saint-Hilaire (1823: 278), known only from the type specimen, collected in an area that has been entirely devastated by mining activities in southern Minas Gerais state (Itabira).

The main studies on morphology and taxonomy of *Simaba* are the monograph by Engler (1874) in *Flora Brasiliensis*, the anatomical study by Boas (1913), the revision by Cronquist (1944), the revision of South American species by Cavalcante (1983), and scattered contributions on new species and synonyms (e.g. Thomas 1984, 1985; Franceschinelli & Yamamoto 1999; Franceschinelli & Thomas 2000). From the 50 binomials already proposed in *Simaba*, just a half are currently accepted as correct. In Brazil, Pirani and Thomas (2015) recognized 23 species. There are several pending taxonomic

problems to be solved in *Simaba*, related to specific and intraspecific circumscription. During the revision of the genus, currently underway, the authors find material of a new species from Central highlands of Brazil, at the Jalapão State Park, in Tocantins state, which is here described and compared to its related taxa.

## MATERIAL & METHODS

Morphological features of the new species (and species here used for comparison) were described using only mature parts of herbarium specimens from CEN, HTO, NY, RB and SPF (acronyms according to Thiers, continuously updated). Measurements were obtained from rehydrated flowers, with use of a stereomicroscope, 10–60 × magnification (SZ-STLA, Olympus). Measurements were taken with a digital caliper, 300 mm. The general morphological terminology follows Harris & Harris (2001) and Radford *et al.* (1976); leaf venation terminology follows Ellis *et al.* (2009); inflorescence morphology follows Endress (2010). Conservation status was assessed using the GeoCAT Tool (Bachman *et al.* 2011). Area of Occupancy (AoO) analysis was run with the IUCN default cell width of 2 km<sup>2</sup>. Values of AoO and Extent of Occurrence (EoO) are given.

## TAXONOMY

*Simaba tocantina* Devecchi & Pirani, *sp. nov.* (Figs. 1, 2)

**Diagnosis:** A *Simaba salubris*, cui affinis, foliorum rachi laevi (striata), inflorescentia laevis (striata) ramis lateralibus elongatis (brevibus) provisa, floribus 2.1–2.5 cm longis (3.1–3.5 cm), gynophoro 2,4–2.9 mm longo (1.6–2 mm) otpime distincta.

**Type:**—BRAZIL. Tocantins: Mateiros, Parque Estadual do Jalapão, Estrada para Boa Esperança, arredores do Morro do Porco, *cerrado*, campo sujo, 10°19'55"S, 46°37'31"W, fl. fr., 20 September 2014, G.M. Antar *et al.* 528 (holotype SPF!, isotype RB!).

Shrubs, 0.3–0.8 m tall, with a thickened underground system; aerial branches 1–3, glabrous or finely pubescent; bark glossy, breaking into irregular plates. Leaves imparipinnate or sometimes paripinnate, clustered near apex; petiole cylindrical, 4.3–8.2(–10.5) cm long, puberulent to pubescent, intumesced at base; rachis cylindrical 12–25 cm long, smooth, pubescent along the adaxial surface, with short, hooked trichomes; petiolules 1–2 mm long, intumescent and wrinkled; leaflets (13–)15–17(–21), opposite or subopposite; lamina of the terminal and lateral-distal leaflets 4.5–7.3 × 1.3–2.4 cm, obovate

to elliptic-obovate in the terminal leaflet, oblong-obovate to narrowly elliptic in the lateral ones, apex acute, base cuneate, coriaceous to subcoriaceous, margin not revolute, discolored, adaxial surface dark green and glossy, abaxial surface light green and dull, glabrous except along the midvein in the upper side, with short, hooked trichomes; venation brochidodromous; midvein prominent on the abaxial surface, slightly to sharply sulcate on the adaxial surface, secondary and tertiary veins prominulous or slightly sulcate on both sides; superficial glands laminar present at the basal half of the lamina on abaxial surface, sometimes also on adaxial surface, apical gland generally present at the apex, not conspicuously developed. Inflorescence a terminal thyrses, the main axis 45–60 cm long, lateral axes poorly developed, up to 10 cm long, puberulent, provided with scattered glandular trichomes; bracts 1.5–2.5 × 1.6–2.6 mm, spathulate to spheroid, reddish-green, puberulent, intumesced with a small hole in the upper side. Flowers: pedicel 2.4–3.2 mm long, pubescent, with glandular trichomes; calyx green turning reddish towards the apex, externally pubescent, internally glabrous, length ratio between tube and lobes 1:1, sepals 5, apex obtuse or acute; petals 5, slightly imbricate, cream to greenish, 21–25 × 3.5–3.9 mm, oblanceolate, apex rounded, glabrous internally, puberulent externally; stamens 10; filaments 18–20 mm long, flattened, provided with an adaxial appendage 16–17 mm long, villous at apex and margins, forming a pseudo-tube by the intertwining of trichomes, the adnate portion length of the appendages relative to the free portion 6:1; anthers dorsifixed, ca. 1.7 mm long, white to cream; gynophore subterete, slightly sulcate, 2.4–2.9 mm long, puberulent; ovary ca. 2 mm long, tomentose; style subterete, 13–15 mm long, bristly near the base; stigma slightly 5-lobed. Fruits with 1–2 drupaceous mericarps (drupelets), immature 14–17 × 11–13 mm, widely elliptic to obovate, greenish, pubescent, with a single seed.

*Additional specimens examined* (paratypes):—BRAZIL. Tocantins: Mateiros, Parque Estadual do Jalapão, estrada para Boa Esperança, Brejo do Guará, campo sujo, 10°19'55"S 46°37'31"W, 420 m, fl., 18 June 2002, T.B. Cavalcanti et al. 2928 (CEN!); ibidem, 10°20'43"S 46°37'34"W, 468 m, sterile, 25 March 2014, M.F. Devecchi et al. 293 (NY!, RB!, SPF!); Ponte Alta do Tocantins, estrada entre Ponte Alta do Tocantins e Mateiros, cerrado, 10°30'58"S 46°53'17"W, 440 m, sterile, 15 July 2014, M.F. Devecchi 312 (HTO!, SPF!).

*Phenology*:—*Simaba tocantina* has been collected with flowers in June and September, and with immature fruits in September.

