



Pollen content in the atmosphere of Lugo (NW Spain) with reference to meteorological factors (1999–2001)

F.J. Rodríguez-Rajo^{1,*}, V. Jato¹ & M.J. Aira²

¹Dept. of Plant Biology and Soil Sciences, Faculty of Sciences, Campus As Lagoas, E-32004 Ourense, Spain;

²Dept. of Vegetal Biology, Faculty of Pharmacy, University of Santiago, Campus Sur, E-15706 Santiago de Compostela, La Coruña, Spain

(*author for correspondence: Phone: 988 387048; Fax: 988 387001; E-mail: javirajo@uvigo.es)

Received 4 September 2002; accepted in final form 14 May 2003

Key words: atmospheric pollen, hourly, Lugo, meteorology, pollen calendar, Spain

Abstract

This study shows the results of monitoring the pollen present in the atmosphere of the city of Lugo for three years (1999–2001) using a Hirst volumetric trap (model Lanzoni VPPS-2000).

During the three-year study, 61,381 pollen grains were counted. Poaceae represents 39.5% of the total pollen identified, *Pinus* 12.3%, *Quercus* 8.7% and *Betula* 8.4%. More than half of the total annual pollen was recorded in June and July. Its correlation was positive with temperature, hours of sun and wind speed, and negative with rainfall and relative humidity. The maximum values were recorded between 11 am and 8 pm, coinciding with the highest temperatures and lowest relative humidity.

1. Introduction

The increase in atmospheric contamination in recent decades and the resulting environmental and health problems have raised the awareness of institutions and the population towards such problems. This has also led to a marked increase in the number of atmospheric monitoring stations. Different authors (Benninghoff 1991; Chanda 1991) have emphasised the importance of controlling atmospheric parameters (meteorological, aerobiotic and chemical parameters). These parameters and their interrelation conditioning the air quality enable us to discern their impact on plants, animals and human health. Atmospheric pollen is an major cause of allergies, historically known as “hay fever” (Leuschner et al. 2000). During the last quarter of the 20th century, an increase in the hypersensitive population to pollen was observed, especially in developed countries. Pollen allergies are mainly caused by *Betula* pollen in North Europe (Spieksma et al. 1993; Leuschner et al. 2000), by the pollen of gramineae followed by *Betula* pollen in central Europe

and by the pollen of gramineae and *Parietaria* in South Europe (Díaz de la Guardia et al. 1998).

In each geographical area, there is a succession of different flowering species throughout the year, following a rhythm mainly established by meteorological conditions. Such conditions influence both the ontogeny of pollen grains and their dispersion. The relief and height of relatively close areas can produce local microclimates, which explain the differences observed regarding the onset of flowering within the same species. It is therefore especially important to increase the number of aerobiological monitoring stations to obtain information on the different climatic and/or phytogeographic areas, and the aerobiological behaviour of the different allergenic species.

Galicia's relief and geographical location in north-west Spain favours climatic and phytogeographic diversity. Consequently, the number of RIAG's (Galician Aerobiological Research Network) aerobiological monitoring stations has been increased in recent years. Pollen control in the city of Lugo was initiated in January 1999. The effect of pollen on the

