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Distribution and composition of the lichenized mycota in a landscape mosaic of southern Brazil[1]

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RESUMO – (Distribuição e composição da micota liquenizada corticícola em um mosaico de paisagem do sul do sul do Brasil). Os fungos liquenizados são componentes epífitos em áreas florestais, sendo que as ações antrópicas podem ocasionar modificações na composição e distribuição espacial das espécies. O objetivo deste trabalho é avaliar como a comunidade liquênica corticícola está distribuída na vegetação nativa e plantada, além de investigar uma possível manifestação de preferência da comunidade liquênica por forófito e sua relação com o pH da casca dos mesmos. Foram analisados 120 forófitos distribuídos em 12 manchas de vegetação nativa e plantada: Floresta Ombrófila Mista, Plantações de Araucária, Pinos e Eucaliptos. Amostras adicionais de fungos liquenizados foram coletadas em todas as manchas de vegetação e/ou trilhas que levavam a estas, em coletas denominadas não sistemáticas. Foram registrados 113 táxons de fungos liquenizados, sendo 78 espécies no levantamento de comparação entre ambientes e 35 acrescentadas através das coletas adicionais. A maior diversidade de espécies foi registrada na Plantação de Araucária, enquanto que a maior ocorrência de táxons de ambientes sombreados foi verificada nas manchas da Floresta Ombrófila Mista. O maior número de táxons liquênicos foi registrado em forófitos com pH da casca básico. As variações registradas na composição e distribuição da comunidade liquênica podem estar relacionadas às características dos forófitos encontrados nestas áreas.
Palavras-chave: Composição, liquens, forófitos, Floresta de Araucária, pH da casca

ABSTRACT – (Distribution and composition of the lichenized mycota in a landscape mosaic of southern Brazil). Lichenized fungi are epiphytic components of forest areas where anthropogenic activities may cause changes in species composition and spatial distribution. The aim of this work is to evaluate how the lichen community is distributed on native and planted vegetation, and also to investigate possible preferences of the lichen community for specific host trees related to bark pH values. A total of 120 host-trees distributed in 12 remnants of native and planted vegetation were analyzed: native Araucaria forest and Araucaria, pine and eucalyptus plantations. Additional samples of lichenized fungi were collected in all vegetation types and adjacent trails, using a non-systematic sampling protocol. One hundred thirteen taxa of lichenized fungi were recorded, of which 78 species originated from the survey comparing the four habitats and 35 were added by additional collections. The highest species diversity was recorded in the Araucaria plantation while the greatest occurrence of shade tolerant taxa was found in the native Araucaria forest type. The largest number of lichen taxa was recorded on host-trees with basic bark pH. The wide variety of lichen community composition and distribution registered may be related to the host-tree characteristics found in these areas.
Key words: Araucaria Forest, bark pH, lichen composition, host-trees

Introduction

Biodiversity conservation has been one of the greatest challenges of the last decades due to intense anthropic interference mainly in forest environments, like the native Araucaria Forests, for example, which are being replaced by cultivation, especially of exotic plants. This vegetation formation, which in the past occupied large territories (Teixeira *et al*. 1986), is currently found in small restricted areas.

The reduction of these forest areas results in changes that affect the structure and dynamics of ecosystems in different ways. Since lichenized fungi are important epiphytes in forest areas (Hale 1983; Negi 2000), they are also influenced by these environmental changes.

Characteristics of the substrate (Hale 1957; Brodo 1973; Jesberger & Sheard 1973; Hawksworth & Hill 1984; Marcelli 1996; Schmidt *et al*. 2001), composition of macro and micro nutrients (Hawksworth 1975), luminosity and humidity (Honegger 1995; Brunialti & Giordani 2003; Martinez *et al*. 2006) are among the factors that most affect lichenized fungi distribution in forest areas. The acidity or alkalinity of the tree bark can also affect species establishment (Brodo 1973; Cáceres *et al.* 2007) and pH can be critical for the reproduction of many species (Hale 1957). Differences in bark pH values can inhibit the establishment of organisms favoring nitrophyte lichens (which occur on host trees with basic pH) or acidophyte lichens (host trees with acid pH). The presence or absence of these species can indicate the degree of eutrophication in the forest area (Herk 2001; Wolseley *et al*. 2006; Fleig & Grüninger 2008).

Currently existing studies on Araucaria forest lichens are mostly related to species surveys, with no ecological connotation (but see Kaffer et al in press). In the region of São Francisco de Paula, the works of Osorio & Fleig (1986b), Fleig (1990a), Fleig & Grüninger (2000) and Fleig & Grüninger (2008) cited 232 corticolous lichen species. Käffer & Martins Mazzitelli (2005) recorded 76 taxa in the sub-basin of Sinos and Taquari – Antas Rivers. For the São Francisco de Paula National Forest only 18 species of lichenized fungi are reported (Osorio & Fleig 1986b).

The aims of this study were: 1) to evaluate how the corticolous lichen community with a foliose, squamulose and filamentous habit is distributed in native and planted vegetation, 2) to investigate a possible manifestation of preference by lichen species for host trees, as well as their interaction in these different vegetation types and; 3) to verify the relationship between host-tree bark pH and

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associated lichen species in the São Francisco de Paula National Forest.

Material and methods

Study area – This study was carried out at the São Francisco de Paula National Forest (FLONA), classified as a Conservation Unit for Sustainable Use, located in the town of São Francisco de Paula (29º 02'S; 50º 23'W), Rio Grande do Sul state, Brazil. The average altitude of the region is 912m above sea level, with an average temperature of 14.5ºC and average precipitation of 2252 mm.year^{-1} (Schneider et al. 1989). It encompasses an area of 1607 hectares, characterized by the dominance of Araucaria angustifolia (Araucariaceae, "Brazilian-pine"), with small monoculture stands of A. angustifolia and of species of the genera Pinus and Eucalyptus (Fig. 1). In native and planted vegetation types at São Francisco de Paula National Forest other tree species associated with A. angustifolia, Pinus spp. and Eucalyptus spp are usually found. They are distinguished by the greatest number of species, representatives of the families Myrtaceae, Lauraceae, Fabaceae, Cunoniaceae, Aquifoliaceae, Euphorbiaceae and Podocarpaceae.

Sampling and identification – The species survey was carried out from March 2003 to April 2004 in the following vegetation types: native Araucaria forest (FO), Araucaria plantation (PA), Pine plantation (PP) and Eucalyptus plantation (PE), and also on the access trails surrounding these stands.

At each vegetation stand (FO, PA, PP and PE) 10 host trees with erect trunks and no branching below 150 cm height and with dbh over 8 cm were randomly sampled, comprising a total of 120 host trees. Each stand was selected based on availability and accessibility, but all stands were at least 1 ha in area and at least 100 m apart. Lichens were registered on tree bark from 30 cm to 150 cm above the ground for each selected tree in each of the four vegetation types. Surveys were performed using the Rubberband Method (Marcelli 1992) and all the species that touched the rubberband were identified in the field or collected for later identification at the lab.