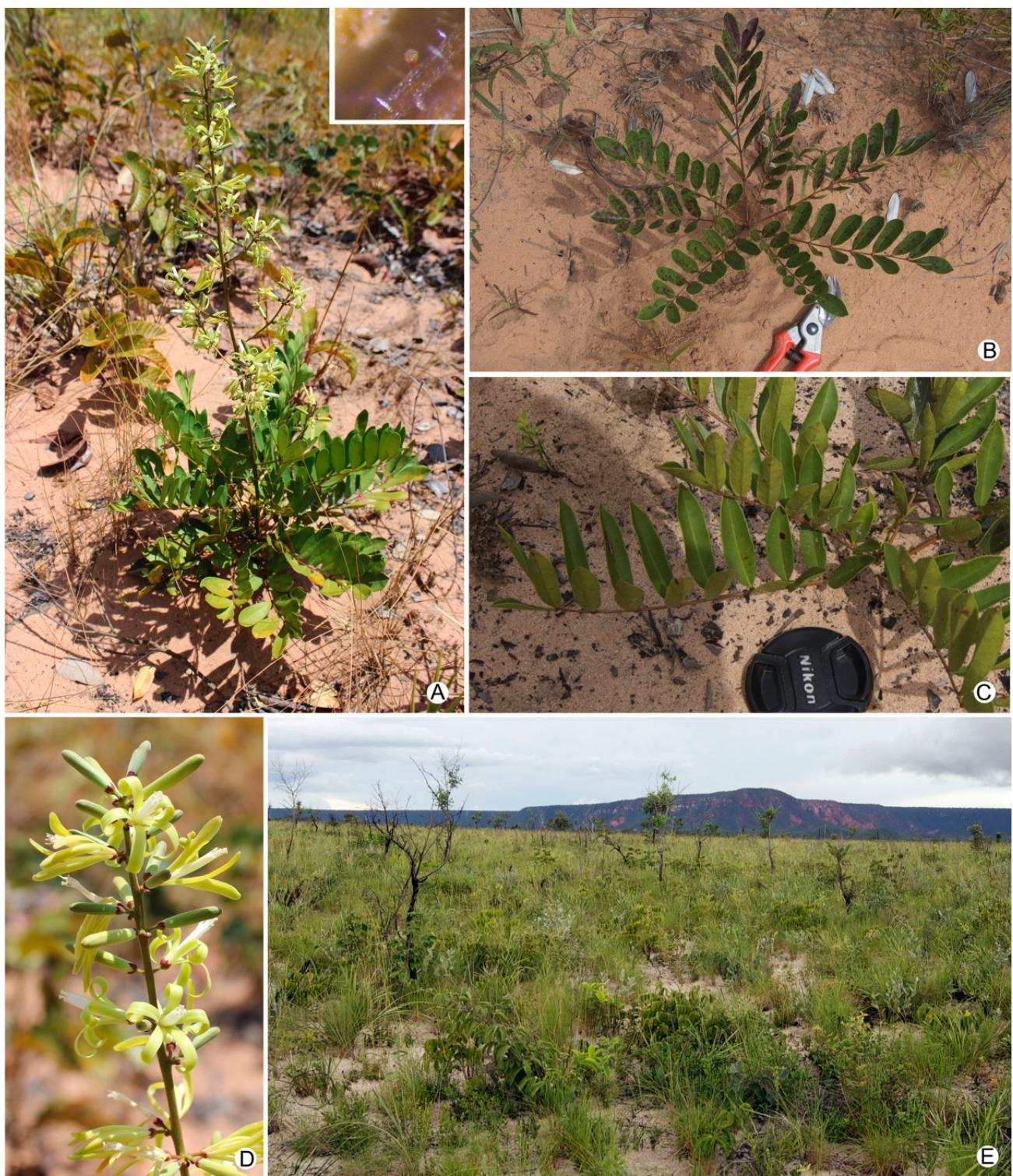


FIGURE 1. *Simaba tocantina*. A. Habit, on top right a detail of a portion of the inflorescence rachis showing glandular trichomes. B. Sterile individual. C. Pinnate leaves with ascending leaflets and petioles covered by sand. D. Distal part of the inflorescence main axis, with floral buds and flowers at anthesis. E. Habitat of the new species, an open campo-cerrado at Jalapão State Park, Tocantins, Brazil. Pictures A and D by Guilheme Antar; B, C and E by the first author.

