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Airborne pollen in Bahía Blanca, Argentina: seasonal distribution of pollen types

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Abstract The composition and seasonal distribution of airborne pollen grains in the atmosphere of Bahía Blanca, Argentina, has been studied between June 2001 and December 2003 using the Rotorod sampler (model 40). The results show that the main pollen types during this period were Cupressaceae, *Fraxinus*, Myrtaceae, Poaceae, *Amaranthus*/Chenopodiaceae, *Pinus*, Urticaceae, *Ulmus*, *Olea* and *Styphnolobium*. The highest concentrations occurred from August to December (end of winter and spring), accounting for 80% of the total annual pollen count. The greatest diversity was found in the spring, with the major of pollen coming from short-flowering plant types, such as *Populus*, *Acer*, *Platanus*, *Juglans*, *Tamarix*, *Ailanthus* and *Typha*. The potential sources of pollen from woody ornamental species are *Cupressus sempervirens*, *Eucalyptus camaldulensis* and *Fraxinus pennsylvanica*. whereas those from herbaceous species are the Chenopodiaceae and Poaceae, which are found within the city and also in the surrounding natural vegetation, and the Urticaceae, which are only present in the city. Marked annual differences were noted during the study period. The increase in 2002 may have been due to the abundant rainfall that occurred prior to the spring season, which would have favored the vegetative stage and flower development of plants. The decrease in pollen concentration in 2003 was mainly due to low rainfall throughout the year.

Keywords Aerobiology · Argentina · Pollen · Pollen season · Volumetric impact sampler

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1 Introduction

Knowledge of the composition, seasonality and abundance of airborne particles of biological origin is of special interest in cities where high levels of pollinosis occur, such as Bahía Blanca, Argentina (Herraiz Ballestero and Monticelli 1943). Variations in airborne pollen content are primarily a function of their abundance and distance from the source of emission, the climatic conditions that affect plant growth and the dynamics of dispersal and transport. As such, the characteristics of the pollen spectrum are specific to a study area.

Airborne pollen grains are one of the principal causes of allergy (Subiza et al. 1998; D'Amato et al. 2007) and, consequently, aerobiological studies with the aim of determining the relationship between pollen concentrations in the atmosphere and allergy symptoms are of great interest from an allergological point of view. Such studies are in the beginning phase in Argentina and other countries of Latin America. Noteworthy publications in this geographical area are those of Latorre and Pérez (1997), Noetinger and Romero (1997), Pérez and Páez (1998), Rojas Villegas and Roure Nolla (2001), Murray et al. (2002), Gattuso et al. (2003), Tejera and Beri (2005), Nitiu and Romero (2001), Bianchi and Olabuenaga (2006), Vergamini et al. (2006), among others. The very early studies carried out in Bahía Blanca used Tauber samplers (Borromei and Quatrocchio 1990; Aramayo et al. 1992), while more recent preliminary studies have used volumetric methodology (Murray et al. 2002).

The objective of this study was to characterize the airborne pollen present in the atmosphere of Bahía Blanca, their seasonal distribution and their relative importance as an indicator for use in determining enivronmental health policy.

2 Materials and methods

Bahía Blanca (38°44′S; 62°16′O) is situated in the southwest of the province of Buenos Aires, in close proximity to the Atlantic coast (Fig. 1). It covers approximately 64 km^2 and has a population of nearly 300,000 inhabitants. There are several large green spaces in the urban zone, such as parks and town squares, and the city is surrounded by extensive agricultural and cattle-raising areas. Towards the west and south, the sea forms a natural limit in the form of a bay.

Phytogeographically, the study area occurs in the southern district of Pampas province, and it borders on the Caldén district of the Espinal province on its western limits (Cabrera 1994). However, some floristic elements typical of the Monte province are also frequently found as natural components of the native plant communities. The natural vegetation types in the region are xerophytic woods, halophilous shrubby steppes, psammophilous steppes and grassy steppes (Cabrera 1963–1970, 1971).

The urban flora differs notably from the native one with many cultivated species of *Fraxinus*, *Cupressus*, *Eucalyptus*, *Populus*, *Acer negundo* L., *Morus alba* L., *Olea europaea* L., *Pinus*, among others (Aramayo et al. 1993; Lamberto 1978). There are more than 30,000 trees in the urban zone (Lamberto 1978). The non-native species are mainly found in parks and gardens, natural grassland, roadsides and railway embankments (Villamil and de Villalobos 2004).

The city has a temperate climate, with mean temperatures of between 14 and 20°C and markedly different seasons, and is influenced by the ocean, which has a particularly modulating effect on air temperature. However, there are also continental features, characterized by a variability in the climate that becomes more intense in zones farther from the coast (Verettoni and Aramayo 1976). Data provided by the Servicio Meteorológico Nacional (SMN) for the 1981–1990 decade show a mean annual temperature of 15.1°C, with the hottest month always January, with a mean temperature of 23.3°C, and the coldest month always July, with a mean of 7.3°C. Annual rainfall varies between 500 and 600 mm, with a high degree of monthly variability. The average relative humidity is 67.6%, and the prevailing winds are N–NW.

Airborne pollen were sampled using a volumetric impact sampler, Rotorod model 40, placed in the downtown area. The methodology described in the operating manual of the Rotorod sampler was followed with respect to placement of the sampler, collection of pollen and analysis of the samples (Brown 1993).

