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Inventory

Selaginella P.Beauv. (Selaginellaceae) in the state of Maranhão, northeastern, Brazil: A floristic survey and a new record for the Cerrado domain

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Abstract: This work is a floristic study of *Selaginella* in Maranhão. The species survey is based on collections from fieldwork conducted between April 2006 and February 2023 and specimens from Maranhão deposited at the CCAA, HBRA, MG, and SLUI herbaria. Ten species were identified: *Selaginella conduplicata, S. convoluta, S. erythropus, S. flagellata, S. gynostachya S. marginata, S. minima, S. radiata, S. simplex,* and *S. sulcata.* We report the first record of *S. gynostachya* for Maranhão and the Cerrado domain in Brazil. Until now, this species was only known from areas of Amazonia. We provide a map with records, an identification key, and comments about the identification and geographic distribution of *Selaginella* species in Maranhão state. For the new record, we also provide photos.
Keywords: *floristics; gallery forest; lycophyte; Northeastern Brazil.*

Selaginella P.Beauv. (Selaginellaceae) no estado do Maranhão, nordeste, Brasil: Levantamento florístico e novo registro para o domínio Cerrado

Resumo: O presente trabalho trata do estudo florístico de *Selaginella* no Maranhão. O levantamento de espécies foi realizado com base em coletas de campo realizadas entre abril de 2006 e fevereiro de 2023 e em análise de espécimes coletados no Maranhão e depositadas nos herbários CCAA, HBRA, MG e SLUI. Foram identificadas 10 espécies: *Selaginella conduplicata, S. convoluta, S. erythropus, S. flagellata, S. gynostachya S. marginata, S. minima, S. radiata, S. simplex* e *S. sulcata.* Relatamos a primeira ocorrência de *S. gynostachya* para o Maranhão e também para o domínio do Cerrado Brasileiro. Até então essa espécie era registrada somente em áreas amazônicas. Neste artigo apresentamos um mapa com pontos de coleta, uma chave de identificação e comentários sobre a identificação, ecologia e distribuição geográfica para as espécies de *Selaginella* do Maranhão. Para o novo registro apresentamos também fotos.
Palavras-chave: *Florística; Licófitas; Mata de galeria; Nordeste do Brasil.*

Introduction

Selaginella P.Beauv. is the most speciose genus in the class Lycopodiopsida (lycophytes). It is estimated that there are approximately 700 species of *Selaginella*; the only genus in Selaginellaceae Wilk., which has a cosmopolitan distribution (PPGI 2016). However, the highest diversity of species is mostly found in the tropics (Jermy 1990, Valdespino 1993, Fraile et al. 1995).

In Brazil, *Selaginella* is represented by 97 species distributed in all phytogeographic domains, and with 38 species endemic to the country

(Góes-Neto et al. 2023). Most of the diversity of the genus in Brazil is in the Amazonia (53 spp.) and the Cerrado domains (11 spp.) (Góes-Neto et al. 2023). The Brazilian Cerrado is notoriously under-collected for all groups of plants, including those in protected areas. For Maranhão, recent studies have increased the number of known *Selaginella* from five (Góes-Neto et al. 2023) to nine species, most of which occur in the Cerrado (Almeida et al. 2020, Fernandes et al. 2022).

Studies about the genus in Brazil have mainly been concentrated on the Atlantic Forest and Amazonia (Bautista 1974a, b, Castellani & Freitas 1992, Hirai & Prado 2000, Prado & Freitas 2005, Prado & Hirai 2008, Heringer et al. 2016, Valdespino 2015a, b, Valdespino et al. 2015, Valdespino et al. 2018a, b, Valdespino 2020). Nevertheless, records from the Cerrado vegetation have been reported in the flora of the Distrito Federal (Hirai 2007), Minas Gerais (Heringer et al. 2016), and recent inventories in Maranhão (Almeida et al. 2020, Fernandes et al. 2022).

Selaginella is a taxonomically complex genus with many polymorphic species (Webster 1992). Additionally, there are some problems with the identification and classification of *Selaginella* species because they mainly are based on observations of herbarium specimens (Setyawan 2011). Alston et al. (1981) provided the last revision of *Selaginella* for tropical South America, including a key, synonymy, exsiccate, and taxa distribution. This work, however, does not include species descriptions, except for new taxa. Generally, the works used to identify neotropical *Selaginella* species are original descriptions and floras (Alston et al. 1981, Jermy 1990, Webster 1992, Valdespino 1992, Cremers & Boudrie 2007, Zhou & Zhang 2015, Heringer et al. 2016, Valdespino 2015a, b, Valdespino et al. 2015, Valdespino et al. 2018a, b, Valdespino 2020, Valdespino et al. 2022a, b, Góes-Neto et al. 2023). The infrageneric circumscription proposed by Jermy (1986, 1990) is widely accepted. In this, the author recognizes five subgenera: *Selaginella* P.Beauv., *Ericetorum* Jermy, and *Tetragonostachys* Jermy, comprising isophyllous species, and *Stachygynandrum* (P.Beauv.) Baker, and *Heterostachys* Baker including anisophyllous species. *Selaginella* P.Beauv., *Ericetorum* Jermy, *Tetragonostachys* Jermy, *Stachygynandrum* (P.Beauv.) Baker, and *Heterostachys* Baker. Of these, the species in the first three are isophyllous and those in the last two are anisophyllous. Nevertheless, recent classifications proposed by Zhou & Zhang (2015) and Weststrand & Korall (2016) based on molecular phylogenetic studies suggest that some of the subgenera recognized by Jermy (1986, 1990) are not monophyletic. Nonetheless, these classifications differ in the number and circumscription of proposed subgenera. Zhou & Zhang (2015) classified the genus *Selaginella* into six subgenera (i.e., *Selaginella*, *Boreoselaginella*, *Pulviniella*, *Ericetorum*, *Heterostachys*, and *Stachygynandrum*), while Weststrand & Korall (2016) recognized seven (i.e., *Selaginella*, *Rupestrae*, *Lepidophyllae*, *Gymnogynum*, *Exaltatae*, *Ericetorum*, and *Stachygynandrum*). As a result, no agreement as to the infrageneric circumscription of the *Selaginella* exists and still there is a need for a comprehensive taxonomic revision of the genus, including an improved delimitation of species complexes.

