

Biology (Plant-Microorganism Interaction)

New Occurrences of Macrofungi (Basidiomycota) in Southern Amazonas, Brazil

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ABSTRACT

Macrofungi are organisms that have macroscopic reproductive structures, called ascocarps and basidiocarps, and are important representatives of Ascomycota and Basidiomycota, respectively. The Amazon rainforest, as it offers a large number of natural resources, is one of the biomes that has been under great environmental pressure and sustainable use that takes into account social, economic and ecological factors is extremely important for protecting the forest. Given this context, this work aimed to present the characterization of the species that constitute occurrences of macrofungi for the Southern region of the state of Amazonas, contributing to the expansion of the knowledge on the geographical distribution of the specimens found. This survey was carried out at the Tenente Pimenta Jungle Base located 20 kilometers from the Municipality of Humaitá- state of Amazonas. The collections were carried out in two different periods, in the pre-existing trails of the Tenente Pimenta Jungle Base (54th BIS). 115 specimens belonging to 11 families were found, with species belonging to Ascomycota and Basidiomycota being identified. The data related to the collection periods of macroscopic fungi were from August 2019 and November 2019. In August 2019, a dry season in the Amazon, with little rain, 70 specimens of macrofungi were collected. In November, a rainy period in the Amazon, 105 specimens of macrofungi were collected. The data obtained from this research will serve as a basis for further studies in the state of Amazonas, since it is a pioneer in the southern region of the state. There is a great diversity of macrofungi in the study area, however, edaphoclimatic factors are relevant at different periods of the year.

Keywords: Fungi; Mycology; Basidiomycota; Southern Amazon; Amazon

1 INTRODUCTION

In the Brazilian Amazon, the dense ombrophilous forest is an ecosystem recognized for its remarkable species richness and high rates of endemism, playing a significant role in Brazil's economic and strategic scenario (MITTERMEIER *et al.*, 2003). Compounding the biotic environment of these forests, fungi participate with great importance in nutrient cycling, degrading lignin and cellulose from plant substrates (HOLF *et al.*, 2004).

High plant diversity in the vegetation of the Amazon biome suggests the diversity of fungi is also significant. According to Mueller *et al.* (2004), vegetation influences occurrence and diversity of fungi in the environment, since plants provide a habitat and energy source for most fungi which, in turn, exhibit some degree of specificity with hosts and/or substrates

The Amazon is a region with the largest extent of tropical forest in the world. It is a biome with unique characteristics, formed by large and dense vegetation, also including vegetation mosaics known as "campina" and "campinarana", and floodplains such as meadows and "igapós". Because it offers a large number of natural resources, it has been under great environmental pressure, and its sustainable use takes into account social, economic and ecological factors (PRANCE, 1975; JUNK; PIEDADE, 2010).

Macrofungi are organisms that have macroscopic reproductive structures, called ascocarps and basidiocarps, and are important representatives of Ascomycota and Basidiomycota, respectively (LODGE *et al.*, 2004). Fungi are the main decomposers of organic matter of plant origin in forest ecosystems, acting in the cycling of limiting nutrients for primary production. Many of them, such as the saprotrophs or decomposers, are a vital part of the food web connections of forest ecosystems, contributing to nutrient cycling (LODGE *et al.*, 1996; URCELAY *et al.*, 2004; MOORE *et al.*, 2011).

In the world, approximately 99,000 species of fungi are described, with the phylum Basidiomycota considered the most complex group within the kingdom, given the complexity of the structures of its species. There are records of more than 29,900 species, with around 1,350 genera, in 130 families, with Basidiomycota being the second largest group. In Brazil, the phylum has 1,730 species divided among 376 genera. In general, they are macroscopic, varying in size, shape and color; they are commonly known as hat mushrooms and “orelha-de-pau” in Brazil (KIRK *et al.*, 2001; KIRK *et al.*, 2008; MAIA; CARVALHO, 2010).

