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BRIEF COMMUNICATION

Airborne fungal spore content in the atmosphere of the city of La Plata, Argentina

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Abstract The aim of this paper is to present the first aeromycological study of the atmosphere of the city of La Plata. Air samples were taken using a Hirst-type volumetric spore trap sampler (Lanzoni, VPPS 2000) for a period of a year (July 2000–June 2001). Seventy-nine morphological types of spores belonging to the Phyla Myxomycota, Zygomycota, Oomycota, Ascomycota, Basidiomycota, as well as anamorphs of Higher Fungi were identified. A total of 171670.21 spores were recorded, with a daily mean of 540 spores/m^3. The spores were present throughout the year the study was carried out. However, there was a wide daily fluctuation in the concentration values with a tendency toward an increase during the summer months. The fungal spores were classified in three categories: *abundant*, having five spore types; *moderate* having 12 types; and *low*, with 62 morphological types which represent 67.2, 24.2, and 8.6%, respectively. The most representative taxa were *Cladosporium cladosporioides*, *Leptosphaeria*, *Cladosporium herbarum*, *Coprinus*, and *Agaricus*, the first two taxa having a high frequency during the year of study. This scientific research reveals a great diversity of morphological types in this outdoor environment, showing a strong dominance of the Imperfect Fungi, whose components have seasonal rates. By this study, the first aeromycological profile of an urban center of Argentina has been portrayed, and new information on the field of aeromycology in the country has been provided.

Keywords Fungal spores · Diversity · Concentration · Frequency · Urban area · Argentina

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1 Introduction

Fungi are cosmopolitan organisms which develop in the most varied substrates and live in virtually all climates in the earth. There is an important qualitative and quantitative variability in the anemophilous mycota of the various environments as well as local seasonal variations, having an impact on human health and air quality (Gregory 1961). These aerosols in particular tend to be especially difficult to study since their production, maturation, release, and eventual concentration of spores in the atmosphere depend on multiple biotic and abiotic local factors, and on those resulting from human activity (Beggs 2004).

In Argentina, there have been few studies on the atmosphere mycobiota. Early aeromycological research in outdoor environments were carried out in the cities of La Plata (Iovannitti and Tiraboschi 1985; Negrin et al. 2007), Córdoba (Quiroga de Pascual and Nobile 1985); Resistencia (Mangiaterra et al. 1993), and Corrientes (Esquivel et al. 2003), by means of the gravitational method. The goals of these studies were the isolation, cultivation, and identification of taxa which were present in the atmosphere; these studies were oriented toward medical purposes. More recent research using Hirst-type samplers was done in the Alto Valle del Río Negro and Neuquén to analyze the presence, concentration, and impact of *Alternaria* spores on human health (Vega et al. 2001). Additionally, the diversity and dynamics of pollen and spores were also analyzed in San Carlos de Bariloche (Bianchi and Olabuenaga 2006). During the 1998–2001 period, an aerobiological monitoring was performed in the city of La Plata making use of the same method. In a first stage of the study, the diversity and concentration of pollen in the atmosphere, its relationship with meteorological features, as well as the pollen types which affect allergic respiratory diseases, was analyzed (Nitiu and Romero 2001, 2002; Nitiu and Mallo 2002; Nitiu 2003, 2004, 2006, 2008).

A second stage began with the analysis of the mycobiota, and its goal was to characterize the fungal portion, given the importance of these particles in the aerobiological record. The aim of this study was to provide the first identification and characterization of atmospheric mycobiota in La Plata by analyzing the diversity, concentration, representation, and frequency of the spores in the air during a year (July 2000–June 2001).

2 Materials and methods

2.1 Description of the area and location of the sampler

The city of La Plata (34°55′S, 57°57′W) is located in the northeast of the Province of Buenos Aires, Argentina. The region lies in the humid and subhumid mesothermal zone (Burgos and Vidal 1951) with a mean annual precipitation of 1,165 mm. Temperature ranges from 2°C in June (mid - winter time) to 38.2°C in January (mid - summer time). The spore trap was placed on the top floor of a building situated at 15 m above ground level, near the geographic center of the city. The area is completely urbanized with green spaces and abundant trees.