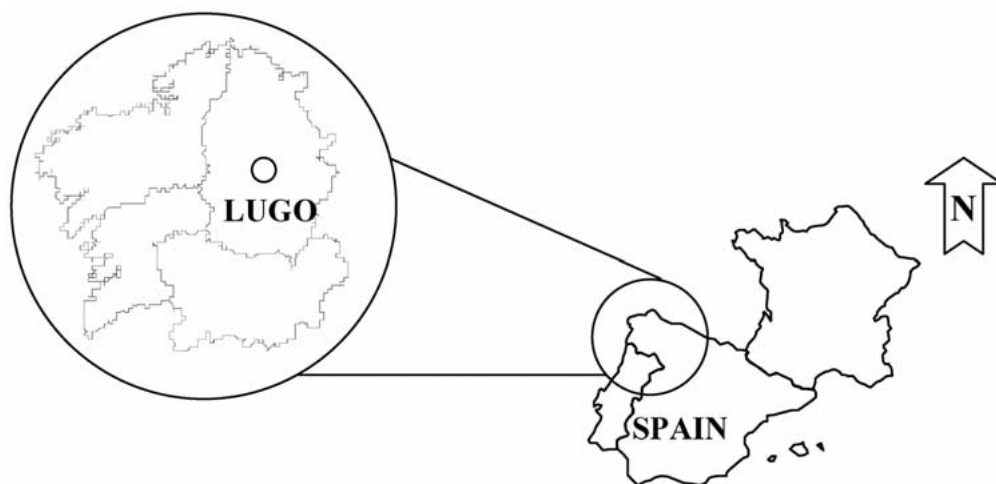


Figure 1. Location of Lugo in Spain.

allergic population in northwest Spain has been studied by different authors (Ferreiro et al. 1998; Belmonte et al. 1998; Arenas et al. 1996; Dopazo 2001; Marcos et al. 2001), who concluded that the allergens of Poaceae, *Parietaria*, *Betula*, *Plantago* and *Quercus* pollen are the main causes of pollen allergies. Furthermore, despite the low allergenic capacity of *Pinus*, patients sensitive to its pollen (even mono-sensitive) were identified (Marcos et al. 2001). The objective of this study is to determine the time of year and the day when the most allergenic pollen types are present in the atmosphere of Lugo, to prevent their effects on sensitive patients and to ascertain the number of days of allergenic risk.

2. Material and methods

This study is based on pollen data obtained from 1st January 1999, to 31st December 2001. Sampling was carried out using a Hirst volumetric trap, model LANZONI VPPS 2000, set up on the fire brigade terrace at a height of 15 m above ground level. Lugo has around 90,000 inhabitants and is located in northwest Spain (43°0' N and 7°53' W; 618193 X-UTM/4761526 Y-UTM) at a height of 454 m above sea level (Figure 1). Climatically speaking, it has a cool, dry ombrothermal regime, with an annual mean temperature of 11.5°C, an average maximum temperature of 16.8°C and an average minimum temperature of 6.2°C. Seasonally, it has a mean temperature of 11.8°C in spring, 16.9°C in summer, 8.9°C in autumn and 6.5°C in

winter. Its annual precipitation is 963 mm, following an irregular pattern throughout the year, with maximums in January and February (124.8 and 104.3 mm), November and December (120.1 and 116.4 mm), and a minimum in July (20.0 mm). During the rest of the year, monthly precipitation oscillates between 27.1 mm in August and 93.2 in March (Carballeira et al. 1983). Biogeographically, it belongs to the Euro-Siberian Region, Cantabrian-Atlantic Province, Galician-Portuguese Sector, Lugo Sub-Sector (Rivas-Martínez 1987). *Vaccinio myrtilli-Quercetum roboris* is the dominant association as the climax stage. Floristically, the most outstanding feature in this association, compared with other areas in northwest Spain, is the abundance of *Betula alba* due to greater precipitation and less evapotranspiration. These are dense, montane forests with a good representation of shrub and herbaceous species, on deep soils with limited bases. *Castanea sativa* is also very abundant in this area.

In degradation stages, frequently produced by forest fires, there are serial birch forests (*Holco mollis-Betuletum celtibericae*), and in more advanced stages, *Spartium junceum* thickets with *Cytisus scoparius* (L.) Link and *Genista florida* subsp. *polygaliphylla* (*Cytisetum scopario-striati*). Stockbreeding strongly conditions the expansion of the climax vegetation, with increasing grassland due to extensive shepherding.

In the valleys and riverbanks, there are frequent riverine tree formations of *Alnus glutinosa* (L.) Gaertner, *Betula alba* and *Salix atrocinerea* Brot.

A large percentage (62%) of the province's land is used for forestry, *Pinus* being the main species; 17% is

used as meadows and, finally 16% for growing crops, including corn, wheat and rye.