The main taxonomic characters used to distinguish *Selaginella* from other lycophytes include the presence of rhizophores, microphylls with ligules at the base, heterospory, and reniform sporangia located adaxially (Jermy 1986, 1990, Webster 1992). In addition, *Selaginella* is ecologically well-adapted to inhabit various environments, such as humid tropical forests, deserts, and temperate forests. Furthermore, species of the genus can be terrestrial, rupicolous, and occasionally also epiphytic (Jermy 1990, Zhou & Zhang 2015, Heringer et al. 2016, Weststrand & Korall 2016).

The objective of this work is to provide a list of the *Selaginella* species occurring in the state of Maranhão, and to newly document the occurrence of a species previously undocumented for the Cerrado domain in Brazil for which a corresponding illustration. Furthermore, a key to identify currently known *Selaginella* species as occurring in the state of Maranhão is provided, as well as a distribution map for each of these taxa. Furthermore, under each species we provide comments related to habitat and distribution, as well as morphological characters to help identify them.

Material and Methods

Maranhão has a tropical, rainy climate (Alvares et al. 2013), average annual temperature between 25 and 26° C, average annual precipitation between 1400 and 1800 mm and is one of the states in northeastern Brazil with the lowest hydric deficit (Martins & Oliveira 2011). The dry period lasts five or six months (July to November or December), when the hydric deficit is 150–300 mm, and the rainy period also lasts five or six months (January to May or June) and is most intense between February and March (IMESC 2021).

Maranhão is an extremely relevant State in terms of biodiversity, housing three different phytogeographic domains, as well as transition areas between them, such as: Amazonia, occupying around 35% of the area of the state territory; Cerrado, around 64%; and Caatinga, around 1%. Furthermore, Maranhão has a large coastal region (around 640 km), also comprising floral elements characteristic of coastal zones, as well as transition zones towards the interior, between this large coastal region, and its continental phytogeographic domains, making the State ecosystems even more interesting and complex (Ab'Saber 2002, Rebêlo et al. 2003, Almeida & Vieira 2010, Spinelli-Araujo et al. 2016, Koerber et al. 2022, Vieira et al. 2023). Areas with *cocais* vegetation in Maranhão (where *Attalea speciosa* Mart. ex Spreng., the *babaçu* palm, is predominant) are locations modified by humans (Oren 1988, Santos-Filho et al. 2013).

The Amazonian region of Maranhão is part of the Belém Center of Endemism, with an area of 243,000 km^2, limited the Tocantins River to the west and the Pindaré River to the east. Less than a third of the forests in the Belém Center of Endemism are preserved, making it the most threatened area of endemism in Brazilian Amazon (Silva et al. 2005, Almeida & Viera 2010). The Cerrado in Maranhão is one of the most threatened areas in Brazil due to increased agricultural practices in the last decades, especially the cultivation of soybeans, corn and cotton (EMBRAPA, 2023). According to Castro & Martins (1999), Maranhão has the largest area of Cerrado in the Northeastern Brazil (328,366 km^2), corresponding to around 60% of the Cerrado in this region. Around 50% of the Brazilian Cerrado has been lost and what remains is becoming increasingly fragmented (Rodrigues et al. 2022).

This study is based on an analysis of material deposited in the CCAA, EAC, HBRA, MG, and SLUI herbaria (acronyms according to Thiers 2023) and field expeditions made between April 2006 and February 2023. The fieldwork was mainly conducted in the following protected areas and surroundings in Maranhão: Área de Proteção Ambiental Inhamum, Reserva Biológica do Gurupi, Parque Nacional Chapada das Mesas, Parque Estadual do Mirador, Reserva Extrativista

