doi: 10.1017/S0960428617000348

REDISCOVERY AND TAXONOMIC REASSESSMENT OF FOUR ANGIOSPERMS IN THE SAVANNAS OF JALAPÃO, CENTRAL BRAZIL

G. M. Antar[1], M. F. Santos[2] & P. T. Sano[1]

Globally, the Cerrado is the most diverse savanna in terms of plant species, as well as one of the most threatened as the result of human impact; it is therefore considered a priority area for conservation. Some areas of the Cerrado have still not been subject to botanical collections and detailed studies, the Jalapão region being one of these. We describe four recently rediscovered species previously known only from type specimens collected at least 160 years ago: *Hyptis caduca* Epling (Lamiaceae), *Duguetia rotundifolia* R.E.Fr. (Annonaceae), *Diospyros ovalis* Hiern (Ebenaceae) and *Rhabdodendron gardnerianum* (Benth.) Sandwith (Rhabdodendraceae). Comments on their ecology, conservation status and occurrence are provided, together with a distribution map. New morphological data have been recorded, and all species are considered to be under some degree of threat. These rediscoveries highlight the importance of further fieldwork in poorly sampled and highly biodiverse regions such as Jalapão and neighbouring areas, as well as the urgent need for conservation of the highly threatened Cerrado biome.

Keywords. Cerrado, conservation, *Diospyros*, *Duguetia*, *Hyptis*, new records, *Rhabdodendron*, Tocantins.

Introduction

Rediscoveries are important to taxonomists, because new collections may provide new morphological data for a taxon, which can be used to help better circumscribe species; to biogeographers, because they add to knowledge of poorly known species distributions and can be used to test theories of human effects on species occurrences (Ladle *et al.*, 2011); and to conservationists, because they reduce uncertainty in extinction risk assessments, thereby contributing to better-grounded threat levels and providing support for conservation interventions (Ladle *et al.*, 2011), which are especially needed in heavily threatened natural biomes.

The Brazilian Cerrado biome is currently highly threatened by human activity, mostly the use of land for mechanised soybean plantations and livestock grazing (Ratter *et al.*, 1997; Klink & Machado, 2005; BFG, 2015). It is estimated that of its original area of approximately 2 million square kilometres, more than 50% has already

[1] Departamento de Botânica, Instituto de Biociências, Universidade de São Paulo, Rua do Matão 277, São Paulo – SP, 05508-090, Brazil. E-mail for correspondence: guilherme.antar@gmail.com
[2] Departamento de Biologia, Campus Sorocaba, Universidade Federal de São Carlos, Rodovia João Leme dos Santos (SP 264), km 110, Sorocaba – SP, 18052–780, Brazil.

been profoundly modified (Beuchle *et al.*, 2015). The Cerrado biome has the highest plant diversity of any savanna in the world, with currently 12,103 species of seed plants recorded, of which 35% are endemic (Forzza *et al.*, 2012; BFG, 2015). This combination of high diversity and endemism with the pressing threat level makes it a priority area for conservation (Myers *et al.*, 2000; Mittermeier *et al.*, 2004).

A large number of plant species that occur on the Cerrrado are known only from historical collections (Martinelli *et al.*, 2014), and some recent research deals with species 'rediscoveries' in this biome (e.g. Echternacht *et al.*, 2010; Medeiros *et al.*, 2011; Bove & Philbrick, 2014; Silva *et al.*, 2015; Borges & Antar, 2016; Scatigna *et al.*, 2016). The first botanical expeditions into the Cerrado biome were carried out by European naturalists during the nineteenth and early twentieth centuries, including William Burchell, Auguste Glaziou, Johann Emanuel Pohl, Jacques Samuel Blanchet, Augustin Saint-Hilaire, Ludwig Riedel, Friedrich Sellow and George Gardner (Urban, 1906), resulting in the description of many new species (Walter *et al.*, 2001). Afterwards, there followed a period without systematic botanical collections in the Cerrado biome, particularly in the core area of the Cerrado (Eiten, 1972) in central-western Brazil, these recommencing only in the early 1960s (Ratter *et al.*, 1997; Walter *et al.*, 2001). Despite these efforts, some Cerrado areas remain under-sampled (BFG, 2015).

One such under-sampled area is the Jalapão region, located in the far east of Tocantins state near the border between Piauí, Tocantins, Maranhão and Bahia states (Proença *et al.*, 2007). Fortunately, the Jalapão region is the best conserved and largest continuous protected area of the Cerrado (Silva & Bates, 2002), with the most important protected areas being the Parque Estadual do Jalapão, the Estação Ecológica Serra Geral do Tocantins and the Parque Nacional das Nascentes do Rio Parnaíba (Schmidt *et al.*, 2007). This region and the surrounding areas were explored relatively late in colonial history, owing to their distance from the coast and the lack of transport infrastructure (Souza-Júnior, 2002). Consequently, few botanical expeditions have been carried out in the area, contributing to a paucity of detailed floristic information (Proença *et al.*, 2007). Recent efforts have been made to improve sampling of the flora of the region (Scariot *et al.*, 2002; Seplan, 2003), most prominently fieldwork by the Brazilian Agricultural Research Corporation (Embrapa) and the University of Brasília. As a result, species lists have been compiled showing high richness (Arruda & Behr, 2002; Scariot *et al.*, 2002; Seplan, 2003), although plant diversity continues to be under-sampled (Antar & Sano, in preparation).

During a recent survey carried out with the aim of producing a new checklist for the Jalapão region (Antar & Sano, in preparation), four rediscoveries of angiosperms were made. The current work reports these and provides new information about the species' morphology, distribution, ecology and conservation status.

Materials and Methods

The Jalapão region, covering an area of approximately 18 million square kilometres, is located in the far east of Tocantins state, near the border between Bahia, Maranhão