The study period was from 1 June 2001 to 31 December 2003. Data are expressed as daily mean number of pollen grains per cubic meter of air (Brown 1993). To determine the main pollen season for each pollen type, we took into account pollen count intensity and the number and behavior of the different species within each pollen type. The cumulative daily pollen grain count (10, 30, 50) was considered to be the indicator of the start and end of the pollen season.

The meteorological data were obtained from the "Central Termoeléctrica Luis Piedrabuena" located 8 km from the center of downtown Bahía Blanca. The correlation between total pollen concentrations and the main meteorological parameters was studied by means of a Spearman correlation test.

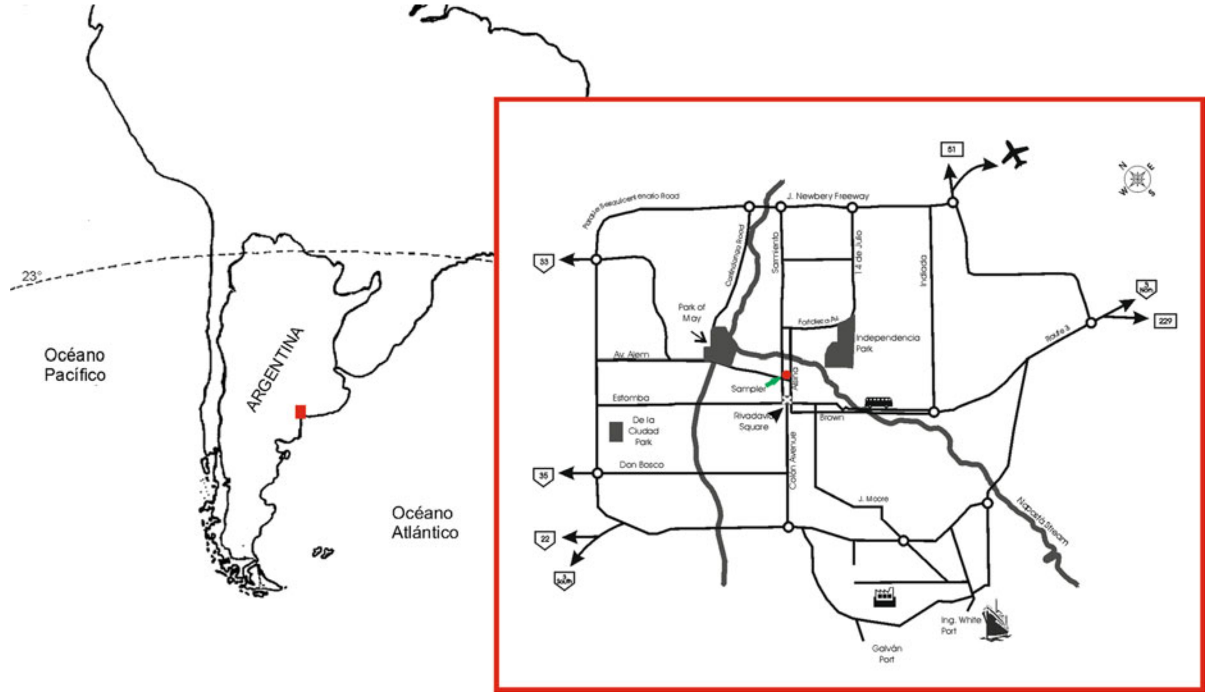


Fig. 1 Map of the study site

3 Results

During the study period 60,195 pollen grains were counted. Out of 61 pollen types identified in the city, 37 belong to trees or shrubs (woody taxa) and 24 to herbaceous plants. The pollen count intensity was lower in 2003 and higher in 2002 (Table 1).

Different peaks were found during different parts of the year, representing the periods of pollen emission of a group of different taxa that make up the pollen spectrum. From early January through to April, there was a slight increase in pollen count, mainly from Myrtaceae, *Amaranthus*/Chenopodiaceae, *Casuarina*, Poaceae and *Aster*. During May to June the levels decreased notably, and from July or the beginning of August, pollen from early-flowering trees began to appear, including that from cypresses, elms, pines and ashes, indicating the start of a new pollen season. The largest quantity of pollen was recorded from August to September, marking the end of winter, and in the early spring (Fig. 2).

In general, the airborne pollen grains from woody species were the predominant types from May to October, mainly due to the presence of *Casuarina*, *Phoenix*, *Cedrus*, Cupressaceae, *Fraxinus*, *Morus*, *Pinus*, *Olea* and *Juglans*, and during December and January, primarily due to the flowering of *Eucalyptus* and *Styphnolobium*. Pollen types from herbaceous plants were more important during November and from February to April due to the flowering of spring grasses and also of different species of *Amaranthus*/Chenopodiaceae, Urticaceae *Ambrosia* and Brassicaceae (Fig. 3).

