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ECOSYSTEMS

New places for treasures of the Caatinga dry forest: the case of *Pleroma caatingae* (Melastomataceae), an unusual and threatened species

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Abstract: Melastomataceae comprises to 5,858 plant species across 173 genera globally. Brazil hosts the highest diversity for this family, including 1,453 species, with a great number of endemics. The Brazilian Caatinga is an important domain for Seasonally Dry Tropical Forests, Shrubs and Woodlands in South America, highlighting exceptional environmental diversity and hosting endemic and rare species. While the representation of Melastomataceae in the Caatinga is limited, the colonization of xeric environments by select species has garnered attention. One of these is *Pleroma caatingae*, a threatened species previously thought to be endemic to the state of Bahia, and recently collected in the Ceará state. This study provides an updated morphological description and uses a predictive Species Distribution Model (SDM) to predict potential species' distribution and conservation status. The findings not only enhance knowledge of neotropical species distribution patterns, but also highlight the importance of preserving overlooked arid habitats, such as the inselbergs, which harbor intriguing biodiversity as well.

Key words: Arid environments, Melastomateae, neotropical flora, plant conservation.

INTRODUCTION

Melastomataceae comprises approximately 5,858 species, distributed across 173 genera, making it one of the world's ten largest families of flowering plants (Ulloa et al. 2022). Brazil is the country with the greatest diversity of Melastomataceae, with 1,453 species (Ulloa et al. 2022). Among these, 929 species are endemic and largely concentrated in the 'campos rupestres' (Goldenberg et al. 2020).

Among Brazil's six phytogeographic domains, the Caatinga comprises the nucleus of Seasonally Dry Tropical Forests and Shrubs and Woodlands (SDTFSW) in South America, which mainly encompasses the Brazilian Northeast region and contains, approximately, 3,347 plant species, including 962 genera and 153 families (Silva et al. 2017, Fernandes et al. 2020). Regionally, the Caatinga has environmental heterogeneity that includes different vegetation types that are often associated with crystalline or sedimentary terrains (Fernandes et al. 2020).

Among the crystalline surfaces the inselbergs are outstanding. These environments consist of rock outcrops that harbor some endemic and rare species that have been neglected by conservation efforts. They have been target of unsustainable activities, such as mining, and which puts at risk their still poorly known flora (Carmo & Jacobi 2013, Moro et al. 2015, Silva 2016). The inselbergs are known to hold a highly distinctive flora, with overall biodiversity patterns that are usually different from the

surrounding. They are true terrestrial island environments still much in need of dedicated conservation attempts (Porembski 2007).

In the Caatinga domain, Melastomataceae are not well represented, which makes some findings interesting regarding the colonization of xeric environments by certain species of this family (Baumgratz et al. 2006, Goldenberg et al. 2012). According to Flora e Funga do Brasil (2024, constantly updated), five *Pleroma* D.Don species are considered endemic from this domain (*P. caatingae* (J.G. Freitas) P.J.F. Guimarães & Michelang, *P. fissinervium* Schrank et Mart. ex DC, *P. gardneri* (Naudin) P.J.F.Guim. & Michelang, *P. glutinosum* (Markgr.) P.J.F.Guim. & Michelang and *P. noblickii* (Wurdack) P.J.F.Guim. & Michelang.). However, only *P. caatingae* and *P. noblickii* are, in fact, associated with caatinga vegetation, being the others documented for the forests within the domain (Freitas et al. 2016).

Pleroma caatingae is a species described as unusual since it its associated with Caatinga vegetation (Freitas et al. 2013). Originally described as *Tibouchina caatingae* J.G. Freitas, this species was until now thought to be endemic from the state of Bahia, where it was collected in the municipalities of Maracás and Quijingue (Freitas et al. 2016).

Despite the international scientific community recognizing its importance, niche-modeling studies in the Caatinga are still scarce (Collevatti et al. 2015, Cavalcante et al. 2020). With climate changes associated with global warming, it is essential to understand what factors influence a species' geographic distribution and how its presence/absence impacts biodiversity (Guisan & Thuiller 2005). This understanding can aid in developing conservation measures for biologically vulnerable natural domains, such as the Caatinga, which retains only 53.4% of its native vegetation (Brasil 2016, Seddon et al. 2016).

In this context, this paper presents the first record of *Pleroma caatingae* for the Ceará state. By acquiring new morphological data, we here provide an updated species description, assess the species' geographic range, and conduct a predictive Species Distribution Model (SDM).

