



## Ferns and Lycophytes as new challenges Exploring the diversity of ferns and lycophytes in the Jardim Botânico do Rio de Janeiro

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### Abstract

The Jardim Botânico do Rio de Janeiro (JBRJ) has an arboretum with 58 hectares of green space, including thematic collections. The *ex situ* collection of ferns and lycophytes is in two greenhouses: Mestre Valentim and the Shade Greenhouse of Horto Florestal. Although the JBRJ Arboretum is a cultivated area, it is adjacent to Parque Nacional da Tijuca (PNT), which is a fragment of the Atlantic Forest that may influence the flora in the garden. Specimens were collected and identified between 2020 and 2023 from all areas of the JBRJ, including the greenhouses. There are 101 species of ferns and lycophytes that belong to 47 genera and 24 families. Pteridaceae (21%) and Polypodiaceae (19%) are the most species-rich families. The collections in the Mestre Valentim and Shade greenhouses comprise 70 species, 35 genera, and 20 families. Five cultivated species are at risk of extinction: *Adiantum mynsseniae*, *Dicksonia sellowiana*, *Anemia blechnoides*, *Doryopteris rediviva*, and *Pteris congesta*. Most of the species inventoried in the JBRJ collection are native to Brazilian ecosystems (70%), including 10 endemic species. A list of species found in the JBRJ, with information about the location, distribution range, vouchers and type of occurrence (collection or spontaneous), is provided.

**Key words:** botanical gardens, checklist, *ex situ* conservation, floristics.

### Resumo

O Jardim Botânico do Rio de Janeiro (JBRJ) possui um arboreto com 58 hectares de área verde incluindo estufas temáticas. A coleção *ex situ* de samambaias e licófitas está reunida em duas estufas denominadas Mestre Valentim e Estufa de Sombra do Horto Florestal. Embora o arboreto do JBRJ seja uma área cultivada, ele está localizado adjacente a Floresta da Tijuca, um fragmento de Mata Atlântica que pode influenciar sua flora. Os espécimes foram coletados e identificados entre 2020 e 2023 em todas as áreas do JBRJ incluindo as estufas. As samambaias e licófitas totalizam 101 espécies, pertencentes a 47 gêneros e 24 famílias, das quais Pteridaceae (21%) e Polypodiaceae (19%) são as mais representativas em número de espécies. As coleções das estufas do Mestre Valentim e da Estufa de Sombra abrigam 70 espécies, 35 gêneros e 20 famílias. Há cinco espécies cultivadas que estão em risco de extinção: *Adiantum mynsseniae*, *Dicksonia sellowiana*, *Anemia blechnoides*, *Doryopteris rediviva* e *Pteris congesta*. As espécies inventariadas no JBRJ são, em sua grande maioria, nativas dos ecossistemas brasileiros (74%), das quais 12 são espécies endêmicas. A lista de espécies ocorrentes no JBRJ, com as informações sobre a distribuição geográfica, vouchers, o local e forma de ocorrência (coleção ou espontâneo) é apresentada.

**Palavras-chave:** jardins botânicos, checklist, conservação *ex situ*, florística.

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## Introduction

The impact of climate change and habitat loss on global environments, mainly from anthropogenic activities, means conservation measures are urgently needed to protect biodiversity from extinction (Sage 2019). As a well-established method, *ex situ* collections are an effective form of conserving threatened species in controlled facilities and support research that increases what is known about conserved groups (Costa & Bajgielman 2016).

Botanical gardens in tropical regions are responsible for maintaining approximately one-third of the endangered flora. The *ex situ* collections within these facilities preserve these species and allow for future reintroductions (CDB 2012; BGCI 2019; Westwood *et al.* 2021). Furthermore, these collections provide samples for future studies, such as phenology or morphological analyses, without harming the *in situ* population. In this context, inventories of the species occurring in these locations (*e.g.*, Muñoz 2013), as well as the characterization of the collection, allow these plants to be used in future research.