2.2 Sampling technique

Over a total period of sampling (1998–2001), data from July 1, 2000 to June 14, 2001 were analyzed. Daily spore concentrations were sampled using a 7-day Hirst-type volumetric spore trap sampler Lanzoni model 2000 (Bologna, Italy). The flow rate was adjusted to 10 l/min. Spores were collected on Melinex adhesive tape and cut into daily segments (48 mm strips representing 24 h of exposure). These segments were then mounted on microscope slides in glycerol jelly containing fuchsine (0.1%) and protected with a cover glass. The spores were observed and identified using an Olympus BH2 microscope at a magnification of 400× along two longitudinal traverses. In order to achieve a more accurate identification, a magnification of 1000× was used in some cases. Spore counts were then converted into spores per cubic meter of air sampled (spore/m^3 day) (Domínguez Vilches et al. 1991). Due to technical failures on the sampler, there was an interruption on data since 20/2/2001 to 8/3/2001 and 22/5/2001 to 29/5/2001.

2.3 Identification criteria

To characterize the different fungal types, the taxonomic and morphological classification of Saccardo (1886) was used. The descriptive terminology used is taken from the specialized bibliography (Barnet and Hunter 1987; Grant Smith 1990; Lacey and West 2006; Swartz 1971; Stearn 1973; Käärik et al. 1983; Ainsworth and Bisby 2001). Also, in the case of Myxomycota, the criteria of different authors (Aira et al. 2005; Lacey and West 2006; Docampo Fernández 2008) were taken into account.

2.4 Analysis criteria

According to the representativeness of each spore type in the total record, the following categories were considered: *abundant*, for those spore types exceeding

5% of the total concentration level; *moderate*, ranging from 1 to 4.99%; and *low*, below 0.99%.

Relative frequency of daily samples was calculated according to the criteria defined by Infante et al. (1991) and adapted by Herrero et al. (1995). The categories used were *very frequent* (75.1–100% of sampled days), *frequent* (36.6–75%), and *unfrequent* (0.1–36.5%).

3 Results

A total of 79 fungal taxa, which belong to Phyla Oomycota (3.8%), Zygomycota (3.8%), Myxomycota (1.26%), Basidiomycota (17.7%), Ascomycota (30.4%), and anamorphs of Higher Fungi (44.3%) were identified. They were classified according to their diagnostic characters (Table 1). Myxomycota spores were taken as a single category since it is very difficult to recognize with this methodology the numerous *taxa* which belong to this Phyllum. The sampling performed resulted in a daily mean concentration of 540 spores/m^3 and a total of 171670.21 spores for the period.

Figure 1 shows the constant presence of spores throughout the year, with a wide fluctuation in the daily values. During the year 2000, there was a daily mean of 284.51 spores/m^3 in winter (June–September), and a mean of 394.98 spores/m^3 in spring (September–December), with maximum values that did not exceed 2,000 spores/m^3 per day. Summer 2001 (December–March) showed an increase in the fluctuations and concentrations rose to a mean value of 814.43 spores/m^3 per day, with a peak of 3478.53 spores/m^3 on 17 February 2001. In autumn (March–June), there was a slight decrease in mean daily values with 714.96 spores/m^3. However, the maximum annual concentration value was recorded on 7 June, with a result of 4753.61 spores/m^3.

A study of the monthly distribution of spore concentration in their respective Phyla (Oomycota, Myxomycota, Zygomycota, Ascomycota, Basidiomycota, and Imperfect Fungi) was carried out; a different dynamics for each group was observed. For example, a combined analysis of the first three Phyla showed that the total maximum monthly concentration of all sporal types (1175.93) was detected in December, with a greater occurrence of Myxomycota (Fig. 2). April showed a high presence of spores, being the month when Zygomycota and Oomycota reached their peak. On the other hand, the minimum monthly concentration (110.49) was registered in October. Spores belonging to Ascomycota, Basidiomycota, and Imperfect Fungi (Fig. 2) were present in high concentrations throughout the year, the monthly total maximums were observed during the period going from December to March. In February, the highest spore concentration (20278.09) was recorded; 69.35% of which were asexual spores. As for diversity, the Imperfect Fungi contributed especially with *Cladosporium*, *Alternaria*, and *Periconia* spores throughout the year, their peak occurring in February. The Phylum Basidiomycota is mainly represented by *Coprinus*, *Agaricus*, and *Agrocybe*, and their maximum concentration values coincided with the previous group. Ascomycota spores mostly corresponded to *Leptosphaeria* and other related phragmospores, being June the month with the highest concentration.

The analysis of representativeness (Table 1) revealed the existence of five morphological types in the *abundant* category accounting for 67.2% of the total record. *Cladosporium cladosporioides*, *Leptosphaeria*, *Cladosporium herbarum*, *Coprinus*, and *Agaricus* were the dominant types. Among *moderates*, 12 *taxa* were identified, most of them conidia, contributing with 24.2% of the total spectrum. The most significant ones were *Alternaria*, *Aspergillus/Penicillium*, *Periconia*, and *Agrocybe*. In the *low* category, 62 spore types were registered which accounted for 8.6% of the total. There is a wide variety of morphologies and components of both sexual and asexual origin, being *Monodyctis* and *Didymella* the most prominent.