The mean annual temperature for each of the three years of the study period was similar, and the average of the 3 years was 15.9°C. The maximum and minimum annual temperatures were also similar throughout the study period. The total annual precipitation during 2001–2003 showed different characteristics, with 2003 being the driest (367.8 mm) years, with an annual mean rainfall lower than that for the 1981–1990 period (613.7 mm), whereas annual rainfall in 2001 (660.0 mm) and 2002 (622.4 mm), respectively, was more similar to the mean for the 1981–1990. In terms of both annual accumulated rainfall and the number of rainy days, the wettest year was 2001. The months in which most of the precipitation was recorded varied according to the year under consideration. In general, the wettest season was the spring and the driest was the winter

Table 1 Absolute and relative monthly and annual values of the pollen index (PI) in the atmosphere of Bahía Blanca from June 2001 to December 2003

Pollen index	January	February	March	April	May	June	July	August	September	October	November	December	June–December	Total
2001														
Pollen grains						149.0	325.3	5,831.2	8,393.9	1,039.8	2,493.5	1,017.2	19,250.0	19,250.0
Percentage of total						–	–	–	–	–	–	–	–	
2002														
Pollen grains	1,554.7	705.5	546.3	416.1	140.0	39.0	1,020.1	6,821.4	9,692.6	1,447.3	2,063.0	1,861.5	22,944.9	26,307.6
Percentage of total	5.9	2.7	2.1	1.6	0.5	0.1	3.9	25.9	36.8	5.5	7.8	7.1	87.2	
2003														
Pollen grains	1,714.1	513.0	609.8	158.3	139.8	54.8	205.1	1,455.3	6,178.2	1,093.4	1,058.6	1,456.9	11,502.4	14,637.5
Percentage of total	11.7	3.5	4.2	1.1	1.0	0.4	1.4	9.9	42.2	7.5	7.2	10.0	78.6	
Total														60,195.0

Monthly percentage for the complete years (2002 and 2003), calculated on the total number of pollen grains per year

with the exception of 2002, in which there was a high value for rainfall at the end of August.

The correlation between total pollen concentration and the main meteorological parameters (maximum, minimum and mean temperature, relative humidity, wind velocity and direction and rainfall) was significant in all cases (Table 2). The parameters that positively influenced the total airborne pollen count in the atmosphere above the city were the mean and maximum temperature; relative humidity and rainfall had a negative influence.

The pollen types were classified into three different groups according to their percentage in the total pollen spectrum.

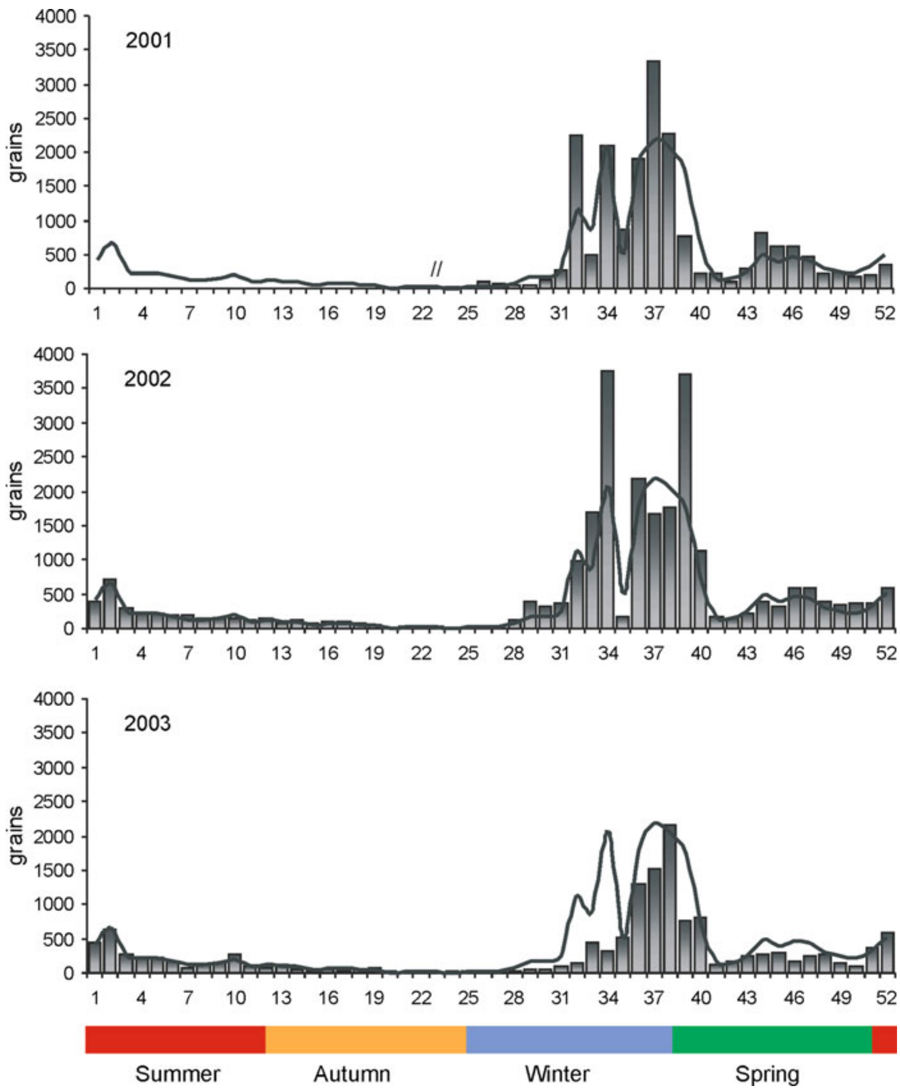
3.1 High to moderate representation of pollen types (percentage >1% of total pollen spectrum)

Among pollen of the different families of the Cupressaceae, pollen of the Cupressaceae are the best represented in Bahía Blanca, with the most important species being *Cupressus arizonica* E. L. Greene, *C. macrocarpa* Hartw and, on a larger scale, *C. sempervirens* L. These species are widely used as ornamentals in parks and gardens and, in certain locations, as street trees. Although the cypresses mainly flower from July to September, relatively lower pollen concentrations can remain in the air for a longer period of time, probably due to re-suspension process (Table 3, Fig. 4).