Free-sporing vascular plants, ferns (Polypodiopsida) and lycophytes (Lycopodiopsida), are two distinct monophyletic lineages with ca. 12,000 species worldwide that mainly occur in tropical regions (PPG I 2016). In Brazil, the Atlantic Forest stands out as the area most diverse in ferns and lycophytes and is one of eight global hotspots for diversity and endemism (Prado *et al.* 2015; Suissa *et al.* 2021).

The Jardim Botânico do Rio de Janeiro (JBRJ) was founded by D. João VI in 1808 as an acclimatization garden for maintaining exotic species (Alfaia *et al.* 1998). Nowadays, the JBRJ is recognized as a UNESCO Biosphere Reserve (Peixoto & Guedes-Bruni 2010) and represents a focal collection for Brazil. It conserves native and exotic species in its facilities and is also an educative space for the visiting public. The JBRJ is surrounded by Atlantic Forest and adjacent to Parque Nacional da Tijuca (PNT). Its 58 hectares of green space includes an arboretum with 122 alleys, 40 sections, 194 plant beds and seven thematic greenhouses, such as bromeliads, orchids, cacti, insectivorous plants, and medicinal plants (Forzza *et al.* 2016). Recently, fern and lycophyte collections were created in the arboretum. Nowadays, the *ex situ* fern and lycophyte collection is in two greenhouses: Mestre Valentim and the Shade Greenhouse at Horto Florestal. Additionally,

some species occur spontaneously (*i.e.*, growing naturally, not as part of the collection) within the JBRJ green space.

Previous surveys of the fern and lycophyte species in the JBRJ are in institutional reports but they were never formally published, except for the *Adiantum* flora (Winter *et al.* 2007). Herein, an up-to-date list of these species in the JBRJ is provided, including where they occur. Additionally, we discuss some challenging aspects of maintaining the *ex situ* collection.

## Material and Methods

The study was carried out in the Jardim Botânico do Rio de Janeiro (JBRJ) (22°58'14"S, 43°13'18"W). The green area was surveyed, including all thematic greenhouses, such as the *ex situ* fern and lycophyte collection in two greenhouses (Mestre Valentim and Shade Greenhouse of Horto Florestal) (Fig. 1). The area has a tropical climate, with a dry season in the winter (< 60 mm rainfall from June to October), mean annual temperatures of ca. 24 °C (minimum) and 26 °C (maximum), and annual precipitation of 1,750 mm. According to the Köppen-Geiger classification system, the climate is categorized as type Aw. The *ex situ* fern and lycophyte collection has automated irrigation but no humidity or temperature controls.

A list of species previously recorded in the JBRJ, based on specimens in the Jardim Botânico do Rio de Janeiro herbarium (RB) and *ex situ* (RBv) and shade (RBvs) collections, was obtained from JABOT (<<http://rb.jbrj.gov.br>>; Silva *et al.* 2017) and used as the starting point of the new survey. Additionally, unpublished surveys in institutional reports were consulted.

Specimens were inventoried between 2020 and 2023 in all areas of the JBRJ, including the greenhouses, thematic collections, alleys, and their surroundings. At least one specimen of each species was collected and included in the RB herbarium. Identification keys available for each group were used to identify the species (Flora e Funga do Brasil 2023, continuously updated).

The species list contains the following: the locality in the JBRJ (Arboretum, Atlantic Forest Trail, Bromeliarium, Cactarium, Insectivorous Plant Collection, Medicinal Collection, Orchidarium, Mestre Valentim, and Shade Greenhouse); presence in the *ex situ* collection (Mestre Valentim and Shade Greenhouses); and distribution range, including the general regions (Neotropical, Paleotropical

and Holartic), countries, and regions of occurrence in Brazil (for the native species). Additionally, an RB voucher number (barcode) for each species is provided.

For comparison, the habit of each species was recorded (aquatic, epiphytic, rupicolous, or terrestrial). The conservation status of each species was verified (Martinelli & Moraes 2013; Flora e Funga do Brasil 2023, continuously updated).