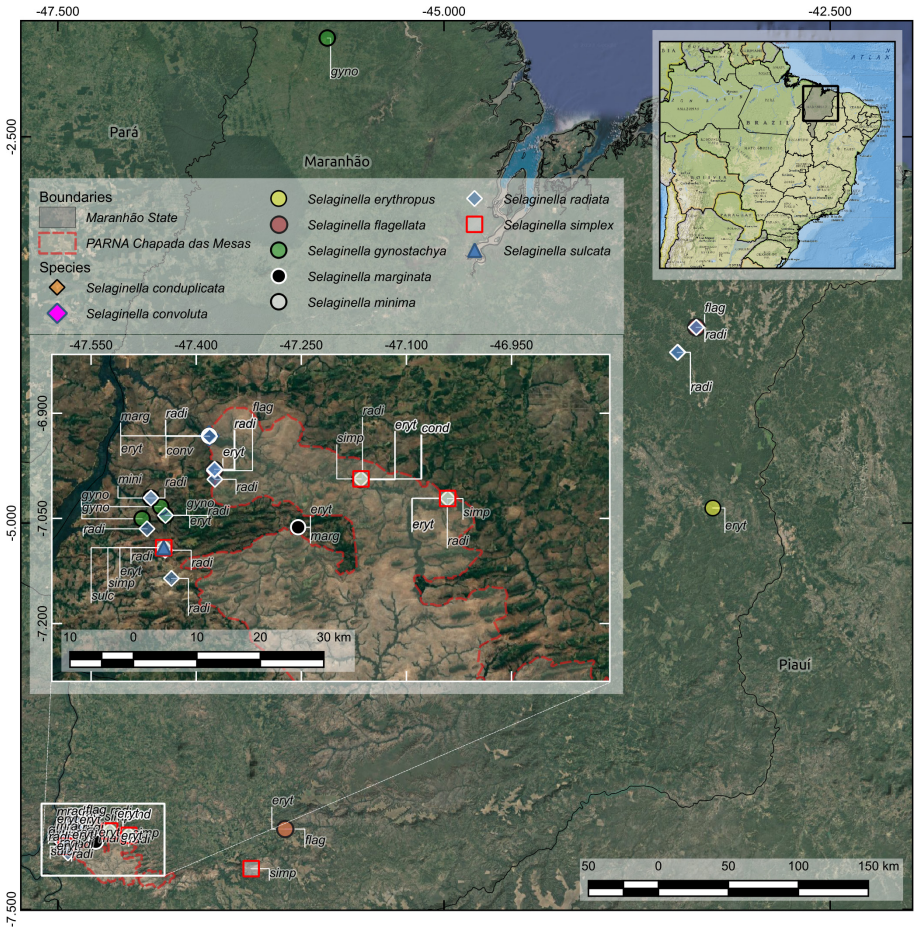

Figure 1. Map of the study area showing the sample sites of *Selaginella* in Maranhão and highlighting Chapada das Mesas National Park.

Chapada Limpa, and Área de Relevante Interesse Ecológico Itamacaoca (Figure 1).

The identification and distribution of the species were based on online databases and specialized literature, such as IPNI (2023), the Flora e Funga do Brasil 2023 monographs, and revisions and regional floras (e.g., Alston et al. 1981, Tryon & Stolze 1994, Moran & Riba 1995, Mickel et al. 2004, Hirai & Prado 2000, Cremers & Boudrie 2007, and Heringer et al. 2016). The terminology follows Lellinger (2002). The family delimitations are based on PPG I (2016). The nomenclature and authors of the species follow the International Plant Names Index (IPNI 2023).

Results

Ten species of *Selaginella* were identified to occur in Maranhão: *Selaginella conduplicata* Spring, *S. convoluta* (Arn.) Spring, *S. erythropus* (Mart.) Spring, *S. flagellata* Spring, *S. gynostachya* Valdespino, *S. marginata* (Humb. & Bonpl. ex Willd.) Spring, *S. minima* Spring, *S. radiata* (Aubl.) Spring, *S. simplex* Baker, and *S. sulcata* (Desv. ex Poir.) Spring ex Mart. Of these, *S. gynostachya* is a new record for Maranhão and the Brazilian Cerrado (Flora e Funga do Brasil 2023). The key below to identify species in Maranhão is based on material here studied and documented, followed by corresponding taxon information.

Identification key to the *Selaginella* species in Maranhão

1. Stem articulate; rhizophores dorsal; dorsal microphylls always auriculate, with one or two auricles.....2
1'. Stem not articulate; rhizophores ventral, axillary, lateral, or rarely dorsal; dorsal microphylls not auriculate or rarely auriculate.....4
2. Dorsal microphylls basifixed ..... ***S. conduplicata***
2'. Dorsal microphylls peltate.....3
3. Axillary microphylls peltate, base with a long auricle that is usually fimbriate or ciliate; lateral microphylls peltate, with a long auricle on the acroscopic portion ..... ***S. marginata***
3'. Axillary microphylls basifixed, base with two denticulate to short-ciliate auricles; lateral microphylls basifixed, with two auricles, the acroscopic auricle more developed, the basiscopic auricle short ..... ***S. sulcata***
4. Stem erect, forming a rosette.....…..... ***S. convoluta***
4'. Stem prostrate, ascendent, decumbent, suberect or erect, not forming a rosette.....5
5. Stem of adult individuals red, reddish or pink, at least at the base until immediately above the first branch.....***S. erythropus***
5'. Stem of adult individuals green, stramineous, or brown.....6

6. Abaxial and adaxial microphyll surfaces conspicuously bicolor; axillary microphylls lanceolate; dorsal microphylls long-aristate .....***S. radiata***

6'. Abaxial and adaxial microphyll surfaces conspicuously concolorous; axillary microphylls ovate-lanceolate to oblong, oblong-ovate to ovate-elliptic or ovate to widely ovate; dorsal microphylls acute, short- to long-acuminate.....7

7. Stem prostrate; lateral microphylls with a truncate base; axillary microphylls with a cordate base.....***S. gynostachya***

7'. Stem erect, ascendent to suberect; lateral microphylls with a rounded to subcordate base; axillary microphylls with a rounded base 8

8. Stem with flagelliform apex; dorsal microphylls with a long-aristate apex.....***S. flagellata***

8'. Stem without a flagelliform apex; dorsal microphylls with an acute, acuminate, or long-acuminate apex.....9

9. Lateral microphylls long-ciliate in the 1/2(–1/3) basal portion; axillary microphylls ciliate in the 1/3 basal portion, serrate to serrulate towards the apex….....***S. minima***

9'. Lateral microphylls denticulate in the lower 1/3, serrulate in the upper 2/3; axillary microphylls sparsely serrulate …….....……..…... ***S. simplex***

Selaginella conduplicata Spring

Specimens examined: BRAZIL, MARANHÃO, **Carolina**, PARNA Chapada das Mesas, Cachoeira do Prata, rio Farinha (bacia do rio Tocantins), ca. 6°59'37"S, 47°09'57"W, 197 m, 06 June 2018, Almeida, F.C.; Silva, J.A.S.; Oliveira, L. & Ottoni, F. 03 (CCAA); idem. ca. 6°59'36,9"S, 47°9'58,5"W, 198 m, 12 March 2017, Silva, L.R. & Pietrobom, M.R. 43 (CCAA); idem. Silva, L.R. & Pietrobom, M.R. 40 (CCAA); idem. ca. 6°59'37,4"S, 47°09'58,0"W, 194 m, 29 October 2017, Silva, L.R. & Almeida, F.C. 84 (CCAA); idem. Estreito, PARNA Chapada das Mesas, Cachoeira do Prata, margem direita do rio Farinha, ca. 6°59'36,7"S, 47°9'53,1"W, 210 m, 06 June 2018, Almeida, F.C.; Silva, J.A.S.; Oliveira, L. & Ottoni, F. 29 (CCAA/HBRA).