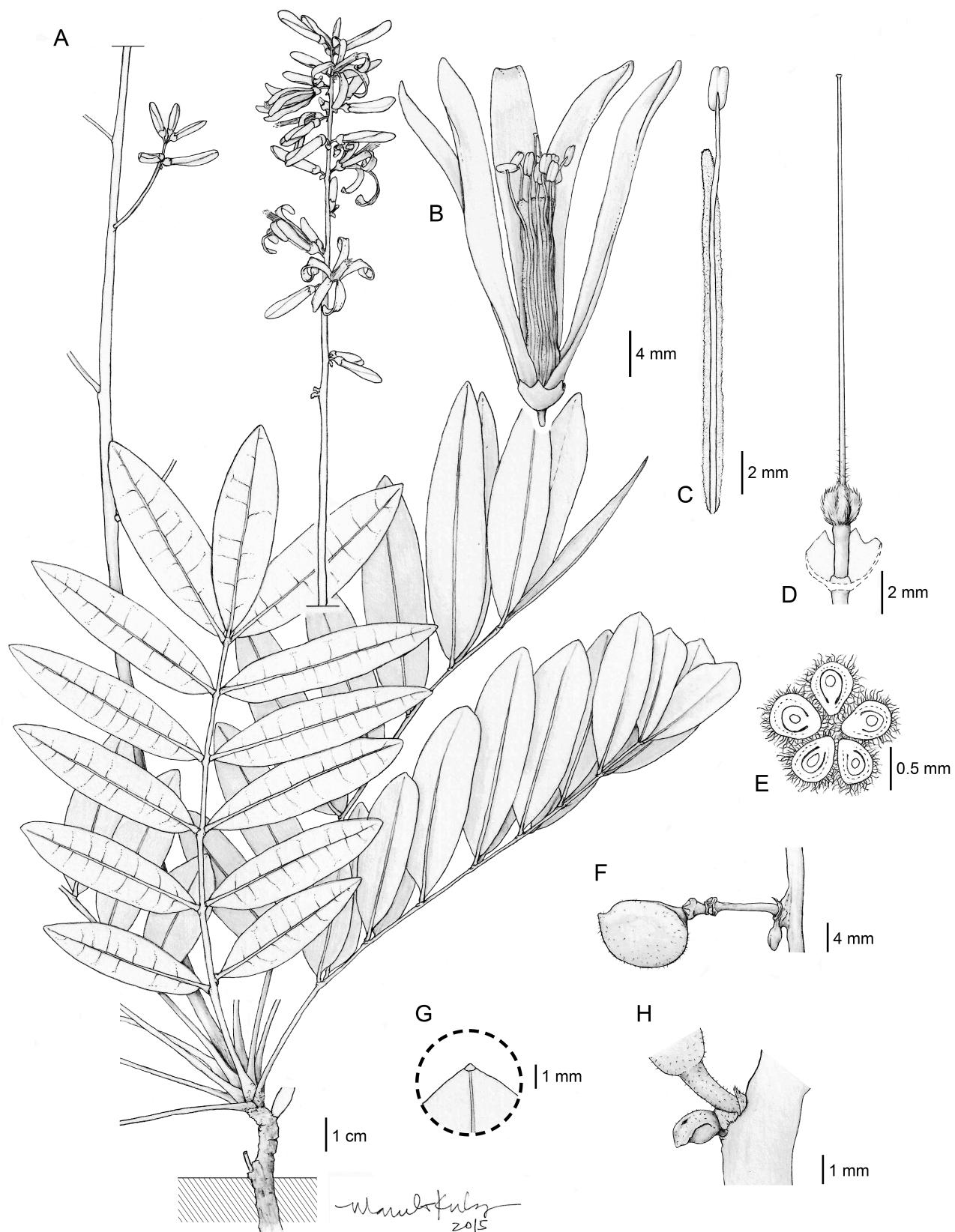


FIGURE 2. *Simaba tocantina*. A. Habit with a subterranean stem and the leaves crowded at the apex. Note the leaflet midvein prominent and the secondary veins slightly sulcate. B. Flower. The filament appendage of the stamens forming a pseudo-tube by the intertwining of trichomes. C. Stamen with filament appendage and dorsifixed anther. D. Gynoecium with a long, subterete gynophore and an elongated style. E. Transverse section of the gynoecium showing five carpels free from each other. F. Fruit, a drupeous mericarp (drupelet), subtended by an intumesced glandular bract (an extrafloral nectary). G. Leaflet apex with an apical nectary. H. Detail of a glandular bract subtending a flower, with a small cavity in the upper side. (A–H. *Antar* 528). Drawings by Marcelo Kubo.

**Distribution and ecology:**—*Simaba tocantina* is endemic to *cerrado* and *campo sujo* on sandy soils of the Jalapão region. Only two populations are known so far: one inside the limits of the Jalapão State Park in the municipality of Mateiros, and the other in the municipality of Ponte Alta do Tocantins (Fig. 3). The geoxyllic habit of the new species may be seen as a putative drought and fire-resistant trait. As well as in several taxa from other families, this kind of life-form usually has been considered to have evolved as an adaptation to drought, or nutrient-deficient soils, or to fire regimes (e.g. Rachid 1947; Rizzini & Heringer 1961; Simon & Pennington 2012). We have some morphological evidence that even though the aerial parts of individual plants of the *S. tocantina* may be completely burned out during a fire event, the protected buds on top of the underground stem can sprout new branches and leaves afterwards, with blooming following these events.

**Etymology:**—The epithet refers to the state of Tocantins, where the species is known to occur.

**Conservation status:**—Critically endangered (CR—B1b [i,ii,iv]). The species is probably endemic to the small area of Jalapão, where only three subpopulations are known. According to the performed GeoCAT analysis and the IUCN (2012, 2014) criteria, the species may be classified as critically endangered. EoO = 71 km<sup>2</sup>; AoO = 12 km<sup>2</sup>.

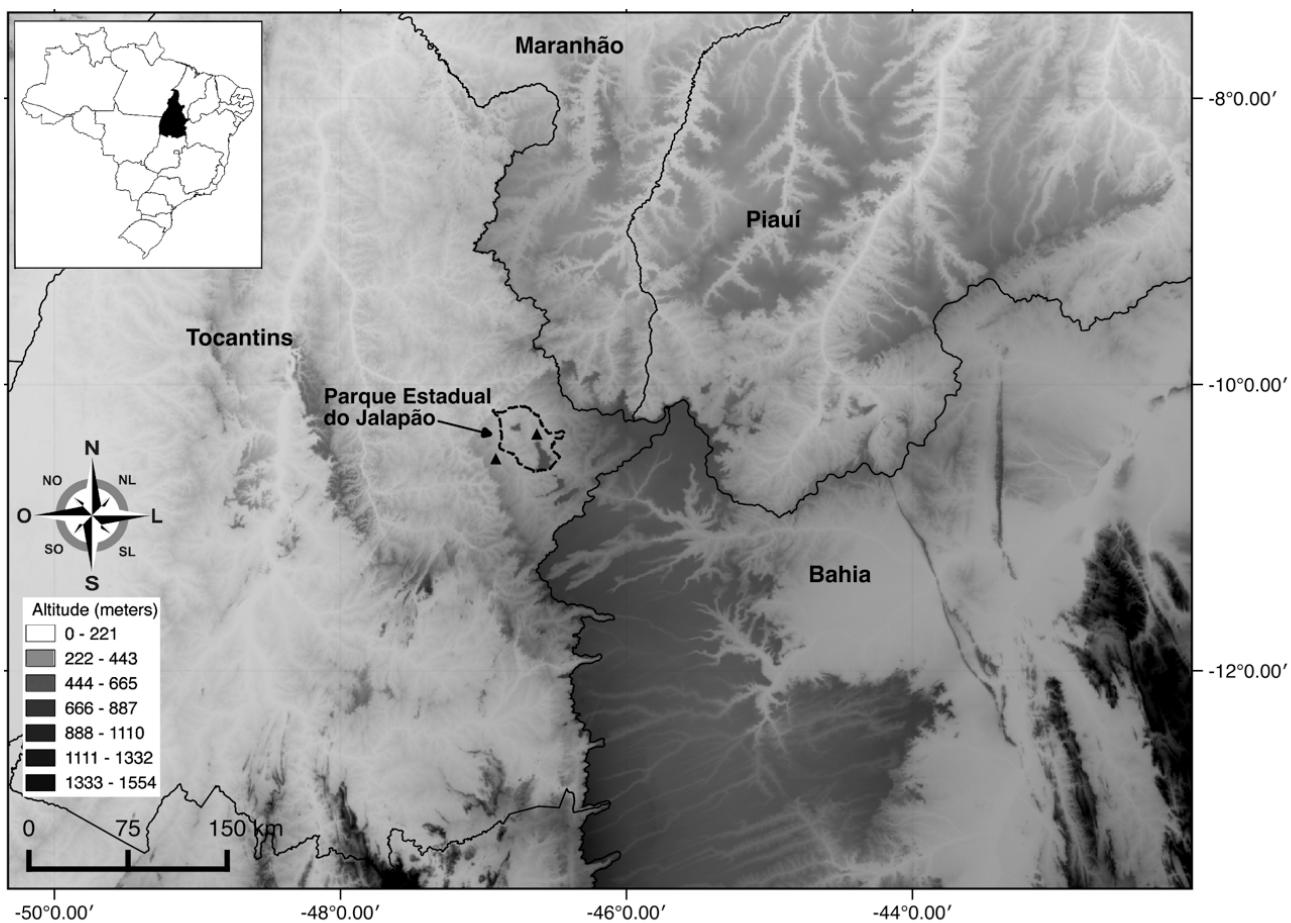


FIGURE 3. Distribution map of *Simaba tocantina*.