MATERIALS AND METHODS

Survey areas and studied species

During field expeditions in Serra de Mucuripe (03°17'58.5 "S, 40°12'56.4 "W, 526 m), in the municipality of Morrinhos, in the state of Ceará, a specimen of *Tibouchina* Aubl. was collected and subsequently identifyied it as *Tibouchina caatingae* J (Freitas et al. 2013) (Fig. 1a). The identification occurred through comparison with the original description of the species and with photos and exsiccate from the HUEFS, HURB, and SP herbaria available virtually (acronyms according to Thiers 2024, constantly updated, CRIA 2024, constantly updated). Later, specialists confirmed this identification and informed us about the recent transfer of this species to the genus *Pleroma*. The accepted name for this taxon is now *Pleroma caatingae* (J.G. Freitas) P.J.F.Guim & Michelang (Guimarães & Michelangeli 2021).

In addition, available data revealed that this species was also collected in two other areas of Ceará: Serra das Flores, in the municipality of Granja (Fig. 1b) (03°18'28.3 "S, 41°08'48.9 "W, 701 m), and in Serra de Meruoca, in the district of Santo Antônio dos Melos, Meruoca, (Fig. 1c) (03°36'58 "S, 40°23'43"W, 811 m) (Fig. 1c). The sampling and collection followed Mori et al. (1989); vouchers have been deposited in the Professor Francisco José de Abreu Matos Herbarium (HUVA), from the Universidade Estadual Vale do Acaraú (UVA), Ceará, Brazil.



Figure 1. New collection environments for *Pleroma caatingae*. a - Serra de Mucuripe, Morrinhos, Ceará, Brazil; b – Serra das Flores, Granja, Ceará, Brazil; c – Santo Antônio dos Melos, Serra da Meruoca, Ceará, Brazil.

Species Distribution Modeling

Species Distribution Modeling was used to provide a more precise overview of the distribution of *P. caatingae* in the Caatinga domain. To build the models, the Maxent algorithm (Phillips et al. 2017) was applied on R 4.3.0 (RCore Team 2016). The available distribution data was downloaded from *SpeciesLink* (CRIA 2024, constantly updated), and was later partitioned in 70% for algorithm training and 30% for model testing. The data was carefully curate, only original occurrences were used to build this model, and the identification of the species was further checked. The climate data used as the source was the 1970-2000 data with 30 arc seconds, available on Worldclimm 2.1 (www.worldclimm.org) (Fick & Hijmans 2017), where 19 bioclimatic variables were used.

These variables were cropped to fit the coordinates of the Caatinga (latitude -20, 0; longitude -50, -34). To remove the colinearity between predictors, the function 'removeColinearity' from the package VirtualSpecies (Leroy et al. 2016) was applied. The models were built on the package 'DISMO'

(Hijmans 2012). Model quality was confirmed by the corrected cAUC (Hijmans 2012) and True Skill Statistics (TSS) (Allouche et al. 2006). Raw data is available at https://github.com/rcgoliveira/pleroma.

Conservation status under IUCN criteria

The protocol implemented on the 'ConR' (Dauby et al. 2017) package was used to access the conservation status for the species (IUCN 2001), based on the number of known occurrence points, the expected Area of Occupancy (AOO), and the Extent of Occurrence (EOO). We further discussed the classification, considering the SDM and the known conditions for the new areas.

RESULTS AND DISCUSSION

Here, an updated description of *P. caatingae* is provided based on the morphological data obtained from the new collections. The species was previously confirmed to occur only in the state of Bahia (Freitas et al. 2013). However, with the discovery of new populations of *P. caatingae* located almost 1500 km away from the type locality, the species can now be considered endemic to the Brazilian Northeast, according to Flora e Funga do Brasil (2024, constantly updated).

Taxonomic Notes

Pleroma caatingae (J.G. Freitas) P.J.F.Guim. & Michelang, Phytotaxa. 480: 94-96 (2021) Type: Brazil. Bahia: Maracás, 13°28'19"S, 40°24'29"W, 850 m, 18 May 2002, *G.E.L. Macedo, M.M.S. Castro, D.S. Carneiro-Torres & L.O. Senra* 23 (holotype: HUEFS 186525; isotype: HUESB) (Fig. 2).