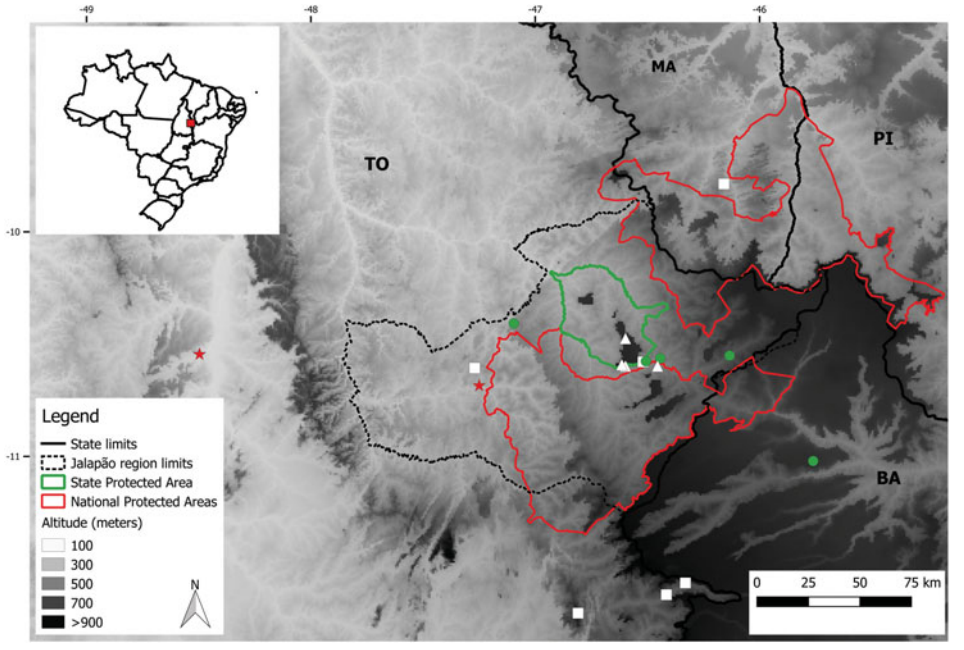

FIG. 1. Study area and distribution of *Hyptis caduca* (red stars), *Duguetia rotundifolia* (white triangles), *Diospyros ovalis* (green circles) and *Rhabdodendron gardnerianum* (white squares). BA, Bahia; MA, Maranhão; PI, Piauí; TO, Tocantins.

and Piauí, and includes the municipalities of Mateiros, Ponte Alta do Tocantins and São Felix do Tocantins (Fig. 1). The climate corresponds to Köppen's category Aw (Alvares *et al.*, 2014), with two well-differentiated seasons: a rainy one from October to March, and a dry one from April to September (Ratter *et al.*, 1997). Mean precipitation is approximately 1500 mm/year, and mean annual temperature is approximately 26°C (SEPLAN, 2012). The soils are sandy, well-drained and nutrient-poor quartzitic neosoils. Elevation ranges mostly from 400 to 550 m above sea level, reaching up to 800 m in some cases (SEPLAN, 2012). The principal phytophysiognomies (*sensu* Ribeiro & Walter, 2008) are swamp forests (*veredas*) accompanying the innumerous drainage lines (Schmidt *et al.*, 2007; Sampaio *et al.*, 2008) and savanna vegetation, mainly open subtypes such as *campo sujo* and *cerrado sensu stricto* (SEPLAN, 2003).

Six field expeditions to the area were undertaken between 2013 and 2015, spanning both dry and wet months. All fertile angiosperms were collected following Filgueiras *et al.* (1994). Specimens collected were processed following Fidalgo & Bonini (1984), with vouchers collected deposited in the SPF herbarium. In addition, the following herbaria (abbreviations according to Thiers, continuously updated) were visited and identifications reviewed: BHCB, CEN, CEPEC, ESA, HCF, HEPH, HRCB, HTO,

HUEFS, HUTO, MBM, RB, SPF, UB and UEC. Images of type specimens of the species rediscovered were studied using JSTOR Global Plants (no date).

Morphological features of the specimens were analysed with a × 10–60 magnification stereomicroscope. Terminology follows Harris & Harris (2001) for general morphology, Hickey *et al.* (1973) for leaf morphology, and specific literature for each taxon: *Hyptis* (Epling, 1949; Harley & Pastore, 2012), *Duguetia* (Maas *et al.*, 2003), *Diospyros* (Hiern, 1873; Wallnöfer, 2001) and *Rhabdodendron* (Prance, 1972; Puff & Weber, 1976; Prance, 2004).

IUCN criteria (IUCN, 2001; IUCN Standards and Petitions Subcommittee, 2016), together with the GeoCAT tool (Bachman *et al.*, 2011), were used to infer conservation status, with IUCN default values for extent of occurrence and area of occupancy analysis. The distribution map was produced in QGIS version 2.8.1 (QGIS Development Team, 2016). When herbarium specimens were not georeferenced, geographical coordinates were approximated using the locality description on the label; in cases of unspecific locality description, the coordinates of the centroid of the municipality were used. In the absence of at least three points of occurrence, mandatory for GeoCAT, existing points were replicated and slightly dislocated on the map, following Borges & Antar (2016).

Results

Four angiosperm species were rediscovered and are described here, with all descriptions including new morphological data. Notes are provided for all taxa clarifying the type collection locality, this being necessary owing to changes in state and municipality borders in Brazil or because of inaccurate descriptions on the original labels. Ecological aspects and conservation status are also discussed.

Hyptis caduca Epling, Repert. Spec. Nov., Beih. 85: 320. 1937. – Type: Brazil, Goiás [Tocantins]: Porto Real [Porto Nacional], April 1829, *Burchell* 8762 (holo US; iso F, GH, K [scan seen – K000192538], P). **Fig. 2**.

Annual herb up to 30 cm. *Stem* internodes usually longer than the leaf, unbranched or once-branched, 2–4(–7) pairs of leaves per branch. *Leaves* opposite, mostly concentrated near the inflorescences; leaf blade 1–2 × 1 cm, linear, crenate, indumentum hirsute of simple delicate trichomes and glandular sessile trichomes; petiole absent to 1–2 mm long. *Inflorescence* capituliform, formed by 2 (or 3) glomerules in the axils of superior leaves; peduncle 1–2(–3) mm long; involucral bracts 5–7 × 2–3 mm, connate at the base, broadly lanceolate, acuminate, acumen c.1 mm long, indumentum hirsute of trichomes concentrated in the margins and glandular sessile trichomes. *Flowers* subsessile on pedicels c.0.5 mm long; calyx at anthesis 3–4 mm long, tube 2–3 mm long, externally hirsute, internally glabrous, the apex of the tube densely hirsute, calyx lobes linear, equal, 1–2 mm long, hirsute, calyx in fruit c.5 mm long; corolla c.4 mm long, tube c.3.5 mm long, narrowly cylindrical, glabrous except

FIG. 2. The second known specimen of *Hyptis caduca* Epling (SPF-223291). Image courtesy of the SPF herbarium; reproduced with permission.

for the hirsute apices of lobes; stamens with glabrous filaments; gynoecium glabrous. *Nutlet* c.1 × 0.5 mm, ellipsoid, glabrous, wrinkled, mucilaginous when wet.

Distribution. *Hyptis caduca* is known only from Tocantins state, occurring in the municipalities of Ponte Alta do Tocantins and Porto Nacional (Fig. 1).

