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EXPLORING THE DIVERSITY OF LICHENS IN THE BRAZILIAN AMAZON AND CERRADO: A COMPREHENSIVE REVIEW

EXPLORANDO A DIVERSIDADE DE LIQUENS NA AMAZÔNIA E NO CERRADO BRASILEIROS: UMA REVISÃO ABRANGENTE

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ABSTRACT

Lichens are symbiotic organisms found on various substrates, including rocks, the soil surface, and on trees. Most lichens acquire most of their nutrients from rainwater and atmospheric deposition; many of them also accumulate atmospheric pollutants and are useful environmental bioindicators. This study presents a timely update of lichen diversity in the Amazon and Cerrado biomes. 150 articles were examined from recent years (2013–2023), from PubMed, Web of Science, Scielo, Scopus, Capes Journals, National Digital Libraries and other academic sources. After applying non-inclusion criteria, 36 studies were selected for closer analysis. The publications revealed a rich diversity of lichens, with a total of 58 families, 241 genera, and 1554 species identified from the two biomes. Notably, 33 families, 96 genera and 293 species were reported from both the Amazon and the Cerrado. The most species-rich families were Graphidaceae, Trypetheliaceae, Parmeliaceae, Arthoniaceae, and Pilocarpaceae, with the most prominent genera being *Astrothelium*, *Glyphis*, *Pyrenula*, *Porina*, *Ocellularia*, and *Heterodermia*. The Amazon had more taxa in all taxonomic categories. The lichens of Brazilian both biomes play significant, but still largely unexplored roles in environmental maintenance. The requirements of most species are almost unknown, with major knowledge gaps also in distribution patterns and habitat ecology. However, many lichens in both regions presumably face significant threats from deforestation, wildfires, mining, and urban sprawl. This emphasizes the need for effective measures to protect and preserve lichens as an integral part of environmental management and the preservation of Brazilian biomes.

Keywords: Biodiversity; Brazilian Biomes; Lichenized Fungi.

RESUMO

Os liquens são organismos simbióticos encontrados em diversos substratos, incluindo rochas, a superfície do solo e árvores. A maioria dos liquens obtém grande parte de seus nutrientes da água da chuva e da deposição atmosférica; muitos deles também acumulam poluentes atmosféricos e são úteis como indicadores ambientais. Este estudo apresenta uma atualização oportuna da diversidade de liquens nos biomas Amazônia e Cerrado. Foram analisados 150 artigos publicados nos últimos anos (2013–2023), provenientes de bases de dados como PubMed, Web of Science, SciELO, Scopus, Portal de Periódicos CAPES, Bibliotecas Digitais Nacionais e outras fontes acadêmicas. Após a aplicação dos critérios de exclusão, 36 estudos foram selecionados para uma análise mais detalhada. As publicações revelaram uma rica diversidade de liquens, com um total de 58 famílias, 241 gêneros e 1.554 espécies identificadas nos dois biomas. Notavelmente, 33 famílias, 96 gêneros e 293 espécies

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foram registradas tanto na Amazônia quanto no Cerrado. As famílias mais ricas em espécies foram Graphidaceae, Trypetheliaceae, Parmeliaceae, Arthoniaceae e Pilocarpaceae, enquanto os gêneros mais representativos foram *Astrothelium*, *Glyphis*, *Pyrenula*, *Porina*, *Ocellularia* e *Heterodermia*. A Amazônia apresentou maior riqueza de táxons em todas as categorias taxonômicas. Os liquens de ambos os biomas brasileiros desempenham papéis importantes, porém ainda amplamente inexplorados, na manutenção ambiental. As exigências ecológicas da maioria das espécies são praticamente desconhecidas, visto que ainda existem grandes lacunas de conhecimento sobre seus padrões de distribuição e ecologia de habitat. Entretanto, muitos liquens dessas regiões presumivelmente enfrentam ameaças significativas decorrentes do desmatamento, incêndios florestais, mineração e expansão urbana. Isso ressalta a necessidade de medidas eficazes para proteger e conservar os liquens como parte integrante da gestão ambiental e da preservação dos biomas brasileiros.

Palavras-chave: Biodiversidade; Biomas Brasileiros; Fungos Liquenizados.

INTRODUCTION

Lichens are found on various substrates, such as rocks, soils, and trees, obtaining nutrients from water and directly from the air. As for the morphological classification, they can be divided into several categories according to the type of thallus: Crustose, Dimorphic, Foliose, Fruticose, Gelatinous, Leprose, and Squamulose lichens. They are symbiotic organisms formed between a fungus (mycobiont) with green algae and/or cyanobacteria (photobionts).