Melindex impregnated with a 2% silicon solution was used as the trapping surface. The exposed tape was cut into seven pieces, which were mounted on separated glass slides. Daily values were represented as the number of pollen grains per m³ of air. A NIKON OPTIPHOT II microscope, with a 40X/0.95 object lens, was used to identify the pollen grains. Counting was done following the model proposed by R.E.A. regarding four continuous longitudinal traverses along the slide (Domínguez et al. 1992).

We studied the characteristics of the pollination period of the nine most important allergenic and abundant pollen types, recording the dates of the beginning and end of the pollen season, maximum pollen count and its date, and the number of days during the pollination period on which the pollen concentration values can produce allergenic risk. To obtain the pollination period, we took into account the period covering 95% of total annual pollen, discarding the initial period until 2.5% is reached and the final period after reaching 97.5% (Andersen 1991). We used the method proposed by Galán et al. (1991) to study intra-diurnal pollen variation. The meteorological data used for the study was supplied by the National Institute of Meteorology, and the main meteorological parameters during the study period are shown in Figure 2.

Finally, the correlation between pollen concentrations during the main pollen season and the main meteorological parameters was studied by means of a Spearman correlation test.

3. Results

Aerobiological monitoring of the city of Lugo's atmosphere was initiated in 1999 and continued non-stop until 2001. During the three-year study, a total of 63,821 pollen grains were counted. The greatest number (25,384) was recorded in 1999 and the lowest annual total in 2000 (17,916), while a total of 20,521 pollen grains were recorded in 2001 (Figure 3). The best-represented pollen type throughout the entire study period was Poaceae, which attained an average of 39.5% of the annual total (Table 1). Other pollen types represented in the city's atmosphere, accounting for an annual total of 55% as a whole, were *Pinus*, *Quercus*, *Betula*, *Urticaceae*, *Plantago*, *Alnus*, *Cupressaceae*, *Castanea* and *Rumex*.

Table 1. Percentage total pollen concentrations

%	1999	2000	2001	Average
Poaceae	40.1	40.4	38.1	39.5
<i>Pinus</i>	7.9	15.6	13.3	12.3
<i>Quercus</i>	8.2	6.7	11.1	8.7
<i>Betula</i>	11.5	2.8	11.0	8.4
Urticaceae	7.5	9.7	6.3	7.8
<i>Plantago</i>	5.1	5.6	4.8	5.2
<i>Alnus</i>	5.5	4.2	4.4	4.7
Cupressaceae	3.4	4.4	2.0	3.3
<i>Castanea</i>	4.1	2.6	2.4	3.0
<i>Rumex</i>	1.2	1.7	1.7	1.5
Ericaceae	0.6	1.0	0.9	0.8
<i>Olea</i>	1.0	0.2	0.5	0.6
<i>Mercurialis</i>	0.5	0.6	0.4	0.5
Fabaceae	0.4	0.5	0.3	0.4
Myrtaceae	0.5	0.3	0.3	0.4
<i>Salix</i>	0.3	0.5	0.4	0.4
<i>Sambucus</i>	0.3	0.5	0.2	0.3
<i>Fraxinus</i>	0.1	0.5	0.3	0.3
<i>Chen.-Amar.</i>	0.2	0.3	0.2	0.2
<i>Corylus</i>	0.2	0.2	0.1	0.2
Compositae	0.1	0.2	0.1	0.1
Others	1.3	1.5	1.2	1.3

Table 2. Percentage monthly pollen concentrations

%	1999	2000	2001	1995–2001
January	4.7	2.1	3.7	3.5
February	3.0	6.1	8.6	5.9
March	5.0	12.5	3.6	7.0
April	17.1	6.3	23.4	15.6
May	13.9	11.3	10.5	11.9
June	23.2	35.5	27.2	28.6
July	29.1	17.1	17.2	21.1
August	2.1	5.7	4.0	3.9
September	1.1	1.4	1.1	1.2
October	0.4	0.3	0.4	0.4
November	0.0	0.3	0.2	0.2
December	0.8	1.4	0.2	0.8