Frequency analysis of fungal spores in the atmosphere (Table 1) revealed the presence of six *very frequent* types: *Leptosphaeria* (91.4%), *Cladosporium herbarum* (86.4%), *C. cladosporioides* (84.8%), *Alternaria* (81.6%), *Agrocybe* (80.7%), and *Agaricus* (80.4%). In the *frequent* category, there were 28 types; the most outstanding representatives were *Periconia* (74.4%), *Arthrinium* (71.2%), and *Coprinus* (70%). In the *unfrequent* category, 45 types were found, among which *Polythrincium* (34.8%) and *Monodyctis* (34.2%) were dominant.

4 Discussion

Consistent with observations in other parts of the world, the atmosphere of the city of La Plata has a

Table 1 Fungal spore types identified in the atmosphere of La Plata during July 2000–June 2001

Phylum	Spore type	Morphological type	Percentage of representation	Category	Frequency (% days)
Oomycota	*Peronospora*	Hyalospore	1.0750	M	**
	Plasmopara	Hyalospore	0.0164	L	*
Zygomycota	*Absidia*	Hyalospore	0.5100	L	*
	Cunninghamella	Hyalospore	0.0900	L	*
	Ryzopus	Hyalospore	0.0800	L	*
Ascomycota	*Amphisphaeria*	Phaeodidymospore	0.0712	L	*
	Caloplaca	Hyalospore	0.0164	L	*
	Chaetomium	Phaeospore	0.4081	L	**
	Chaetosphaerella	Phaeophragmospore	0.0053	L	**
	Cryphonectria	Hyalodidymospore	0.0800	L	**
	Diaporthe	Hyalodidymospore	0.0890	L	*
	Diatrypaceae	Hyaloscolecospore	0.0266	L	*
	Didymella	Hyalodidymospore	0.5100	L	**
	Didymosphaeria	Phaeodidymospore	0.4178	L	**
	Leptosphaeria	Hyalophragmospore	8.1953	A	***
	Lophiostoma	Phaeophragmospore	0.7965	L	*
	Massariosphaeria	Phaeophragmospore	0.4425	L	*
	Melanomma	Phaeophragmospore	0.8850	L	*
	Mycosphaerella	Hyalodidymospore	0.5310	L	**
	Paraphaeosphaeria	Phaeophragmospore	1.0050	M	**
	Pleospora	Phaeodictyospore	1.2730	M	*
	Saccobolus	Phaeodidymospore	0.0091	L	*
	Sporormiella	Phaeodidymospore	0.1386	L	*
	Sordaria	Phaeospore	0.2765	L	*
	Trichocladium	Phaeodidymospore	0.0996	L	*
	Venturia	Hyalodidymospore	0.0052	L	*
	Xylariaceae	Phaeospore	1.0252	M	**
Anamorph	*Alternaria*	Phaeodictyospore	3.8372	M	***
	Arthrinium	Phaeospore	1.7976	M	**
	Aspergillus/Penicillium	Hyalospore	3.8821	M	**
	Bipolaris	Phaeophragmospore	0.6315	L	**
	Botrytis	Hyalospore	0.2152	L	*
	Briosia	Hyaloarthrospore	0.0267	L	*
	Cercospora	Hyaloscolecospore	0.2334	L	*
	Cerebella	Phaeodictyospore	0.0195	L	*
	Cladosporium cladosporioides	Hyalospore	31.7595	A	***
	Cladosporium herbarum	Hyalospore	11.4551	A	***
	Curvularia	Phaeophragmospore	0.3181	L	**
	Epicoccum	Phaeodictyospore	0.6547	L	**
	Exosporium	Phaeophragmospore	0.1653	L	**
	Exserohilum	Phaeophragmospore	0.0826	L	**
	Fusarium	Hyalophragmospore	0.3114	L	*