They stand out as excellent bioindicators and important for environmental biomonitoring due to their wide geographic distribution and remarkable ability to accumulate pollutants, and may be present in forest succession after fires, especially the Cladoniaceae and Parmeliaceae families. All the metabolites and elements absorbed during their life are stored in their thalli. In addition, they have low sensitivity to seasonal changes and do not have protective structures, which exposes them directly to the environment (Costa, 2018a; Santos, Ingride Natane Miguel, 2022)**.**

Brazilian biomes, rich in biodiversity and peculiarities, play a fundamental role as biodiversity reservoirs (Nascimento, Edvaneide Leandro de Lima, 2017; Marques *et a*l.,

2020). The lichens of the Amazon and the Cerrado have different shapes, colors, sizes and adaptations reflecting their habitats. They can be found both in the forest, in open areas or transition regions between biomes. The lichens of the Amazon excel for their richness and variety of corticolous forms (which grow on the bark of trees), while the lichens of the Cerrado outshine for their diversity of saxicolous (which grow on rocks) and terrestrial (which grow on the ground) forms (Consentine, 2018; Nascimento, Edvaneide Leandro de Lima, 2017).

The objective of this study was to make a bibliographic survey of the diversity of lichens described in these two Brazilian biomes (Amazon and Cerrado). Our hypothesis is that the biodiversity of lichens in the Amazon and the Brazilian Cerrado is remarkable, reflecting the ecological complexity of these biomes.

The conservation of lichens in the Amazon and Cerrado is a challenge, as these biomes suffer from deforestation, fires, mining activity, agriculture and urbanization advance, which affect the quality and quantity of lichens in diferent habitats. In addition, there are few studies and records on the distribution, ecology, and taxonomy of lichens in these regions (Consentine, 2018). In short, this study emphasizes the importance of lichens in Brazilian biomes, providing fundamental information about the biodiversity of this group. Knowledge about lichens contributes not only to the preservation of biological diversity, but also to the promotion of sustainable practices and the protection of Brazilian ecosystems.

METHODOLOGY

Scientific articles, dissertations, and thesis published in the period from 2013 to 2023 were screened. For this investigation, the following platforms were consulted: PubMed (https://pubmed.ncbi.nlm.nih.gov/), Web of Science (https://l1nk.dev/WebofScience), Scielo (https://www.scielo.br/), Scopus (https://acesse.one/Scopuss), Periódicos Capes (https://acesse.one/Periodicos-capes) and National Digital Libraries Dissertations and Theses

(Brazilian Digital Library of Theses and Dissertations - BDTD (https://bdtd.ibict.br/vufind/) and the Brazilian Portal of Publications and Scientific Data in Open Access - Oasisbr (https://oasisbr.ibict.br/vufind/). The research of the works was conducted by combining these keywords with the use of the Boolean operators "OR" and “AND". In order to improve the specificity of the study, the following keywords were adopted in three languages: Portuguese: "Liquens" (Variations: Microbioma, Associação Liquênica, Fungos liquenizados), "Amazônia" and "Cerrado"; English: Lichens (Variations: Microbiome, Lichen Associations, Lichenized Fungi) "Amazonia" and "Cerrado"; and in Spanish: Líquenes (Variaciones: Microbioma, asociaciones de líquenes, hongos liquenizados) "Amazonia" and "Cerrado".

Review articles, abstracts, and works that were only taxonomic descriptions, occurrences that did not address an analysis of lichen diversity in the target regions, as well as those related to methods of identification of organisms belonging to other taxonomic groups, were excluded.