Additional samples of lichenized fungi were collected in all vegetation stands and adjacent trails, using a non-systematic sampling protocol. These samples aimed to record species that were not registered in the stands and were used as duplicates to be deposited as herbarium specimens. Some specimens were taken from the same sampled host trees, but at a point higher than 150 cm, and others were collected from twigs and branches that fell from tree crowns.

Lichen identification was carried out by observing anatomical sections of thallus and fructifications using stereoscopic and optical microscopes. The external characteristics of the lobes, such as color and thallus aspect, lobe width and length, presence of pycnidia and rhizines, cilia and aspect of apothecia were also analyzed. Coloration tests with potassium hydroxide 20% (KOH), sodium hypochlorite ($CaClO_2$), para-phenylenediamine (P) and fluorescence under UV-light (long wave) were used to determine the presence of acid substances in the cortex and medulla, besides help from specialized literature for each taxonomic group and checking it against materials from the Prof. Dr. Alarich Schultz Herbarium (HAS) at Fundação Zoobotânica, Rio Grande do Sul state, Brazil. Identified samples were incorporated into the Prof. Dr. Alarich Schultz Herbarium (HAS) of Fundação Zoobotânica, Rio Grande do Sul state, Brazil. The collected material is catalogued under numbers 43994 to 44130 in the above mentioned Herbarium (HAS).

Characterization of the host trees – A total of 120 host trees were sampled and characterized regarding bark type and pH. For the species that were not recognized in the field, collections of branches and/or twigs were carried out for later identification with the help of specialists and/or specialized literature. For each tree species the following bark types were identified: furrowed, fibrous, and smooth by using specific literature for the species. Tree bark pH was determined in the field, in a clean space on the tree trunk free of lichens and bryophytes by using a digital pH meter model PH – 1700 – Instrutherm, measured right after lichenized fungi were registered. Bark pH values have been characterized as acid (0 to 6.9), neutral (7.0) and basic (7.1 to 14).

Data analysis – In order to verify if the number of interactions between lichenized fungi and host trees is modified between native and planted stands, matrices of lichen x host-tree interaction were built for each vegetation type. From these matrices an index of connectance (c) was calculated for each stand by dividing the number of registered interactions by the number of possible interactions. For both the analyses mentioned above, only data from the lichenized fungi recorded in the survey of native and planted stands were used.

In order to investigate lichenized fungi distribution, their preference for host trees and the relation between bark pH and specimens, host-tree wealth and bark pH values were evaluated, as well as the wealth of lichenized mycota on each host tree.

Results

Species composition – A total of 113 taxa of lichenized fungi is recorded, of which 78 species were sampled during the survey for comparison between vegetation types and 35 added through additional non-systematic collections. The reported taxa are distributed in 24 genera, five of which comprise new species to science, such as: *Hypotrachyna* sp*.*, *Canoparmelia* sp*.*, *Parmotrema* sp. 1, *Parmotrema* sp. 2 and *Parmelinella* sp*.* Eight species are new records for Brazil: *Hypotrachyna croceopustulata*, *Hypotrachyna singularis*, *Lobaria* cf. *casarettiana*, *Lobaria intermedia*, *Pannaria* cf. *saubinetti*, *Physcia atrostriata*, *Physcia erumpens* and *Pseudocyphellaria subrubella*. Eight species are reported for the first time in Rio Grande do Sul state: *Erioderma leylandi*, *Hypotrachyna steyermarkii*, *Leptogium* cf. *bullatum*, *Leptogium isidiosellum, Parmotrema bangii, Parmotrema gardneri*, *Parmotrema neosubcrinitum* and *Parmotrema* aff. *subarnoldii* (Tab. 1).

Of all the reported species, 76.1% are colonized by chlorophyceans and 23.9% by cyanobacteria. In total, 41 species were registered in the *Araucaria* forest, 61 in *Araucaria* plantations, 31 in *Pinus* plantations and 40 in *Eucalyptus* plantations. In relation to species that were found exclusively in each habitat, there were 23 species found only in native Araucaria forests, with 25 taxa found exclusively in *Araucaria* plantations, seven found only in pine plantations, and 16 species in *Eucalyptus* plantations. We also found that 42 species occurred in more than one vegetation type. Of the material identified, 38% of the species belong to the Parmeliaceae family, followed by Stictaceae (16.8%) and Collemataceae (12.4%). Regarding habit, foliose species represent 93.8%, squamulose 4.4% and filamentous 1.7%. The most representative genus was *Parmotrema* with 17 species, followed by *Leptogium* and *Sticta* with 13 taxa. The genera *Lobaria*, *Hypotrachyna* and *Heterodermia* also stand out with 12, nine and eight species, respectively.

Characterization of the host trees and interactions with the lichenized fungi – Of the total number of host trees sampled, *Araucaria angustifolia* showed the highest frequency (23.3%), followed by *Pinus* spp. (20%) and *Eucalyptus* spp. (19.2%). In native *Araucaria* forests, dominance of host-tree species was low. In the *Araucaria* plantations the predominant species was *A. angustifolia,*