Table 1 continued

Phylum	Spore type	Morphological type	Percentage of representation	Category	Frequency (% days)
	Fusicladium	Hyalodidymospore	0.0100	L	*
	Geotrichum	Hyaloarthrospore	0.0267	L	*
	Gliomastix	Phaeospore	0.0014	L	*
	Helicomyces	Sympodulospore	0.0125	L	*
	Helminthosporium	Phaeophragmospore	0.2479	L	**
	Monodyctis	Phaeodictyospore	0.7942	L	*
	Nigrospora	Phaeospore	0.0699	L	*
	Ochroconis	Phaeodidymospore	0.1139	L	**
	Oidiodendron	Hyaloarthrospore	0.0106	L	*
	Oidium	Hyalospore	1.6244	M	*
	Paecilomyces	Hyalospore	0.0190	L	*
	Periconia	Phaeospore	3.3005	M	**
	Pestalotiopsis	Phaeophragmospore	0.0012	L	*
	Pithomyces	Phaeodictyospore	0.2169	L	**
	Podosporium	Phaeophragmospore	0.0025	L	*
	Polythrincium	Hyalodidymospore	0.3055	L	**
	Pseudocercospora	Phaeoscolecospore	0.0496	L	*
	Spegazzinia	Phaeostaurospore	0.0509	L	*
	Sporidesmium	Phaeophragmospore	0.0826	L	**
	Stemphylium	Phaeodictyospore	0.2063	L	**
	Tetraploa	Phaeostaurospore	0.0202	L	*
	Torula	Phaeophragmospore	0.9960	M	**
Basidiomycota	*Agaricus*	Phaeospore	5.1937	A	***
	Agrocybe	Phaeospore	2.7537	M	***
	Coprinus	Phaeospore	6.8508	A	**
	Cortinarius	Phaeospore	0.3376	L	*
	Ganoderma	Hyalospore	0.6220	L	**
	Gymnopilus	Phaeospore	0.0924	L	*
	Inocybe	Phaeospore	0.0007	L	*
	Lepiota	Hyalospore	0.0430	L	*
	Lycoperdon	Phaeospore	0.0307	L	*
	Puccinia	Phaeospore	0.3132	L	*
	Psathyrella	Phaeospore	0.0228	L	*
	Tilletia	Phaeochlamydospore	0.1608	L	*
	Uredinales	Hyalospore	0.4102	L	**
	Ustilaginales	Phaeospore	0.0758	L	*
Myxomycota		Phaeospore	1.1853	M	**

Representativeness (*A* abundant; *M* moderate; *L* low). Frequency: (*** very frequent, ** frequent and * unfrequent)

wide diversity of spore types with a significant contribution of mitotic spores and elements belonging to Oomycota, Myxomycota, Zygomycota, Ascomycota, and Basidiomycota (Aira et al. 2006; Calderón et al. 1997; De Antoni Zoppas et al. 2006; Díez Herrero et al. 2006; Fernández et al. 1998; Grinn-Gofrón and Rapiejko 2009; Ibañez Henriquez et al. 2001; Stepalska and Wolek 2005).

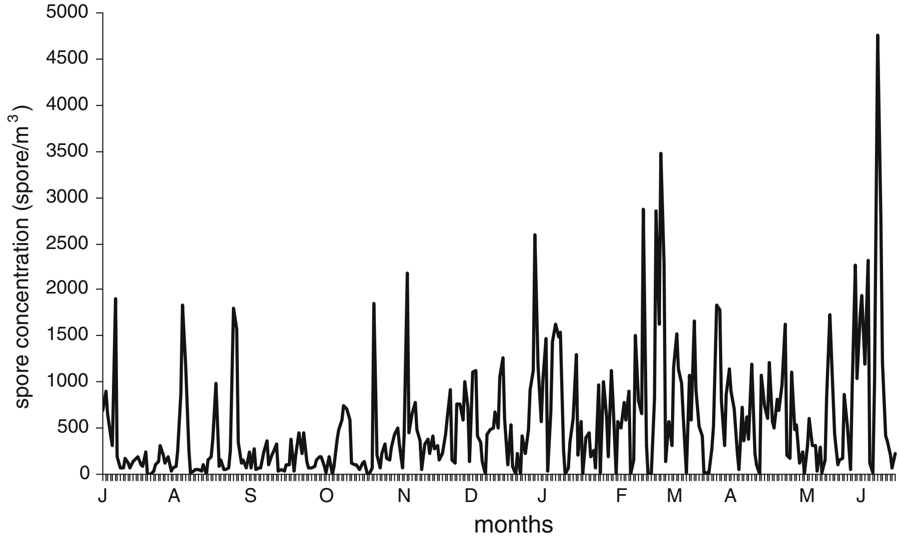

Fig. 1 Total daily concentration of fungal airborne spores in La Plata during July 2000–June 2001