The highest percentages in relation to the annual total were obtained during June and July (Figure 4), both of which accounted for half of the recorded pollen (Table 2). High concentrations were likewise obtained in spring, although the values were lower than the ones obtained during the summer. This spring peak takes place in April, accounting for an average of 15.6%

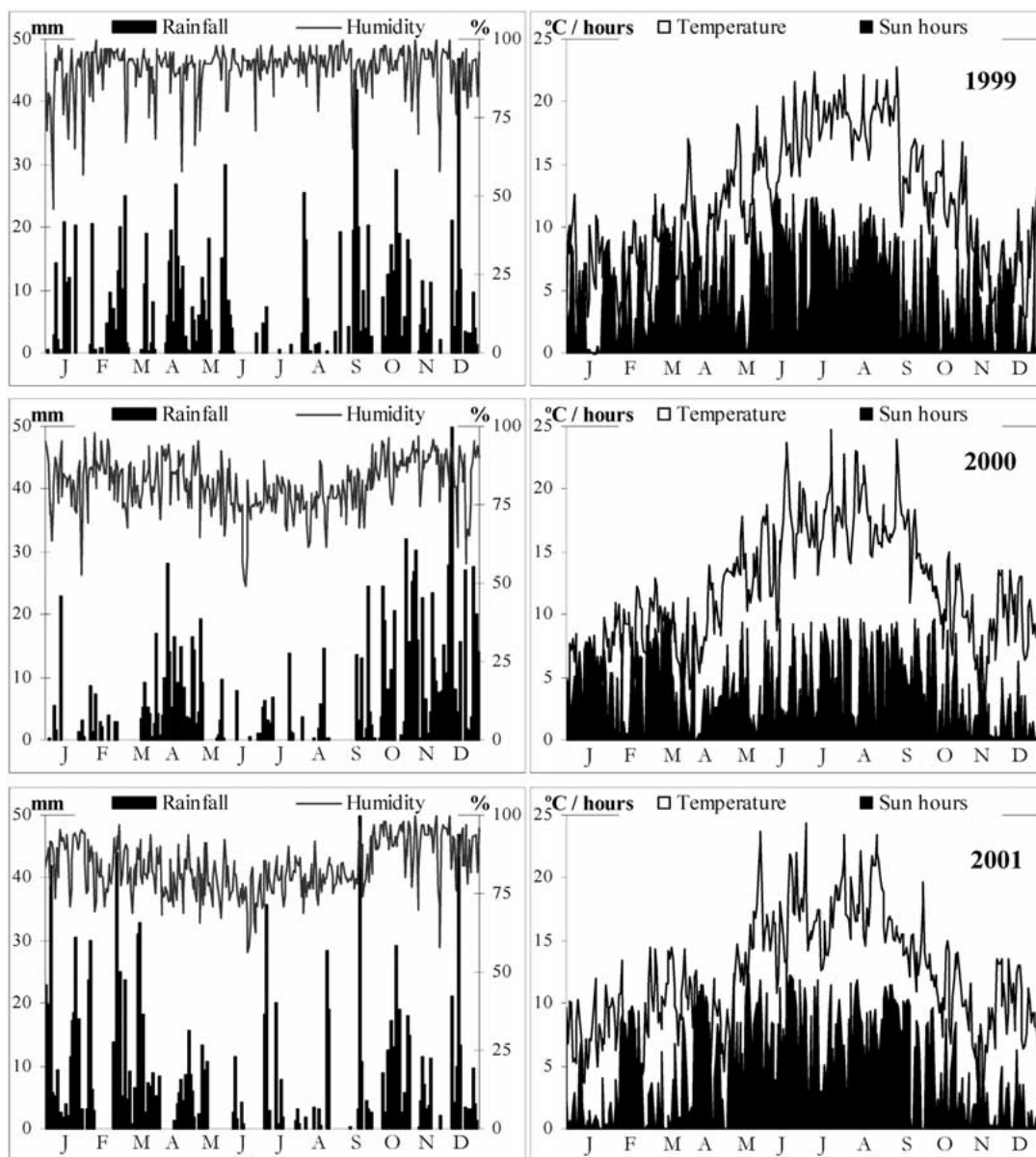


Figure 2. Annual variation of the main meteorological parameters during the three years of the study.

of total annual pollen. September, October, November and December were the months with the lowest pollen values, frequently including days with an absence of atmospheric pollen due to constant precipitation and limited flowering species.