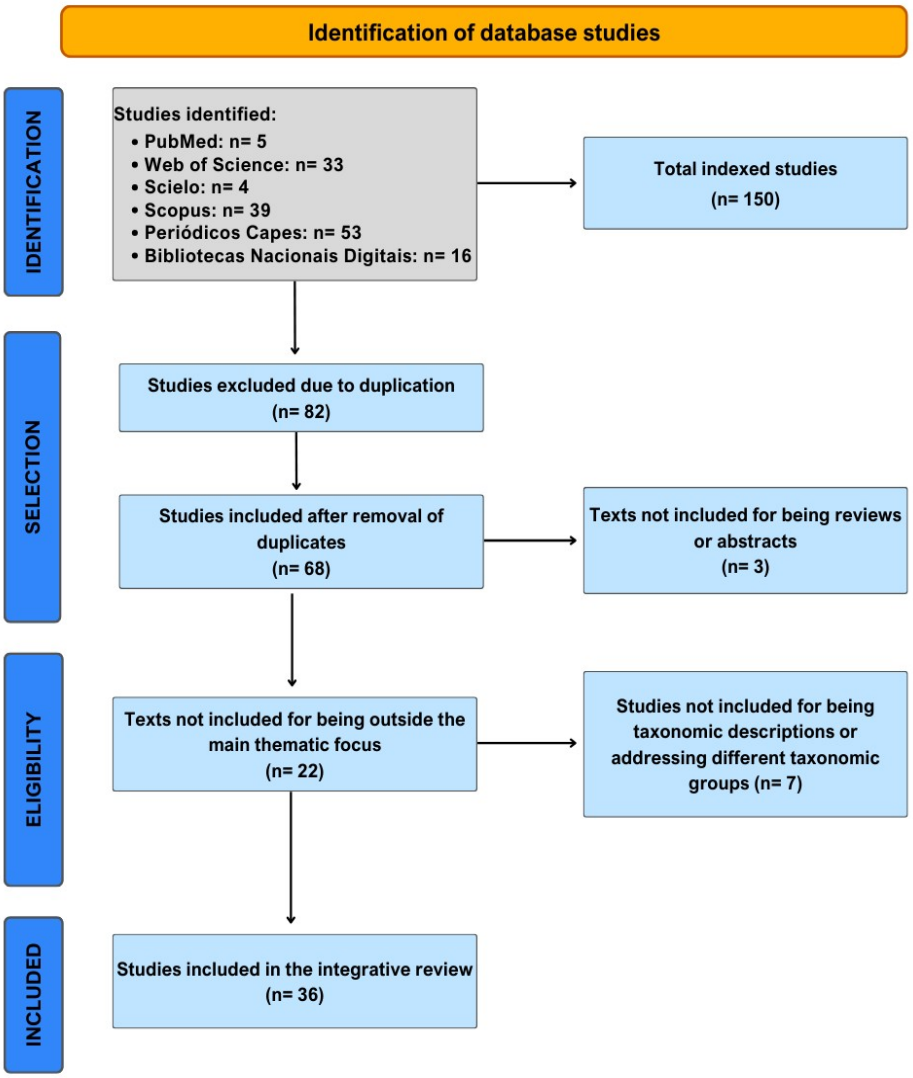
RESULTS

This study employed a systematic methodology for the selection of relevant articles related to the topic addressed. From the database, it was possible to identify through PubMed: five articles; Web of Science: 33 articles; Scielo: four articles; Scopus: 39 articles; Capes Journals: 53 articles; and in the National Digital Libraries of Theses and Dissertations (BDTD and Oasisbr): 16 studies (four articles, six thesis and six dissertations). The results were then listed, and a total of 150 articles were found to be relevant within the inclusion criteria using the listed keywords in a ten-year window (2013–2023).

Of the 150 papers initially identified, 82 were excluded due to duplication in multiple research sources. In addition, 22 studies were discarded because they did not meet the inclusion criteria, either because they were taxonomic descriptions or because they addressed different taxonomic groups. Another three texts were eliminated because they were reviews or

abstracts, while seven articles were excluded because they were in taxonomic studies of different groups or did not address the diversity of lichens. After applying these non-inclusion criteria, 36 studies remained and were maintained in the integrative review (Figure 1).

Figure 1. Steps of the integrative review



Source: Authors, 2024.

Analyzing the publications with the respective regions of development of the studies and collection sites, we observed a varied and significant geographic distribution. In the Southeast, São Paulo (Zanetti; Marcelli; Jungbluth, 2015) registered one publication, while Minas Gerais presented two (Costa, 2018a). Following this, in the South region, Rio Grande do Sul recorded three publications (Zanetti; Marcelli; Jungbluth, 2015; Gumboski et al., 2018), Santa Catarina with two (Zanetti; Marcelli; Jungbluth, 2015; Souza; Aptroot; Spielmann, 2022). In addition to these regions, in the Midwest, Mato Grosso do Sul led with seven publications (Aptroot; Souza; Spielmann, 2021; Torres et al., 2021). Notably, Goiânia accounted for three publications , while Mato Grosso (Aptroot; Souza, 2021) and Brasília had one each (Silva; Aptroot; Cáceres, 2023). Futhermore, in the Northeast, Sergipe (Santos, Ingride Natane Miguel, 2022) and Ceará (Alves et al., 2014) with one publication while in contrast Pernambuco (Santos, Viviane Monique dos, 2015; Nascimento, Edvaneide Leandro de Lima, 2017), Maranhão and Tocantins with two publications each (Cunha; Marcelli; Pereira, 2015; Aptroot et al., 2017), and Paraíba three (Nascimento, T. Pajeú et al., 2014; Santiago et al., 2018; Feuerstein et al., 2022).