Shrubs, (0.5)1-2 m tall. Young branches tetrahedral, the mature ones cylindrical, strigose, rarely glabrous, wingless, brown to gray. Leaves opposite, petiolate, approx. 0.5-2(3.5) cm long, crowded at the apex of branches; leaf blades (2)3-7 × (1)2-4 cm, elliptic to ovate, apex acuminate, base obtuse to subcordate, margin entire, coriaceous, discolorous; adaxial surface strigose and abaxial surface sericeous, 5-nerved, with prominent veins on the abaxial surface. Inflorescences thyrsoid, terminal, congested, or slightly branched, (1.5) 2-7 cm long. Flowers with pedicels about 0.2-0.9 cm long; bracteoles in pairs, 0.5-1.2 × 0.3-0.5 cm, elliptic to lanceolate, sericeous; hypanthia about 0.6-1.5 × 0.3-0.5 cm, oblong, sericeous. Calyx lobes deciduous, 0.6-0.8 × 0.1-0.2 cm, greenish-violet, apex acute, base irregular, margins entire, ciliate; corolla 5-merous, 1.6-2 × 1-1.5 cm, purple, glabrous, margins ciliate, sometimes with glandular trichomes; ten subisomorphic stamens, with glabrous connectives, about 0.2-0.4 cm long, prolonged at the basis of the anthers; anthers 0.8-1.5 cm long, lilac. Capsules about 0.5-1.2 × 0.3-0.5 cm, sericeous, with simple trichomes. Seed about 0.07-0.1 cm long, cochleate.

Specimens examined.- Brazil. Bahia: Castro Alves, Serra da Jibóia, 31 Aug 2021, *L.Y.S. Aona et al* 6075 (HURB 26552); Maracás, 02 Jun 1993, *L.P. Queiroz* 3284 (HUEFS 13648); 19 Jul 2012, *E. Melo et al* 11370 (HUEFS 186638); Quijingue, 15 May 2005, *D. Cardoso* 533 (HUEFS 95620). Ceará: Morrinhos, Serra de Mucuripe, 06 May 2022, *E.B. Souza et al* 6396 (HUVA 25222); Granja, Serra das Flores, 15 Jan 2022, E.B. *Souza et al* 6214 (HUVA 25223); Meruoca, Distrito Santo Antônio dos Melos, 08 Mar 2018, *E.B. Souza et al* 4979 (HUVA 22978).

Pleroma caatingae resembles *Pleroma noblickii* and *P. litophilum* in its habit, leaf distribution on the branches and colors of the petals and stamens. However, the distinctive characteristics of *P. caatingae* are the larger leaves (3-7 × 2-4 cm *vs* 1,5–2,8 × 0,8–1,8 cm in *P. noblickii* and 1,5–3,5 × 0,9–1,6 cm in *P. lithophilum*), a more congested inflorescence, oblong hypanthium, and glabrous connectives of the stamens (Freitas et al. 2013).