The cycling of nutrients caused by these microorganisms is extremely important in the stability and improvement of the functioning of ecosystems present in the soil (PAN *et al.*, 2008). In addition to their environmental importance, soil-dwelling fungi and their metabolic derivatives have great biotechnological potential, such as bioinoculants for agroforestry production, biological control, drug production, among others (GOI; SOUZA, 2006).

Therefore, the fungus has been studied with the representation of some of its phyla, but more information about the description of its representatives is still needed, such as knowledge about the taxonomy, phylogeny, ecology, composition and geographical distribution of these individuals, so that, in this way it is possible to provide necessary knowledge to assist in the study of biodiversity and diversity of fungal species.

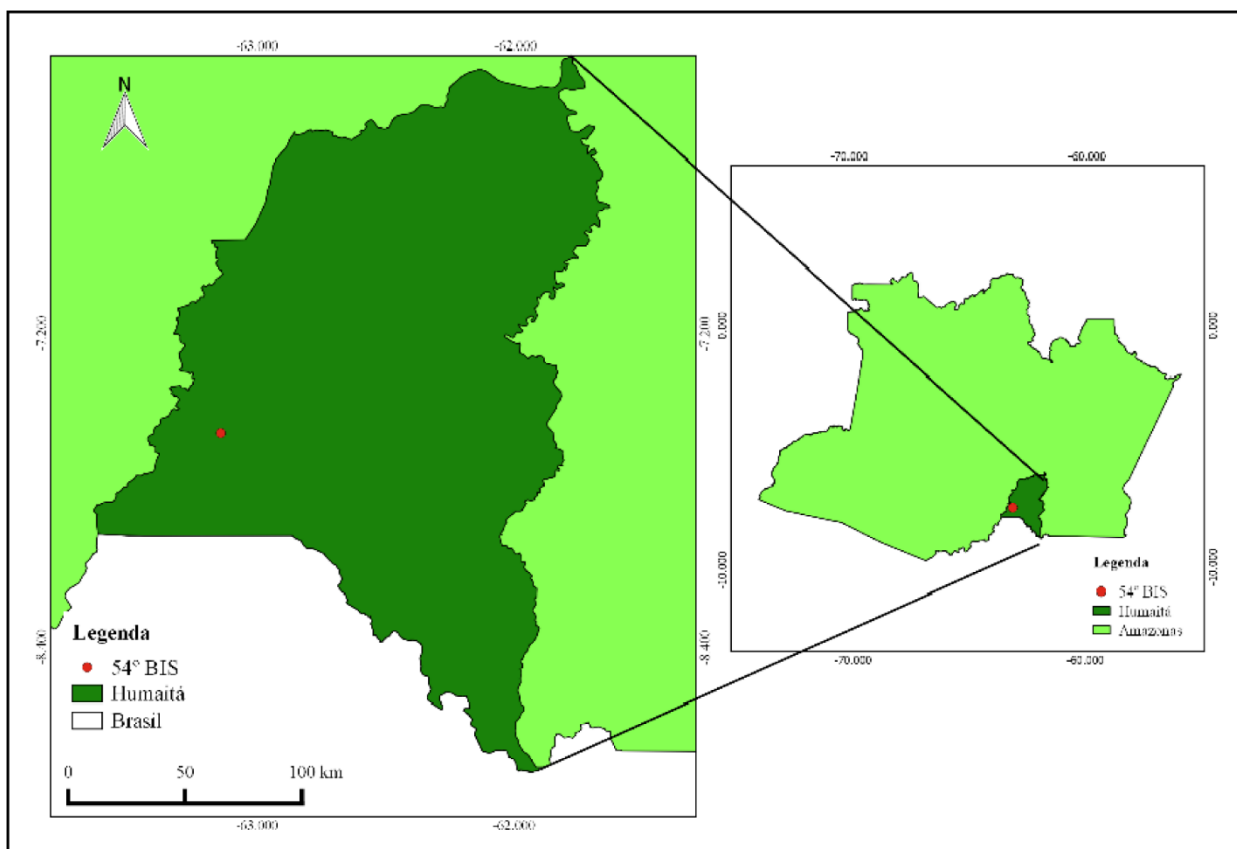
Thus, collections were carried out at the Jungle Base Tenente Pimenta, a forest area under the protection of the 54th Infantry and Jungle Battalion of the Brazilian Army (54^o BIS). Within this context, this work aimed to present the characterization of the species that constitute new occurrences of macrofungi for the Southern region of the Amazonas state, in order to expand the knowledge about the geographical distribution of the specimens found.