## Results

Currently, there are 101 species of ferns and lycophytes in the JBRJ, which belong to 47 genera and 24 families. Among these, 70 species, 35 genera, and 20 families are represented in the *ex situ* collection in the Mestre Valentim Greenhouse and Shade Greenhouse (Tab. S1, available on supplementary material <<https://doi.org/10.6084/m9.figshare.24424534.v1>>; Fig. 2). Pteridaceae and Polypodiaceae stand out as the most representative families in the garden, with 21% and 19% of the species, respectively (Fig. 3). The most species-rich genera in the *ex situ* collection are *Adiantum* and *Diplazium* (9 spp. Each), followed by *Asplenium* (7 spp.) (Fig. 4). Five cultivated species are in more threatened categories of extinction risk; two are Endangered (*Adiantum mynsenianae* and *Dicksonia sellowiana*) and three are Vulnerable (*Anemia blechnoides*, *Doryopteris rediviva*, and *Pteris congesta*).

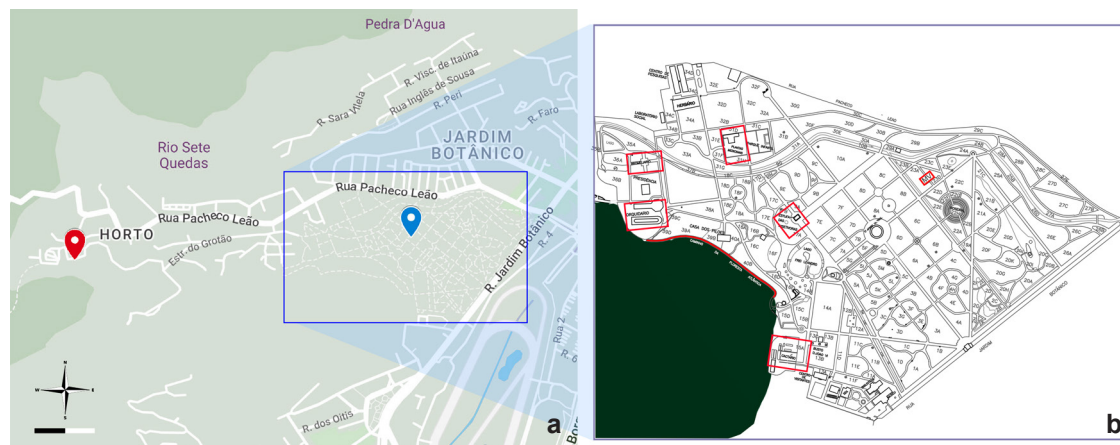
The cultivated species are mainly native to Brazilian ecosystems (70%). Among these, 11 are endemic. The remaining non-native species (30%)

are mainly used as ornamentals, such as *Davallia feejensis*, *Equisetum hyemale*, *Nephrolepis brownii*, *N. cordifolia*, *Platynerium bifurcatum*, and *Microsorium punctatum*.

When comparing substrates, most of species are terrestrial (50.5%). Rupicolous and aquatic species are represented by 24.2% and 2.2%, respectively. Epiphytic ferns and lycophytes represent 23.1% of collection diversity.

Using JBRJ institutional reports (from 1989 and 2006) as diversity “checkpoints” and comparing them with our results, we found a small quantitative variation for the *ex situ* collection. In 1989, 92 species were listed, and our survey found 70 species. However, the species composition of the collections varied over time. The 2006 survey cites only 33 species compared to the 92 species in 1989 (*i.e.*, a loss of 66%). Our list has 16% of the species cited for the collection in 1989. On the other hand, there has been an increase in the number of families (35%) and genera (40%), and the current collection contains more species native to Brazilian biomes.