Fraxinus is well represented in the city, being used for both forestry and ornamental purposes, mainly in the streets of the city center. The most abundant species is *Fraxinus pennsylvanica* Marshall (Achinelli and Delucchi 1999), although some specimens of *F. excelsior* L. (common ash and golden ash) are also found. It flowers in winter before the leaves emerge. This pollen type was found in the air from August to October (Fig. 4; Table 4). In 2001, the pollen season started earlier than in the other two study years and also reached relatively higher pollen concentrations in the air.

The Myrtaceae pollen type is mainly represented by *Eucalyptus camaldulensis* Dehnh, which is present in the city and surroundings, and, to a lesser extent, by some other ornamental species of *Callistemon* sp. in gardens and on the streets. *E. cinerea* F. v. Muell. can be also found in some districts of the city.

Fig. 2 Weekly variation in the total pollen count for each year (*bars*) in relation to the average of the study period (*solid line*). The *double slash marks* indicate the start of sampling (1 June 2001)



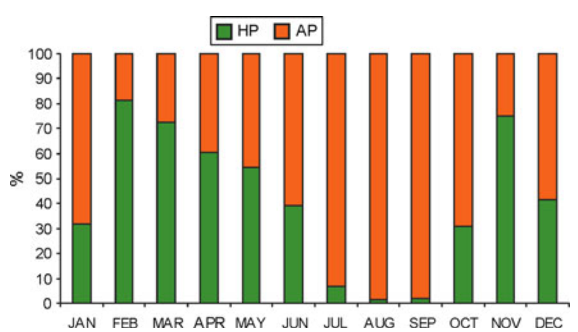


Fig. 3 Average monthly percentages (for 2 years from January to July and for 3 years from August to December) of pollen types of woody (*WP*) and herbaceous (*HP*) species during the study period

Table 2 Coefficients of correlation between total pollen concentration and main meteorological parameters using Spearman correlation test

Parameters	Total pollen
Maximum temperature (°C)	0.437**
Mean temperature (°C)	0.427**
Minimum temperature (°C)	0.383**
Relative humidity (%)	−0.315**
Wind velocity	0.088**
Maximum wind	0.173**
Rainfall (mm)	−0.066*

Level of significance: * 95%, ** 99%

Table 3 Sum of daily data and percentage of total number or grains of each pollen type studied in the atmosphere of Bahía Blanca from January 2002 to December 2003

Pollen type	Total	Percentage of total
Cupressaceae	12,501.85	30.5
Fraxinus	11,036.55	27.0
Myrtaceae	4,007.07	9.8
Poaceae	3,960.00	9.7
Amaranthus/Chenopodiaceae	1,503.55	3.7
Pinus	881.48	2.2
Urticaceae	829.24	2.0
Ulmus	665.05	1.6
Olea	566.26	1.4
Styphnolobium	512.16	1.3
Morus	379.70	0.9
Phoenix	293.45	0.7
Casuarina	284.10	0.7
Aster	210.14	0.5
Ambrosia	200.72	0.5
Brassicaceae	196.84	0.5
Centaurea	160.11	0.4
Ailanthus	133.64	0.3
Cyperaceae	130.03	0.3
Tamarix	127.88	0.3
Cedrus	126.78	0.3
Populus	106.11	0.3
Apiaceae	93.22	0.2
Platanus	89.45	0.2
Nothofagus	85.96	0.2
Celtis	84.40	0.2
Acer	84.21	0.2
Juglans	81.36	0.2
Schinus	72.90	0.2
Plantago	71.76	0.2
Ligustrum	65.83	0.2
Artemisia	63.18	0.2
Rumex	49.70	0.1
Typha	45.96	0.1
Papilionoideae	45.80	0.1
Prosopis	36.75	0.1
Betula	27.45	0.1
Ephedra	11.27	0.03
Lagerstroemia	11.03	0.03
Alnus	10.49	0.03
Taraxacum	10.43	0.03
Typha latifolia	7.73	0.02
Lycium	7.09	0.02
Acacia	6.48	0.02
Solanum	6.08	0.01
Salix	4.63	0.01
Laurus	4.01	0.01
Araucaria	3.70	0.01
Echium	3.39	0.01
Prunus	3.08	0.01
Prosopidastrum	2.47	0.01
Melia	2.29	0.01
Spartium	2.16	0.01
Juncaceae	2.16	0.01
Gomphrena	1.85	0.005
Lamiaceae	1.53	0.004
Robinia	1.23	0.003
Caryophyllaceae	1.23	0.003
Alternanthera	0.62	0.002
Ricinus	0.31	0.001
Geraniaceae	0.31	0.001
Unidentified	1,031.64	2.5

Although pollen type was recorded throughout the year, the maximum values occur in December and January (Fig. 4). The Poaceae type includes a large number of species, commonly known as grasses. However, even though grassland is the dominant natural vegetation type towards the east and northeast of the city, this area has been greatly modified by agriculture and cattle production. However, some grassland is still found in waste areas, railway embankments and roadsides in the outskirts of the urban area. Most species flower from 15 October to 15 November (Aramayo et al. 1993). The main pollen season occurs between August and April, but pollen grains can be found in the air nearly all year round, although at low concentrations for long periods (Fig. 4, Table 4).