2 MATERIALS AND METHODS

2.1 Study site

Humaitá is a Brazilian municipality located in the interior of the state of Amazonas, belonging to the mesoregion of Southern Amazonas and the Madeira microregion. Its population is approximately 52,354 inhabitants (IBGE, 2017). It is located on the banks of the Madeira River, has an area of 33,071.8000 km², fiscal module of 100 ha, minimum fraction of land plots = 4 ha. The main access is by river, with a distance of 591.03 km from the capital Manaus -AM. It is also possible to reach the municipality through the BR-230 and BR-319 highways or via regular air transport (INCRA, 2016).

Figure 1 – Collection area of the 54th BIS



Source: Own authorship

The collection was carried out at the Tenente Pimenta Jungle Base, located 20 kilometers from the Municipality of Humaitá- state of Amazonas (7°35'2.400"S 63°8'33.360" W). The 54° BIS was created by Decree number 71,785, of January 31, 1973, being organized with the 1st Company of the 54° Jungle Infantry Battalion, in accordance with Reserved Ordinance number 079 of December 12, 1974. It is an area of terra firma forest, in which there are areas in process of regeneration (secondary forest) near primary forest areas. The vegetation indicates peculiar environments, such as the water regime, natural fertility, and soil aeration. There is a close relationship between the type of vegetation and the properties of the soil above which this vegetation occurs (RESENDE *et al.*, 1988) (Figure 1).

2.2 Collection and Identification of Fungi of the phylum Basidiomycota

The collections were carried out in two different periods of 2019: August (dry season) and November (wet season) on the pre-existing trails of the 54th BIS. The trail was chosen at random, where macrofungi were looked in all substrates such as trunks, branches, leaves, and other humid environments. In this way, a GPS receiver (Global Positioning System) was used to contribute to the studies of the geographic distribution of the species. The area demarcation was delimited by 40 x 10m transects, determining that each transect was approximately 200m away from the reserve trail, and approximately 100m from the headquarters in the straight line. For this purpose, a measuring tape was used to assist in the delineation of the area.

With respect to the identification of the fungi, identification guides and database platforms were strictly followed, including the *Index Fungorum* to aid in the taxonomy of the Fungi kingdom and the *Tree of Life Web Project*, which provides information on the diversity and phylogeny of Fungi. The identification of taxa at the morphological level was carried out at the Laboratory of Biology of the Federal University of Amazonas.

According to Singer (1986), the main characteristics to be noted are pilear surface, hymenial surface and stipe. The collected materials were identified at family and species level, based on Dennis (1970), Singer (1975, 1986) and Pegler (1977). Through the number of registered species, it was possible to analyze the quantitative data, highlighting the ecological, food and medicinal importance. Finally, the data from the fungal survey carried out were tabulated with the aid of the software Microsoft Excel® and analyzed descriptively.