Identification. *Selaginella conduplicata* is characterized by the biauriculate lateral microphylls with a denticulate margin, generally more developed acroscopic auricle that overlap the stem and curves downward, and short, less evident, denticulate, basiscopic auricle, as well as the axillary microphylls with a biauriculate base and two, long, denticulate auricles that are generally unequal in size.

Habitat and distribution. Colombia, Venezuela, Guyana, Suriname, French Guiana, Peru, and Brazil (Acre, Amapá, Amazonas, Maranhão, Mato Grosso, Pará, Pernambuco, and Roraima). In the study area, it grows in gallery forests with rocky outcrops.

Selaginella convoluta (Arn.) Spring

Specimens examined: BRAZIL, MARANHÃO, **Carolina**, PARNA Chapada das Mesas, Cachoeira do Porão, ca. 06°55'55,6"S, 047°22'53,6"W, 174 m, 04 February 2020, Oliveira, S.S. & Pietrobom, M.R. 31 (CCAA/HBRA). **Grajaú**, estrada para a cachoeira do Viriato, córrego com leito rochoso, 05°50'32"S, 46°07'36"W, 10 February 2023, A.W.C. Ferreira 1047 & D. O. Costa (SLUI).

Identification. *Selaginella convoluta* is mainly characterized by the rosette stem and very curled dry branches. Additionally, the lateral microphylls have a whitish acroscopic margin, which is generally fimbriate or ciliate throughout, and an acute, acuminate, or apiculate apex; microphylls have obscure idioblasts in the upper surfaces and, no stomata, and an acute to acuminate apex.

Habitat and distribution. Mexico, Guatemala, Honduras, Nicaragua, Cuba, Haiti, Dominican Republic, Colombia, Venezuela, Guyana, French Guiana, Peru, Brazil (Alagoas, Bahia, Ceará, Espírito Santo, Goiás, Mato Grosso do Sul, Maranhão, Minas Gerais, Paraíba, Paraná, Pernambuco, Piauí, Rio Grande do Norte, Rio de Janeiro, São Paulo, and Sergipe), Bolivia, Paraguay and Argentina. In the study area, this species grows in open gallery forests, on rocks, mainly in xeric environments exposed to the sun.

Selaginella erythropus (Mart.) Spring

Specimens examined: BRAZIL, MARANHÃO, **Carolina**, Resort da Pedra Caída, Cachoeira do Santuário Ecológico, ca. 07°02'44,2"S, 047°26'38,0"W, 128 m, 07 February 2020, Oliveira, S.S. & Pietrobom, M.R. 160 (CCAA); idem. Oliveira, S.S. & Pietrobom, M.R. 164 (CCAA/HBRA); idem. Oliveira, S.S. & Pietrobom, M.R 156 (CCAA/HBRA); idem. Topo do Morro do Dôdo, ca. 07°05'30,1"S, 047°26'46,8"W, 389 m, 06 February 2020, Oliveira, S.S. & Pietrobom, M.R. 130a (CCAA/HBRA); idem. PARNA Chapada das Mesas, Passagem da dona Lena, ca 07°03'45,1"S, 047°15'16,2"W, 230 m, 05 February 2020, Oliveira, S.S. & Pietrobom, M.R. 85 (CCAA); idem. Próximo a Cachoeira do Siduca, ca. 06°58'54,1"S, 047°22'26,8"W, 241 m, 04 February 2020, Oliveira, S.S. & Pietrobom, M.R. 43 (CCAA); idem. Cachoeira do Porão, ca. 06°55'55,6"S, 047°22'53,6"W, 174 m, 04 February 2020, Oliveira, S.S. & Pietrobom, M.R. 33 (CCAA); idem. Cachoeira do Prata, rio Farinha, ca. 6°59'37,4"S, 47°09'58,0"W, 194 m, 29 October 2017, Silva, L.R. & Almeida, F.C. 91 (CCAA); idem. Silva, L.R. & Almeida, F.C. 90 (CCAA); idem. Silva, L.R. & Almeida, F.C. 100 (CCAA); idem. ca. 6°59'36,9"S, 47°9'58,5"W, 198 m, 12 March 2017, Silva, L.R. & Pietrobom, M.R. 39 (CCAA); idem. ca. 6°59'37"S, 47°09'57"W, 197 m, 06 June 2018, Almeida, F.C.; Silva, J.A.S.; Oliveira, L. & Ottoni, F. 08 (CCAA); idem. Almeida, F.C.; Silva, J.A.S.; Oliveira, L. & Ottoni, F. 14 (CCAA); idem. Almeida, F.C.; Silva, J.A.S.; Oliveira, L. & Ottoni, F. 09 (CCAA); idem. ca. 6°59'41,3"S, 47°9'57,4"W, 213 m, 12 March 2017, Silva, L.R. & Pietrobom, M.R. 37 (CCAA); idem. Cachoeira da Ponta da Serra, riacho Lajes, ca. 6°58'47,4"S, 47°22'25"W, 235 m, 11 October 2017, Silva, L.R. & Pietrobom, M.R. 24 (CCAA); idem. Silva, L.R. & Pietrobom, M.R. 29 (CCAA); idem. Cachoeira São Romão, rio Farinha, ca. 7°01'15,4"S, 47°02'28,2"W, 241 m, 31 October 2017, Silva, L.R. & Almeida, F.C. 183 (CCAA); idem. ca. 7°01'17,1"S, 47°02'27,1"W, 256 m, 07 June 2018, Almeida, F.C.; Silva, J.A.S.; Oliveira, L. & Ottoni, F. 65 (CCAA); idem. Estreito, PARNA Chapada das Mesas, Cachoeira do Prata, margem direita do rio Farinha, ca. 6°59'36,7"S, 47°9'53,1"W, 210 m, 06 June 2018, Almeida, F.C.; Silva, J.A.S.; Oliveira, L. & Ottoni, F. 26 (CCAA); idem. Almeida, F.C.; Silva, J.A.S.; Oliveira, L. & Ottoni, F. 28 (CCAA); idem. **Caxias**, Povoado Altos, 01 April 2006, R. S. Fernandes 73 (EAC, MG); Correntinho, 27 May 2007, R. S. Fernandes et al. 92 (MG, EAC); idem. **Fortaleza dos Nogueiras**, cachoeira Castanhão, ca. 06°58'51"S, 46°01'42"W, 20 February 2022, A.W.C. Ferreira, 522, 523 (CCAA).