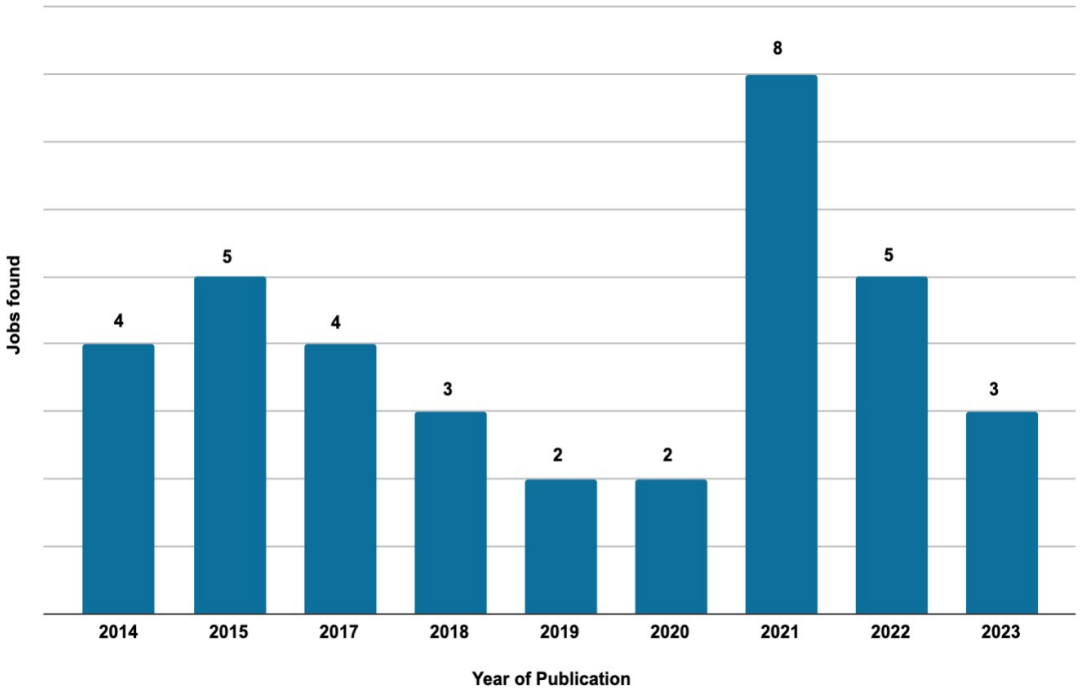
Finally, in the North region, Rondônia (Cáceres, Marcela; Aptroot; et al., 2014; Cáceres, Marcela; Lima; et al., 2014) and Amazonas (Womack et al., 2015; Cáceres, Marcela Eugenia da Silva; Aptroot, 2017) had two publications each, and Pará had one (Aptroot et al., 2017). In addition to the Brazilian territory, Ecuador registered one publication (Déleg et al., 2021), Colombia presented two (Soto-Medina; Londoño-Lemos; Díaz-Escandón, 2015; Medina; Díaz; Montaño, 2021), and Venezuela had one record (Marcano; Sipman, 2021), with studies carried out in the Amazon (Figure 2). These countries are located within this biome, which highlights the regional relevance of this research.

Figure 2. Map of the regions where the main studies took place used in the integrative review

Source: Authors, 2024.

Figure 3 shows the number of studies found during the search for articles on platforms and integrated into this study. These were analyzed by year of publication in the period from 2013 to 2023. No studies were found for the years 2013 and 2016. In 2021, a significant peak stands out, with eight papers published, representing the highest number during the analyzed period. In contrast, the years 2019 and 2020 had the lowest numbers of published papers, with only two in each year.

Figure 3. Distribution of the years of publication of the articles found between 2013 and 2023 used in this integrative review.



Source: Authors, 2024.