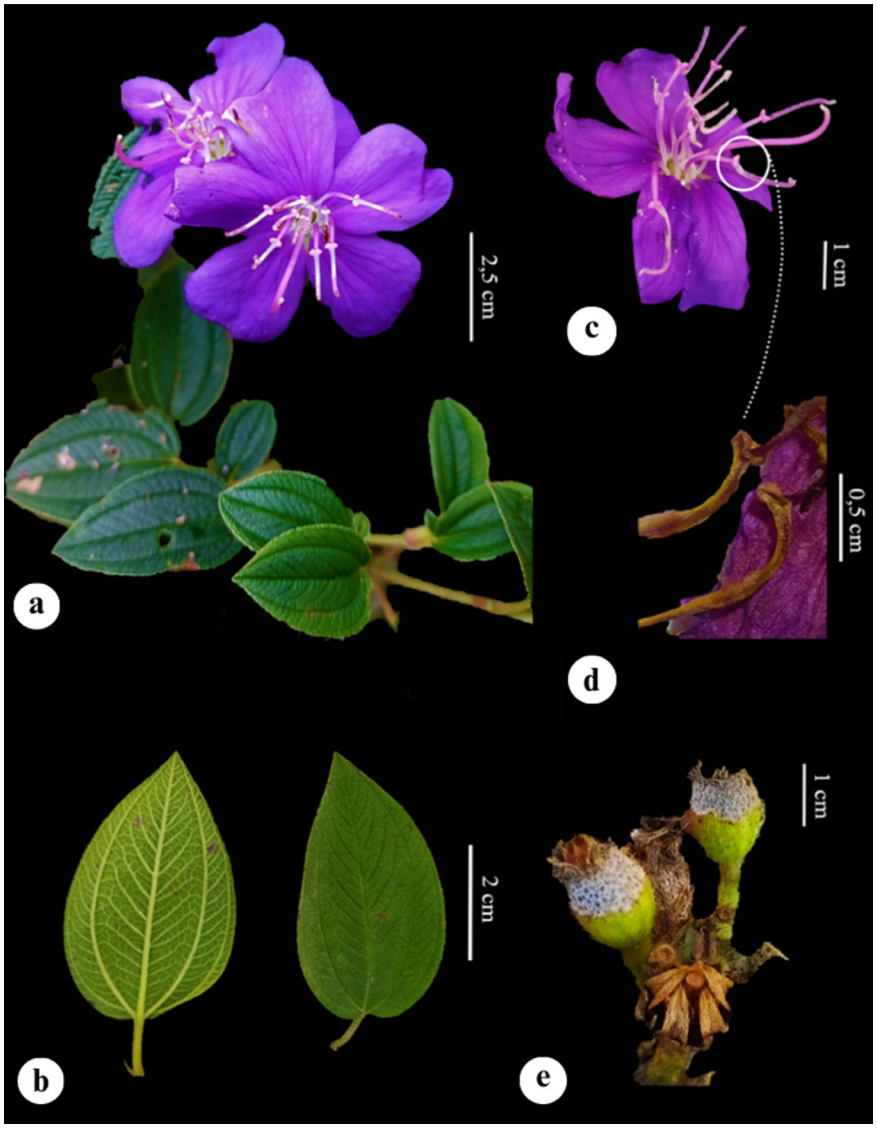


Figure 2. Morphology of *Pleroma caatingae*. a – habit; b – leaves (adaxial and abaxial surfaces); c – corolla; d – glabrous connective; e – fruits.

The specimens from Ceará exhib variation in height values (reaching up to 2 meters *vs* 1.5 meters from the original description), petiole length (up to 3.5 cm in some individuals *vs* 1–1,5 cm in the original description), leaf blades (individuals with a length of 2 cm by 1 cm width *vs* 5–7 × 3–4 cm), and inflorescences (starting from 1.5 cm in some individuals *vs* 2–7 cm). Additionally, the stem are glabrous in some specimens. Reproductive characteristics, however, did not show significant difference based on fertile individuals collected observed from January to June.

Geographic distribution and ecology

The distribution of *P. caatingae* remains restricted to areas of Caatinga, environments generally uncommon for species of Melastomataceae (Baumgratz et al. 2006). It is emphasized that the vegetation types of the collection sites in Ceará are similar to those where the species was initially collected: caatinga vegetation associated with rocky outcrops, between 500-820 meters (Freitas et al. 2013).

The populations of *P. caatingae* in Serra do Mucuripe can be found both on the plateau (above 500 meters) and at the foot of the

mountain (above 300 meters), always associated with rock outcrops. In both Serra das Flores and Serra da Meruoca, only one individual had been found in a single location within the two areas, both on the ascent to the plateau, in a transition area between humid forest and rocky Caatinga, under high insolation. The Serra do Mucuripe and Flores have quartzite as their geological material, while Serra da Meruoca has granitic substrates (Radambrasil 1981) and in all of them *P. caatingae* tends to be associated with the same plant species, such as *Dyckia spectabilis* (Mart. ex Schult. & Schult.f.) Baker and *Pilosocereus* sp. (Freitas et al. 2013).

In addition to the known distribution of the species, the Species Distribution Model (SMD) revealed that suitable conditions for the occurrence of *P. caatingae* are similar to areas of rocky outcrops at high elevations (above 500 meters), such as those in the Chapada Diamantina in Bahia, where the species was first described, and in rocky outcrops of crystalline massifs in Ceará, where this species has been recently collected. Similar conditions were also predicted for the Borborema Plateau, between the states of Paraíba and Pernambuco, however no record of this species is known for the area so far (Fig. 3).