Specimen examined. Brazil: **Tocantins**: Ponte Alta do Tocantins, Jalapão, 28 v 2008, *J.M. Silva* et al. 6817 (MBM!, SPF!).

Habitat. The species can be found from 400 to 500 m above sea level in dry sandy fields (*campo limpo*).

Phenology. Fertile specimens of *Hyptis caduca* were collected in April and May.

Conservation status. The area of occupancy is reduced, being just 8000 km², and the extent of occurence is 0.456 km². None of the collections were found inside protected areas, although populations of *Hyptis caduca* probably occur inside the nearby protected areas of Jalapão. The type populations may be extinct owing to urbanisation and agriculture in Porto Nacional. The conservation status of this species is assessed as Critically Endangered according to IUCN criteria B1ab(iii)+2ab(iii) (IUCN, 2001).

Hyptis caduca was previously known only from the type specimen, collected by Burchell in 1829, in the municipality of Porto Nacional, Tocantins state (Epling, 1949; Harley & França, 2009). Tocantins state was created in 1989, when it was separated from Goías. Before 1861, when Tocantins was still part of the state of Goiás, the locality was known as Porto Real (Dias, 2016). This re-collection occurs after 179 years, in the municipality of Ponte Alta do Tocantins, c.125 km east of Porto Nacional.

Duguetia rotundifolia R.E.Fr., Bull. Herb. Boissier, ser. 2. 7: 1003. 1907. – Type: Brazil: Goiás [Tocantins], Mission of Duro [Dianópolis], ix 1839, *Gardner* 2998 (holo K [scan seen – K000487384]). **Fig. 3 A,B.**

Shrubs 0.4–2 m tall. *Stems* covered with stellate scales. *Leaves* alternate, arranged along the entire stem; leaf blade 2.5–9.8 × 1.7–5.5 cm, ovate, elliptic or orbicular, apex rounded to emarginated, rarely slightly acute, base obtuse to rounded, adaxially glabrous, shiny, abaxially sparsely covered with stellate scales, more densely dispersed in the midrib, brown; petiole 1–2(–3) mm long. *Inflorescence* 1-flowered, subaxillary; peduncle 2–3(–5) mm long, densely covered with stellate scales, external bract 5–7 mm long, triangular, adaxially glabrescent, abaxially densely covered with stellate scales, upper bract 4–7 mm long, adaxially glabrescent to pubescent with simple trichomes, abaxially densely covered with stellate scales. *Flowers* with pedicels 8–10 mm long, densely covered with stellate scales; flower buds deltoid; calyx 1-whorled, sepals brown, 14–22 × 12–20 mm, broadly ovate, apex acute, base rounded, adaxially tomentose with simple tricomes, abaxially densely covered with stellate hairs; corolla 2-whorled, petals cream, subequal, 11–15 × 11–14 mm, deltoid, apex obtuse, base rounded to truncate, abaxially covered with stellate hairs, adaxially tomentose with

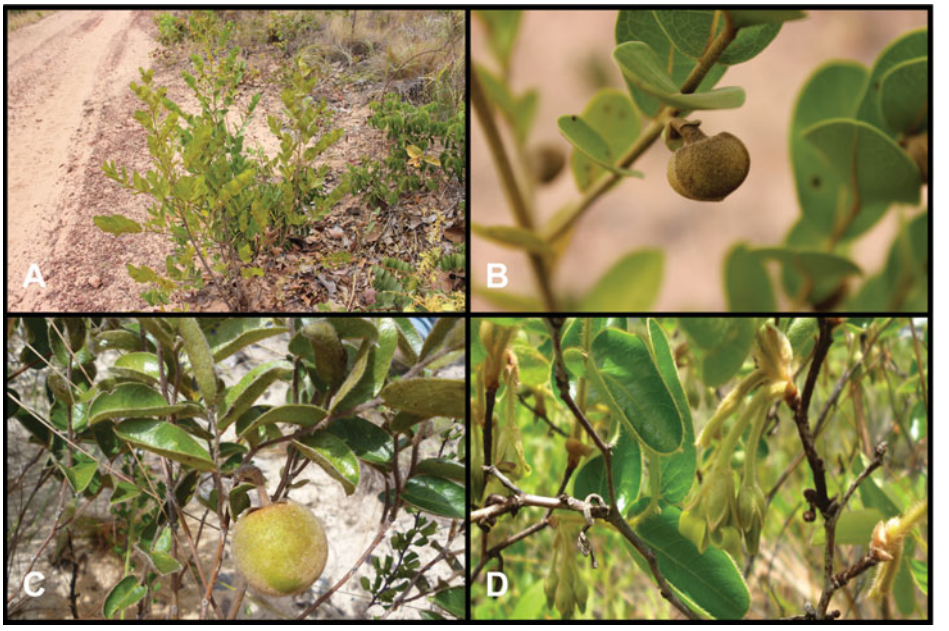

FIG. 3. A, B. *Duguetia rotundifolia*. A, Habit; B, flower buds. C, D, *Diospyros ovalis*. C, Habit and fruits; D, flowers.

simple trichomes; stamens numerous, c.1 mm long; carpels numerous, c.4 mm long, stigma glabrous, ovary tomentose with simple trichomes and some stellate scales. *Fruit* not seen.

Distribution. Duguetia rotundifolia is known from Tocantins and Maranhão states, occurring in the municipalities of Ponte Alta do Tocantins (Tocantins), Porto Nacional (Tocantins) and Alto Parnaíba (Maranhão) (Fig. 1).

Specimens examined. BRAZIL, **Maranhão**: Alto Parnaíba, estrada de acesso ao povoado Curralinho, 09°47′10.26″S, 46°01′51.28″W, xi 2013, *H.G. Silva* et al. 236 (SP, SPF!). **Tocantins**: Dianópolis, 11°33′55″S, 46°19′50″W, 26 ix 2003, *A.O. Scariot* 776 (CEN, SPF!); Ibidem, 11°37′03″S, 46°24′55″W, 27 ix 2003, *A.O. Scariot* 924 (CEN, SPF!); Mateiros, 10.5623°S, 46.4426°W, 7 x 2007, *J. Paula-Souza* et al. 9136 (CTES, SI, SPF!); Ibidem, Parque Estadual do Jalapão, 10°34′40.25″S, 46°31′09.78″W, 21 ix 2014, *G.M. Antar* et al. 536 (SPF!, W!); Ponte Alta do Tocantins; 10.6055°S, 47.2701°W, 6 x 2007, *J. Paula-Souza* et al. 9011 (SPF!).