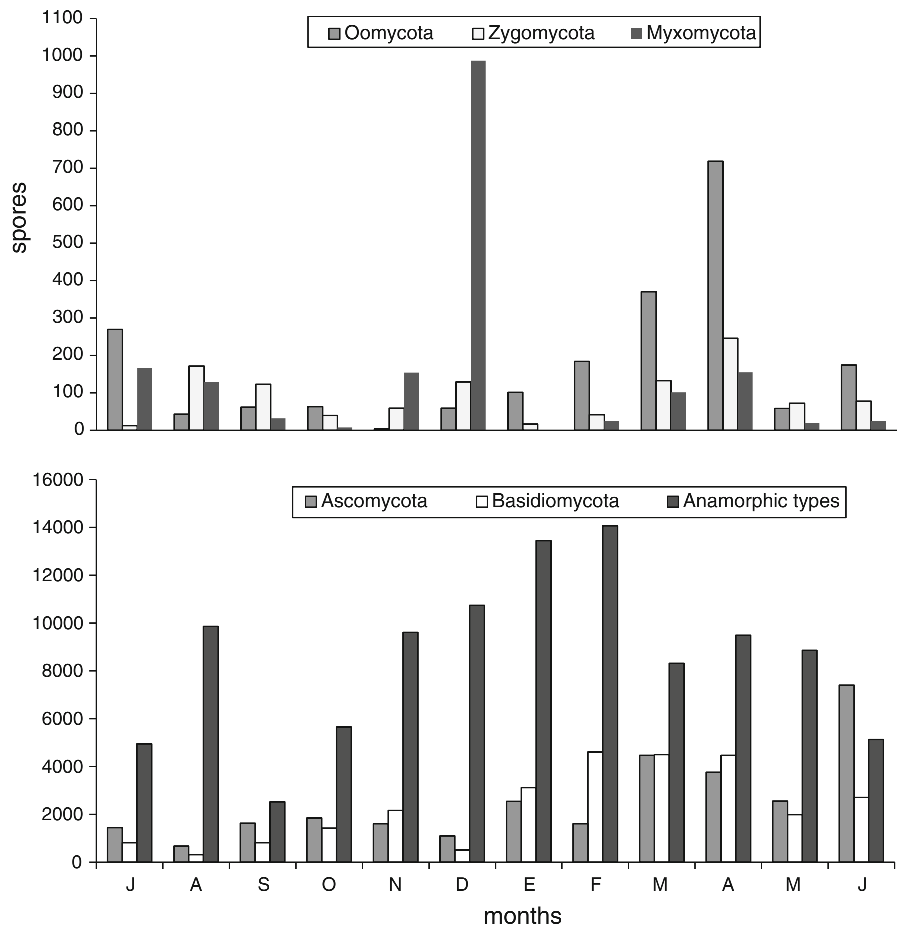

Fig. 2 Monthly concentration of anemophilous spores belonging to the Phyla Oomycota, Zygomycota, Myxomycota, Ascomycota, Basidiomycota, and Anamorphic Types

This study revealed a greater diversity in comparison with studies carried out in other cities of Argentina such as: Resistencia, Corrientes, and Córdoba (Mangiaterra et al. 1993; Esquivel et al. 2003; Quiroga de Pascual and Nobile 1985); similar results were obtained from prior aerobiological studies made in the city of La Plata (Iovannitti and Tiraboschi 1985; Negrin et al. 2007). However, it is difficult to make comparisons in terms of diversity and spore concentrations due to the different methodologies used in the area; it is therefore advisable to use combined both, viable and no viable volumetric methods.

Quantitative seasonal variation shows an increase in concentrations as the year goes by, and peaks occur in summer and late fall. It was observed that in moderate climates the highest spore concentrations occur during this period (Kasprzyk 2008).

Asexual spores are dominant in the total record. Among them, *Alternaria* and *Cladosporium* are highly abundant throughout the year, reaching their peak, together with the Basidiomycota spores, during summer.

The most abundant spores are also characterized by their frequency during the year. Thus, *Leptosphaeria* and *Cladosporium* in their two forms (*C. cladosporioides* y *C. herbarum*) occur almost throughout the period. Previous spore types are common anemophilous components of the atmosphere of La Plata and other cities worldwide (Horner et al. 1995; Cruz et al. 1997; Myskowska et al. 2002; Corden et al. 2003).

5 Conclusions

Fungal spores are present throughout the year in the atmosphere but their diversity and concentration show seasonal fluctuations. Despite their great diversity, only five morphological types are the main contributors to the studied record, and these fungal spores contain allergens involved in respiratory diseases (Simmon Nobbe et al. 2008). Imperfect Fungi spores are prevalent in the warmer and dry months. On the contrary, in cool periods of high relative humidity, highest concentrations of Ascomycota are detected.

By this study, the first aeromycological profile of an urban center of Argentina has been portrayed, and new information on the field of aeromycology in the country has been provided.

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