Identification. *Selaginella erythropus* is characterized by the dark red to reddish stem, patent to ascendent lateral microphylls that are ovate in the most basal portion, and become ovate-lanceolate, lanceolate or

slightly falcate towards the apex of the branch, acroscopic margin that is hyaline and ciliate along the basal portion and denticulate along the apical portion, and basiscopic margin that is greenish, narrowly hyaline, and entire or denticulate to serrulate along the apical portion.

Habitat and distribution. Costa Rica, Colombia, Ecuador, Peru, Brazil (Bahia, Ceará, Distrito Federal, Goiás, Maranhão, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Pará, Paraíba, Piauí, Rio Grande do Norte, Rio de Janeiro, and Tocantins) and Bolivia. In the study area, it grows in closed gallery forests in sandy soils and on rocks near waterfalls.

Selaginella flagellata Spring

Specimens examined: BRAZIL, MARANHÃO, **Carolina**, PARNA Chapada das Mesas, próximo a Cachoeira do Siduca, ca. 06°58'54,1"S, 047°22'26,8"W, 241 m, 04 February 2020, Oliveira, S.S. & Pietrobom, M.R. 46 (CCAA); idem. Chapadinha, Localidade Xororó, 14 September 2022, M.A F. Rodrigues & A.L.F. Rodrigues, 41 (CCAA); Localidade Xororó, 10 September 2016, M.A.F. Rodrigues & A.L.F. Rodrigues, 16 (CCAA); idem. **Caxias**, Povoado Altos, 01 April 2006, R. S. Fernandes 72 (EAC, MG); **Fortaleza dos Nogueiras**, cachoeira Castanhão, ca. 06°58'51"S e 46°01'42"W, 20 February 2022, A.W.C. Ferreira, 520 (CCAA).

Identification. *Selaginella flagellata* is characterized by the long-aristate dorsal microphylls, with an arista that is often half the length of the microphyll and an asymmetric base that sometimes forms a short external auricle, and axillary microphylls with conspicuously hyaline margins that are ciliate at the base and turn denticulate towards the apex. Sterile individuals of the species can be identified by the stem apex which is usually flagelliform.

Habitat and distribution. Mexico, Guatemala, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Venezuela, Trinidad and Tobago, Guyana, Suriname, French Guiana, Ecuador, Peru, Brazil (Acre, Amapá, Amazonas, Maranhão, Mato Grosso, Pará, Piauí, Rondônia, and Tocantins) and Bolivia. In the study area, this species grows in closed gallery forests, in sandy ravines, and almost always in shady areas.

Selaginella gynostachya Valdespino

Figure S1

New records: BRAZIL – MARANHÃO, **Cândido Mendes**, Fazenda Sete Irmãos, 1°51'39.7"S, 45°45'21.5"W, 56 m alt.; 26 October 2019; W.R. Silva Junior, A.W.C. Ferreira 154 (SLUI); idem. 26 October 2019; W.R. Silva Junior, A.W.C. Ferreira 155; (CCAA); idem. 26 October 2019; W.R. Silva Junior, A.W.C. Ferreira 290; (CCAA); idem. **Carolina**, Resort da Pedra Caída, Cachoeira do Santuário Ecológico, ca. 07°02'44,2"S, 047°26'38,0"W, 128 m, 07 February 2020, Oliveira, S.S. & Pietrobom, M.R. 142 (CCAA/HBRA); idem. Oliveira, S.S. & Pietrobom, M.R. 144 (CCAA/HBRA); idem. Oliveira, S.S. & Pietrobom, M.R. 152 (CCAA/HBRA); idem. Oliveira, S.S. & Pietrobom, M.R. 159 (CCAA/HBRA); idem. Cachoeira da Pedra Furada, ca. 07°01'59,3"S, 047°27'01,9"W, 195 m, 07 February 2020, Oliveira, S.S. & Pietrobom, M.R. 175 (CCAA/HBRA); idem. Oliveira, S.S. & Pietrobom, M.R. 176 (CCAA/HBRA); idem. Cachoeira do Capelão, ca. 07°03'01,5"S, 047°28'37,9"W, 216 m, 07 February 2020, Oliveira, S.S. & Pietrobom, M.R. 199 (CCAA/HBRA); idem, cachoeira do Garrote, 07°01'01"S, 47°28'38"W, 11 March 2022, A.W.C. Ferreira 576.

Identification. The presence of idioblasts in the upper surface of the axillary microphylls and the denticulate to ciliate-denticulate margins of the lateral microphylls are variable characteristics that must be carefully observed (Cremers & Boudrie 2007).