**Notes:** The presence of large and sparsely branched inflorescences, producing 2.1–2.5 cm long flowers, with staminal appendages covered by intertwined trichomes forming a pseudotube around the gynoecium places the new species in *Simaba* sect. *Grandiflorae* Engler (1874: 209). Even though *Simaba tocantina* is very similar to *S. salubris* in having a shrubby habit, with short branches sprouting from a thickened underground system, it is distinct from the latter by the presence of a smooth leaf rachis (vs. striate), the presence of glandular trichomes in the inflorescence axis (vs. absence thereof), the shorter flower length (2.1–2.5 cm vs. 3.1–3.5 cm long), the gynophore size (2.4–2.9 mm vs. 1.6–2 mm tall), and by the ratio of the adnate and free part to the staminal appendages (6: 1 vs. 10: 1 or more). The other species belonging to *S. sect. Grandiflorae* are shrubs or small trees with conspicuous aerial stems. They also differ from the new species mainly by the following characters: the staminal appendages are 18–20 mm long in *S. tocantina*, while in *S. cedron*, *S. pohliana* Boas (1913: 337) and *S. trichilioides* Saint-Hilaire (1823: 279) they are shorter (11–17 mm long); the ovary is tomentose in *S. tocantina*, but villous to velutinous in the three other species. All distinctive features are depicted in Table 1, and a key to the species of *S. sect. Grandiflorae* is also provided below.

Table 1. Some characters distinguishing *Simaba tocantina* from the remaining species belonging to *Simaba* sect. *Grandiflorae* Engl. (? Not seen).

Species /Characters analyzed	<i>Simaba tocantina</i>	<i>Simaba cedron</i>	<i>Simaba maiana</i>	<i>Simaba pohliana</i>	<i>Simaba salubris</i>	<i>Simaba trichilioides</i>
Habit	Shrub	Treellets	Shrub	Shrub	Shrub	Shrub
Bulk of stem	Subterranean	Aerial	Aerial	Aerial	Subterranean	Aerial
Petiolule surface	Rugose	Rugose	Smooth	Rugose	Smooth	Rugose
Leaflets: trichomes on abaxial surface	Absent	Only along the midrib region	Only along the midrib region	Absent	Only along the midrib region	All surface
Leaflets: trichomes on adaxial surface	Only along the midrib region	Only along the midrib region	Absent	Absent	Only along the midrib region	All surface
Leaflets: apical gland	Not conspicuously developed	Developed	Not conspicuously developed	Developed	Not conspicuously developed	Developed
Inflorescence: glandular trichomes on the axis	Present	Present	?	Present	Absent	Present
Petal size	21–25 mm	25–29 mm	20–23 mm	20–24 mm	31–35 mm	26–28 mm
Calyx: tube length relative to the lobes	1:1	2:1	2:1	2:1	2:1	2:1

Species /Characters analyzed	<i>Simaba</i> <i>tocantina</i>	<i>Simaba</i> <i>cedron</i>	<i>Simaba</i> <i>maiana</i>	<i>Simaba</i> <i>pohliana</i>	<i>Simaba</i> <i>salubris</i>	<i>Simaba</i> <i>trichilioides</i>
Filament appendage: adnate portion length relative to the free portion	6:1	4:1	4:1	2:1	10:1 or more	5:1

Key to the species of *Simaba* sect. *Grandiflorae*

1. Shrubs with a thick underground system and a few short aerial branches; leaflet apical gland not conspicuously developed; ovary tomentose ..... 2
  - Shrubs or treelets with a conspicuous, long aerial stem; apical gland present at the apex, conspicuously developed and visible to the naked eye; ovary villous to velutinous ..... 3
    2. Leaflet abaxial surface glabrous; petals 2.1–2.5 cm long; adnate portion length of the filament appendage relative to the free portion 6:1; gynophore 2.4–2.9 mm long (Brazil: Tocantins) ..... *S. tocantina*
      - Leaflet abaxial surface with trichomes along the midvein region; petals 3.1–3.5 cm long; adnate portion length of the filament appendage relative to the free portion 10:1 or more; gynophore 1.6–2 mm long (Brazil: São Paulo and Mato Grosso do Sul) ..... *S. salubris*
    3. Leaf rachis length relative to the petiole 2:1; leaflets opposite, completely glabrous or with trichomes only along the midvein region on both surfaces; gynophore 2.6–2.7 mm long. ..... 4
      - Leaf rachis length relative to the petiole 1:1; leaflets opposite to subopposite, with trichomes scattered all over both surfaces; gynophore 1.2–1.6 mm long (eastern Paraguay; central and northeastern Brazil) ..... *S. trichilioides*
  4. Leaves with 7–14 pairs of leaflets; Leaflets with trichomes along the midvein region on abaxial surface; adnate portion length of the filament appendage relative to the free portion 4:1 ..... 5
    - Leaves with up to 4 pairs of leaflets; Leaflets completely glabrous on both surfaces; adnate portion length of the filament appendage relative to the free portion 2:1 (Brazil: Pará and Tocantins) ..... *S. pohliana*
  5. Treelets; surface of petiolule rugose; apex of the leaflets with a gland conspicuously developed and visible to the naked eye (widely distributed in tropical northern and eastern South America) ..... *S. cedron*
    - Shrubs; surface of petiolule smooth; leaflet apical gland not conspicuously developed (Brazil: Rio de Janeiro) ..... *S. maiana*

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ATTACHMENT:  
TWO.



## *Simaba arenaria* (Simaroubaceae): a New Species from Sandy Coastal Plains in Northeastern Brazil, with Notes on Seedling Morphology

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**Abstract**—In this paper we describe and illustrate a new species of *Simaba* from sandy coastal plains in northeastern Brazil, and discuss the controversial limits of the three sections proposed in the genus by Englerian classification. *Simaba arenaria* has a restricted distribution: it is known only from two small, somewhat disturbed areas, in restinga vegetation of Bahia and Sergipe states. The evaluation of its threatened status indicates that it is an endangered taxon, according to the IUCN Red List categories and criteria. We also provide novel data on the seedling of this species.

**Resumo**—Neste artigo descrevemos e ilustramos uma nova espécie de *Simaba* das planícies arenosas costeiras do Nordeste do Brasil, e discutimos os limites controvertidos entre as três seções propostas no gênero por Engler (1874). *Simaba arenaria* tem distribuição restrita: é conhecida de apenas duas áreas de extensão reduzida e perturbadas, em vegetação de restinga, nos estados da Bahia e Sergipe. A avaliação de seu status de conservação indica-a como espécie ameaçada, de acordo com os critérios da Lista Vermelha da IUCN. Também apresentamos dados da plântula desta espécie.