Habitat. Duguetia rotundifolia occurs in different phytophysiognomies of the Cerrado: open fields (*campo sujo*) and savanna (*cerrado s.s.*) on dry sandy soils, and near swamp forests (*veredas*) on wetter soils. It was also recorded as occurring in disturbed savanna. It can be found from 450 to 750 m above sea level.

Phenology. Duguetia rotundifolia was found in flower from September to November. Fruiting period is unknown.

Conservation status. The area of occupancy is 24 km² and the extent of occurrence 14,823.217 km². Collections were found inside the Parque Estadual do Jalapão and Parque Nacional das Nascentes do Rio Parnaíba protected areas. The conservation status is assessed as Vulnerable according to IUCN criteria B1ab(iii)+2ab(iii) (IUCN, 2001).

Duguetia rotundifolia was previously known only from the type specimen, collected by Gardner in 1839 (Maas *et al.*, 2003; CNCFlora, 2012), and considered to be rare (Rodrigues, 2009a). It is rediscovered after 164 years, and the petals are described for the first time. Although it is now known from the type and six additional specimens, fruiting material is still unknown.

Mission of Duro is a rather common locality in Gardner's expedition collections. According to Hind (2012), he stayed in the area for several days and collected a large number of specimens. Comparing his diary with maps (IBGE, 1984), it is possible to determine that this locality is in the current municipality of Dianópolis in the state of Tocantins, as supported by Arbo (1993), Cavalcanti (1995) and Dias (2016).

Diospyros ovalis Hiern, Trans. Cambridge Philos. Soc. XII: 248. 1873. – Type: Brazil, Pernambuco [Bahia]: Rio Preto [Formosa do Rio Preto], ix 1839, *Gardner* 2813 (syn F, K [scan seen – K000644381], MG, P). **Fig. 3 C,D.**

Subshrubs to shrubs 0.3–1 m tall, dioecious. *Stems* ferruginous-sericeous when young, the older ones becoming glabrous. *Leaves* alternate, present only in new season branches and concentrated in the upper parts of stems; leaf blade 1.5–5.1 × 0.8–2.6 cm, elliptic, oval to ovate, apex obtuse with a tuft c.1 mm long of trichomes coming from the abaxial midrib, base cordate to rounded, adaxially shiny, black to dark grey when dried, glabrescent to sericeous in younger leaves, trichomes concentrated in the midrib, abaxially ferruginous, sericeous, mostly in the midrib; petiole almost absent to 1 mm long, sericeous. *Inflorescence* cymose, 1- to 6-flowered, axillary, bracts c.0.5 × 0.4 mm, sericeous, oval, concave. *Flowers* tetramerous (trimerous); pedicels 2–6 mm long; bracteoles soon deciduous c.3 mm long; calyx sericeous, brown, sepals 5–7 × 2–3.5 mm, lanceolate, slightly connate at the base; corolla infundibuliform, externally sericeous just alongside the central portion, internally glabrous, green, petals c.10–12 × 3–4 mm, lanceolate, connate in the base; male flowers with 20–28 stamens, subequal, the inner ones shorter than the outer or equal, all attached together at base and to the base of the corolla, 3–5 mm long, glabrous, anthers linear; pistilode 1–3 mm long, hispid. Female flowers with few staminodes or absent, if present adnate to the base of corolla, c.3 mm long, ovary c.5 mm long, hispid, ovoid, stigma 3. Fruit a fleshy berry, sericeous, globose, not seen in mature condition.

Distribution. Diospyros ovalis is known from Tocantins and Bahia states, occurring in the municipalities of Dianópolis, Mateiros, Ponte Alta do Bom Jesus and Ponte Alta do Tocantins in Tocantins and Formosa do Rio Preto in Bahia (Fig. 1).

Specimens examined. Brazil: **Tocantins**: Dianópolis, 11°40′14,7″S, 46°40′37″W, 17 x 2008, *R.C. Mendonça* et al. 6263 (IBGE, SPF!); Mateiros, 10.5623°S, 46.4426°W, 7 x 2007, *J. Paula-Souza* et al. 9136 (CTES, SI, SPF!); Ibidem, Parque Estadual do Jalapão, 10°34′31″S, 46°30′22.9″W, 30 x 2013, *G.M. Antar & M. Escaramai* 296 (CEN!, RB!, SPF!); Ponte Alta do Bom Jesus, 11°47′44″S, 46°22′51″W, 20 iv 2017, *G.M. Antar* et al. 1551 (SPF!); Ponte Alta do Tocantins, 10.4091°S, 47.0956°W, 6 x 2007, *J. Paula-Souza* et al. 9085 (CTES, SI, SPF!).

Habitat. Occurring in open fields (*campo sujo*) and savanna (*cerrado s.s.*) on dry sandy soils.

Phenology. *Diospyros ovalis* was found in bloom from September to October and in fruit in October.

Conservation status. The area of occupancy is 24 km² and the extent of occurrence 13,057.486 km². Some collections were found inside the protected area Parque Estadual do Jalapão. Because of the few records of *Diospyros ovalis* (six collections), its conservation status is assessed as Vulnerable according to IUCN criteria B1ab(iii)+2ab(iii) (IUCN, 2001).

Diospyros ovalis was previously known only from the type specimen and was referred to as the least known species of the genus in Brazil (Cavalcante, 1963). Recent collections made in the Jalapão region led to its rediscovery after 168 years. Personal observations suggest that despite having a small area of occurrence, *Diospyros ovalis* is rather common throughout the area. Female flowers are described for the first time. A lectotype of *Diospyros ovalis* will soon be provided by the specialist in the genus (B. Wallnöfer, Vienna, personal communication).

Pernambuco province encompassed the areas east of the São Francisco river, and was therefore referred to as Comarca de São Francisco until 1827, when it was transferred to Bahia (Brandão, 2010; IBGE, 2011). Gardner gathered the type collection of *Diospyros ovalis* in 1839 when the area was already part of Bahia province, but he was using the old delimitation and annotated the specimen as coming from Pernambuco (Urban, 1906; Hind, 2012). The locality Rio Preto listed by Gardner, and neighbouring localities such as Santa Rosa, Santa Maria, Serra do Mato Grosso and Serra da Batalha, were a source of confusion among different botanists. These localities were misplaced in Piauí (e.g. Epling, 1949; Stafleu, 1953; Rodrigues, 1976; Pennington, 1990; Koschnitzke & Martins, 2007), Pernambuco (e.g. Trelease, 1916; Irwin & Barneby, 1982; Khan, 2007; Souza & Giulietti, 2009; Oliveira & Bove, 2015) or Mato Grosso (e.g. Lima *et al*., 2014). According to the nearby places listed in Gardner's diary (Hind, 2012) and cartographic information (IBGE, 1984), these localities are part of the actual municipality of Formosa do Rio Preto in Bahia, near the border between Bahia, Piauí, Tocantins and Maranhão. This conclusion is also supported by other botanists (Urban, 1906; Prance, 1972; MacLeish, 1987; Harley, 1988; Prance, 2004).