Selaginella gynostachya, a species recently recorded for Brazil (Góes-Neto et al. 2015), resembles *S. karowtipuensis* Valdespino (which occurs in Guyana). However, the latter differs because it has dorsal microphylls with a subcordate to rounded base, idioblasts in the upper surface of the lateral microphylls and dorsal microphylls with a long-acuminate to short-aristate apex, while *S. gynostachya* has dorsal microphylls with a sub-truncate to rounded base, lacks idioblasts in the upper surface of the lateral microphylls, and has elliptic to ovate-elliptic or widely ovate dorsal microphylls with an acute to short-acuminate apex. This is the first record of this species for the Brazilian Cerrado and Maranhão. Previous records are all from areas in Amazonia, Brazil (Flora e Funga do Brasil 2023).

Habitat and distribution. Venezuela, Guyana, French Guiana, and Brazil. In Brazil, this species was known only from Amazonia, in Pará (Flora e Funga do Brasil 2023), and it is now also known to occur in the Cerrado in Maranhão. In the study area, *S. gynostachya* grows in closed gallery forests near water courses and on rocks near waterfalls.

Selaginella marginata (Humb. & Bonpl. ex Willd.) Spring

Specimens examined: BRAZIL, MARANHÃO, **Carolina**, PARNA Chapada das Mesas, Passagem da dona Lena, ca. 07°03'45,1"S, 047°15'16,2"W, 230 m, 05 February 2020, Oliveira, S.S. & Pietrobom, M.R. 89 (CCAA/HBRA); idem. Cachoeira do Porão, ca. 06°55'55,6"S, 047°22'53,6"W, 174 m, 04 February 2020, Oliveira, S.S. & Pietrobom, M.R. 29 (CCAA/HBRA).

Identification. *Selaginella marginata*, in addition to its articulate stem, is characterized by the lateral microphylls with an auriculate base, with a long auricle on the acroscopic portion that is curved towards the base, and axillary microphylls with a long auricle on the base that is almost always fimbriate or ciliate.

Habitat and distribution. Mexico, Venezuela, Brazil (Bahia, Distrito Federal, Goiás, Maranhão, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Pará, Paraná, Piauí, Rio de Janeiro, Rio Grande do Sul, Rondônia, Santa Catarina, São Paulo, and Tocantins), Bolivia, Paraguay and Argentina, Uruguay. In the study area, it grows in the interior of gallery forests and on rocky outcrops exposed to light near waterfalls.

Selaginella minima Spring

Specimens examined: BRAZIL, MARANHÃO, **Carolina**, Estância Ecológica Vereda Bonita, ca. 07°01'14,8"S, 047°27'52,6"W, 191 m, 06 February 2020, Oliveira, S.S. & Pietrobom, M.R. 90 (CCAA/HBRA).

Identification. *Selaginella minima* is 1–9 cm tall and has totally dimorphic microphylls along the length of its stem. The margins of the lateral and dorsal microphylls and sporophylls have 2 to 5 rows of idioblasts that give the border of the leaves a whitish appearance. The dorsal microphylls are ovate and have an asymmetric (the internal base tends to be truncate and the external base forms a poorly differentiated external auricle) or oblique base, margins that are serrate to finely serrate or short-ciliate along the proximal half and finely serrate along the distal half, with an internal side that is serrate to finely serrate, and an apex that is acute to acuminate. In addition, rarely, there are scattered, short trichomes on the upper surface of the lateral microphylls, mainly towards the basiscopic half of the lamina (see the illustration of this species in Mickel et al. 2004, fig. 271).

Habitat and distribution. Mexico, Honduras, Nicaragua, Costa Rica, Panama, Venezuela, Trinidad and Tobago, French Guiana, Brazil (Amapá, Amazonas, Goiás, Maranhão, Mato Grosso, Pará, Piauí, and Rondônia) and Bolivia. In the study area, it grows in closed gallery forests on rocks (with almost no organic material) exposed to light.