**Keywords**—Bahia state, Brazil, conservation, Neotropical flora, Sapindales, Sergipe state, taxonomy.

## INTRODUCTION

*Simaba* Aubl. is the largest genus of the Simaroubaceae, a family composed of tropical, subtropical and temperate elements, currently placed within Sapindales (Clayton 2009). *Simaba* is tropical and comprises about 25 species (Clayton 2011), mainly distributed in South America. Most species occur in Brazil, and most have restricted ranges, but some extend into Central America (e.g. *Simaba cedron* Planch. and *S. polyphylla* (Cavalcante) W. W. Thomas). *Simaba* species are morphologically and ecologically diverse, occurring in a wide range of different habitats. In Brazil, the genus is well represented in both the Amazonian forest (tropical moist forest) and Atlantic forest (either in moist or seasonal forests), as well as in open areas, especially in the Cerrado (savannas of the Brazilian Plateau) and in sandy coastal savannas known as Restingas. Species can be trees up to 30 m tall or shrubs, the latter commonly with a thickened underground system. The leaves are pinnate with opposite leaflets, or less frequently subopposite. The leaflets often have an apical gland that can be very conspicuous or not to the naked eye. The flowers are bisexual, (4–)5(–6)-merous, with sepals partially connate and petals free, and puberulent to tomentose. The androecium is composed of 10 stamens, each one bearing a basal appendage totally or partially fused to the filament. The gynoecium is formed of five uniovulate carpels which are united only by the styles. The flowers are produced on terminal or subterminal panicles or thyrses. The fruit is a schizocarp generally with only one or two drupaceous fruitlets.

There are two contrasting infrageneric classifications proposed for *Simaba*. One of them divides the genus into three sections, based mainly on flower morphology and geographic distribution (Engler 1874). The other recognizes only two sections based on anatomy (Boas 1913). Most taxonomic treatments follow the Englerian classification (e.g. Cronquist 1944, Cavalcante 1983), but the limits of the sections need a reevaluation, as suggested by morphological studies (e.g. Thomas 1984; Franceschinelli and Yamamoto 1999) and a phylogenetic analysis (Clayton et al. 2007).

During the examination of the collections of the herbaria ALCB and ASE, we found specimens of an undescribed species. In a subsequent field trip to localities in Bahia and Sergipe states we found natural populations and collected fresh material, enabling a proper description the new taxon. We also address the problem of ascribing the new species to one of the Englerian *Simaba* sections.

## MATERIALS AND METHODS

To circumscribe and characterize the new species, we described its morphological features using field observations and specimens from the following herbaria: ALCB, ASE and SPF (acronyms according to Thiers, continuously updated). We obtained measurements through a 10–60 × magnification

stereomicroscope, using only fully developed, mature organs, from dried leaves and floral parts preserved in 70% ethanol. The general morphological terminology follows Radford et al. (1976), Hickey and King (2000) and Ellis et al. (2009). The seedling morphology follows Garwood (2009). We produced a distribution map using QGIS 2.6.1 Brighton software (2015), with geographical coordinates obtained from all available herbarium specimens. The conservation status was assessed using the GeoCAT Tool (Bachman et al. 2011) and IUCN (2012, 2014) categories and criteria. Area of occupancy (AoO) analysis was run with the IUCN default cell width of 2 km<sup>2</sup>. Values of AoO and extent of occurrence (EoO) are given.

#### TAXONOMIC TREATMENT

*Simaba arenaria* Devecchi & Pirani, sp. nov.—TYPE: BRAZIL. Sergipe: Pirambu, SE-100, ca. 2.5 km na estrada antes do povoado de Lagoa Redonda, restinga sobre dunas, 10°41'13"S 36°48'47"W, 11 Feb 2015, Devecchi & Franco 399 (holotype SPF!, isotypes NY!, RB!).

*Simaba arenaria* ab omnibus congeneribus filamentis staminum sinuosis optime distincta.

Shrubs to treelets 0.3–2 m tall; stem unbranched and covered with a thick bark, strongly grooved and splitting into irregular plates. Leaves mostly imparipinnate, clustered near the stem apex; petiole cylindrical, 9–15 cm long, pubescent to glabrescent, slightly swollen at base; rachis cylindrical, 19–56 cm long, smooth, with short, white trichomes, glabrescent; petiolules 2–4 mm long, swollen and wrinkled; leaflets (11–)13–25, opposite or subopposite; blades of the terminal and lateral-distal leaflets 7.5–14(–16) × 2.6–5.9 cm, the terminal leaflet obovate to broadly-obovate, the lateral ones narrowly elliptic or oblong-obovate, the apex acute to widely acute, the base cuneate or rounded, the margin slightly to conspicuously revolute, venation brochidodromous, midvein prominent on the abaxial surface, slightly to sharply sulcate on the adaxial surface, secondary veins prominulous or slightly sulcate on both sides; a pair of superficial glands present near the lamina apex, out of the secondary veins arches on adaxial surface; apical gland generally present at the lamina apex, not conspicuously developed; coriaceous to rigid-coriaceous, discolorous, the adaxial surface dark green and shiny, the abaxial surface light green and dull; glabrous except along the midvein on adaxial surface, with short trichomes. Inflorescence a lax, terminal thyrsse, the main axis 47–95 cm long, the basal lateral ones 30–54 cm long, more distal ones gradually shorter towards the apex, pubescent, with scattered glandular trichomes; bracts 2.5–4(–7) × 1.8–2.3(–4.5) mm, elliptic to widely depressed obovate, reddish-green, pubescent, tip swollen with a gland or the whole bract modified as an ellipsoid gland. Floral buds ovoid to oblong-ovoid, petals imbricate. Flowers: pedicel 3.4–7.6 mm long, pubescent, with scattered glandular trichomes; calyx green to ferruginous, pubescent abaxially, glabrous adaxially, tube and lobes