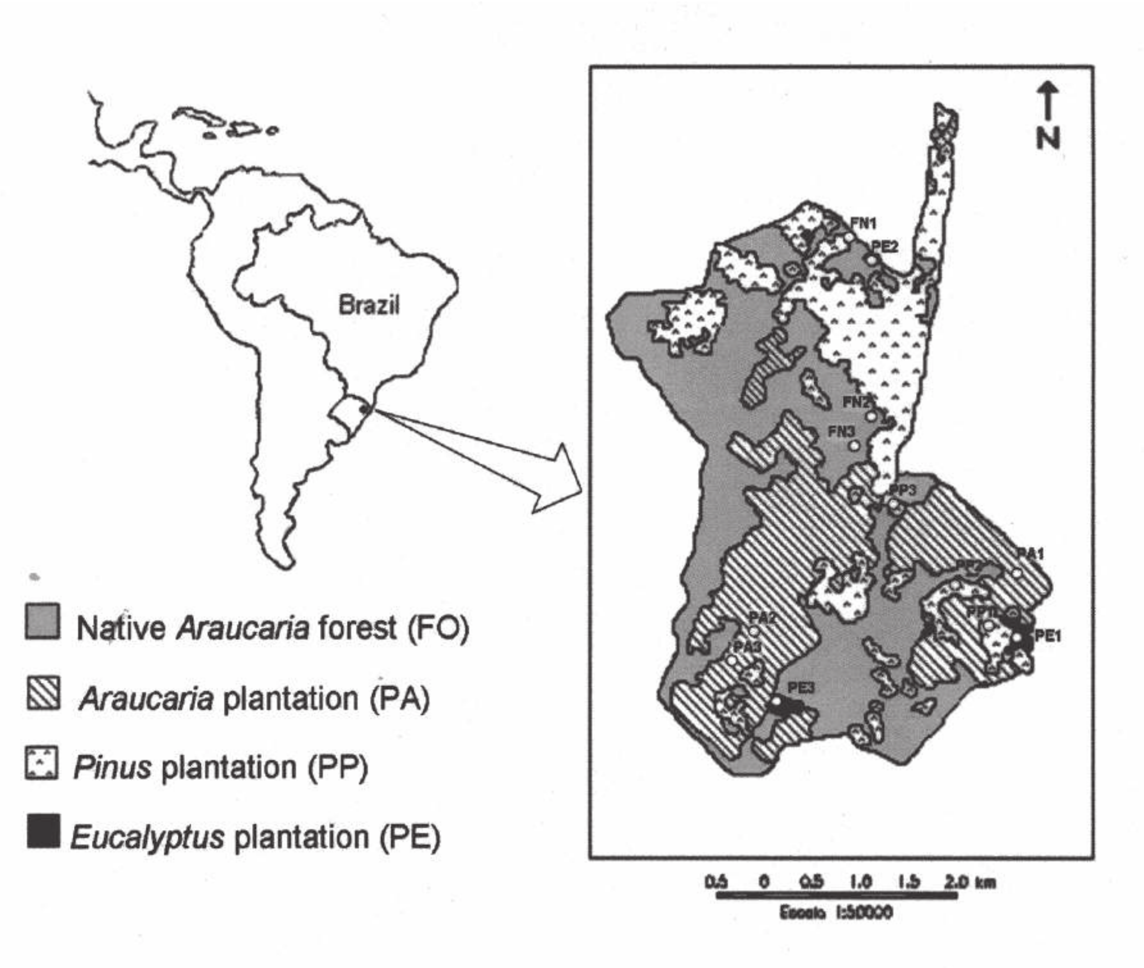

Figure 1. Map of the study area representing the locations of the different vegetation types studied at the National Forest of São Francisco de Paula, southern Brazil.

in pine plantations *Pinus* spp was the dominant tree representing 80% of the sampled host trees, while in the *Eucalyptus* plantation *Eucalyptus* represented 76.7% of the sampled host trees (Tab. 2).

When the interaction matrices between lichenized fungi and host trees were analyzed the occurrence of a greater number of interactions among taxa and host trees was clearly seen in *Eucalyptus* plantations. In native *Araucaria* forests and pine plantations, the number of interactions was similar, while the lowest connectance rates were observed in the *Araucaria* plantation. In native *Araucaria* forests, lichenized fungi taxa established themselves in greater number on *Casearia decandra* and *A. angustifolia*; in the Araucaria plantation most of the specimens used *A. angustifolia* as host tree; in the pine plantation *Pinus* spp. dominated, and in the *Eucalyptus* plantation the host tree with the greater number of interactions was *Myrsine coriacea* (Tab. 3). The connectance index was 36% for PE, 21% for FO, 21% for PP and 16% in the PA (Fig. 2).

Distribution of the lichenized fungi and preference for host trees – Of lichenized taxa occurring in the vegetation-type survey, 47.4% of the specimens were recorded on basic pH host trees, 38.5% were recorded on host trees with indifferent pH values (acid, basic and/or neutral), 12.8% on acid pH host trees and 1.3% on neutral pH host trees. The most representative genera occurring in acid pH were *Canomaculina* and *Coenogonium* with two specimens each, while only one species with cyanobacteria was recorded on these host trees, *Coccocarpia erythroxyli*. A greater number of representatives of the Parmeliaceae family (45.9%) occurred at basic pH, while 24.3% were lichens with cyanobacteria, *Leptogium* and *Sticta* being the genera that contributed the greatest number of specimens (Tab. 4).

Regarding host trees, 15.8% had basic bark pH, 81.7% host trees had indifferent bark pH, 1.7% individuals had acid bark pH and 0.8% of the individuals had neutral bark pH (Fig. 3). The lowest values of bark pH (4.9 to 5.7) were recorded on 12 individuals of *Eucalyptus* and on 50% of these there was no occurrence of lichenized fungi. The highest pH values (8.3 to 9.2) were seen on 24 individuals, 37.5% from *Araucaria angustifolia,* 33.3% from *Pinus* and the remaining 29.2% represented by *Blepharocalyx*

Table 1. Composition and occurrence of lichen species in four vegetation types in south Brazil: FO = native *Araucaria* forest, PA= *Araucaria* plantation, PP = Pine plantation and PE = *Eucalyptus* plantation. Caption: • new report for Brazil, ■ new species, ▲ new report for RS state, cl = chlorophycean, ci = cyanobacteria.

Taxa of lichenized fungi	Vegetation types				Algae	Habit	Family
	FO	PA	PP	PE			
Canomaculina subcaperata (Kremp.) Elix				x	clorof.	Fol.	Parmeliac.
Canomaculina subsumpta (Nyl.) Elix		x			clorof.	Fol.	Parmeliac.
Canomaculina uruguensis (Kremp.) Elix				x	clorof.	Fol.	Parmeliac.
Canoparmelia caroliniana (Nyl.) Elix & Hale		x	x	x	clorof.	Fol.	Parmeliac.
Canoparmelia sp. 1 ■		x			clorof.	Fol.	Parmeliac.
Cladonia ceratophylla (Sw.) Spreng.	x		x		clorof.	Esq.	Cladoniac.
Cladonia ochrochlora Flörke			x		clorof.	Esq.	Cladoniac.
Coccocarpia erythroxyli (Spreng.) Swinsc. & Krog				x	ciano	Fol.	Coccocarpiac.
Coccocarpia palmicola (Spreng.) Arvidsson & Galloway	x				ciano	Fol.	Coccocarpiac.
Coccocarpia pellita (Ach.) Müll. Arg. ex R. Sant.		x			ciano	Fol.	Coccocarpiac.
Coenogonium linkii Ehrenb.	x				clorof.	Fil.	Gyalectac.
Coenogonium cf. *interplexum*Nyl.	x				clorof.	Fil.	Gyalectac.
Dictyonema glabratum (Spreng.) D. Hawksw.				x	clorof.	Fol.	Thelephorac.
Dirinaria applanata (Fée) Awasthi	x				clorof.	Fol.	Physciac.
Dirinaria picta (Sw.) Clements & Shear				x	clorof.	Fol.	Physciac.
Erioderma leylandi (Taylor) Müll.Arg. ▲		x		x	clorof.	Fol.	Pannariac.
Heterodemia galactophylla (Tuck.) W. L. Culb.	x	x			clorof.	Fol.	Physciac.
Heterodermia flabellata (Fée) Awasthi				x	clorof.	Fol.	Physciac.
Heterodermia japonica (Sato) Swinsc. & Krog		x		x	clorof.	Fol.	Physciac.
Heterodermia leucomela (L.) Poelt.	x	x	x	x	clorof.	Fol.	Physciac.
Heterodermia lutescens Follmann		x			clorof.	Fol.	Physciac.
Heterodermia obscurata (Nyl.) Trevis	x	x	x	x	clorof.	Fol.	Physciac.
Heterodermia speciosa (Wulf.) Trevis	x	x		x	clorof.	Fol.	Physciac.
Heterodermia vulgaris (Vain.) Follmann & Redón		x			clorof.	Fol.	Physciac.
Hypotrachyna croceopustulata (Kurok.) Hale •			x		clorof.	Fol.	Parmeliac.
Hypotrachyna livida (Taylor) Hale		x	x	x	clorof.	Fol.	Parmeliac.
Hypotrachyna aff. *livida* (Taylor) Hale			x		clorof.	Fol.	Parmeliac.
Hypotrachyna cf. *peruviana* (Nyl.) Hale			x		clorof.	Fol.	Parmeliac.
Hypotrachyna singularis (Hale) Hale •		x	x		clorof.	Fol.	Parmeliac.
Hypotrachyna steymarkii (Hale) Hale ▲			x		clorof.	Fol.	Parmeliac.
Hypotrachyna sp. 1		x	x		clorof.	Fol.	Parmeliac.
Hypotrachyna sp. 2				x	clorof.	Fol.	Parmeliac.
Hypotrachyna sp. 3			x	x	clorof.	Fol.	Parmeliac.
Leptogium austroamericanum (Malme) Dodge	x	x	x		ciano	Fol.	Collematac.
Leptogium azureum (Sw.) Mont.	x	x	x	x	ciano	Fol.	Collematac.
Leptogium cf. *bullatum* (Ach.) Nyl. ▲		x			ciano	Fol.	Collematac.
Leptogium cochleatum (Dicks.) P. M. Jorg. & James	x	x			ciano	Fol.	Collematac.
Leptogium aff. *cochleatum* (Dicks.) P. M. Jorg. & James		x			ciano	Fol.	Collematac.
Leptogium chloromelum (Sw.) Nyl.	x				ciano	Fol.	Collematac.
Leptogium cyanescens (Ach.) Körb.	x			x	ciano	Fol.	Collematac.
Leptogium cf. *pichneum* (Ach.) Malme		x			ciano	Fol.	Collematac.
Leptogium isidiosellum (Riddle) Sierk ▲				x	ciano	Fol.	Collematac.
Leptogium marginellum (Swartz) S. Gray				x	ciano	Fol.	Collematac.
Leptogium moluccanum (Pers.) Vain.		x			ciano	Fol.	Collematac.
Leptogium sp. 1	x	x			ciano	Fol.	Collematac.
Leptogium sp. 2		x			ciano	Fol.	Collematac.
Lobaria cf. *casarettiana* (De Not.) Trev. •		x			ciano	Fol.	Collematac.
Lobaria cuprea (Müll. Arg.) Zahlbr.				x	clorof.	Fol.	Lobariac.