Although the SDM was built using the only available occurrence data, the model was of good quality (cAUC 0.862, TSS 0.396) and reveals that this species tends to occur in ecotonal areas with elevation, such as the original area next to the Atlantic Forest in Bahia, Pernambuco and Paraíba, as well as in high-elevation areas near forest in Ceará, although elevation explains about to only 4% of the models. The most important variables, and those that most

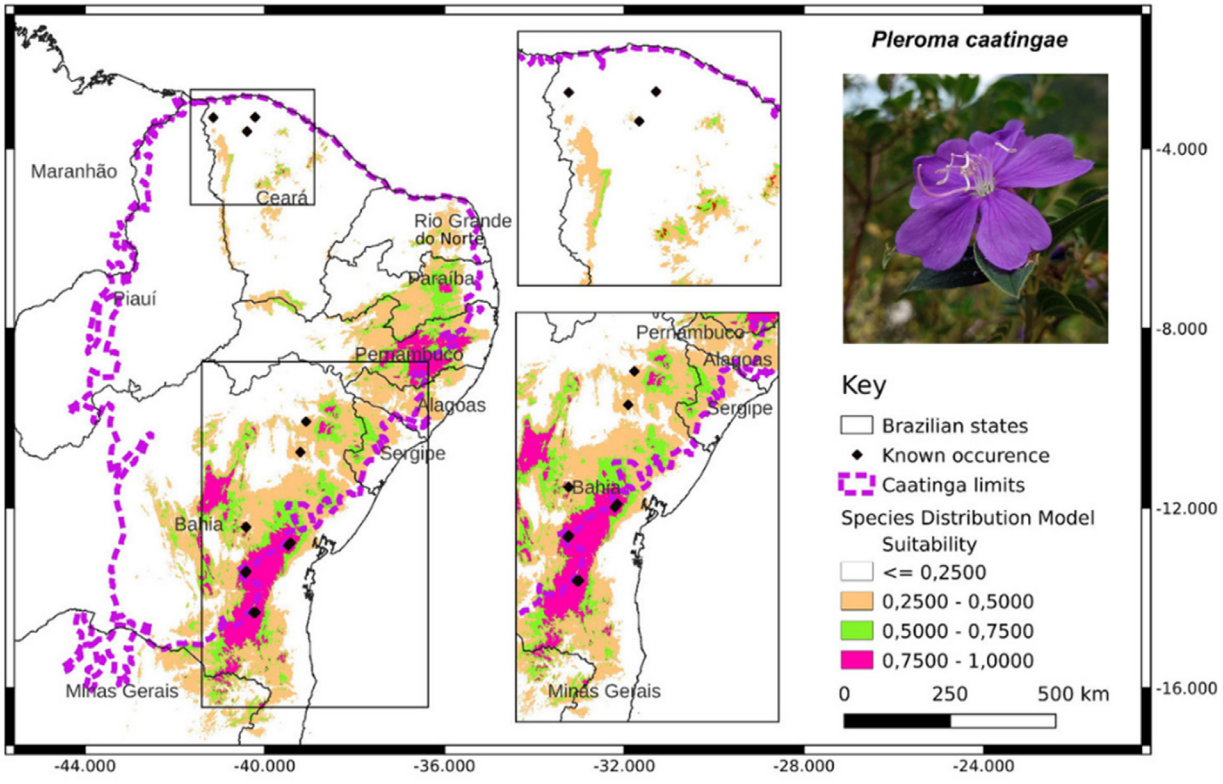


Figure 3. ***Pleroma caatingae*** **distribution model generated through MaxEnt. The colors pink and green represent higher environmental suitability, while the other colors represent lower suitability for the species.**

contributed to the models were temperature seasonality (collinear with Temperature Annual Range) and mean annual precipitation, which are features expected to limit the distribution of Caatinga species.

There has been considerable discussion about the origin and distribution of forest refuges within the Caatinga domain, known as 'brejos de altitude', which were already treated as relicts of a continuous flora between the coastal Atlantic Forest in Pernambuco and the Amazon (Andrade-Lima 1982). Whereas, flora comparisons do not support this distribution, but rather correlates with areas such as the Serra de Baturité, on Ceará, to Amazon forests, and areas on the Borborema Plateau to the Pernambuco Coastal Forests (Santos et al. 2007).

The presence of *P. caatingae* in the state of Ceará, distant from its previously known distribution in the Caatinga, probably reflects the limited collection efforts in these environments because of accessibility challenges. Additionally, the absence of this species in the Borborema Plateau may also reflect insufficient collection efforts, as the genus is strongly associated with niche conservatism, which is the ability to maintain its ancestral ecological traits (Crisp et al. 2009, Michelangeli et al. 2013). However, it can also be due to other conditions, such as soil or interspecific competition. Further investigation in the area is expected to clarify this issue.