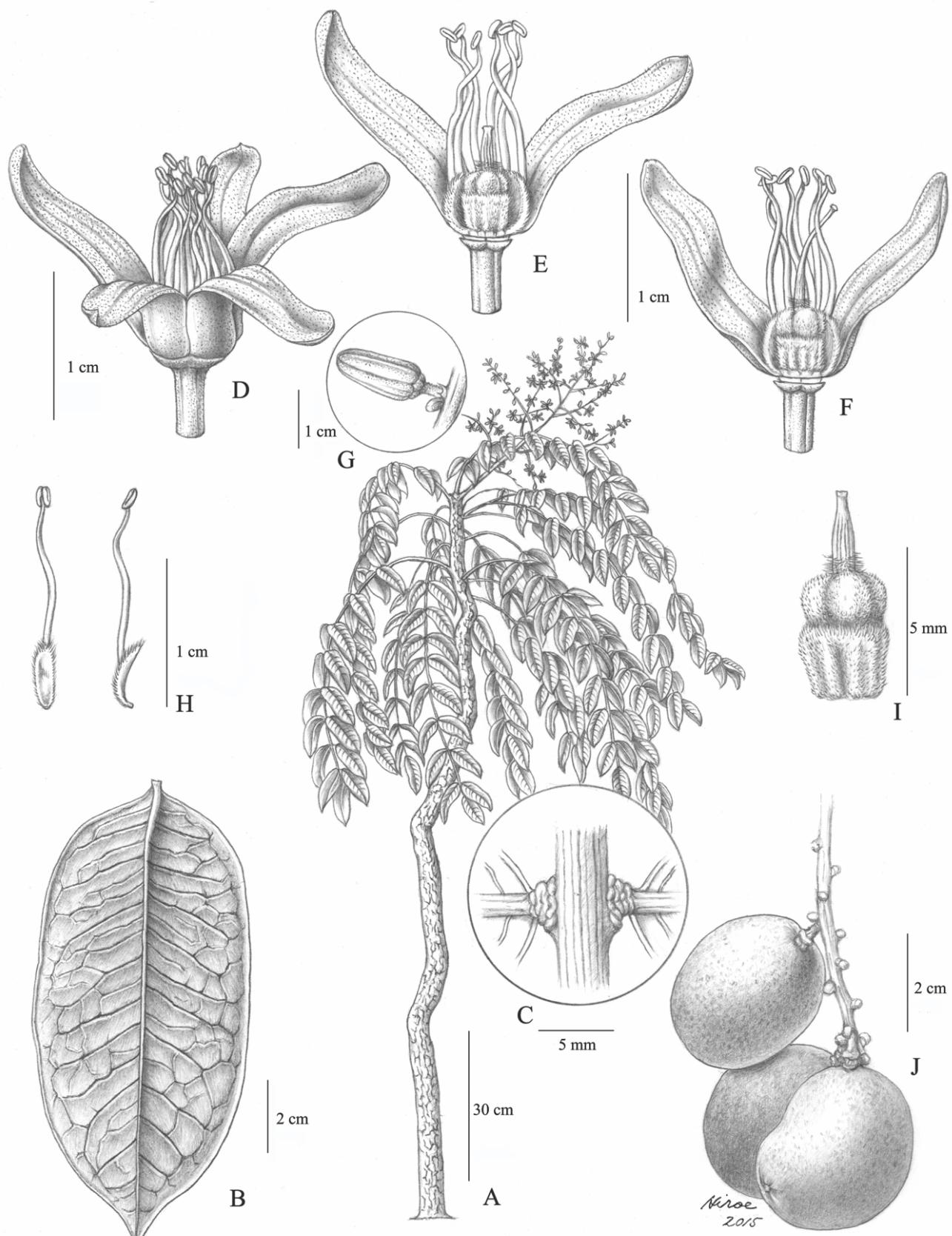


FIG. 1. *Simaba arenaria*. A. Habit. B. Leaflet, abaxial surface showing the prominent midvein and sunken secondary veins. C. Detail of leaflet base showing a pair of petiolules. D. Flower. E. and F. Flowers in two different stages of maturity (three petals removed). G. Floral bud and subtending glandular bract. H. Stamens with anther, filament and filament appendage. I. Gynoecium on top of a gynophore and a short style. J. Mature fruits attached to a lateral

branch of the infructescence, each one subtended by a persistent glandular bract. (A–I. Devecchi & Franco 399, J. Devecchi & Franco 396).



FIG. 2. *Simaba arenaria*. A. Habit in a coastal dune in Sergipe, with the first author. B. Inflorescence, a terminal, long, lax thyrsse. C. Inflorescence axis with floral buds and flowers at anthesis. D. Detail of a flower at anthesis showing the peculiar stamens with sinuous filaments. E. Detail of the stem with thickened and strongly grooved bark. F. Ants foraging on inflorescence axis with floral buds and active glandular bracts. G. Four young fruitlets united by the distal portions of their styles. H. Immature fruits with five young drupaceous mericarps

(drupelets). I. Mature fruits turning ferrugineous. J. Habitat of the new species (one individual in bloom is indicated by the white arrow), on a sandy dune with *restinga* vegetation, in Pirambu, Sergipe, Brazil. of equal length; sepals 5, apex acute or obtuse; petals 5, slightly imbricate, 14.4–18 × 3.8–4.6 mm, oblong to oblanceolate, apex rounded, greenish to ferrugineous, tomentose on both surfaces; stamens 10; filaments 9.9–13.7 mm long, terete, sinuous, glabrous, provided with an adaxial appendage 3.9–5.6 mm long, the basal half adnate to the filament, the distal half free and slightly reflexed, obscuring the ovary, abaxially velutinous, the free portion adaxially glabrous; anthers dorsifixed, 1.3–2.1 mm long, yellow; gynophore subterete, slightly 10-costate, 1.2–2.3 mm long, pubescent; ovary 1.6–2.7 mm long, velutinous; style subterete, 2.4–6.8 mm long, bristly near the base; stigma slightly 5-lobed. Fruit with 1–2 drupaceous mericarps (drupelets), when mature 3.1–3.7 × 2.6–3.2 cm, broadly ellipsoid, yellowish to ferrugineous, pubescent, with a single seed. Figures 1, 2.

*Seedling Development*—The seeds of *Simaba arenaria* are surrounded by a hard endocarp wall and bear two thick storage cotyledons (Fig. 3a). Seedlings display a cryptocotylar and hypogeal germination, in which the cotyledons (Fig. 3b, c) do not emerge from the seed coat. The radicle is the first structure to emerge from the seed during germination. The radicular system is axial (Fig. 3b, c), featuring robust development and producing few secondary and tertiary roots (Fig. 3c). The hypocotyl is very short though thick (Fig. 3b, c), the epicotyl elongation is rapid and it soon turns green. One or more cataphylls (Fig. 3b, c) are produced in alternate position, preceding the formation of the first leaf (Fig. 3c), which is petiolate, imparipinnate with five leaflets, and shows a conduplicate induplicate vernation pattern.

*Additional Specimens Examined*—BRAZIL. Bahia: Salvador, Parque das Dunas, arredores da Lagoa do Urubu, restinga sobre dunas, 12°55'41.6"S, 38°21'12.5"W, 6 Feb 2015, Devecchi et al. 393 (ALCB, NY, SPF); idem, 12°55'35.8"S, 38°21'06.2"W, 41 m alt, 6 Feb 2015, Devecchi et al. 394 (NY, SPF); Dunas do Abaeté, 13°56'S, 39°21'W, 24 Nov 1997, Guedes & Dirceu 5536 (ALCB); idem, Santos s.n. (ALCB); Sergipe: Pirambu, SE-100, ca. 5 km da Lagoa Redonda, 10°41'15.3"S, 36°49'57.9"W, 11 Feb 2015, Devecchi & Franco 400 (G, SP, SPF); idem, 10°41'40.3"S, 36°50'44"W, 11 Feb 2015, Devecchi & Franco 396 (NY, RB, SPF); idem, 10°41'38.4"S, 36°50'43.5"W, 11 Feb 2015, Devecchi & Franco 398 (K, NY, SPF); Estrada para Ponta dos Mangues, próximo a ponte, 28 Jan 1992, Farney et al. 2973 (RB, SPF); idem, Povoado Lagoa Redonda, 29 Mar 2011, Farinaccio et al. 845 (ASE); idem, Assentamento São Sebastião, 14 Apr 2012, Oliveira 167 (ASE); idem, caminho para Lagoa Redonda, 12 Jan 2012, Melo et al. 25 (ASE); idem, 10°43'59.0"S, 36°52'00.0"W, 9 May 2013, Freire et al. 101 (ASE).

*Phenology*—*Simaba arenaria* has been collected with flowers in January, February, May and November; with immature fruits in January and with mature fruits in February and March.