Continues

Table 1. Continuation.

Taxa of lichenized fungi	Vegetation types				Algae	Habit	Family
	FO	PA	PP	PE			
Lobaria discolor (Bory ex Delise) Hue	x				clorof.	Fol.	Lobariac.
Lobaria cf. *discolor* (Bory ex Delise) Hue	x				clorof.	Fol.	Lobariac.
Lobaria erosa (Eschw.) Nyl.		x		x	clorof.	Fol.	Lobariac.
Lobaria cf. *erosa* (Eschw.) Nyl.				x	clorof.	Fol.	Lobariac.
Lobaria patinifera (Taylor) Hue	x	x		x	clorof.	Fol.	Lobariac.
Lobaria intermedia (Nyl.) Vain. •		x			clorof.	Fol.	Lobariac.
Lobaria tenuis Vainio	x				clorof.	Fol.	Lobariac.
Lobaria sp. 1		x			clorof.	Fol.	Lobariac.
Lobaria sp. 2	x	x			clorof.	Fol.	Lobariac.
Lobaria sp. 3	x				clorof.	Fol.	Lobariac.
Normandina pulchella (Borrer) Nyl.			x		clorof.	Fol.	F. imperfeitos
Pannaria rubiginosa (Ach.) Bory	x	x			ciano	Esq.	Pannariac.
Pannaria cf. *saubinetti* (Mont.) Nyl. •		x			ciano	Esq.	Pannariac.
Paraparmelinella sp. ■	x				clorof.	Fol.	Parmeliac.
Parmelinopsis horrescens (Taylor) Elix & Hale		x	x		clorof.	Fol.	Parmeliac.
Parmelinopsis cf. *minarum* (Vain.) Elix & Hale			x		clorof.	Fol.	Parmeliac.
Parmotrema bangii (Vain.) Hale ▲		x			clorof.	Fol.	Parmeliac.
Parmotrema catarinae Hale	x				clorof.	Fol.	Parmeliac.
Parmotrema chinense (Osbeck) Hale & Ahti				x	clorof.	Fol.	Parmeliac.
Parmotrema crinitum (Ach.) M. Choisy		x			clorof.	Fol.	Parmeliac.
Parmotrema eciliatum (Nyl.) Hale		x	x	x	clorof.	Fol.	Parmeliac.
Parmotrema gardneri (Dodge) Sérusiaux ▲		x	x	x	clorof.	Fol.	Parmeliac.
Parmotrema hypomiltoides (Vain.) Fleig		x			clorof.	Fol.	Parmeliac.
Parmotrema melanothrix (Mont.) Hale		x			clorof.	Fol.	Parmeliac.
Parmotrema mellissii (Dodge) Hale		x	x	x	clorof.	Fol.	Parmeliac.
Parmotrema neosubcrinitum Ribeiro & Marcelli ▲		x			clorof.	Fol.	Parmeliac.
Parmotrema rampoddense (Nyl.) Hale	x	x	x	x	clorof.	Fol.	Parmeliac.
Parmotrema rigidum (Lynge) Hale		x	x	x	clorof.	Fol.	Parmeliac.
Parmotrema robustum (Degel.) Hale		x	x	x	clorof.	Fol.	Parmeliac.
Parmotrema aff. *subarnoldi* (Abb.) Hale ▲		x			clorof.	Fol.	Parmeliac.
Parmotrema cf. *subrugatum* (Kremp.) Hale		x			clorof.	Fol.	Parmeliac.
Parmotrema sp. 1 ■		x	x		clorof.	Fol.	Parmeliac.
Parmotrema sp. 2 ■	x				clorof.	Fol.	Parmeliac.
Peltigera sp.	x				ciano	Fol.	Peltigerac.
Phyllopsora confusa Swinsc. & Krog	x				clorof.	Esq.	Biatorac.
Physcia atrostriata Moberg •				x	clorof.	Fol.	Physciac.
Physcia erumpens Moberg •	x				clorof.	Fol.	Physciac.
Pseudocyphellaria aurata (Ach.) Vain.		x		x	clorof.	Fol.	Stictac.
Pseudocyphellaria cf. *berberina* (G. Forster) Galloway & P. James •	x				clorof.	Fol.	Stictac.
Pseudocyphellaria clathrata (De Not.) Malme		x			clorof.	Fol.	Stictac.
Pseudocyphellaria subrubella Räs. •	x				clorof.	Fol.	Stictac.
Pseudocyphellaria sp. 1				x	clorof.	Fol.	Stictac.
Pseudocyphellaria sp. 2	x			x	clorof.	Fol.	Stictac.
Punctelia constantimontium Sérusiaux	x				clorof.	Fol.	Parmeliac.
Punctelia graminicola (W. L. Culb.) & C. F. Culb.) Krog	x	x			clorof.	Fol.	Parmeliac.
Punctelia reddenda (Sirt.) Krog		x	x		clorof.	Fol.	Parmeliac.
Punctelia riograndensis (Lynge) Krog				x	clorof.	Fol.	Parmeliac.
Rimelia cetrata (Ach.) Hale & Fletcher		x		x	clorof.	Fol.	Parmeliac.
Rimelia homotoma (Nyl.) Hale & Fletcher				x	clorof.	Fol.	Parmeliac.