The *Amaranthus*/Chenopodiaceae pollen type is well represented in the study area due to different species belonging to *Atriplex*, *Bassia*, *Beta*, *Heterostachys*, *Suaeda*, *Salsola*, *Allenrolfea* and *Sarcocornia* in saline soils. Species of *Amaranthus* and *Chenopodium* are found in cultivated areas, road verges, pavements and close to inhabited areas or on railway embankments and other open spaces. The large number of different species means that

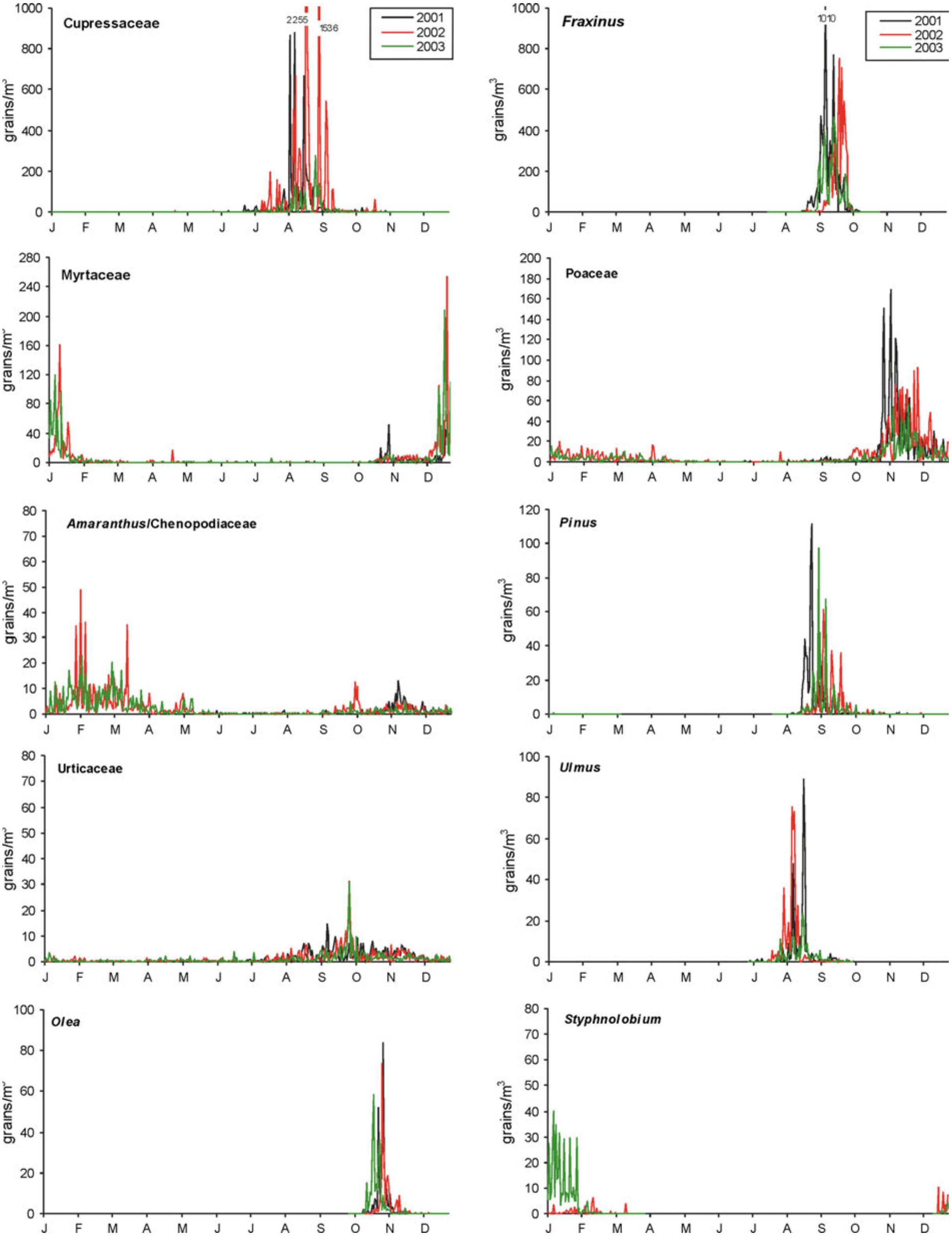


Fig. 4 Daily concentrations (grains/m^3) during the study period

Table 4 The main pollen season in terms of start, peak day, value on peak day, end and pollen index of the season (PI) of those pollen types representing >0.5% of the total pollen spectrum of the city during the study period