Selaginella radiata (Aubl.) Spring
Specimens examined: BRAZIL, MARANHÃO, **Carolina**, Estância Ecológica Vereda Bonita, ca. 07°01'14,8"S, 047°27'52,6"W, 191 m, 06 February 2020, Oliveira, S.S. & Pietrobom, M.R. 100 (CCAA); idem. Resort da Pedra Caída, rio Vão Feio, próximo a Cachoeira da Caverna, ca. 07°03'53,2"S, 047°28'12,6"W, 200 m, 07 February 2020, Oliveira, S.S & Pietrobom, M.R. 187 (CCAA/HBRA); idem. Cachoeira do Santuário Ecológico, ca. 07°02'44,2"S, 047°26'38,0"W, 128 m, 07 February 2020, Oliveira, S.S. & Pietrobom, M.R. 161 (CCAA); idem. Cachoeira do Dôdo, ca. 07°05'43,0"S, 047°26'39,5"W, 234 m, 06 February 2020, Oliveira, S.S. & Pietrobom, M.R. 118 (CCAA/HBRA); idem. Topo do Morro do Dôdo, ca. 07°05'30,1"S, 047°26'46,8"W, 389 m, 06 February 2020, Oliveira, S.S. & Pietrobom, M.R. 130b (CCAA/HBRA); idem. Morro do Dôdo, ca. 07°05'39,3"S, 047°26'39,3"W, 256 m, 06 February 2020, Oliveira, S.S. & Pietrobom, M.R. 126 (CCAA/HBRA); idem. Oliveira, S.S. & Pietrobom, M.R. 121 (CCAA/HBRA); idem. Entorno do PARNA Chapada das Mesas, riacho da RPPN Mansinha, ca. 7°08'07,7"S, 47°26'07,1"W, 286 m, 08 June 2018, Almeida, F.C.; Silva, J.A.S.; Oliveira, L. & Ottoni, F. 126 (CCAA); idem. Almeida, F.C.; Silva, J.A.S.; Oliveira, L. & Ottoni, F. 120 (CCAA/HBRA); idem. PARNA Chapada das Mesas, Cachoeira do Porão, ca. 06°55'55,6"S, 047°22'53,6"W, 174 m, 04 February 2020, Oliveira, S.S. & Pietrobom, M.R. 24 (CCAA/HBRA); idem. próximo a Cachoeira do Porão, ca. 06°55'58,2"S, 047°22'50,8"W, 175 m, 04 February 2020, Oliveira, S.S. & Pietrobom, M.R. 36 (CCAA/HBRA); idem. ca. 06°55'58,2"S, 047°22'50,8"W, 175 m, 04 February 2020, Oliveira, S.S. & Pietrobom, M.R. 39 (CCAA); idem. próximo a Cachoeira do Siduca, ca. 06°58'54,1"S, 047°22'26,8"W, 241 m, 04 February 2020, Oliveira, S.S. & Pietrobom, M.R. 50 (CCAA/HBRA); idem. Riacho Lajes, próximo a Cachoeira do Siduca, ca. 06°59'38,99"S, 047°22'23,9"W, 243 m, 04 February 2020, Oliveira, S.S. & Pietrobom, M.R. 58 (CCAA/HBRA); idem. Cachoeira São Romão, ca. 7°1'17,2"S, 47°2'27,8"W, 258 m, 13 March 2017, Silva, L.R. & Pietrobom, M.R. 59 (CCAA/MG); idem. Silva, L.R. & Pietrobom, M.R. 55 (CCAA/MG); idem. 7°01'17,1"S, 47°02'27,1"W, 256 m, Almeida, F.C.; Silva, J.A.S.; Oliveira, L. & Ottoni, F. 47 (CCAA); idem. Cachoeira da Ponta da Serra, riacho Lajes, ca. 6°58'47,4"S, 47°22'25"W, 235 m, 11 March 2017, Silva, L.R. & Pietrobom, M.R. 22 (CCAA/MG); idem. ca. 6°58'47,1"S, 47°22'25,5"W, 238 m, 08 June 2018, Almeida, F.C.; Silva, J.A.S.; Oliveira, L. & Ottoni, F. 114 (CCAA); idem. **Estreito**, PARNA Chapada das Mesas, margem direita do rio Farinha, ca. 6°59'36,7"S, 47°9'53,1"W, 210 m, 12 March 2017, Silva, L.R. & Pietrobom, M.R. 47 (CCAA/MG); idem. **Chapadinha**, próximo ao Povoado Cumprido, 22 February 2022, R.S. Fernandes & NA Mendonça 17 (CCAA); Estrada Próximo ao Riacho da Raiz, 22 February 2022, R.S. Ottoni & NA Mendonça 14 (CCAA); Povoado Centro Velho, 29 March 2022, J.A.S. SILVA 396a (CCAA); RESEX Chapada Limpa, Povoado Mata do Jeroca, 17 July 2019, JAS Silva 392a (CCAA); RESEX Chapada Limpa, Povoado Mata do Jeroca, 11 July 2019, R.S. Fernandes 1070 (CCAA); Povoado Centro Velho, 29 March 2022, J.A.S. Silva 396 (CCAA); Estrada próximo ao Riacho da Raiz, 23 August 2022, N.A. Mendonça & RS Fernandes 33 (CCAA).
Identification. *Selaginella radiata* is characterized by dorsal microphylls that are widely elliptic to widely orbicular with a rounded to subcordate base, arched central vein, making the inner half of the lamina wider than the outer half of the lamina, long, grooved apex (1/4–3/4 of the lamina length), and upper surface with more visible stomata (easily seen in specimens not preserved in alcohol). Additionally, the upper surface of the dorsal and lateral microphylls often have idioblasts that are difficult to see in specimens preserved in alcohol. The margins of the dorsal microphylls are long-ciliate, at least along the proximal 1/3–1/2 (to 3/4) of the lamina. Further, it has an erect habit and is at least 30 cm tall, the sporophyte is deltoid and 3–4-pinnate, and the microphylls on the main stem, until the first branch, tend to look monomorphic.
Habitat and distribution. Colombia, Venezuela, Guyana, Suriname, French Guiana, Ecuador and Brazil (Amapá, Amazonas, Bahia, Maranhão, Mato Grosso, Pará, Piauí, and Rondônia). In the study area, it grows in wet soils and the shade in gallery forests and on rocky outcrops.

Selaginella simplex Baker
Specimens examined: BRAZIL, MARANHÃO, **Estreito**, PARNA Chapada das Mesas, Cachoeira do Prata, margem direita do rio Farinha, ca. 6°59'36,7"S, 47°9'53,1"W, 210 m, 06 June 2018, Almeida, F.C.; Silva, J.A.S.; Oliveira, L. & Ottoni, F. 25 (CCAA); idem. Almeida, F.C.; Silva, J.A.S.; Oliveira, L. & Ottoni, F. 30 (CCAA); idem. Almeida, F.C.; Silva, J.A.S.; Oliveira, L. & Ottoni, F. 27 (CCAA/HBRA); idem. 12 March 2017, Silva, L.R. & Pietrobom, M.R. 48 (CCAA/MG); idem. Silva, L.R. & Pietrobom, M.R. 46 (CCAA/MG); idem. Cachoeira São Romão, ca. 7°1'17,2"S, 47°2'27,8"W, 258 m, 13 March 2017, Silva, L.R. & Pietrobom, M.R. 58 (CCAA/MG); idem. **Carolina**, Topo do Morro do Dôdo, ca. 07°05'30,1"S, 047°26'46,8"W, 389 m, 06 February 2020, Oliveira, S.S. & Pietrobom, M.R. 129 (CCAA/HBRA); idem. **Nova Colinas**, Parque Aquático Três Marias, ca. 07°14'14"S e 46°14'55"W, 22 February 2022, A.W.C. Ferreira 520 (CCAA).
Identification. *Selaginella simplex* is a small, delicate plant that reaches 5 cm long. It can also be characterized by the ovate to ovate-elliptic lateral microphylls with a rounded base, acroscopic base sometimes overlapping the stem, acroscopic margin greenish, narrowly hyaline, denticulate at the base, serrulate towards the apex, basiscopic margin greenish, narrowly hyaline, serrulate mainly along the upper middle, and lower surface of the lateral microphylls occasionally with idioblasts. The dorsal microphylls are around 1.0 mm apart and have margins that are greenish, narrowly hyaline and denticulate, an upper surface without idioblasts or stomata, and an acuminate to long-acuminate apex.
Habitat and distribution. Mexico, Costa Rica, Panama, Venezuela, Trinidad and Tobago, Ecuador, Brazil (Bahia, Goiás, Maranhão, Mato Grosso, Pará, Pernambuco, and Sergipe) and Bolivia. It occurs in gallery forests in sandy, wet ravines and on wet rocks near waterfalls.