Continues

Table 1. Continuation.

Taxa of lichenized fungi	Vegetation types				Algae	Habit	Family
	FO	PA	PP	PE			
Rimelia macrocarpa (Pers.) Hale & Fletcher		x	x	x	clorof.	Fol.	Parmeliac.
Rimelia reticulata (Taylor) Hale & Fletcher		x	x		clorof.	Fol.	Parmeliac.
Rimelia simulans (Hale) Hale & Fletcher		x	x		clorof.	Fol.	Parmeliac.
Sticta damaecornis (Sw.) Ach.	x				clorof.	Fol.	Stictac.
Sticta sinuosa Pers.	x				clorof.	Fol.	Stictac.
Sticta variabilis (Bory) Ach.	x				clorof.	Fol.	Stictac.
Sticta weigelii (Ach.) Vain.	x	x			ciano	Fol.	Stictac.
Sticta sp. 1	x				ciano	Fol.	Stictac.
Sticta sp. 2	x	x			ciano	Fol.	Stictac.
Sticta sp. 3		x	x		ciano	Fol.	Stictac.
Sticta sp. 4		x			ciano	Fol.	Stictac.
Sticta sp. 5		x		x	ciano	Fol.	Stictac.
Sticta sp. 6	x				clorof.	Fol.	Stictac.
Sticta sp. 7		x			clorof.	Fol.	Stictac.
Sticta sp. 8			x	x	ciano	Fol.	Stictac.
Sticta sp. 9		x			clorof.	Fol.	Stictac.

Table 2. Host-tree characteristics and occurrence in four vegetation types at the National Forest of São Francisco de Paula. Vegetation types represent: FO = native *Araucaria* forest, PA= *Araucaria* plantation, PP = Pine plantation and PE = *Eucalyptus* plantation.

Species	Number of individuals	Bark pH	Vegetaion types	Structure bark
Araucaria angustifolia (Bert.) O. Ktze.	28	6,3 - 9,1	FO, PA, PP	furrowed
Eucalyptus spp	21	4,9 - 6,2	PE	furrowed
Pinus taeda L.	17	6,3 - 8,9	PP	fissured
Myrsine coriacea (Sw.) R.Br.	7	6,5 - 7,4	PA, PP, PE	fissured
Pinus elliottii Engelm	7	7,6 - 8,8	PP	fissured
Calyptranthes concinna DC.	6	7,0 - 8,2	FO	furrowed
Casearia decandra Jacq.	6	6,1 - 8,4	FO	fissured
Cinnamomum glaziovii (Mez) Kosterm.	4	6,7 - 7,0	FO	fissured
Cryptocarya aschersoniana Mez	4	7,7 - 7,9	FO	fissured
Ilex paraguariensis A. St.Hil.	3	7,9 - 8,1	PA, PP, PE	fissured
Eucalyptus viminalis Labill.	2	5,9 - 7,8	PE	smooth
Inga vera Willd.	2	6,9 - 8,8	PA, PE	furrowed
Ocotea pulchella (Nees) Mez	2	7,8 - 8,4	FO, PA	fissured
Sapium glandulosum (L.) Morong	2	7,1 - 7,5	PA, PP	fissured
Weinmannia paulliniifolia Pohl ex Ser.	2	7,3 - 8,0	FO	fissured
Casearia silvestris Sw.	1	7,0	FO	fissured
Podocarpus lambertii Klotzsch ex Endl.	1	8,0	FO	fissured
Blepharocalyx salicifolius (Kunth) O. Berg	1	8,4	PA	furrowed
Myrcia oligantha O. Berg	1	8,7	FO	furrowed
Luehea divaricata Mart. et Zucc.	1	7,8	PA	furrowed
Aegiphila sp.	1	7,8	PP	fissured
Ilex dumosa Reissek	1	7,1	PA, PP	fissured

Table 3. Connectance matrix between taxa of lichenized fungi and host-trees in four vegetation types at the National Forest of São Francisco de Paula.

Number of individuals host-trees	28	21	17	7	7	6	6	4	4	3	2	2	2	2	1	1	1	1	1	1	117	12
Taxa lichenized fungi/Host-trees	*A. angustifolia*	*Eucalyptus* spp	*P. taeda*	*P. elliottii*	*M. coriacea*	*C. decandra*	*C. concinna*	*C. glaziovii*	*C. aschersoniana*	*I. paraguariensis*	*I. vera*	*W. paullinifolia*	*S. glandulosum*	*O. pulchella*	*B. salicifolius*	*P. lambertii*	*C. silvestris*	*I. dumosa*	*M. oligantha*	*Aegiphila* sp.	Total of lichens	Vegetation types
Canoparmelia sp. 1	1																				1	PA
Lobaria cf. *casarettiana*	1																				1	PA
Sticta sp. 4	1																				1	PA
Parmotrema melanothrix	1																				1	PA
Parmotrema hypomiltoides	2																				2	PA
Parmotrema crinitum	2																				2	PA
Parmotrema aff. *subarnoldi*	1																				1	PA
Coccocarpia pellita	2																				2	PA
Parmotrema neosubcrinitum	5																				5	PA
Parmotrema bangii	2																				2	PA
Hypotrachyna sp. 1	1												1								2	PA, PP
Sticta sp. 2	1								1												2	FO, PA
Sticta sp. 3	1									1											2	PA, PP
Pseudocyphellaria clathrata	2										1										3	PA
Lobaria sp. 2	2														1						3	FO, PA
Heterodermia japonica	6										1										7	PA, PE
Lobaria tenuis	1						1	1	1			1									4	FO
Sticta sinuosa	1					2			1							1					4	FO
Sticta damaecornis	2							1	1							1					5	FO
Pannaria rubiginosa	2							1				1						1			3	FO, PA
Leptogium azureum	1	1			2	1	1			1	1	1	2	1	1		1		1	1	15	FO, PA, PP, PE
Rimelia cetrata	5	1			1					1	1										4	PA, PE
Parmotrema rigidum	1	1	1																		3	PA, PP, PE
Parmotrema mellissii	7	1	6	6																	13	PA, PP, PE
Parmotrema gardneri	3	1	2	2																	5	PA, PP, PE
Rimelia macrocarpa	3	1		2																	6	PA, PP, PE
Parmotrema robustum	3	1		1																	2	PA, PP, PE
Heterodermia speciosa	6	2			1				1						1						5	FO, PA, PE
Leptogium cyanescens	2	1			1	2															4	FO, PE
Lobaria erosa	4	1			1					1								1			4	PA, PE
Canoparmelia caroliniana	3		4	2	1	1															8	PA, PP, PE
Parmelinopsis horrescens	3		3	2																	5	PA, PP
Parmotrema sp. 1	2		1																		3	PA, PP
Hypotrachyna singularis	1		2																		3	PA, PP
Parmotrema ecilitum	7		1		1						1										3	PA, PP, PE
Parmotrema rampoddense	6		2		1																3	FO, PA, PP, PE
Punctelia semansiana	2				1				1												2	FO, PA
Rimelia reticulata	9			1																	10	PA, PP
Rimelia simulans	7			1																	8	PA, PP
Punctelia reddenda	1			3																	4	PA, PP
Leptogium austroamericanum	1			1		1															3	FO, PA, PP
Hypotrachyna livida	3				2																2	PA, PE
Heterodermia obscurata	8				3					1				1	1						6	FO, PA, PP, PE
Heterodermia leucomela	4				2					1	1		1					1			6	FO, PA, PP, PE