Rhabdodendron gardnerianum (Benth.) Sandwith, J. Arnold Arb. 24: 224. 1943. – Type: Brazil, Pernambuco [Bahia]: Rio Preto [Formosa do Rio Preto], ix 1839, *Gardner* 2814 (holo K [scan seen]; iso BM [scan seen], CGE, GH, NY, OXF, P). **Fig. 4**.

FIG. 4. One of the re-collections of *Rhabdodendron gardnerianum* from Jalapão region (SPF-211693), *Borges* et al. 849. Image courtesy of the SPF herbarium; reproduced with permission.

Shrubs 0.4–1.0 m tall. *Stems* covered with peltate trichomes when young, the older ones glabrous. *Leaves* alternate; leaf blade (1.2–)3–7.1 × (0.5–)2.5–4.8 cm, orbicular, broadly elliptic or narrowly oblong, apex shortly acuminate, obtuse or rarely emarginated, base cordate, rounded, subcuneate or cuneate, margin slightly revolute, adaxially glabrous, frequently shiny, smooth or slightly rugose, midrib plane, primary veins obscured, abaxially sparsely covered with peltate trichomes to glabrous, midrib prominulous, primary veins inconspicuous; petiole (1–)3–5(–8) mm long, covered with peltate trichomes to glabrous. *Inflorescence* racemose, axillary; bracts and bracteoles scale-like, 1(–2.5) mm long, lanceolate, covered with peltate trichomes; prophylls scale-like, up to 3 per flower. *Flower* pedicels (2–)3–5 mm long, sparsely covered with stellate scales, green to vinaceous; receptacles broad, concave; calyx pentamerous, sepals up to 1 mm long, connate at the base, apex broadly obtuse, covered with peltate trichomes; corolla pentamerous, aestivation imbricate, caducous, petals 4–5 mm long, c.2 mm wide, oblong-elliptic, apex rounded, base truncate, minutely punctate; stamens c.45–50, 2–3 mm long, filaments minute, persistent, anthers linear, erect; ovary globose, apex covered with trichomes, 2-ovulate, c.1 mm long, style arising from base of ovary to one side of it. *Fruit* a drupe, subglobose, 5–7 mm diameter, exocarp pubescent, shiny, dark green, wrinkled when dry.

Distribution. Rhabdodendron gardnerianum is known from Tocantins and Bahia states, occurring in the municipalities of Mateiros (Tocantins) and Formosa do Rio Preto (Bahia) (Fig. 1).

Specimens examined. Brazil: **Tocantins**: Mateiros, 10°28′23,9″S, 46°27′17″W, 20 xi 2012, *L.M. Borges* et al. 849 (CEN!, SPF!); Ibidem, 10°35′47,2″S, 46°35′51,9″W, 10 iii 2006, *M.L.O. Trovó* et al. 245 (SPF!); Mateiros, Parque Estadual do Jalapão, Serra do Espírito Santo, 10°35′25.6″S, 46°36′50.5″W, 30 viii 2010, *M.G. Caxambu* et al. 3224 (HCF!); Mateiros, Parque Estadual do Jalapão, 10°35′47.3″S, 46°35′52″W, 30 vi 2014, *J.A. Lombardi* et al. 10230 (HRCB!, UPCB). 46°22′08″W.

Habitat. Occurring in open fields (*campo sujo*), rocky fields, and savanna (*cerrado s.s.)* on dry sandy soils.

Phenology. Rhabdodendron gardnerianum was found with flowers in September and with fruits between March and September.

Conservation status. The area of occupancy is 16 km² and the extent of occurrence 119.501 km². Although most collections were made inside the area of the Parque Estadual do Jalapão, the species is only known from five specimens. The conservation status is assessed as Endangered, following IUCN criteria B1ab(iii)+2ab(iii) (IUCN, 2001).

Rhabdodendron gardnerianum was previously known only from the type specimen collected in Formosa do Rio Preto (Prance, 1972, 2004), and considered to be rare (Rodrigues, 2009b) or thought to be extinct (Prance, 2004). It has been rediscovered

in Jalapão after 167 years. The type locality is the same as previously discussed for *Diospyros ovalis*.

Fruits of *Rhabdodendron gardnerianum* are described for the first time, as well as trichomes on the ovary and fruits. This observation contrast with reports in the literature (Prance, 1972; Puff & Weber, 1976; Prance, 2004), in which the family is described as having glabrous ovary and fruits, based on the two other species of the genus. Scanning electron microscopy is needed to clarify the type of the trichomes.

When compared with the type material (*Gardner* 2814), the specimens of *Rhabdodendron gardnerianum* found in the Jalapão region have significant morphological differences, especially in leaf morphology. Gardner's specimen shows narrower leaves that are aggregate, perhaps indicating a resprout after a fire event. Despite that, because the collections were made in nearby areas and the differences are small, we here propose an expansion of the concept of *Rhabdodendron gardnerianum* to encompass the morphology found in Jalapão region. Further collections, particularly in the municipality of Formosa do Rio Preto (Bahia), may clarify the species circumscription.

Discussion

Of the few large areas of conserved Cerrado that still exist, Jalapão region is the largest and best conserved (Silva & Bates, 2002), owing to its very low population density and the historically limited human economic activities in the area (Seplan, 2003). The economy is poorly developed, mostly owing to the poor sandy soils, which are unsuitable for traditional agriculture. The high biodiversity near roads and the absence of exotic species of Poaceae in Jalapão that are so common in more disturbed areas of the Cerrado (Pivello *et al.*, 1999) are good indications of the well-conserved nature of the region (Filgueiras, 2002). Nonetheless, growing tourism and especially the rapid advance of the agricultural frontier, mainly with soybean cultivation and *Eucalyptus* cropping encouraged by the Brazilian government (e.g. the creation of MATOPIBA; Presidência da República, 2015), are beginning to be seen in the surrounding areas, replacing the natural vegetation of the region. Nearby areas from the state of Bahia (particularly the municipality of Formosa do Rio Preto, where Gardner made some of his collections) are already highly degraded as a result of agricultural activity, which is now advancing towards the Jalapão region (Borges & Antar, 2016). To better conserve an area, scientific knowledge is highly desirable, because it valorises biodiversity and supports proposals for well-grounded conservation strategies (Mace, 2004). The rediscovery of these four rare plants is important, because it extends the knowledge of plant diversity in the Jalapão and draws attention to its high plant richness, the rapid deforestation of the Cerrado and the lack of an acceptable floristic knowledge of the region, thereby contributing to the conservation of a highly threatened biome.