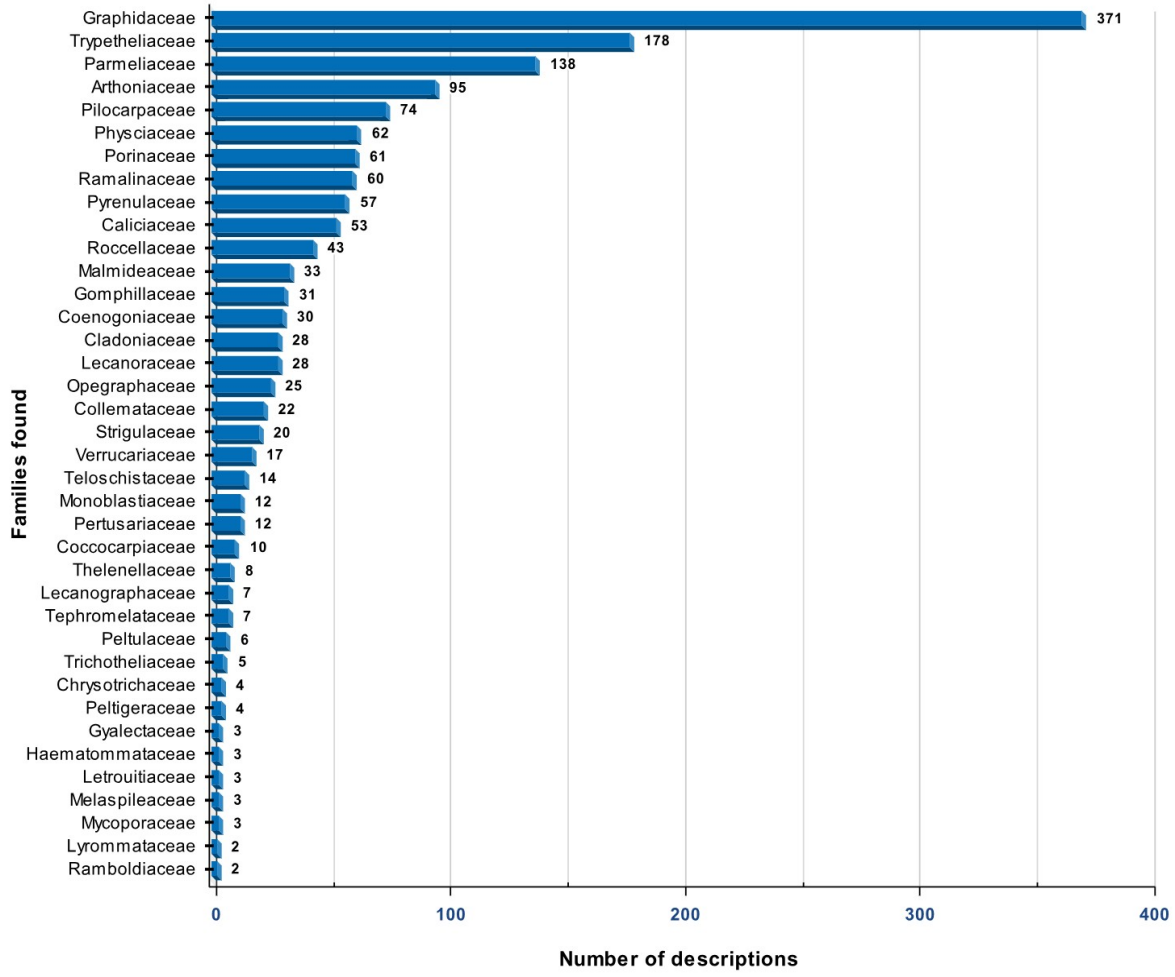
After a systematic review of the articles selected for this study, we identified a total of 58 families, 241 genera and 1554 species, belonging to both biomes analyzed. When analyzing the descriptions of species and genera, we observed that the Graphidaceae family presented the greatest diversity, with 371 descriptions of lichens among the studies analyzed. Then, the families Trypetheliaceae, Parmeliaceae, Arthoniaceae and Pilocarpaceae stood out with 178, 138, 95 and 74 descriptions, respectively. Families that presented in Figure 4.

By analyzing the Graphidaceae family, it was possible to identify the greatest diversity of lichens recorded, with a total of 371 species found in the biomes studied, distributed in 47 genera. Among the genera belonging to this family, the genus *Glyphis* stands out, with 63 species described, presenting the largest variety of lichens within this family. In addition, the

genera *Ocellularia*, *Fissurina* and *Phaeographis* also stand out, with 28 and 27 species described, respectively.

Of the 241 genera described, the greatest diversity of species was found belonging to the genus *Astrothelium*, with 106 descriptions, followed by the genera *Glyphis*, with 63 descriptions, *Pyrenula* and *Porina*, both with 52 descriptions, *Ocellularia*, with 44, and *Heterodermia*, with 30 descriptions. All other genera had fewer than 30 descriptions.

Figure 4. Families found and the number of lichens described belonging to each family.



Source: Authors, 2024.

When analyzing the diversity of lichens described by biomes, we observed that the Amazon presented a greater diversity in terms of families, genera and species. 16 families, 169 genera and 855 species exclusive to the Amazon were identified. In comparison, the Cerrado exhibited less diversity, with 10 families, 59 genera and 406 species exclusive to this biome.

From the Amazon, the Graphidaceae family stood out as the most diverse, with 244 species descriptions. Then, the families Trypetheliaceae, Arthoniaceae, Pilocarpaceae and Porinaceae presented 105, 65, 58 and 50 species descriptions, respectively. All other families had fewer than 50 descriptions. Among the genera, *Astrothelium* stood out as the most diverse, with 83 species described, belonging to the Graphidaceae family. Then, followed by the genera *Ocellularia* (n=42), *Glyphis* (n=38), *Porina* (n=37) and *Pyrenula* (n=32). All other genera had fewer than 30 descriptions during the last ten years.