Pollen type	Season	Date of start	Date peak day	Peak concentration (grains/m^3)	Date of end	Pollen index (PI)
Amaranthus/Chenopodiaceae[a]	2001/02	27 Aug	01 Feb	49	09 May	753
	2002/03	18 Sept	02 Feb	23	11 May	764
Ambrosia[b]	2002	07 Feb	03 March	7	21 March	83
	2003	01 Feb	06 March	10	28 March	79
Aster[c]	2001/02	07 Sept	09 Dec	4	07 Aug	152
	2002/03	29 Aug	10 March	4	03 Aug	108
Brassicaceae[c]	2001/02	07 Aug	04 April	6	28 May	128
	2002/03	04 Aug	24 Feb	6	04 June	95
Casuarina[b]	2002	18 Feb	16 April	33	29 April	134
	2003	02 March	05 March	55	10 May	131
Cupressaceae[d]	2001	–	11 Aug	883	01 Nov	–
	2002	24 April	22 Aug	2,255	31 Oct	10,595
Fraxinus[e]	2001	26 Aug	11 Sept	1,010	05 Oct	7,653
	2002	09 Sept	24 Sept	758	04 Oct	5,907
	2003	05 Sept	19 Sept	463	04 Oct	4,945
Morus[e]	2001	04 Sept	11 Sept	20	14 Oct	148
	2002	07 Sept	30 Sept	23	16 Oct	210
	2003	03 Sept	21 Sept	14	14 Oct	164
Myrtaceae[d]	2001/02	23 Oct	10 Jan	161	21 April	1,434
	2002/03	22 Oct	26 Dec	255	12 April	1,944
Olea[c]	2001	15 Oct	02 Nov	84	22 Nov	309
	2002	24 Oct	01 Nov	74	12 Dec	278
	2003	16 Oct	24 Oct	58	06 Dec	289
Phoenix[c]	2001/02	14 Sept	21 Jan	24	04 Aug	253
	2002/03	20 Sept	06 Feb	8	24 Aug	62
Pinus[b]	2001	15 Aug	28 Aug	112	12 Oct	538
	2002	17 Aug	08 Sept	61	04 Oct	409
	2003	20 Aug	03 Sept	97	01 Oct	435
Poaceae[e]	2001/02	21 Aug	08 Nov	169	15 April	2,544
	2002/03	22 Aug	02 Dec	93	14 April	2,356
Styphnolobium[c]	2001/02	01 Jan	11 Feb	6	13 March	45
	2002/03	21 Dec	06 Jan	40	19 Feb	455
Ulmus[b]	2001	29 July	21 Aug	89	07 Sept	346
	2002	19 July	10 Aug	76	29 Aug	448
	2003	26 July	20 Aug	24	14 Sept	208
Urticaceae[f]	2001/02	24 June	11 Sept	15	26 June	416
	2002/03	06 July	01 Oct	31	30 June	403

Method used to determine the main pollen season: [a] cumulative daily pollen counts reach 10, [b] consecutive days with no pollen grains, [c] time elapsing between the first to last days recorded, [d] cumulative values reach 20, [e] cumulative values reach 50, [f] cumulative values reach 30

flowering can occur during many different time periods (Aramayo et al. 1993); consequently, this pollen type is present in the air practically throughout the year, although in very low concentrations during several months (Fig. 4, Table 4). The most abundant species with the *Pinus* pollen type is *Pinus halepensis*

Mill. and to a lesser extent *P. radiata* D. Don, *P. pinea* L. and *P. canariensis* Smith., with the latter two occurring very sporadically. These species are used as ornamentals in town squares and gardens or on streets in the urban zone. They generally flower from August to October, depending on the different species. The *Pinus* pollen type was recorded in the air from the end of July to March, with the highest values being at the end of August or the first two weeks of September. However, the main pollen season in 2001 was longer, with a higher pollen count than in the other 2 years (Fig. 4, Table 4).

The Urticaceae pollen type is represented by several species of this family, such as *Parietaria debilis* G. Forst., *P. officinalis* L. and *Urtica urens* L. These plants are found all over the city, particularly *Parietaria* , which is is found in disturbed ground, pavements and railway embankments as well as in walls made of old bricks. In general, the Urticaceae have a long pollen season, being most abundant from September to November (Fig. 4, Table 4). The *Ulmus* pollen type is widely represented in the city by *Ulmus pumila* L. *U. americana* L., *U. glabra* Huds. 'Pendula' and *U. carpinifolia* Gleditsch. 'Umbraculifera' are found to a lesser extent, primarily in wooded areas, town squares and gardens. The main pollen season is between July and September, with maximum values in August (Fig. 4, Table 4). Different peaks in the curve can be due to the consecutive flowering of the different species.

The *Olea* type is represented by only one species, *Olea europaea* L, which is found as an ornamental in town squares, gardens and streets in the city. There are also some crops outside the city. The *Olea* pollen type was recorded in the air from October to December, with the maximum values occurring at the end of October or during the first two weeks of November (Fig. 4, Table 4). Our data indicate that the duration of the season is variable (Table 4) with the values obtained oscillating between 39 days in 2001 and 52 days in 2003. The *Styphnolobium* pollen type is represented only by *Styphnolobium japonicum* (L.) Schott (syn. *Sophora japonica* L.). It is widely distributed and normally flowers in December–January. Although pollination is entomophilous, this pollen type is found in the air of the city from December to March, with the highest values recorded in January (Fig. 4, Table 4).

3.2 Pollen types with a low representation: 1–0.5% of the total pollen spectrum

The *Morus* pollen type mainly includes pollen from *Morus alba* L. This species can be found on streets and town squares and in gardens throughout the city. The main pollen season lasts for an average of 40 days, starting at the beginning of September and ending in the second half of October (Table 4). The quantity of total annual pollen (PI) detected was similar for the years of the study period.