These rediscoveries are also important because in all cases they expand the known areas of occurrence, reveal new morphological data that can be used to help better circumscribe species (especially in the case of *Rhabdodendron gardnerianum*), and

enable the systematic positioning of species (particularly *Duguetia rotundifolia*, which has an unresolved phylogenetic position within the genus; Maas *et al*., 2003).

The species treated here were either considered to be extinct, as with *Rhabdodendron gardnerianum* by Prance (2004), or thought to be rare, as in the cases of *Hyptis caduca* (Harley & França, 2009), *Duguetia rotundifolia* (Rodrigues, 2009a) and *Rhabdodendron gardnerianum* (Rodrigues, 2009b). In the Cerrado Red List, all were classified as Data Deficient, except for *Diospyros ovalis*, which was not considered. According to Penedo *et al*. (2015), indicating that a species to be extinct when it still exists in nature is very harmful for its conservation. The preliminary assessments of the conservation status of these species made here is a useful starting point, but further collections are needed to make final assessments.

These four rediscoveries in the Jalapão region are, following Ladle *et al*. (2011), categorised as rediscoveries of species poorly represented in museums that occur in areas with poor accessibility and lack of sampling. This highlights that the flora of Jalapão region and its neighbouring areas, extending to the borders of Bahia, Piauí, Pernambuco and Maranhão states, remains poorly known. Better sampling of these areas will make it possible to detail their biodiversity, allowing more accurate proposals in conservation plans. The region would be an ideal target for further taxonomic work, as the plants restricted to the area are mostly represented by few collections in herbaria.

Categories of extinction threat for the rediscovered species were assessed. They must be considered in conservation plans for the area, and new populations should be searched for, marked and used as indicators to promote the conservation of the area (Ladle *et al*., 2011).

Acknowledgements

We appreciate the help of L. Nascimento, M. Escaramai, U. R. Chagas and H. P. Antar for fieldwork; the staff of the Estação Ecológica Serra Geral do Tocantins and Parque Estadual do Jalapão for fieldwork logistics; Frederico Alves, Elizabeth Nichols, Ghillean Prance and Cristina Banks-Leite for comments on early versions of the manuscript; Jenifer Carvalho Lopes for helping with the bibliography; Roberta Figueiredo for providing the plant images; and Gisele Alves for helping with the understanding of *Rhabdodendron gardnerianum* indumentum. G.M.A. thanks CAPES, FAPESP (2014/01851-7) and Idea Wild. M.F.S. and P.T.S. thank CNPq (grant #150217/2016-1, grant #310437/2015-6) for financial support.

References

Alvares, C. A., Stape, J. L., Sentelhas, P. C., Gonçalves, J. L. M. & Spavorek, G. (2014). Köppen's climate classification map for Brazil. *Meteorol. Z.* 22(6): 711–728.

Arbo, M. M. (1993). Nuevas espécies americanas de *Turnera* (Turneraceae). *Bonplandia* 7(1–4): 63–99.

Arruda, M. B. & Behr, M. V. (eds) (2002). *Jalapão: Expedição Científica e Conservacionista*. Brasília: Ibama.

Bachman, S., Moat, J., Hill, A. W., Torre, J. & Scott, B. (2011). Supporting Red List threat assessments with GeoCAT: geospatial conservation assessment tool. *ZooKeys* 150: 117–126.

Beuchle, R., Grecchi, R. C., Shimabukuro, Y. E., Seliger, R., Eva, H. D., Sano, E. & Achard, F. (2015). Land cover changes in the Brazilian Cerrado and Caatinga biomes from 1990 to 2010 based on a systematic remote sensing sampling approach. *Appl. Geogr.* 58: 116–127.

BFG [Brazil Flora Group] (2015). Growing knowledge: an overview of Seed Plant diversity in Brazil. *Rodriguésia* 66(4): 1085–1113.

Borges, L. M. & Antar, G. M. (2016). Four they are! Broadening the description of *Mimosa flabelifolia* (Leguminosae Mimosoideae), a rare species from the Brazilian Cerrado. *Phytotaxa* 243(2): 155–162.

Bove, C. P. & Philbrick, C. T. (2014). Rediscovery of a Neotropical rheophyte (Podostemaceae) after 160 years: implications for the location of conservation unit boundaries (Tocantins, Brazil). *Check List* 10(5): 1170–1173.

Brandão, P. R. B. (2010). A formação territorial do Oeste Baiano: a constituição do além São Francisco (1827–1985). *GeoTextos* 6(1): 35–50.

Cavalcante, P. B. (1963). Nova contribuição ao conhecimento do gênero *Diospyros* Dalech. (Ebenaceae) no Brasil. *Bol. Mus. Paraense 'Emílio Goeldi'* 21: 1–17.

Cavalcanti, T. B. (1995). *Revisão de Diplusodon Pohl (Lythraceae)*. Doctoral dissertation, University of São Paulo.

CNCFlora [Centro Nacional de Conservação da Flora] (2012). *Duguetia rotundifolia*. In: *Lista Vermelha da Flora Brasileira*, version 2012.2. Online. Available: http://cncflora.jbrj.gov.br/portal/pt-br/profile/Duguetia rotundifolia (accessed 15 May 2017).

Dias, A. L. C. (2016). *Toponímia dos primeiros municípios tocantinenses*. Masters dissertation, Universidade Federal de Goías.

Echternacht, L., Trovó, M. & Sano, P. T. (2010). Rediscoveries in Eriocaulaceae: seven narrowly distributed taxa from the Espinhaço Range in Minas Gerais, Brazil. *Feddes Repert*. 121(3–4): 117–126.

Eiten, G. (1972). The cerrado vegetation of Brazil. *Botanical Review* 38(2): 201–341.

Epling, C. (1949). Revisíon del gênero *Hyptis* (Labiatae). *Revista Mus. La Plata, Secc. Bot.* 7: 153–497.

Fidalgo, O. & Bononi, V. L. (1984). *Técnicas de Coleta, Preservação e Herborização de Material Botânico*. São Paulo: Instituto de Botânica.

Filgueiras, T. (2002). Herbaceous plant communities. In: Oliveiras, P. S. & Marquis, R. J. (eds) *The Cerrado of Brazil: Ecology and Natural History of a Neotropical Savanna*, pp. 121–139. New York: Columbia University Press.