3 RESULTS AND DISCUSSION

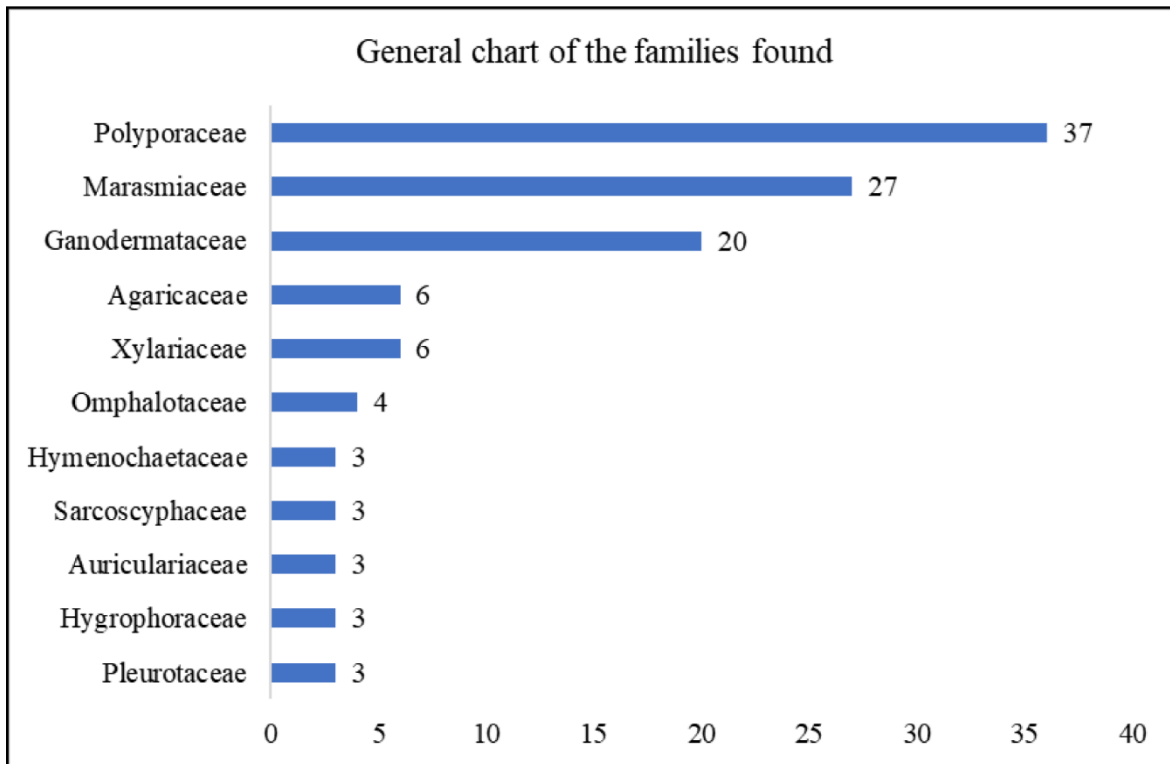
115 specimens belonging to 11 families were found, with species belonging to Ascomycota and Basidiomycota being identified. The data related to the collection periods of macroscopic fungi during the periods of August 2019 and November 2019 are shown in figure 2.

In August 2019, a dry period in the Amazon region, with little rain, 70 specimens of macrofungi were collected. In November, a rainy period in the Amazon region, 105 specimens of macrofungi were collected.

The relationship between the collection period and the number of specimens is due to seasonality. In the August collection, there was a smaller number of specimens, as they were collected during the dry season, but there was a large representation of the Polyporaceae Family, while in November there was a number of specimens of the Marasmiaceae family in the rainy season, therefore, the breeding frequency occurs in the period when there is more humidity.

Seasonality is one of the most important issues when trying to estimate macrofungal diversity, in which the emergence of basidiocarps depends on factors such as temperature, precipitation, soil pH, nutrient availability and patterns of vegetation succession. Studies on the seasonal distribution of macroscopic fungi are scarce in the literature and most of those that exist only address mycorrhizal fungi (CARVALHO; AMAZONAS, 2002).

Figure 2 – Families identified at the Jungle Base Tenente Pimenta, including the Family Xylariaceae, representing the phylum Ascomycota, whereas the other families represented the phylum Basidiomycota



Source: Own authorship

According to Serra (2017), the dependence of fungi on biotic and abiotic factors determines their role as a bioindicator to assess the impact of climate change and the influence of anthropic action. Monitoring the seasonality of the fruiting bodies as well as the succession of fungal species of a region over time can assist in the assessment of the environment sustainability. For this reason, monitoring, collection, and registration of species must be carried out continuously.