Selaginella sulcata (Desv. ex Poir.) Spring ex Mart.
Material Examined. BRAZIL, MARANHÃO, **Carolina**, Topo do Morro do Dôdo, ca. 07°05'30,1"S, 047°26'46,8"W, 389 m, 06 February 2020, Oliveira, S.S. & Pietrobom, M.R. 130 (CCAA/HBRA).
Identification. *Selaginella sulcata* is characterized by lateral microphylls with a biauriculate base, acroscopic auricle generally more developed, overlapping the stem, curved towards the bottom, denticulate to short-

ciliate, basiscopic auricle short, less evident, denticulate to short-ciliate, base of dorsal microphylls auriculate, with one or two auricles, external auricle more developed, auricles denticulate to short-ciliate, and base of the axillary microphylls with two denticulate to short-ciliate auricles.
Habitat and distribution. Suriname, French Guiana, Peru, Brazil (Acre, Alagoas, Amapá, Amazonas, Bahia, Ceará, Espírito Santo, Goiás, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Pará, Paraíba, Paraná, Pernambuco, Piauí, Rio de Janeiro, Rio Grande do Sul, Santa Catarina, and São Paulo), Bolivia, Paraguay and Argentina. In the study area, it grows in closed gallery forest, on rock walls, almost always in the shade.

Discussion

The representatives of *Selaginella* in Maranhão mainly occur in the Cerrado region where there are nine recorded species (Fernandes et al. 2022); there is only one recorded species in the Amazonian region (Silva Junior et al. 2020, Goés-Neto et al. 2023). The first record of *S. gynostachya* for the Cerrado domain in Brazil shows that this region is under-collected, as noted by Fernandes et al. (2022) in a floristic study of ferns and lycophytes in the region of Chapada das Mesas. The occurrence of *S. gynostachya* in the ecotonal zone in Maranhão also demonstrates that individuals of this species can adapt and colonize a greater diversity of microenvironments and microclimates. This species has also been observed in an area of Amazonia in Maranhão. In this domain, *S. gynostachya* was collected as a terrestrial plant on the margin of a seasonal stream, while in the Cerrado in Maranhão it was mainly found as a rupicolous plant near waterfalls. The common factor in these areas was the presence of humidity and shade provided by the canopy.

Before this study, the only survey specifically about lycophytes in Maranhão was conducted in the region of Chapada das Mesas (Almeida et al. 2020), which recorded six species, including four Sellaginelaceae: *Selaginella conduplicata* Spring, *S. erythropus* (Mart.) Spring, *S. radiata* (Aubl.) Baker, and *S. simplex* Baker. Almeida et al. (2020) also recorded *S. conduplicata* and *S. radiata* for the first time for the Cerrado phytogeographic domain in Brazil, and *S. conduplicata* was a new record for Maranhão. Another study about ferns and lycophytes in Maranhão, which was also conducted in the region of Chapada das Mesas (Fernandes et al. 2022), recorded 17 species of lycophytes, including 12 species of *Selaginella* (three not identified). Of these, three were new records for Maranhão: *Selaginella convoluta* (Arn.) Spring, *S. minima* Spring., and *S. sulcata* (Desv. ex Poir.) Spring ex Mart.

For the present study, which was based on previous surveys and new collections, we recorded ten *Selaginella* species, of which *S. gynostachya* is a new record for Maranhão and the Brazilian Cerrado. Despite this new record, for plants, there are still many poorly sampled areas in Maranhão and we expect that this number of *Selaginella* species and the numbers for other plant species will increase.

Various recent floristic studies confirm that Maranhão is under-collected (Ferreira et al. 2017, Ferreira et al. 2018, Ferreira et al. 2019a, b, Ferreira et al. 2022, Gomes et al. 2021, Guarçoni et al. 2018a, b, Guarçoni et al. 2020, Oliveira et al. 2021, Oliveira et al. 2022, Pessoa et al. 2022, Scatigna et al. 2020, Silva et al. 2022). There are few surveys of the fern and lycophyte species in Maranhão (Almeida et al. 2020, Silva Junior et al. 2020, Fernandes et al. 2022), suggesting the need for new botanical studies in the state to update the Flora e Funga do Brasil database, which currently only lists five *Selaginella* species.

Supplementary Material

The following online material is available for this article:

Figure S1 – *Selaginella gynostachya* Valdespino. A. Habit. B. Part of the stem showing an axillary rhizophore. C. Axillary microphyll. D. Dorsal microphyll. E. Lateral microphyll. F. Dorsal sporophylls with microspores (L.R. Silva & M.R. Pietrobom 39 [CCAA819]). Scale bar: A = 1cm; B = 0.5 mm; C; D; E; F = 1 mm.

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Conflicts of Interest

We have no conflict of interest.

Data Availability

Supporting data are available at <https://data.scielo.org/dataset.xhtml?persistentId=doi:10.48331/scielodata.PKGQSM>.

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