The *Phoenix* pollen type includes pollen from *Phoenix canariensis* Hort. ex Chabaud and *Chamaerops humilis* L., with *Phoenix* palms being the more abundant of the two species. These plants can be found in various places, such as parks and large gardens. They start to flower in October and continue flowering throughout the summer. Although pollination is fundamentally entomophilous, this pollen type can be found practically throughout the year, although in very low concentrations (<5 grains/m^3). The PI was found to vary considerably over the study years, with that for 2001/2002 being threefold higher than the PI for each of the other two years. The main pollen season started in September and the maximum peak was between the end of January and the beginning of February (Table 4). The greatest quantities of pollen in the atmosphere were recorded from the second half of January to the first two weeks in May.

The *Casuarina* pollen type includes pollen of *Casuarina cunninghamiana* Miq, which is used as an ornamental and is found in various parks and large gardens as well as on the city ring road and other locations. Although this species flowers in autumn, the two seasons studied showed specific characteristics. Two periods are represented in each season: from February to March and then from April to May (Table 4).

The *Aster* pollen type includes pollen from many species of the Asteraceae, which as found in different habitats, with the most common being flowerbeds, pavements, gardens, road verges and railway embankments as well as disused sections and waste land. Different species flower throughout the period from August to May. Pollination is generally entomophilous, but some genera have anemophilous pollination. *Aster* pollen is present practically all year round; however, it is detected at very low concentrations for several months of the year (Table 4). As numerous species with different flowering times make up this pollen type, the pollen series can be clearly separated into at least two periods: one running from September to mid January, and the other running from mid January to May (Table 4).

The *Ambrosia* pollen type includes only one species, *Ambrosia tenuifolia* Spreng., also belonging to Asteraceae. This plant can be found in dry sandy and somewhat saline soils, road verges and railway embankments as well as on disused sections and waste land. It flowers from December to May. The highest values recorded each year were on the first days of March; however, the concentrations were very low compared to those of other pollen types (Table 4).

The Brassicaceae pollen type includes pollen from many species in the Brassicaceae. These species may be found in disturbed habitats, such as flowerbeds, pavements, gardens, disused sections, waste places, road verges and railway embankments. Pollination is mainly entomophilous; however, some grains appear in pollen counts. The Brassicaceae pollen type is present practically all year round, but there were no values >6 grains/m^3. The main Brassicaceae pollen season occurs from August to June; however, the highest concentrations are reached between February and April (Table 4) when *Diplotaxis tenuifolia* is flowering.

3.3 Pollen types that appear sporadically: less than 0.5% of the total pollen spectrum

The types that appeared every season sporadically during the study period were *Acacia*, *Acer*, *Ailanthus*, *Alnus*, Apiaceae, *Araucaria*, *Artemisia*, *Betula*, *Cedrus*, *Celtis*, *Centaurea*, Cyperaceae, *Echium*, *Ephedra*, *Gomphrena*, *Juglans*, *Lagerstroemia*, Lamiaceae, *Laurus*, *Ligustrum*, *Lycium*, *Nothofagus*, Papilionoideae, *Plantago*, *Platanus*, *Populus*, *Prosopidastrum*, *Prosopis*, *Robinia*, *Rumex*, *Salix*, *Schinus*, *Solanum*, *Tamarix*, *Taraxacum*, *Typha* and *Typha latifolia*. Some pollen types appeared in two seasons, such as pollen from *Alternanthera*, Caryophyllaceae, Juncaceae, *Melia* and *Prunus*, or only in one year and then in very small quantities, such as pollen from Geraniaceae, *Ricinus* and *Spartium*. Two pollen types included in this group were clearly identifiable as coming from outside the region: the *Nothofagus* type includes pollen of *Nothofagus antarctica* (G. Forst.) Oerst., *N. dombeyi* (Mirb.) Oerst. and *N. pumilio* (Boepp. & Endl.) Krasser (Fagaceae).[1] These species are not found in the area, but they are common in the Subantarctic phytogeographic province, more than 600 km to the south and west (Cabrera 1994; Gassmann and Pérez 2006). The *Celtis* pollen type includes pollen of *Celtis australis* L. and *C. tala* Gillies ex Planch (Celtidaceae). Both species are very uncommon in the city, suggesting the pollen comes from extra-regional sources, such as the Tala subdistrict or other districts in the Espinal province in the north and center of the country (Parodi 1940; Cabrera 1994).

4 Discussion

The results of our study on the biodiversity and seasonal distribution of different pollen types in Bahía Blanca are reported here. The most common airborne pollen types in the pollen spectrum of the city were Cupressaceae, *Fraxinus*, Myrtaceae, Poaceae, *Amaranthus*/Chenopodiaceae, *Pinus*, Urticaceae, *Ulmus*, *Olea* and *Styphnolobium*.

A marked inter-annual difference was noted, most probably due to the different meteorological conditions. In general, lower airborne pollen concentrations were detected during 2003, probably due to the lower rainfall in this year. However, similar airborne pollen concentrations were detected in 2001 and 2002, although some pollen types were present at lower or higher concentrations depending on the rainfall distribution. The highest annual rainfall was in 2001 and was concentrated in the autumn, while in 2002 more rainfall occurred at the end of the winter, just before the beginning of spring, which probably favored the vegetative stage and flower development of plants.