*Distribution and Ecology*—*Simaba arenaria* is known only from a few localities in the states of Bahia and Sergipe in northeastern Brazil. It occurs in sandy coastal plain savannas and thickets locally known as restingas. These are the prevailing vegetation type found on sandy Quaternary substrates and are

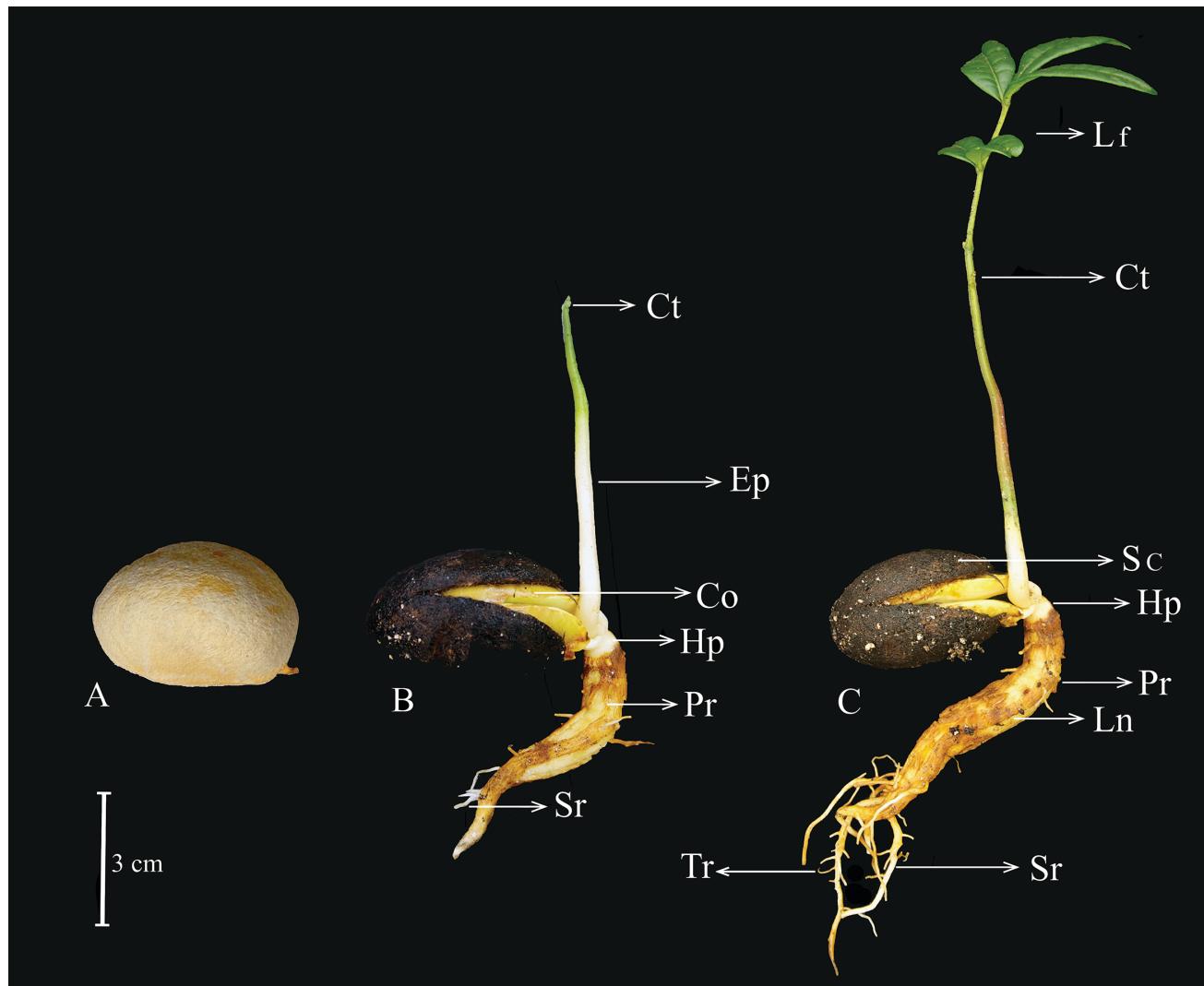


FIG. 3. Seed and seedling of *S. arenaria*. A. Fruitlet stone (the seed surrounded by a rigid endocarp wall). B. Seedling at an early stage, with an elongate primary root and a developing epicotyl. C. Seedling at a later stage, with the first leaf. (Leaf: Lf, Cataphylls: Ct, Epicotyl: Ep, Seed coat: Sc, Hypocotyl: Hp, Primary root: Pr, Lenticel: Ln, Secondary root: Sr, Tertiary root: Tr, Cotyledon: Co).

usually restricted to areas near the coast (Flexor et al. 1984; Scarano 2002; Thomas and Barbosa 2008). Some of the morphological features of this new heliophytic species of *Simaba*, such as its rigid, coriaceous leaflets with revolute margins, conspicuous venation, and the thick epicuticular layer of wax, are clearly related to the harsh environmental conditions of the restinga habitat, caused mostly by full exposure to sunlight, high temperatures, and low water retention in the sandy soil. The young, pleistocene to holocene ages of these habitats have not provided sufficient time for high speciation rates, a factor often cited as major explanation for scarcity of endemic taxa (e.g. Scarano 2002).

Nevertheless, they are also among the least-known Brazilian vegetation types in terms of diversity and conservation, and that is why some taxonomic novelties and endemic species have been recently described for the *restingas*. As in other species of *Simaba*, populations of *S. arenaria* are small, with few clustered individuals. Only two populations are known: one in the Lagoas e Dunas do Abaeté Metropolitan Park, in the municipality of Salvador, Bahia, and the other near the village of Lagoa Redonda in the municipality of Pirambu, Sergipe. Both are somewhat disturbed areas (Fig. 4).