Apart from the collections, some other species stand out that occur naturally within the arboretum. *Adiantum latifolium*, *Asplenium pulchellum*, *Didymoglossum krausii*, and *Pteris brasiliense* only occur in areas closer to the native forest on the Atlantic Forest Trail and surroundings. *Adiantum raddianum*, *Blechnum occidentale*, *Christella dentata*, *Macrothelypteris torresiana*, and *Pteris vittata* are more frequent in plant beds, drainage channels, and on walls of buildings



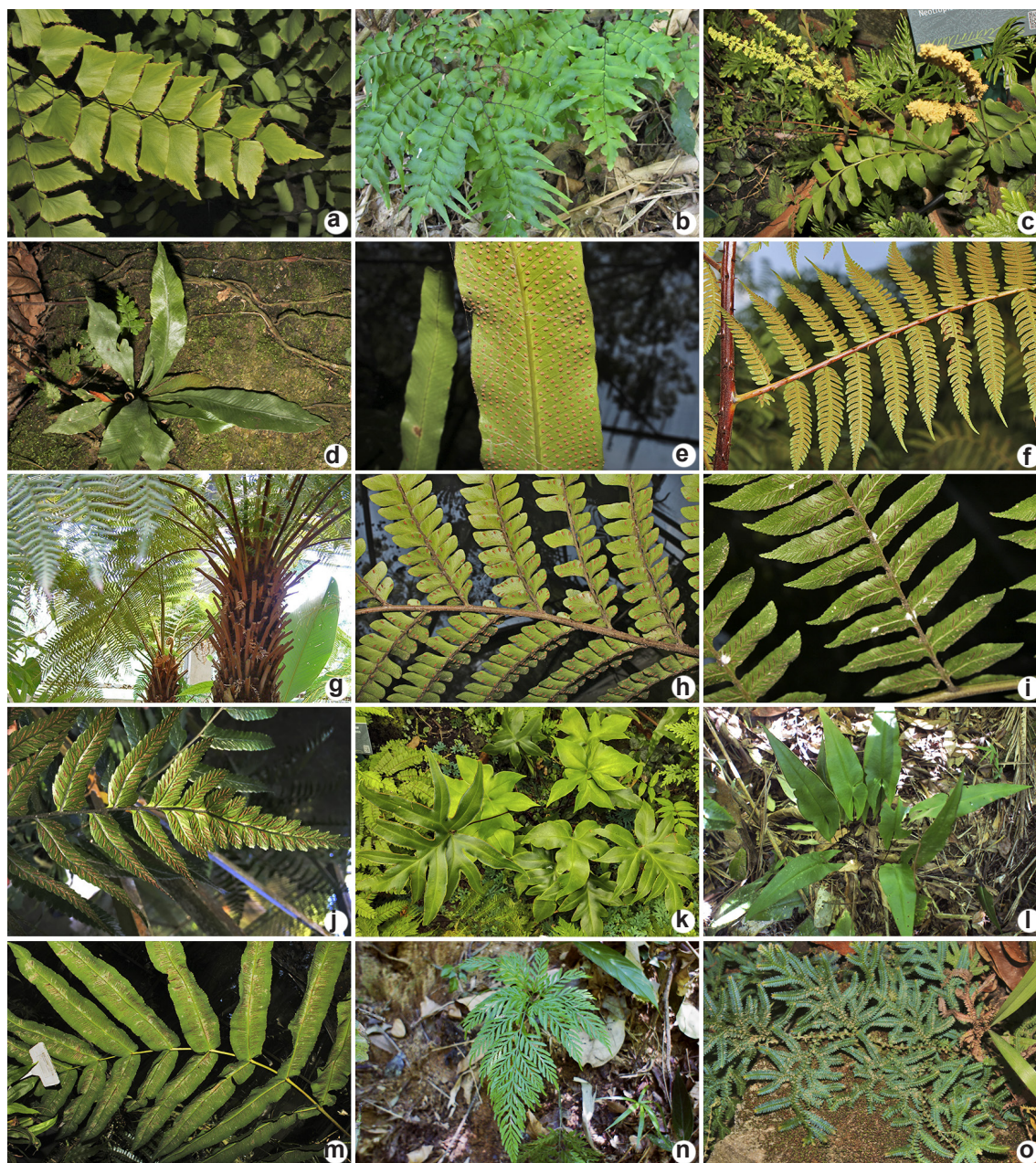
**Figure 1** – a-b. Jardim Botânico do Rio de Janeiro facilities map – a. the red pin indicates Horto Florestal, which includes the Shade Greenhouse. The blue pin represents the arboretum area; b. detailed view of the arboretum. The red rectangles and line indicate thematic collections; “MV” represents the Mestre Valentim Greenhouse.