From the Cerrado, the Parmeliaceae family stood out for the greatest diversity of lichens described, with 106 species belonging to this family. In addition, the Physciaceae family presented 48 described species, while the Graphidaceae and Caliciaceae families had 46 descriptions each. All other families had fewer than 30 descriptions. As for the genera of the cerrado, the genus with the highest number of species described was *Heterodermia*, with 28 descriptions, belonging to the family Physciaceae. Then, the genera *Lecanora*, *Hypotrachyna* and *Parmotrema* stood out with 24, 21 and 20 descriptions, respectively. All other genera recorded fewer than 20 descriptions.

By analyzing the described lichens present in both biomes, we identified a total of 33 families, 96 genera and 293 species. The Graphidaceae family showed the greatest diversity, with 81 descriptions, followed by the Trypetheliaceae family, with 57, and Arthoniaceae, with 22 descriptions. Among the most diverse genera, the genus *Glyphis* stands out, with 24 descriptions, which belongs to the Graphidaceae family, followed by the genera *Astrothelium* and *Polyblastidium*, both with 21 descriptions each.

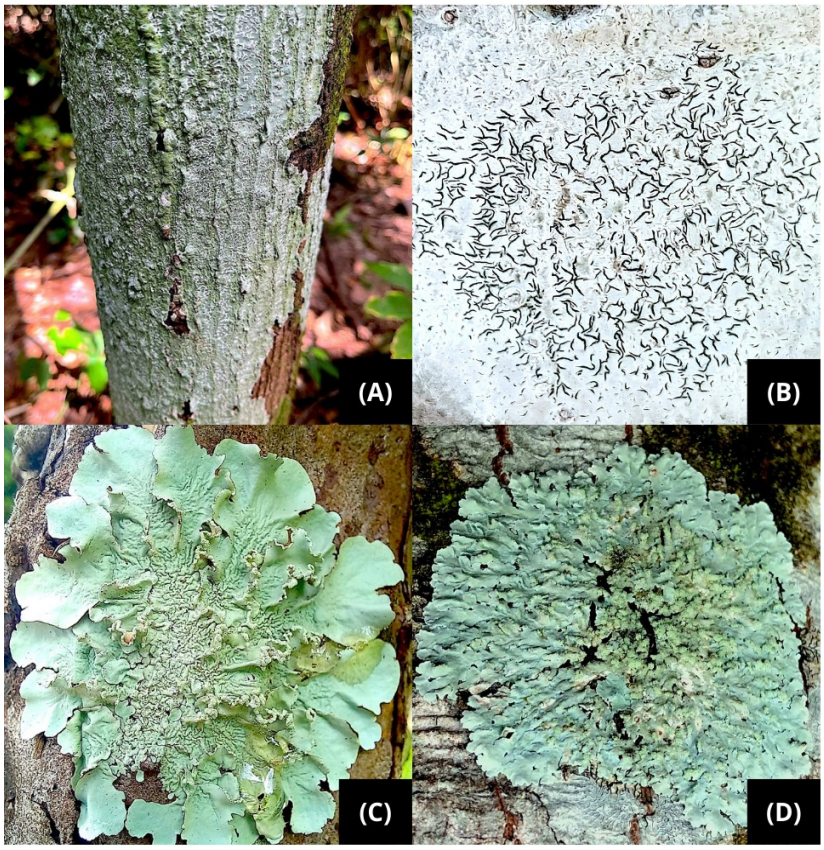
After the literature review, two species described from the Amazon were classified as "Uncertain", due to the difficulty in determining their families: *Psammina tropica* and *Milospium graphideorum*. These species were not considered in the analyses conducted in this study, due to the lack of sufficient information on their classification.

DISCUSSION

Although in our study the Graphidaceae family was mentioned more often in surveys of species diversity in the Amazon and Cerrado, with 371 species found, it is important to emphasize that Parmeliaceae stands out as the most representative. On the other hand, the Lecanoraceae family is recognized by the largest number of morphological variations within the lichen group (Costa, 2018b; Santos, Viviane M.; da Silva Cáceres; Lücking, 2020). The genus *Glyphis*, belonging to the Graphidaceae family, has adaptations and characteristics that allow it to thrive in various environments. This crustose lichen has been widely described in the two biomes investigated, showing a remarkable ability to attach to tree trunks, rocks and other substrates, which facilitates its permanence in this environment (Cáceres, Marcela; Aptroot*; et a*l., 2014; Castelli, 2017; Feuerstei*n et a*l., 2022).

In the Amazon, lichens of the family Graphidaceae (Figure 5A) are common in a variety of habitats, from humid tropical forests to more open areas. They can be found growing on tree trunks, rocks, soil, and even other plants. Their presence is indicative of good air quality, as they are sensitive to pollution (Cáceres, Marcela; Aptroot*; et a*l., 2014). Research by Plata *et al.* (2011) highlights the complexity of the Graphidaceae family, indicating that *Allographa*, a genus that also belongs to this family, is genetically close to several other genera, including *Glyphis*. This genetic proximity suggests a close evolutionary relationship between *Glyphis* and other family members (Figure 5B) (Rivas Plat*a et a*l., 2011).