The availability of macrofungi in nature showed climatic references, where seasonality is widely observed that describe what season of the year they are found and what they need to grow. According to the study by Souza *et al.* (2015) he mentions that, in the view of the informants in his study, the diversity of fungi decreased due to the “scarcity” of the rains, with the species known as wood ear being the most prevalent.

In general, fungi depend on environmental variables, including rainfall, soil moisture, temperature and variety of existing substrates (LAZAROTTO *et al.*, 2014).

The Polyporaceae family presented the highest number of genera and species in the dry season, in August 2019. The largest number of species observed in Polyporaceae was already expected since this family is among those that have the greatest species diversity among polypore fungi (ALEXOPOULOS *et al.*, 1996). These results agree with studies on macroscopic fungi in Brazil and the State of Amazonas. For the Amazon region and the state of Amazonas, Gomes-Silva; Gibertoni (2009a, 2009b) released a list of the Agaricomycetes fungi, with 216 species for the order Polyporales, disclosing the largest number of species (146), families (07) and genera (61). For the state of Rondônia, Capelari; Maziero (1988) refer to 28 species of porous Agaricomycete fungi. In the state of Amapá, Sotão *et al.* (1991) disclosed a list of 33 species of Basidiomycetes, with 20 taxa of poroid Agaricomycetes, in which the Polyporaceae family had the largest number of representatives.

The family Marasmiaceae, which belongs to the order Agaricales, subclass Agaricomycetidae, class Agaricomycetes, subphylum Agaricomycotina, phylum Basidiomycota and kingdom Fungi, is cosmopolitan, being the family one of the most numerous in species and occurring with greater abundance in tropical regions. than in temperate or colder regions (SINGER 1986; ANTONÍN; NOORDELOOS, 2010).

The species of the genus are essentially saprophytic, degrading plant debris (litter) in humid forest areas and with good vegetation cover, playing a very important ecological role, which is the cycling of nutrients in the forests. A few species, such as *Marasmius oreades* (Bolton) Fr., occur in areas that are not covered and sunny, such as lawns, or covered by herbaceous plants, but most of them develop better in shaded environments.

Ganodermataceae is characterized by pileate, sessile to stipitate, poroid basidiocarps, di-trimitic hyphal system with the presence of arboriform skeletal

hyphae and by the presence of double-walled basidiospores, where the inner wall is usually ornamented, being this an exclusive characteristic of the taxon (FURTADO, 1962; RYVARDEN, 2004). The family was proposed in 1948 to include the genera *Amauroderma* Murril and *Ganoderma* Karst, previously belonging to the subfamily Ganodermatoideae Donk of Polyporaceae Corda (FURTADO, 1981; MONCALVO; RYVARDEN, 1997). Ganodermataceae has a cosmopolitan distribution, with an approximate variation of 117 to 220 described species, according to Kirk *et al.* (2010) and Moncalvo; Ryvarden (1997), respectively. The species cause white rot in wood or are associated with roots of live or dead trees (FURTADO 1981; RYVARDEN, 2004).

Other families belonging to Basidiomycota registered were Agaricaceae, Omphalotaceae, Hygrophoraceae, Hymenochaetaceae and Pleurotaceae. The following families belonging to the phylum Ascomycota have been registered: Sarcoscyphaceae, Tricholomataceae and Xylariaceae. Ascomycota and Basidiomycota are sister groups called Neomycota by Cavalier; Smith (1998).

The most frequent species in this study were: *Ganoderma* sp. (10 occurrences), *Marasmius* sp. and *Polyporus* sp. (nine occurrences each), *Trametes* sp. (eight occurrences), *Amauroderma* sp. (six occurrences), *Caripia montagnei*, *Panus velutinus* and *Xylaria* sp. (four occurrences each), *Hygrocybe* sp., *Marasmius haematocephalus* and *Panus strigellus* (Berk.) Overh (three occurrences), while the other species presented only one or two occurrences. The first three species are described in the course of the article in relation to their taxonomy and ecology (Table 1).