Continues

Table 3. Continuation.

Number of individuals host-trees	28	21	17	7	7	6	6	4	4	3	2	2	2	2	1	1	1	1	1	1	117	12
Taxa lichenized fungi/Host-trees	*A. angustifolia*	*Eucalyptus* spp	*P. taeda*	*P. elliottii*	*M. coriacea*	*C. decandra*	*C. concinna*	*C. glaziovii*	*C. aschersoniana*	*I. paraguariensis*	*I. vera*	*W. paullinifolia*	*S. glandulosum*	*O. pulchella*	*B. salicifolius*	*P. lambertii*	*C. silvestris*	*I. dumosa*	*M. oligantha*	*Aegiphila* sp.	Total of lichens	Vegetation types
Lobaria patinifera	2				1																1	FO, PA, PE
Hypotrachyna sp. 2		1	2	3	1																7	PP, PE
Punctelia riograndensis		1			1																2	PE
Canomaculina uruguensis		1																			1	PE
Coccocarpia erythroxyli		2								1											3	PE
Canomaculina subcaperata		2																			2	PE
Hypotrachyna steymarkii			1	1																	2	PP
Parmelinopsis cf. *minarum*			1	1																	2	PP
Hypotrachyna cf. *peruviana*			4																		4	PP
Hypotrachyna croceopustulata			2																		2	PP
Cladonia ceratophylla			2			1															3	FO, PP
Hypotrachyna aff. *livida*				1																	1	PP
Lobaria cuprea					1																1	PE
Leptogium marginellum					1																1	PE
Leptogium isidiosellum					1																1	PE
Heterodermia flabellata					1																1	PE
Physcia erumpens					1																1	PE
Pseudocyphellaria aurata					1																1	PA, PE
Coenogonium linkii						2		1													3	FO
Lobaria cf. *discolor*						1		1													2	FO
Coenogonium cf. *interplexum*								1				1					1				3	FO
Physcia astrotriata								1													1	FO
Sticta variabilis								1	1			1					1				4	FO
Phyllopsora confusa							1	1	2					1			2				6	FO
Heterodemia galactophylla								1		1				1							3	FO, PA
Leptogium sp. 1												1			1						2	FO, PA
Lobaria sp. 1															1						1	PA
Lobaria intermedia															1						1	PA
Heterodermia vulgaris															1						1	PA
Rimelia homotoma											1										1	PE
Leptogium cf. *pichneum*																		1			1	PA
Sticta sp. 1						1										1					2	FO
Sticta weigelii													1			1					2	FO, PA
Sticta sp. 6																1					1	FO
Total number of occurrences of lichenized fungi	187	60	68	41	40	24	15	18	17	14	11	10	9	8	10	7	7	6	3	3	484	

salicifolius, Calyptranthes concinna, Casearia decandra, *Inga vera*, *Cryptocarya aschersoniana*, *Myrcia oligantha* and *Ocotea pulchella*. Of these 24 individuals no lichenized fungi occurred on 20.8%. In table 4 there is a list of the lichen taxa related to host-tree bark pH values in sampled vegetation types from São Francisco de Paula National Forest.

Discussion

This work reveals that a fair number of lichen species could colonize tree plantation stands. This pattern is mainly related to the light management procedures used at this National Forest where tree plantations were allowed to grow for longer periods than the usual seven years applied to