The climatic fluctuations of the Pleistocene contributed to speciation events and adaptive radiation related to habitat fragmentation (Collevatti et al. 2012). In a study with the *Pleroma pereirae* (Brade & Markgr.) P.J.F.Guim. & Michelang species complex, Freitas (2017) described that its diversification occurred during drier climates and after the Last Maximum Glaciation (LMG), with high portions of Cadeia do Espinhaço serving as refuges for flora adapted to open ecosystems during interglacial periods.

Species such as *P. caatingae*, along with other members of the Melastomateae tribe, emerged through these mechanisms and have constrained themselves to high-elevation open environments due to their limited ability for long-distance dispersal while adjusting to soil scarcity on rocky outcroppings in those regions (Clausing & Renner 2001, Silveira et al. 2016). These aspects reinforce the strategies developed by plant species to sustain their populations in arid and semi-arid environments (Lebrija-Trejos et al. 2010).

According to Flora e Funga do Brasil (2024, constantly updated), the only two *Pleroma* species with confirmed occurrence for Ceará are *P. gardneri* and *P. heteromallum* D.Don. Both species are endemic of Brazil and, within the state, are associated with relicts of humid forests of the Serra do Baturité, Maranguape and Guaramiranga and Araripe and Ibiapaba plateau (CRIA 2024, constantly updated), which is a common observation for the few Melastomataceae found in regions where the Caatinga *stricto sensu* predominates (Goldenberg et al. 2012).

Conservation status

Freitas et al. (2013), based on the IUCN criteria, classified the species as "endangered" (in the EN B2-a category), since it had collected in two fragmented areas subjected to anthropogenic actions such as burning of vegetation for the establishment of pastures. We here note that it is still valid to propose a conservation status as "endangered", since the Serra do Mucuripe and Serra das Flores are under pressure from mining and energy companies, respectively, and the Serra da Meruoca has suffered from the expansion of real estate market activities.

By using the IUCN criteria implemented on ConR, based on the AOO (44 km²) and the EOO (90,487 km²), the species should be categorized

as "vulnerable" [VU B2-ac(i,ii)]. However, considering the aforementioned conditions for the new occurrence areas allied to a scattered predicted distribution, our "vulnerable" ranking is changed to VU D1 since this species may not be experiencing a decline in population size overall, but a sharp reduction in the number of mature individuals. This makes them especially vulnerable to random events and various threats (IUCN 2001).

It is important to note that a Conservation Unit protects only one of the areas where the species was collected. The Serra da Meruoca Environmental Protection Area, classified as Sustainable Use, despite being protected by law, continues to face challenges from real estate speculation, as previously mentioned (Mendes et al. 2019). Otherwise, the Serra das Flores area, also in Ceará, is in the process integration into the Carnaúbas State Park (PEC), where it will be transformed into the Serra das Flores State Park, maintaining its category and expanding its boundaries by about 3,000 hectares (Ceará 2023). The objective is to honor its classification as a Montane Ecological Refuge, with an extreme biological importance (Giulietti et al. 2002).

The Wallacean shortfall (Bini et al. 2006) regards the lack of knowledge about the distribution of the species. Studies like this reveal that, although knowledge about the Brazilian flora has increased significantly in recent years, there are still gaps regarding the distribution of these species and their environment. The case of *P. caatingae* provides scope for studies that seek to understand the dynamics of its populations (Soriano-Redondo et al. 2019) and, consequently, for the development of conservation projects (Elith & Leathwick 2009).

The information presented here will provide further knowledge available for other initiatives, such as the projects "Flora of Ceará: conhecer para conservar" (Loiola et al. 2020) and "Flora e Funga do Brasil" (BFG 2021), and will complement what is already known about the distribution of the family Melastomataceae within the Caatinga domain. The most arid and representative environments of the Caatinga, which include the inselbergs, are underestimated in terms of their biodiversity, which, in turn, is full of interesting novelties (Fabricante et al. 2010, Rabarimanarivo et al. 2019).

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LUÍS HENRIQUE X. PORTELA, JULIANA GOMES FREITAS and ELNATAN B. DE SOUZA led the fieldwork and conducted the taxonomic descriptions. RODRIGO CÉSAR GONÇALVES-OLIVEIRA built the SDM and analyzed the statistical data. All authors participated in the writing.

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