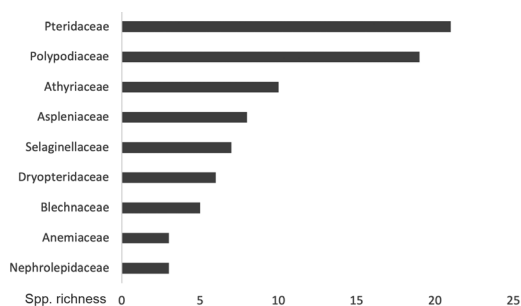
near the perimeter of the JBRJ. Some epiphytic species are widespread throughout the garden, such as *Microgramma vacciniifolia*, *Phlebodium aureum*, *Pleopeltis pleopeltifolia*, and *Serpocaulon triseriale*.

## Discussion

Despite being an artificial environment within an urban area, but with part of its perimeter connected to a preserved fragment of Atlantic Forest, the JBRJ has distinct microhabitats that are



**Figure 2** – a-o. Cultivated species in the Jardim Botânico do Rio de Janeiro *ex situ* collection – a. *Adiantum mathewsianum*; b. *A. mynsseniae*; c. *Anemia colina*; d. *Asplenium coronatum*; e. *Campyloneurum rigidum*; f. *Cyathea microdonta*; g. *Dicksonia sellowiana*; h. *Didymochlaena pulcherrima*; i. *Diplazium ambiguum*; j. *Diplazium werckleanum*; k. *Doryopteris rediviva*; l. *D. sagitifolia*; m. *Hemidictyum marginatum*; n. *Pteris congesta*; o. *Selaginella uncinata*.



**Figure 3** – Diversity of the fern and lycophyte families in the Jardim Botânico do Rio de Janeiro (2020–2023).

mostly within the arboretum and allow different spontaneous species to occur. Adjacent to the Atlantic Forest fragment, the Atlantic Forest Trail, Cactarium Complex and Orchidarium external area have native flora elements similar to those found by Mynssen *et al.* (2002). These contrast with those cultivated in greenhouses or that occur in other sites of the garden.

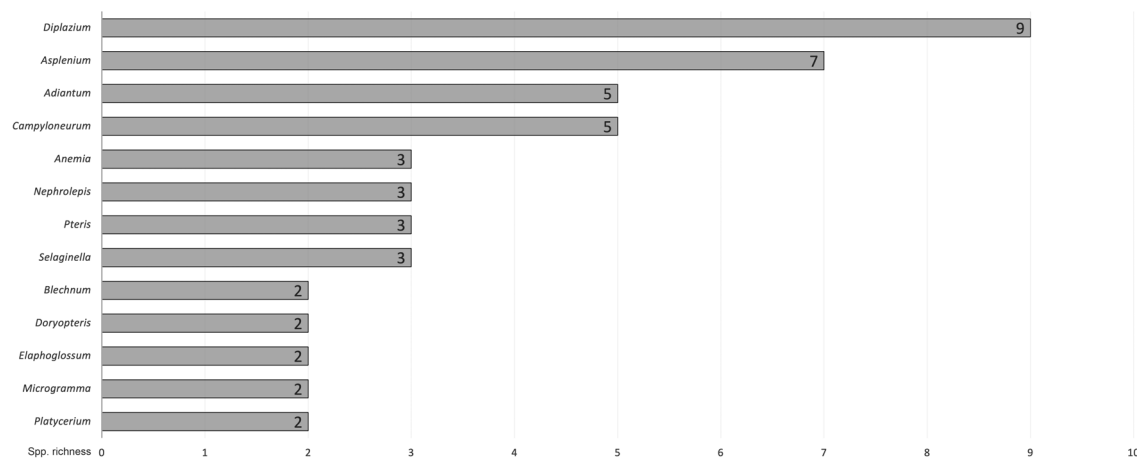
For a long time, the fern collection shared spaces with other thematic collections, such as the Orchidarium and the current Bromeliarium. *Adiantum*, *Platynerium*, and *Selaginella* stood out for their rare and numerous species kept in the collection. However, different policies, greenhouse renovations, and changes in space seem to have affected the decline in specimens and species that were part of this old, rich *ex situ* collection. Our survey results show that 16% of the species remain in the collection compared to previous species lists.