Table 1 – Macrofungal species collected at the Tenente Pimenta Jungle Base

Family	Species	Dry Period	Rainy Period	Occurance (State)
Agaricaceae	<i>Leucoagaricus rubrotinctum</i>		X	RS, BA
	<i>Leucocoprinus fragilissimus</i>		X	RO, PR, PE, RN, SP, PR, SC

Continued...

Table 1 – Continuation

Family	Species	Dry Period	Rainy Period	Occurance (State)
Agaricaceae	<i>Leucocoprinus cf. brunneoluteus</i>		X	AM, ES, SP, SC
	<i>Leococoprinus birnbaumii</i>		X	BA, PR, MS, SP, PR, RN, SC
Auriculariaceae	<i>Auricularia sp.</i>	X		AM, AP, RO, RR, BA, SP, PR, RS, SC
	<i>Auricularia delicata</i>	X		RO, BA, SP, RS, SC
Dacrymycetaceae	<i>Dacryopinax spathularia</i>		X	SP, PR, RS
Ganodermataceae	<i>Ganoderma sp.</i>	X		AC, AM, AP, PA, RO, RR, AL, BA, CE, PB, PE, SE, MT, MS, ES, MG, RJ, SP, PR, RS, SC
	<i>Amauroderma sp.</i>	X		AC, AM, PA, RO, RR, AL, BA, PB, PE, SE, GO, MT, MS, MG, RJ, SP, PR, RS, SC
	<i>Amauroderma trichodermatum</i>	X		PA, PR
	<i>Amauroderma subrugosum</i>		X	PA
Hygrophoraceae	<i>Hygrocybe sp.</i>		X	RO, SP, PR, RS,
	<i>Hygrocybe firma</i>		X	SP
	<i>Hygrocybe occidentalis</i>		X	RO, SP, PR
Hymenochaetaceae	<i>Fulvifomes fastuosus</i>	X		AM, PA, RO, RR, TO, BA, PE, RN, MS, SP, PR, RS
	<i>Oxyporus corticola</i>		X	PR RS, SC
Marasmiaceae	<i>Marasmius sp.</i>		X	AC, AM, PA, RO, PR, PE, RN, GO, MG, RJ, SP, PR, RS, SC
	<i>Marasmius haematocephalus</i>		X	AM, RO, MG, RJ, SP
	<i>Marasmius AFF. Rotalis</i>		X	SP
	<i>Trogia sp.</i>		X	RO, SP
	<i>Marasmius guyanensis</i>		X	AC
Mycenaceae	<i>Mycena sp.</i>		X	RO, SP, PR, RS

Continued...