During the 3 years of the study, some tree pollen types showed a greater between-year variation (Cupressaceae, *Ulmus* or *Pinus*) while others showed

[1] The pollen type identified in the city is the "Nothofagus–Dombeyi type" (Heusser 1971). Pollen grains of *N. alpina* (OPEP. & Ende.) Oerst. and *N. obliqua* (Mirb.) Oerst. correspond to the "Nothofagus–Obliqua type", which have different morphological characteristics to that identified in this study.

similar behavior (*Olea* and Myrtaceae). Different behaviors were observed among the herbaceous species; for example, Poaceae responded positively to the meteorological conditions during the spring of 2001 and 2002, which favored the vegetative stage of this rather late-flowering species, while *Amaranthus*/Chenopodiaceae showed a similar response during 2002 and 2003, mainly due to the meteorological conditions of the summer–autumn (the season in which most species of this pollen type flower).

The concentration of airborne pollen grains in the atmosphere of Bahía Blanca differs greatly from that of a number of other cities, such as La Plata (Hirst-type sampler; Nitiu and Romero 2001) and Mar del Plata (Hirst-type; Latorre and Pérez 1997). One possible explanation is the different methodology used in our study. However, the values for the total pollen obtained in Bahía Blanca during our study period are comparable to those observed in the city during 1996–1999 (Rotorod sampler; Murray et al. 2002). However, similar data have been obtained in other cities, such as Rosario (Rotorod; Gattuso et al. 2003), Buenos Aires (Rotorod; Noetinger and Romero 1997), Montevideo, Uruguay (Rotorod; Tejera and Beri 2005), Santiago, Chile (Hirst-type; Rojas Villegas and Roure Nolla 2001) and Caxias do Sul, Brazil (Hirst-type; Vergamini Duso 2003).

We found that the greatest pollen type diversity in the city occurred from October to January; however, this is not associated with higher pollen concentrations, which were recorded in August and September. The main source of pollen comes from woody species or herbs and, therefore, varies depending on the period of the year.

Data from other studies in South America reveal that pollen type diversity varies in each city, with the composition of the vegetation being largely determined by the climate and the typical vegetation communities of the phytogeographical zone in which they occur as well as by the taxa selected by public institutions for planting in the parks and streets and other green spaces. In Caxias do Sul, Brazil, which has a tropical climate with seasonal rainfall, the vegetation is very different from that of Bahía Blanca, and 40 types of pollen were identified of which 29 were from tree or shrub species and 11 from herbs (Vergamini Duso 2003). In Santiago de Chile, 103 taxa were identified, of which most are introduced species (Rojas Villegas and Roure Nolla 2001).

In Bahía Blanca, the potential source of pollen from woody species is from urban trees, such as *Cupressus sempervirens*, *Eucalyptus camaldulensis* and *Fraxinus pennsylvanica*, among others. *Cupressus* and *Fraxinus* are abundant in the area and are anemophilous with a high production of pollen (Tormo Molina et al. 1996; Hidalgo et al. 1999). All of these characteristics result in very high levels of pollen in the atmosphere. However, the herbs are also important in the city, even though they represent a much smaller percentage of the total number of taxa. Natural habitats near the city are also a potential source of pollen (halophilous shrub steppe with a predominance of Chenopodiaceae and grass steppe), resulting in high levels of *Amaranthus*/Chenopodiaceae and Poaceae pollen types in the air and the long duration of their pollen seasons.

The pollen spectrum of Bahía Blanca did show large inter-annual differences during the study period. Analyses of pollen diversity allow us to better understand the pollen spectrum throughout the year, and a well-based knowledge of this diversity can help explain changes in the ecosystems under different conditions and changes in the composition of the surrounding vegetation (e.g. natural causes or anthropogenic modifications).

This study provides additional data to those reported by Murray et al. (2002), providing more detail on the pollen sources and analyzing factors influencing the dispersion dynamics of pollen. The total annual amount of pollen was similar in the 3 years of the study, although the composition of the pollen spectrum did vary. It is therefore important to handle the pollen types individually in order to be able to analyze their behavior during the year.

The total pollen amount for some species showed a twofold (*Olea europaea*) or threefold increase (*Fraxinus*) in different years. The reason for these differences seems to be the number of new trees planted in the city area in the case of *Fraxinus*, but this does not apply to *Olea*, and a longer period must be studied to understand such dynamics. On the other hand, a decrease in the annual amount of the herbaceous components was detected. An analysis over time of the individual dispersion curves in relation to meteorological variables will provide significant information for the interpretation of pollen dynamics in Bahía Blanca.

5 Conclusions

Between-year differences were detected in the content of airborne pollen in the atmosphere over Bahía Blanca, with the largest difference observed between 2002 and 2003 when the annual values were reduced by nearly 30% from 1 year to the next, probably due to a lack of water availability (lower rainfall). Although pollen was detected in the atmosphere throughout the year, the highest concentrations were recorded from the end of winter to the end of spring, when approximately 80% of the total annual pollen content occurred. The greatest diversity of pollen types was found in the spring, with the pollen types mainly originating from taxa with short pollen seasons; the lowest diversity occurred in May and June with the first frosts. Nearly 78% of all the pollen grains of Bahía Blanca recorded in our study are from woody species (such as *Cupressus sempervirens*, *Eucalyptus camaldulensis* and *Fraxinus pennsylvanica*, among others) and 22% are from herbaceous species, mainly from the Chenopodiaceae and Poaceae family. The meteorological parameters with the most influence on the airborne pollen in the atmosphere above Bahía Blanca were temperature (mean and maximum) and relative humidity.

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