Filgueiras, T. S., Nogueira, P. E., Brochado, A. L. & Guala, G. F. (1994). Caminhamento: um método expedito para levantamentos florísticos qualitativos. *Cad. Geoci.* 12: 39–43.

Forzza, R. C., Baumgratz, J. F. A., Bicudo, C. E. M., Canhos, D. A. L., Carvalho, A. A. Jr, Coelho, M. A. N., Costa, A. F., Costa, D. P., Hopkins, M. G., Leitman, P. M., Lohmann, L. G., Lughadha, E. N., Maia, L. C., Martinelli, G., Menezes, M., Morim, M. P., Peixoto, A. L., Pirani, J. R., Prado, J., Queiroz, L. P., Souza, S., Souza, V. C., Stehmann, J. R., Sylvestre, L. S., Walter, B. M. T. & Zappi, D. C. (2012). New Brazilian floristic list highlights conservation challenges. *BioScience* 62(1): 39–45.

HARLEY, R. M. (1988). Revision of generic limits in *Hyptis* Jacq. (Labiatae) and its allies. *Bot. J. Linn. Soc.* 98(2): 87–95.
HARLEY, R. M. & FRANÇA, F. (2009). Lamiaceae. In: GIULIETTI, A. M., RAPINI, A., ANDRADE, M. J. G., QUEIROZ, L. P. & SILVA, J. M. C. (eds) *Plantas Raras do Brasil*, pp. 192–200. Belo Horizonte: Conservação Internacional.
HARLEY, R. M. & PASTORE, J. F. B. (2012). A generic revision and new combinations in the Hyptidinae (Lamiaceae), based on molecular and morphological evidence. *Phytotaxa* 58: 1–55.
HARRIS, J. G. & HARRIS, M. W. (2001). *Plant Identification Terminology: an Illustrated Glossary*, 2nd edition. Spring Lake,Utah: Spring Lake Publishing.
HICKEY, L. J. (1973). Classification of the architecture of dicotyledonous leaves. *Amer. J. Bot.* 60(1): 17–33.
HIERN, W. P. (1873). A monograph of Ebenaceae. *Trans. Cambridge Philos. Soc.* 12: 27–300.
HIND, D. J. N. (2012). *Catalogue of Brazilian Plants: a Transcription of George Gardner's Manuscript*. Richmond: Royal Botanic Gardens, Kew.
IBGE [INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA] (1984). *Carta Altimétrica do Município de Formosa do Rio Preto, Folha SC-23-Y-D*. Secretaria do Planejamento da Presidência da República, Brazil.
IBGE [INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA] (2011). *Evolução da Divisão Territorial do Brasil 1872–2010*. Documentos para Disseminação. Rio de Janeiro: IBGE.
IRWIN, H. S. & BARNEBY, R. C. (1982). The American Cassiinae. *Mem. New York Bot. Gard.* 35: 455–918.
IUCN (2001). *The IUCN Red List of Threatened Species*, version 2010.4. Online. Available: http://www.iucnredlist.org/ (accessed 14 May 2017)
IUCN STANDARDS AND PETITIONS SUBCOMMITTEE (2016). *Guidelines for Using the IUCN Red List Categories and Criteria*, version 12. Online. Available: http://www.iucnredlist.org/documents/RedListGuidelines.pdf (downloaded 6 May 2017).
JSTOR GLOBAL PLANTS (no date). Electronic database. Online. Available: https://plants.jstor.org/ (accessed May 2017).
KHAN, S. A. (2007). *New delimitations and phylogenetic relationships of Sabiceeae (Ixoroideae, Rubiaceae) and revision of the Neotropical species of Sabicea Aubl.* Masters dissertation, University of Bayreuth.
KLINK, C. A. & MACHADO, R. B. (2005). Conservation of Brazilian Cerrado. *Conservation Biol.* 19(3): 707–713.
KOSCHNITZKE, C. & MARTINS, A. B. (2007). Nomenclatural alterations in Microlicieae (Melastomataceae). *Novon* 17(4): 472–475.
LADLE, R. J., JEPSON, P., MALHADO, A. C. M., JENNINGS, S. & BARUA, M. (2011). The causes and biogeographical significance of species' rediscovery. *Frontiers Biogeogr.* 3(3): 111–118.
LIMA, L. C. P., QUEIROZ, L. P., TOZZI, A. M. G. A. & LEWIS, G. P. (2014). A taxonomic revision of *Desmodium* (Legumonosae – Papilionoideae) in Brazil. *Phytotaxa* 169(1): 1–119.
MAAS, P. J. M., WESTRA, L. Y. T. & CHATROU, L. W. (2003). *Duguetia. Fl. Neotrop. Monogr.* 88: 1–274.
MACE, G. M. (2004). The role of taxonomy in species conservation. *Philos. Trans. Roy. Soc. London* 359: 711–719.
MACLEISH, N. F. F. (1987). Revision of *Eremanthus* (Compositae: Vernonieae). *Ann. Missouri Bot. Gard.* 74(2): 265–290.

Martinelli, G., Messina, T. & Santos-Filho, L. (2014). *Livro Vermelho da Flora do Brasil: Plantas Raras do Cerrado*. Rio de Janeiro: Instituto de Pesquisas Jardim Botânico do Rio de Janeiro, CNCFlora.

Medeiros, D., Alves, R. J. V. & Senna-Valle, L. (2011). Rediscovery of *Croton josephinus* (Euphorbiaceae) in Minas Gerais, Brazil. *Edinburgh J. Bot.* 68(1): 33–38.

Mittermeier, R. A., Gil, P. R., Hoffman, M., Pilgrim, J., Brooks, T., Mittermeier, C. G., Lamoureux, J. & Fonseca, G. B. A. (2004). *Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*. Mexico City: Cemex.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Fonseca, G. A. B. & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.

Oliveira, A. L. R. & Bove, C. P. (2015). *Eriocaulon* L. from Brazil: an annotated checklist and taxonomic novelties. *Acta Botanica Brasil*. 29(2): 175–189.

Penedo, T. S. A., Moraes, M. A., Borges, R. A. X., Maurenza, D., Judice, D. M. & Martinelli, G. (2015). Considerations on extinct species of Brazilian flora. *Rodriguésia* 66(3): 711–715.

Pennington, T. D. (1990). Sapotaceae. *Fl. Neotrop. Monogr*. 52.

Pivello, V. R., Shida, C. N., Meirelles, S. T. (1999). Alien grasses in Brazilian savannas: a threat to the biodiversity. *Biodivers. & Conservation* 8(9): 1281–1294.