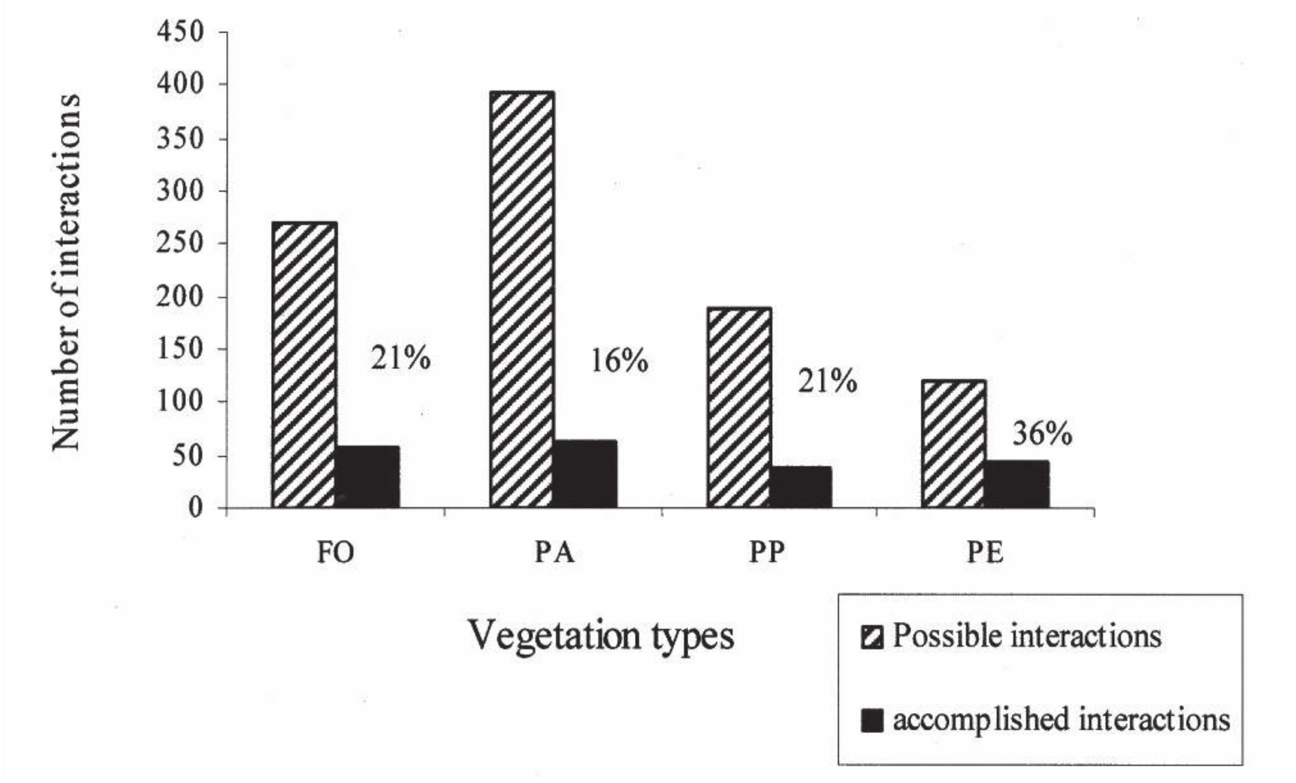

Figure 2. Connectance matrix (possible and accomplished interactions) between lichenized fungi taxa and host-trees in four vegetation types at the National Forest of São Francisco de Paula: FO = native Araucaria forest, PA= *Araucaria* plantation, PP = Pine plantation and PE = *Eucalyptus* plantation.

Table 4. Occurrence of lichenized fungi taxa according to bark pH in the four vegetation types at the National Forest of São Francisco de Paula.

Taxa	Acid	Basic	Indifferent	Neutral
Canomaculina subcaperata	x			
Canomaculina uruguensis	x			
Canoparmelia caroliniana	x			
Cladonia ceratophylla	x			
Coenogonium linkii	x			
Coenogonium cf. *interplexum*			x	
Heterodermia flabellata	x			
Rimelia homotoma	x			
Canoparmelia sp. 1		x		
Coccocarpia pellita		x		
Coccocarpia erythroxyli	x			
Heterodermia speciosa			x	
Heterodermia leucomela			x	
Heterodemia galactophylla			x	
Heterodermia vulgaris		x		
Heterodermia obscurata			x	
Heterodermia japonica			x	
Hypotrachyna sp.1		x		
Hypotrachyna sp. 2			x	
Hypotrachyna livida			x	
Hypotrachyna aff. *livida*		x		
Hypotrachyna singularis		x		
Hypotrachyna croceopustulata		x		
Hypotrachyna steymarkii		x		
Hypotrachyna cf. *peruviana*			x	

Continues

Table 4. Continuation.

Taxa	Acid	Basic	Indifferent	Neutral
Leptogium cf. *pichneum*		x		
Leptogium cyanescens			x	
Leptogium azureum			x	
Leptogium austroamericanum		x		
Leptogium sp. 1		x		
Leptogium isidiosellum		x		
Leptogium marginellum		x		
Lobaria cuprea		x		
Lobaria aff. *discolor*			x	
Lobaria erosa			x	
Lobaria cf. *casarettiana*		x		
Lobaria sp. 1		x		
Lobaria sp. 2			x	
Lobaria intermedia		x		
Lobaria patinifera			x	
Lobaria tenuis			x	
Parmelinopsis horrescens		x		
Parmelinopsis cf. *minarum*		x		
Parmotrema melanothrix	x			
Parmotrema robustum		x		
Parmotrema sp. 1			x	
Parmotrema eciliatum			x	
Parmotrema rampoddense		x		
Parmotrema crinitum		x		
Parmotrema mellissii			x	
Parmotrema gardneri			x	
Parmotrema hypomiltoides		x		
Parmotrema rigidum			x	
Parmotrema aff. *subarnoldi*		x		
Parmotrema aff. *subarnoldi*			x	
Parmotrema bangii		x		
Pannaria rubiginosa			x	
Phyllopsora confusa			x	
Physcia erumpens		x		
Physcia astrotriata				x
Pseudocyphellaria aurata		x		
Pseudocyphellaria clathrata		x		
Punctelia reddenda		x		
Punctelia graminicola		x		
Punctelia riograndensis			x	
Rimelia simulans		x		
Rimelia cetrata			x	
Rimelia macrocarpa			x	
Rimelia reticulata			x	
Sticta damaecornis			x	
Sticta sinuosa		x		
Sticta variabilis			x	
Sticta weigelii		x		
Sticta sp. 1		x		
Sticta sp. 2		x		
Sticta sp. 3			x	
Sticta sp. 4		x		
Sticta sp. 6		x		

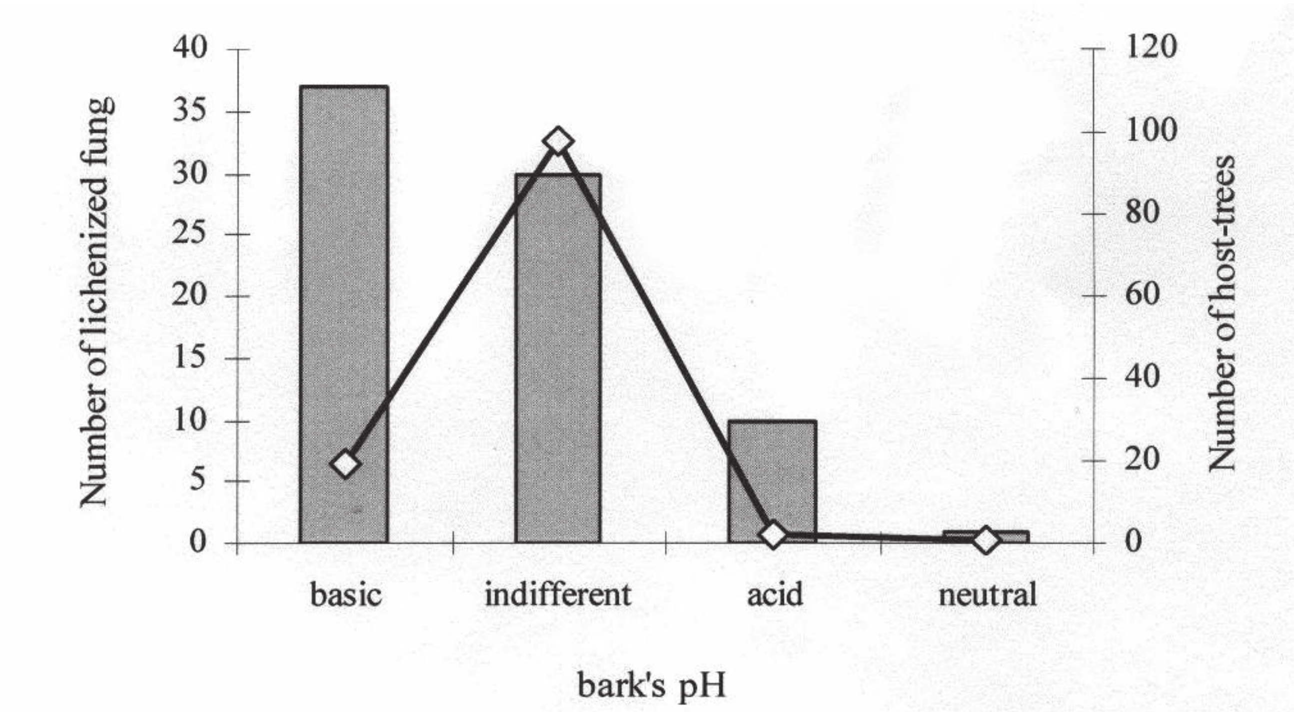

Figure 3. Relationship between lichenized fungi taxa and their host-trees according to the values of bark pH in the four vegetation types at the National Forest of São Francisco de Paula.

economically driven tree plantations. Moreover, plantations were of small size and surrounded by large areas of native forest which allows flora and fauna colonization to take place (Fonseca *et al*. 2009). However, the greatest occurrence of characteristic shade tolerant species was found in the native Araucaria forests and Araucaria plantations, with an increase in light demanding lichen species in the pine and *Eucalyptus* plantations (see also Kaffer *et al.* 2009).