Table 1 – Conclusion

Family	Species	Dry Period	Rainy Period	Occurance (State)
Omphalotaceae	<i>Caripia montagnei</i>	X		PA, PE, RN, SE
Pleurotaceae	<i>Pleurotus djamor</i>		X	AM, AP, PA, RO, PB, PE, RJ, SP, PR, RS
	<i>Pleurotus ostreatus</i>		X	PR, SC
Polyporaceae	<i>Polyporus sp.</i>	X		AC, AM, AP, PA, RO, RR, TO, AL, BA, CE, MA, PB, PE, PI, RN, SE, MS, MT, MG, RJ, SP, PR, RS, SC
	<i>Panus CF Similis</i>	X		N.E
	<i>Lentinus crinitus</i>	X		AM, AP, PA, RO, AL, BA, PR, PE, RN, MS, MT, ES, SP, PR, SC
	<i>Polyporus leprieurii</i>	X	X	AC, AM, PA, RO, AL, BA, MA, PB, PE, SE, MT, SP, PR, RS, SC
	<i>Trametes sp.</i>	X		AC, AM, AP, PA, RO, RR, AL, BA, PB, PE, SE, MS, MT, MG, RJ, SP, PR, RS, SC
	<i>Panus strigellus (Berk.) Overh.</i>	X		SP, PR, SC
	<i>Datronia mollis</i>		X	AC, SP, PR, RS, SC
	<i>Panus velutinus</i>	X		AM, PA, RO, AL, BA, PB, PE, GO, MT, RJ, SP, PR, RS, SC
	<i>Lentinus berteroi (Fr) Fr</i>		X	N.E.
	<i>Perenniporia medulla-panis</i>	X		PA, BA, SE, SP, PR, RS, SC
Sarcoscyphaceae	<i>Cookeina tricholoma</i>		X	PE, RS
	<i>Cookeina speciosa</i>		X	N.E.
Tricholomataceae	<i>Tricholoma flavovirens</i>		X	N.E.
Xylariaceae	<i>Xylaria sp.</i>		X	AC, AM, AP, PA, RO, RR, BA, CE, PB, PE, GO, MT, MG, RJ, SP, PR, RS, SC
	<i>Kretzschmaria clavus</i>		X	AM, BA, PR, PE, MT, RJ, SP, PR, RS
	<i>Camillea leprieurii</i>		X	AM, PA, RO, RR

Source: Own authorship

The georeferencing of the collection was made according to the following criteria: scale of the Study Area: Local Scale, Area 54° Infantry Battalion and Jungle of the Brazilian Army (54° BIS) located 20 kilometers from the Municipality of Humaitá-AM. (7°35'2.400 "S 63°8'33.360" W) Coordinates: 7 ° 35'02.4 "S 63 ° 08'33.4" W. Data source: GPS, point obtained at the location: Latitude: -7.5840 , Longitude: -63,1426 - Converted and moved to Google Earth and finished in QGiz. Data format: Shapefile.

Ganoderma sp. is the largest genus of the Ganodermataceae family, being cosmopolitan and causing white rot in wood by decomposing lignin, cellulose and, other polysaccharides. It grows on several species of trees, many of economic importance such as palms, rubber trees, peach trees, among others, causing great damage to production and, as a consequence, great losses, in addition to attacking urban trees causing the deterioration of their roots, collars and/or trunks (ADASKAVEG *et al.*, 1993; ARIFFIN *et al.*, 2000).

Figure 3 – Species of the Ganodermataceae family collected at the T. Pimenta Jungle Base



Source: Felipe Sant'Anna Cavalcante (2019)

Poroid fungi can cause two types of wood rot: brown rot and white rot. Fungi that secrete enzymes that degrade cellulose and hemicellulose are known to cause brown rot, reducing the substrate to brownish, brittle, cubic pieces, which are cracked in the direction of the fibers, due to the presence of residual lignin; those

that, in addition to these substances also degrade lignin, are responsible for white rot, which causes the substrate to present a whitish, soft, fibrous and spongy appearance (RYVARDEN, 1991; SAMUELSSON *et al.*, 1994). However, because of its decomposition capacity, they can be a problem for the country's economy, as they cause deterioration of lampposts, bridges, timber reserves in warehouses and even tree species that can be harnessed by man.

The species of the genus *Marasmius* spp. are mostly saprophytes, occurring mainly in the leaf litter, and their greatest importance, in ecological terms, is the role they play in nutrient cycling in tropical and subtropical regions. Some species are of great relevance for agriculture, as they cause diseases in tea, sugar cane (*Marasmius sacchari* Wakker, *Marasmius plicatulus* Peck, *Marasmius stenophyllus* Mont.), coffee (*Marasmius viegasii* Singer) and rubber tree plantations (*Hevea* spp.) They are also known to cause "witch rings" in pastures and lawns (SINGER, 1986).