Figure 5. Images representing the most frequent genera and families in the Amazon and Cerrado regions, according to the bibliographic survey. Graphilaceae Family (A); *Glyphis* sp. (B); Parmeliaceae Family (C); *Heterodermia* sp. (D).



Source: Authors (2025)

In contrast to the Amazon, where the family of lichens with the most descriptions was the Graphidaceae, in the Cerrado, the Parmeliaceae is the family of lichens that presented the highest number of descriptions, with 28 species. The Parmeliaceae family stands out as one of the most complex and diverse of this group of organisms, encompassing 80 genera and more than 1700 described species (for example Figure 5C) (Cunha; Marcelli; Pereira, 2015; Santos, Viviane M.; da Silva Cáceres; Lücking, 2020; Santos, Jayane Sous*a et a*l., 2021). Although the genus *Parmotrema* is widely dominant, representing one of the largest groups of folious lichenized fungi globally, our study revealed that the genus *Heterodermia* was the one that

presented the highest number of occurrences in the cerrado (Figure 5D) (Santos, Jayane Sous*a et a*l., 2021). The Parmeliaceae family is known for its ecological importance, being used in air pollution assessment studies being used as bioindicators in different ecosystems (Costa, 2018b; Abri*l et a*l., 2021; Santos, Jayane Sous*a et a*l., 2021).

The genus *Astrothelium*, a member of the lichenized fungi family Trypetheliaceae, is a significant component of corticolousl (fixed to bark) lichen communities found primarily in tropical to subtropical forests (Cáceres, Marcela Eugenia da Silva; Aptroot, 2017; Jian*g et a*l., 2022). In addition, the distribution of *Astrothelium species* has been documented in several regions, including the Amazon rainforest, where new species have been identified in studies conducted by Aptroot; Souza (2021) and Aptroot (2023). In our research, we highlight the richness and variety of this genus within the various Brazilian biomes, emphasizing its importance and diversity. Crucially, throughout the study, this genus emerged as the one with the highest number of descriptions, totaling 106 identified species.

Regarding the family Arthoniaceae stands out as a diverse and widely distributed group of lichens, encompassing species with global distribution. With a large number of varieties, the genus *Arthonia* contains approximately 140 globally described species (Alves *et a*l., 2014; Ertz *et a*l., 2018; Wijayawarden*e et a*l., 2022). Moreover, the Pilocarpaceae family encompasses a diverse group of lichens, mainly crustose, with a wide distribution, and more than 400 described species encompassing 32 genera. Among the members of the Pilocarpaceae, the genus *Fellhanera* stands out, constituting the base of this family that comprises predominantly tropical species, with many foliicolous representatives which grow on leaves (Spier; Aptroot; Herk, 2002; Hyd*e et a*l., 2019; Wan*g et a*l., 2020). The ecological importance of these families is remarkable, especially when it comes to monitoring the health of ecosystems.

Analyzing the family of lichenized fungi Porinaceae, it was observed that the genera *Porina* and *Trichothelium* were the most described within this family in the Amazon region (Lücking *et a*l., 2013; Sobreira; Aptroot; Cáceres, 2016). The distribution and preference for

different habitats have also been explored, with studies investigating the presence of Porinaceae in tropical forests, such as in Brazil. In addition, the taxonomic composition and geographic distribution of Porinaceae also vary in different environments (Leit*e et a*l., 2015; Santos, Viviane M.; da Silva Cáceres; Lücking, 2020).

In the Porinaceae family of lichenized fungi, it was observed in this study that the genera *Porina* and *Trichothelium* were the most described within this family in the Amazon region (Nascimento, T. Paje*ú et a*l., 2014; Santiag*o et a*l., 2018). The distribution and preference for different habitats have also been explored, with studies investigating the presence of Porinaceae in tropical forests, such as in Brazil. In addition, the taxonomic composition and geographic distribution of the Porinaceae also vary in different environments. The Caliciaceae family represents a significant group within lichens, especially in Brazil. In this study, it was observed that the genus most frequently found within this family was *Pyxine*. It is well described as belonging to the Cerrado biome. The research carried out by Aptroot (2019) seeks to understand the diversity and distribution of lichens of the Caliciaceae family, which has been investigated in several regions, with an emphasis on Brazilian biomes (Aptroo*t et a*l., 2019).