**Etymology**—The epithet refers to the sandy soils in which the new species grows.

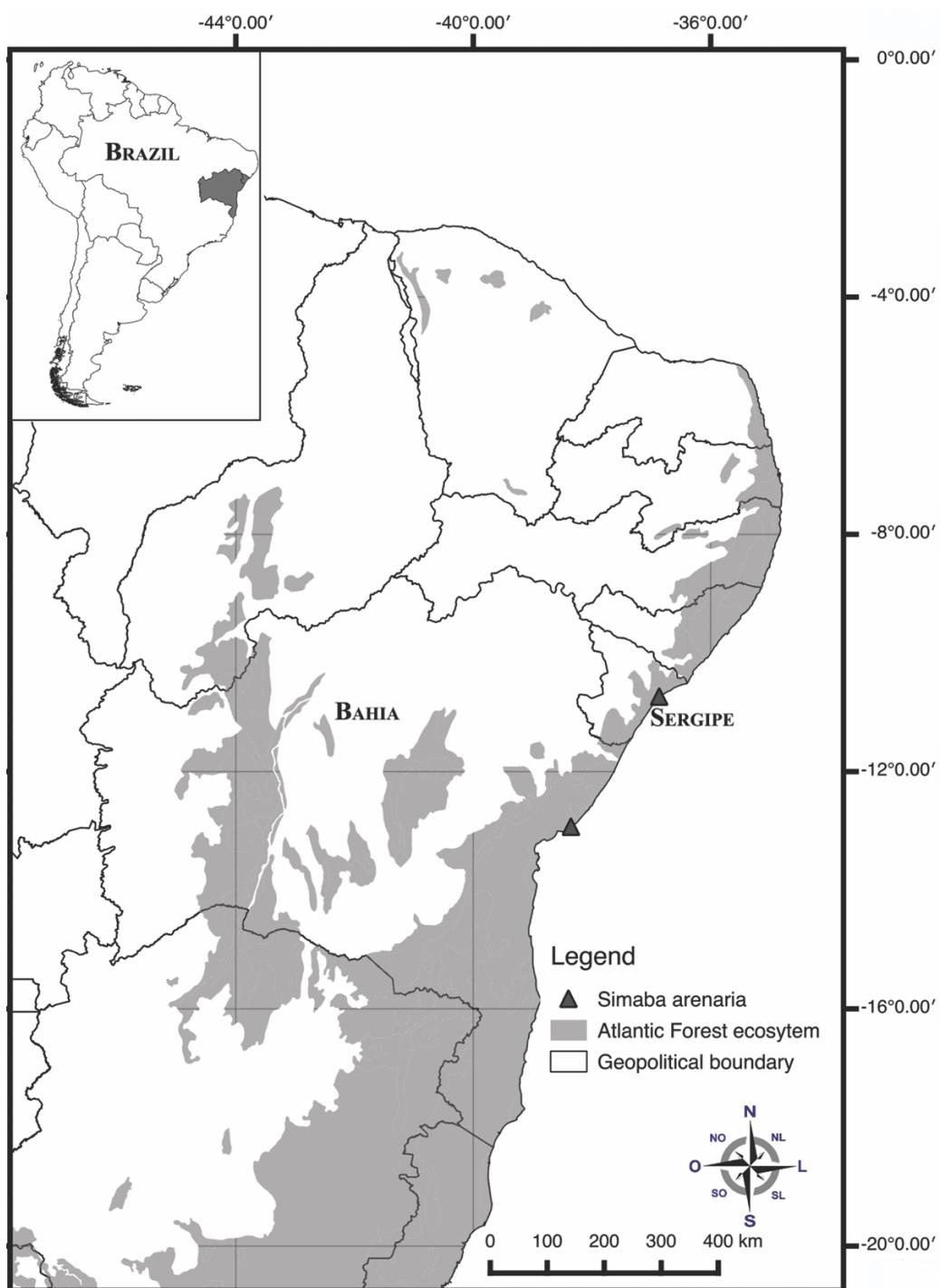
**Conservation Status**—Endangered (EN—B1b [i, ii, iv]). The *restinga* vegetation is one of the most threatened natural environments in Brazil, due to conversion of this natural habitat into beachfront settlements (Pinto et al. 1984; Britto et al. 1993). A GeoCAT analysis and IUCN (2012, 2014) criteria suggest that *Simaba arenaria* should be classified as endangered. EoO = 303.623 km<sup>2</sup>; AoO = 12 km<sup>2</sup>.

**Taxonomic Notes**—*Simaba arenaria* is similar to *S. cedron* and *S. insignis* A.St.-Hil & Tul. in having a treelet habit, with the leaves clustered at the unbranched stem apex, but it is distinct from the first by the presence of shorter flowers, with petals up to 18 mm long (vs. 25–30 mm long) and by the apical gland present at the leaflet apex, not conspicuously developed (vs. conspicuously developed). It differs from the second species by the length of the filament (9.9–13.7 mm vs. 6.5–8 mm long) and the fruits (31–37 × 26–32 mm, broadly elliptic, not laterally flattened vs. 36–40 × 32–37 mm, obovate, laterally flattened).

This new species combines characters related to all three sections of the genus (Table 1). The presence of small staminal appendages, less than 1/3 of the filament length, is diagnostic of species belonging to *S. sect. Tenuiflorae* Engl., a group mostly restricted to the Amazon (with a single species occurring also in the Atlantic Forest of southern Bahia). On the other hand, long, few branched inflorescences like those of *S. arenaria* are usually found in species of *S. sect. Grandiflorae* Engl. The petal size in *Simaba arenaria* is intermediate between the petal size of species belonging to *S. sect. Floribundae* Engl. and to *S. sect. Grandiflorae*, but the calyx shape and indumentum type of the new species indicate a stronger affinity to species from *S. sect. Floribundae*. Thomas (1984) and Franceschinelli and Yamamoto (1999), when describing new species of *Simaba*, highlighted the existence of several intermediate characters between sections *Floribundae* and *Grandiflorae*, suggesting the acceptance of the fusion of both sections proposed by Boas (1913), based on leaf anatomical evidences. In the molecular phylogenetic analysis by Clayton et al. (2007), members of the three sections formed two sister clades, which essentially correspond to Boas's (1913)

proposition. Taxonomic and phylogenetic studies which are underway by the authors shall bring further evidence toward a better understanding of groups within *Simaba*.

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FIG. 4. Distribution map of *Simaba arenaria* in BrazilTABLE 1. Position of *Simaba arenaria* according to morphological characters in the Englerian infrageneric classification (Engler 1874).

Species and sections /Characters analyzed	<i>Simaba arenaria</i>	<i>Simaba</i> sect. <i>Tenuiflorae</i>	<i>Simaba</i> sect. <i>Floribundae</i>	<i>Simaba</i> sect. <i>Grandiflorae</i>
Inflorescence type	Large and few-branched thyrses	Thyrses or small, few-flowered panicles	Large, densely branched panicles	Large and few-branched panicles or thyrses with reduced lateral axis
Petal length (mm)	14.4–18	4–7	7.5–15	15–35

Petal indument	Tomentose	Puberulent	Villous to tomentose	Puberulent to pubescent
Stamen appendage indument	Hairy, united, but not forming a pseudotube	Glabrescent to hairy, free from each other or slightly united, but not forming a pseudotube	Hairy, free or united, but not forming a pseudotube (except <i>S. paraensis</i> and <i>S. docensis</i> )	Hairy on their edges, hairs intertwined forming a staminal pseudotube
Stamen appendage length	1/3 of the filament length, entirely covering the ovary	1/3 to 1/2 of the filament length, covering the basal part of the ovary to the whole ovary	1/2 to 3/4 of the filament length, covering the ovary and part of the style	Almost the same length as the filament, covering the ovary and almost the whole style
Gynophore length	The same length or slightly greater than the ovary	To half the size of the ovary	The same length as the ovary	Mostly larger than the ovary (except <i>S. cedron</i> )
Geographical distribution	Extra-Amazonian	Mostly Amazonian	Mostly extra-Amazonian	Mostly extra-Amazonian

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