Currently, the genus *Marasmius* comprises about 500 species, of which the majority are of tropical distribution (KIRK *et al.*, 2001), but this number may be much higher, reaching approximately 1,000 species (WILSON; DESJARDIN, 2005). More than 1,600 epithets have been published for the genus, although many are considered synonyms of other taxa, non-valid names, dubious names or names transferred to other genera (DESJARDIN *et al.*, 2000).

Descriptions of the species collected

Figure 4 – Identification of specimens from the Marasmiaceae family collected at the T. Pimenta Jungle Base T. Pimenta



Source: Felipe Sant'Anna Cavalcante (2019)

The Polyporaceae family had the highest number of genera and species in the dry season in August 2019. The largest number of species observed in Polyporaceae was already expected, as this family is among those that have the greatest specific diversity among polypore fungi (ALEXOPOULOS *et al.*, 1996). These results corroborate with studies on macroscopic fungi in Brazil and in the State of Amazonas.

The species of the genus *Polyporus* are recognized mainly, for presenting stipitate basidiocarps and a dimitic hyphal system, with skeleto-binding hyphae, that is, with a central axis, presenting different types of branching patterns, usually arboriform with dichotomous branches and the branched segments ending in thin tips; it contains generative hyphae with handles and basidiospores being cylindrical to subcylindrical in shape; with respect to their ecology, they are saprophytes that mainly grow on trunks of dead angiosperms (RYVARDEN, 1991).

Descriptions of the species collected:

Figure 5 – Specimens of the Polyporaceae family collected at the Base of Selva T. Pimenta



Source: Felipe Sant'Anna Cavalcante (2019)

Hawksworth (2001) points out that, although the megadiversity of tropical fungi is widely recognized, there is a need for more systematic studies, which expand not only knowledge about their diversity, but also about their relationship with the organisms on which they live and feed.

Thus, Mendoza *et al.* (2018) state that the Amazon region is a center of diversity and home to an expressive diversity of fungi that decompose organic matter, configuring an area of great ecological importance for the conservation of the ecosystem, in addition to presenting edible and medicinal species. However, more studies must be carried out - since this is the first survey conducted on one of the trails in the area - covering more places, thus verifying the systematic importance and deepening the knowledge on basidiomycetes.

Knowledge about Amazonian biodiversity is still restricted due to constant environmental changes, lack of financial investment and lack of qualified human resources to carry out collections, which contributes to low scientific production in this area of knowledge. In this context, there is a need to increase the knowledge on the endogenous mycobiota of the state of Amazonas, thus making it essential to assess the fungal diversity of this region. According to Moore; Frazer (2002), there was a drop in identifications between the 1980s and 2000s, probably because classic (morphological) taxonomy is of no longer interest. This, coupled with the popularity of other areas of study, has caused the training of professionals in classic taxonomy to decrease. Many species of the Polyporaceae family may, in this case, be extinct in the Amazon region even before they are described (OLIVEIRA *et al.*, 2015).

The identification of local biodiversity provides subsidies for monitoring and analyzing the interactions between the species found, specifically basidiomycete fungi, which may have economic applications (CAVALCANTE, 2020).

Fungi are considered to be comparatively the most studied microorganisms in Brazil. However, in the state of Amazonas, in the analyzed databases, few scientific records were identified. Despite the volume of information available in the literature, this group has a great diversity of species that deserves dedication. Fungi have potential according to economic and medicinal interests, which are important for the environment and for Amazonian populations because they use traditional knowledge in favor of Science (CAVALCANTE *et al.*, 2020).

4 CONCLUSIONS

The data survey from this research will serve as a basis for new studies in the state of Amazonas since it is pioneer in the southern region of the state. There is a great diversity of macrofungi in the study area. However, edaphoclimatic factors are relevant at different time periods throughout the year, since the area is extremely important for conservation and recognition of the local fungal biodiversity, harboring an expressive diversity of macroscopic fungi. The knowledge about the richness and distribution of species in the Amazonian biome provides important subsidies for bioprospecting the mycobiota, aiming to explore its potential for different uses.

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