Nowadays, the increase in taxonomic groups maintained in cultivation, particularly species

occurring in the Atlantic Forest, highlights the role of the JBRJ in the conservation of native species in the region. Changes to the collections reflect the efforts by the team of students and researchers associated with the institution over the past decade. However, there have been challenges in relation to cultivating epiphytes that are primarily due to substrate transplantation. Therefore, the collection predominantly comprises rupicolous and terrestrial specimens, which acclimate easier to the available substrates.

As part of the changes, the Shade Greenhouse is a crucial facility for the cultivation of ferns and lycophytes, serving as both an acclimatization site for species and a matrix for other collections, such as the Mestre Valentim Greenhouse. However, similar to cultivation sites within the arboretum, humidity and temperature are not controlled, except for light that is filtered by a shade cloth. Furthermore, since the Shade Greenhouse is fully enclosed and small, cultivating different species promotes competition because spores from some vigorous species (*e.g.*, *Serpocaulon triseriale*, *Deparia petersenii*, and *Nephrolepis brownii*) can disperse into other specimen pots and compete for space (personal observation).

In parallel, cultivation of ferns and lycophytes in a dedicated site within the arboretum, facilitated by the Mestre Valentim Greenhouse, increases knowledge about cultivated native and non-native species. All species are tagged with taxonomic information, such as the species and family names, as well as the vernacular name if available. Additionally, a QR code is provided, which enables visitors to access a digital page with



**Figure 4** – The most species-rich genera in the Jardim Botânico do Rio de Janeiro *ex situ* collection.



comprehensive details about each species (Fig. 5). The integration of educational methodologies with the *ex situ* conservation of these species operates synergistically to effectively contribute to the preservation and conservation of ecosystems (Ibars & Estrelles 2012).

Despite the re-establishment of collections and the creation of dedicated greenhouses for ferns, acclimatizing new specimens and maintaining the cultivation structures are still a challenge. In an attempt to overcome these problems, a gardening program outlining maintenance methods has been developed by the team, which serves as a valuable tool for both training staff and providing a protocol for maintaining specimens (Bial 2022).

In addition to the acquisition of new specimens that are sporophytes, new propagation protocols that do not involve transplanting a mature sporophyte (*e.g.*, cultivating plants from gametophytes) are alternative methods to avoid plant mortality due to non-acclimatization. As an

example, producing young plants by germinating spores sown in sterilized soil or from the spore bank in the soil were successful to cultivate the endangered species *Pteris congesta* (Bastos *et al.* 2023). Although such protocols require more steps and greater infrastructure, they can result in more assertive responses in the conservation of threatened species (Ibars & Estrelles 2012). Furthermore, the description of the present diversity in the JBRJ, as well as challenges related to growing these plants, may help researchers more effectively conserve species in the future.

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**Figure 5** – a-b. Illustration of an information tag – a. attached to an *Asplenium nidus* specimen, displaying species information; b. details of a tag, including the species name, distribution, and a QR code.

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### Data availability statement

In accordance with Open Science communication practices, the authors inform that all data are available within the manuscript.

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