The study carried out by Santos (2022) highlights the Cladoniaceae and Parmeliaceae Families as the most prevalent among the lichens found in the Cerrado (Santos, Ingride Natane Miguel, 2022). These families play an essential role in forest succession and are commonly observed in areas that have suffered fires. In addition, the work of Costa (2018) complements by indicating that the Lecanoraceae and Caliciaceae families are also quite common in this biome, being fundamental for the biomonitoring of environmental pollutants (Costa, 2018b). Lichens play a key role as pioneers in the colonization of areas recently affected by natural disturbances. However, it is important to note that human activities can cause changes in the diversity of these organisms, thus affecting the dynamics of ecological succession (Costa, 2018b; Déle*g et a*l., 2021; Santos, Ingride Natane Miguel, 2022).

Studies carried out in Colombia in the Valle del Cauca region highlight the main genera of lichens present in the Amazon rainforest. Among the genera of endemic lichens present in the Amazon rainforest are: *Arthotheliopsis, Brasilicia, Caleniopsis, Dimelaena, Eremothecella, Lasioloma, Loflammea, Loflammiopsis, Microtheliopsis, Phylloblastia, Phyllogyalidea, Physcidia, Platythecium and Rubrotricha.* These comparative studies between the regions not only highlight the richness of the ecosystems around the Colombian Amazon rainforest, but also reinforce the importance of conserving these endemic lichen genera, which play essential roles in the ecology and maintenance of Amazonian biodiversity (Medina; Díaz; Montaño, 2021).

The lichen genera *Crostospathula* and *Physcidia*, identified in Rondônia, are considered rare. In addition, these same genera can be found in Latin American countries and in countries on the African continent, such as French Guiana (Aptroot; Cáceres, 2014; Cáceres, Marcela; Aptroot*; et a*l., 2014). The identification of *Cladonia curta* Ahti & Marcelli in the Pampa ecosystem in Brazil is a surprising find. Although this species is commonly associated with the Brazilian Cerrado, its presence in the Pampa reveals a remarkable ability to adjust to different environments (Gumbosk*i et a*l., 2018). Despite having a wide geographic distribution, the rarity of these lichen genera in Rondônia and other distinct biomes highlights the need to carry out additional studies for a deeper understanding of their ecology and possible interactions with local environmental factors.

Lichens are organisms that have a great diversity of genera, each with distinct ecological characteristics. The integrative review of the selected works reveals a wide variety of lichenic species, with emphasis on different genera, among them: *Glyphis, Astrothelium, Ocellularia*, *Fissurina*, *Phaeographis, Pyrenula, Porina*, *Heterodermia*, *Lecanora, Hypotrachyna and Parmotrema*, are just a few examples of this vast group. Several studies have contributed significantly to the understanding of these genera, which are well described in the biomes studied, demonstrating a wide distribution, interactions and importance as environmental indicators, which are important components for the biodiversity of these

regions (Cáceres, Marcela; Aptroot*; et a*l., 2014; Cunha; Marcelli; Pereira, 2015; Soto-Medina; Londoño-Lemos; Díaz-Escandón, 2015; Cáceres, Marcela Eugenia da Silva; Aptroot, 2017; Gumboski *et a*l., 2018).

CONCLUSION

After a detailed analysis of the previous studies, we found a great diversity of lichens in the Amazon and Cerrado biomes. In total, 58 families, 241 genera and 1554 species were identified. The Graphidaceae family stands out as the most diverse, with 371 species described. Beyond this, we observed that the Amazon has a greater diversity compared to the Cerrado, with 16 families, 169 genera and 855 exclusive species, while the Cerrado has 10 families, 59 genera and 406 exclusive species.

The analysis of the genera revealed that *Astrothelium* and *Glyphis* are the most diverse, with 106 and 63 species, respectively, in the Amazon, while *Heterodermia* stands out in the Cerrado, with 28 species. In addition, 33 families, 96 genera, and 293 species were found in both biomes, with Graphidaceae as the most diverse family.

The families Lecanoraceae, Arthoniaceae, Pilocarpaceae and Porinaceae have also been highlighted to contribute to the lichenic diversity of ecosystems. The Parmeliaceae family, in particular, has been recognized for its ecological complexity and diversity, and is used in ecological biomonitoring studies. In addition, comparative studies between regions have highlighted the importance of conserving endemic genera of lichens in the Amazon forest.

The analyses carried out in this study highlight how lichens are truly amazing in their ability to adapt to a wide variety of environments. When we look at the description of these organisms in different biomes, it is impressive to see how some species of lichens are so versatile, managing to establish themselves in such diverse environments. Consequently, the occurrence of these organisms in both the Cerrado and the Amazon not only increases the

diversity of these places but also offers us valuable information about several species that can be useful for monitoring and environmental conservation of these areas.

Understanding how lichens adapt to different environmental conditions is crucial to ensure the preservation of these ecosystems. he presence of shared species between the Cerrado and the Amazon provides valuable information for monitoring and environmental conservation of these areas. After all, they are always subject to both natural and human-caused impacts. Therefore, it is essential that we continue to study and value these organisms, which play such an important role in maintaining the ecological health of our natural environments.

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