Prance, G. T. (1972). Rhabdodendraceae. *Fl. Neotrop. Monogr.* 11.

Prance, G. T. (2004). *Rhabdodendraceae*. In: Smith, N. P., Mori, S. A., Henderson, A., Stevenson, D. W. & Heald, S. V (eds) *Flowering Plants of the Neotropics*, pp. 321–322. Princeton: Princeton University Press.

Presidência da República (2015). Decreto no. 8.447/2015. Online. Available: http://www.planalto.gov.br/ccivil_03/_Ato2015-2018/2015/Decreto/D8447.htm (accessed 7 March 2016).

Proença, C. E. B., Farias-Singer, R. & Gomes, B. M. (2007). *Pleonotoma orientalis* (Bignoniaceae – Bignonieae): expanded description, distribution and a new variety of a poorly known species. *Edinburgh J. Bot.* 64(1): 17–23.

Puff, C. & Weber, A. (1976). Contributions to the morphology, anatomy and karyology of *Rhabdodendron*, and a reconsideration of the systematic position of the Rhabdodendraceae. *Plant Syst. Evol.* 125(4): 195–222.

QGIS Development Team (2016). *QGIS Geographic Information System*. Beaverton, Oregon: Open Source Geospatial Foundation Project.

Ratter, J. A., Ribeiro, J. F. & Bridgewater, S. (1997). The Brazilian cerrado vegetation and threats to its biodiversity. *Ann. Bot.* 80(3): 223–230.

Ribeiro, J. F., Walter, B. M. T. (2008). As principais fitofisionomias do bioma Cerrado. In: Sano, S. M., Almeida, S. P. & Ribeiro, J. F. (2008). *Cerrado: Ecologia e Flora*, vol. 1, pp. 153–212. Brasília: Embrapa.

Rodrigues, W. A. (1976). *Revisão taxonômica das espécies de Virola (Myristicaceae) do Brasil*. Doctoral dissertation, State University of Campinas.

Rodrigues, W. A. (2009a). Annonaceae. In: Giulietti, A. M., Rapini, A., Andrade, M. J. G., Queiroz, L.P. & Silva, J. M. C. (2009). *Plantas Raras do Brasil*, pp. 52–53. Belo Horizonte: Conservação Internacional.

Rodrigues, W. A. (2009b). Rhabdodendraceae. In: Giulietti, A. M., Rapini, A., Andrade, M. J. G., Queiroz, L. P. & Silva, J. M. C. (eds) *Plantas Raras do Brasil*, pp. 350. Belo Horizonte: Conservação Internacional.

Sampaio, M. B., Schmidt, I. B. & Figueiredo, I. B. (2008). Harvesting effects and population ecology of the Buriti palm (*Mauritia flexuosa* L.f., Arecaceae) in the Jalapão Region, Central Brazil. *Econ. Bot.* 62(2): 171–181.

Scariot, A., Cavalcanti, T. B., Sevilha, A. C., Sampaio, A. B., Silva, M. C. & Silva, G. P. (2002). *Flora e Vegetação do Entorno do Parque Estadual do Jalapão (TO)*. Brasília: Embrapa.

Scatigna, A. V., Amaral, A. G., Munhoz, C. B. R., Souza, V. C. & Simões, A. O. (2016). The rediscovery of *Philcoxia goiasensis* (Plantaginaceae): lectotypification and notes on morphology, distribution and conservation of a threatened carnivorous species from the Serra Geral de Goías, Brazil. *Kew Bull*. 71: 41–47.

Schmidt, I. B., Figueiredo, I. B. & Scariot, A. (2007). Ethnobotany and effects of harvesting on the population ecology of *Syngonanthus nitens* (Bong.) Ruhland (Eriocaulaceae), a NTFP from Jalapão region, Central Brazil. *Econ. Bot.* 61(1): 73–85.

Seplan [Secretaria do Planejamento e Meio Ambiente do Estado de Tocantins] (2003). *Plano de Manejo da Área de Proteção Ambiental do Jalapão*. Palmas: Seplan.

Seplan [Secretaria do Planejamento e Meio Ambiente do Estado de Tocantins] (2012). *Atlas do Tocantins: Subsídios ao Planejamento da Gestão Territorial*. Palmas: Seplan.

Silva, J. M. C. & Bates, J. M. (2002). Biogeographic patterns and conservation in the South America Cerrado: a tropical savanna hotspot. *BioScience* 52(3): 225–234.

Silva, M. J., Sodré, R. C. & Berry, P. E. (2015). An enigmatic species of *Croton* (Euphorbiaceae) is rediscovered after more than 100 years in Midwestern Brazil. *Phytotaxa* 221(1): 83–88.

Souza, V. C. & Giulietti, A. M. (2009). Levantamento das espécies de Scrophulariaceae *sensu lato* nativas do Brasil. *Pesq. Bot.* 60: 7–288.

Souza-Júnior, W. C. (2002). *Análise de Viabilidade Sócio-Econômico-Ambiental da Transposição de Águas da Bacia do Rio Tocantins para o Rio São Francisco na Região do Jalapão/TO*. Brasília: Conservation International do Brazil.

Stafleu, F. A. (1953). A monograph of the Vochysiaceae III: *Qualea*. *Acta Botanica Neerl.* 2(2): 144–217.

Thiers, B. (continuously updated). *Index Herbariorum: a Global Directory of Public Herbaria and Associated Staff. New York Botanical Garden's Virtual Herbarium.* Online. Available: http://sweetgum.nybg.org/ih/ (accessed 8 May 2017)

Trelease, W. (1916). *The Genus* Phoradendron. *A Monographic Revision*. Urbana, Illinois: University of Illinois.

Urban, I. (1906). Vitae itineraque collectorum botanicorum, notae collaboratum biographicae, Florae brasiliensis ratio edendi chronologica, systema, index familiarum. In: Martius, C. F. P. & Eichler, A. G. (eds) *Flora Brasiliensis*, vol. 1, part 1, pp. 239–268. Munich: C. F. P. von Martius, A. W. Eichler e I. Urban.

Wallnöfer, B. (2001). The biology and systematics of Ebenaceae: a review. *Ann. Naturhis. Mus. Wien* 103B: 485–512.

Walter, B. M. T., Cavalcanti, T. B. & Filgueiras, T. S. (2001). Coletas botânicas no Distrito Federal, Brasil. In: Cavalcanti, T. B., Ramos, A. E. (orgs) *Flora do Distrito Federal, Brasil*, vol. 1, pp. 43–56. Brasília: Embrapa Recursos Genéticos e Biotecnologia.

Received 12 July 2017; accepted for publication 24 October 2017; first published online 1 December 2017