In the native Araucaria forest the greatest occurrence of species from genera *Phyllopsora* and *Coenogonium* was recorded. They were absent in other environments. These areas present denser, stratified tree tops which could favor lower light penetration encouraging typical shade tolerant species to become established. *Leptogium* is another genus that is characteristic of shady, humid environments (Wolseley 1991), however, species of this genus occurred in several environments, especially *Leptogium azureum* that was found in the four habitats studied, probably because it is one of the genera which has the greatest adaptability to different types of environment (Wolseley 1991). In the Araucaria forests, gelatinous lichens, such as those from the genus *Leptogium*, occur in the lower humid layers and they do not become very abundant (Fleig & Grüninger 2008).

Tree plantations showed a large number of light demanding taxa from the family Parmeliaceae, a group which was responsible for 40% of the total species recorded in all environments. Species from the genus *Parmotrema* were largely abundant in forest plantations. Only 5.7% of Parmeliaceae species were recorded in the native Araucaria forest environment; the greater representativeness of the family Parmeliaceae found in this study corroborates other studies carried out in native Araucaria forest areas in Rio Grande do Sul (Fleig & Grüninger 2000; Käffer & Martins –Mazzitelli 2005; Käffer *et al*. 2009).

Differences in lichen species composition recorded in the Araucaria plantation when compared to the other vegetation types could, among other reasons, be related to the characteristics of the host trees found in these areas. In the *Araucaria* plantation stands, 76.7% of the host trees analyzed were *Araucaria angustifolia*. Studies carried out in forest areas have confirmed that alterations in the lichen community may be attributed to host-tree composition and to the features of host-tree bark (Hale 1983; Ferry & Lodge 1996; Lõhmus *et al*. 2007). Of all the host trees sampled, 50% had bark with rough structure; 23.3% of these belong to *A. angustifolia* and 43.3% are characterized by fissured structure. Differences in substrate texture are one of the most obvious effects favoring lichen species colonization (Brodo 1973). However, this specificity of lichens to the substratum may also be related to other factors, such as bark porosity and water retention (Jesberger & Sheard 1973; Kuusinen 1996; Schmidt *et al*. 2001). Although other host trees have rough bark structure, the main occurrence of lichenized fungi was recorded on *A. angustifolia*.

Variations in lichen composition related to host-tree bark pH were also observed. The greatest number of lichen taxa (37) was recorded on host-tree bark with basic pH, while 30 specimens seemed indifferent. Species that colonize indifferent substrata tend to have a wide distribution due to the greater offer of substrata (Valencia & Ceballos 2002).

Recent studies have related lichenized fungi establishment to host-tree bark pH and ammonia levels coming from anthropogenic sources, such as agriculture and pasture (Loppi 1996; Herk 2001; Wolseley *et al*. 2006). These variations in nitrogen ion concentration on host-tree bark could be influencing lichen species establishment favoring nitrophyte lichen species (Kermit & Gauslaa 2001; Wolseley *et al*. 2006; Fleig & Grüninger 2008). Some lichen species with cyanobacteria are associated with trunks with pH above 5.0 (Goward & Arsenault 2000; Will-Wolf *et al*. 2002). In native and planted vegetation types at FLONA only 15.4% of the taxa colonized by cyanobacteria were recorded on host trees with pH above 5.0, from which *Leptogium* can be pointed out, since it showed the greatest occurrence on these trees. Fleig & Grüninger (2008) cited *Phaeophyscia hispidula* (Ach.) Moberg, *Physcia aipolia* (Ehrenb. ex Humb.) Fürnrohr, *Physcia erumpens* Moberg, *Dirinaria applanata* (Fee) Awasthi and *Canoparmelia caroliniana* (Nyl.) Elix & Hale as species that indicate eutrophication. In the FLONA areas, *P*. *erumpens* occurred on host-trees with basic pH, while *C. caroliniana* occurred on bark with acid pH.

Regarding the host trees, there are a few studies on tree bark pH concerning the lichenized mycota. In Brazil, there is only a record of host trees in mangrove regions (Marcelli 1992), while for trees from native *Araucaria* forests, *Pinus* and *Eucalyptus* monocultures, so far almost no data has been published (but see Kaffer et al. 2009). In regions of Europe and North America, studies indicate that conifers usually have low pH, with variations between 3.0 and 6.0 (Hale 1983; Sillet *et al*. 2000a; Kermit & Gauslaa 2001; Löbel *et al*. 2006; Wolseley *et al*. 2006; Larsen *et al*. 2007). For the FLONA areas, individuals from the same species, as for example, *A. angustifolia*, *Pinus taeda* and *P*. *elliottii* and from the same genus, as *Eucalyptus* sp. presented bark with acid, basic and/or neutral pH. Sillet *et al*. (2000b) also recorded variations in pH values among the same host-tree species. These variations in pH values on host-tree bark in native and planted vegetation types at FLONA could be associated, among other factors, with soil type, host-tree age, tree physiological characteristics as well as with the influence of anthropogenic activities that are intense in the regions within the FLONA boundaries.

Diversity loss and changes in lichen communities in forest and managed areas have been frequently described by many researchers (Lesica *et al*. 1991; Hilmo & Sastad 2001; Kanowski *et al*. 2003; Kantvilas & Jarman 2004; Lõhmus *et al*. 2007). In Brazil, some studies have demonstrated the great diversity of lichenized fungi in threatened environments. Marcelli (1992) recorded 289 lichen taxa on two species of host trees in a mangrove area on the São Paulo coast, while Martins (2006) identified 161 taxa on only a single host-tree species in a coastal restinga area, in Rio Grande do Sul state. For the native Araucaria forest area, the percentage of recorded lichen species may be considered low as yet, compared to the total number of referred species for Rio Grande do Sul (Spielmann 2006). However, the great species richness of corticolous lichenized taxa, plus records of new species for science and new occurrences for Brazil and Rio Grande do Sul state, indicate the ability of establishment of this group in different forest compositions as FLONA. Nevertheless, the differences observed in the lichenized mycota composition in this landscape mosaic demonstrate a tendency for species replacement, especially the ones related to shaded environments.

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