In relation to the order in which the taxa appears in the atmosphere, the first pollen grains in January belong to *Alnus*, and Cupressaceae, with an average of 3.5% of total annual pollen being recorded in this month (Figure 5). These taxa begin flowering dur-

ing December, although their highest daily values are generally recorded in January. The maximum values during this period were obtained on 5th January 1999, with 213 grains/m³ attained by Cupressaceae, and 152 grains/m³ on 30th January 1999, and 5th February 2000, obtained by *Alnus* (Table 3).

Pollen concentrations decrease in the second fortnight of February and in March, while the temperature increase that usually takes place then favours the onset of the flowering of the tree taxa *Betula*, *Pinus* and

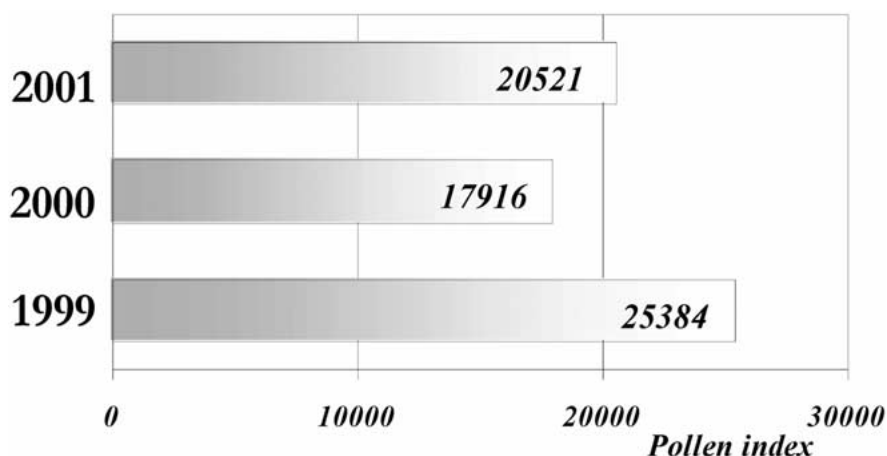


Figure 3. Total annual pollen concentrations.

Quercus. Due to the abundance of these taxa in the surroundings of the city of Lugo, 7% of total annual pollen is recorded in this month, rising to 15.6% during April. *Pinus* is the most abundant tree in northeast Galicia as a result of the major reforestation carried out from the fifties onwards. It therefore has the highest daily concentration peak in spring, attaining a value of 306 grains/m³ on 8th March 2000 (Table 3). The maximum daily concentration attained by *Betula* was recorded on 9th April 2001, with 248 grains/m³. *Quercus* is the dominant tree in the characteristic plant formations of Galicia's woodland. It therefore attained high concentrations, with a maximum of 198 grains/m³ recorded on 24th April 2001.

Pollen concentrations decrease in May since the spring species end their flowering. The quantities of pollen released into the atmosphere increases again during June and July, attaining concentrations that represent 49.7% of total annual pollen. This increase is caused by the flowering of herbaceous species, among which the pollen types Poaceae, Urticaceae and *Plantago* stand out, *Castanea sativa* being the only tree species attaining high concentrations. The highest values at this time are recorded by Poaceae, whose concentrations gradually increased from the beginning of June, attaining a maximum peak on 7th July 1999, with 835 grains/m³. The second-most important pollen type during the summer belongs to the Urticaceae family, whose maximum daily value was recorded on 29th July 2001, with 129 grains/m³. *Castanea* had a maximum value of 118 grains/m³ on 10th July 1999. Finally, the maximum concentrations of *Plantago* pollen never surpassed 52 grains/m³ during the three years of study. In August, there is a gradual decline

in pollen concentrations due to the decrease of the anemophilous pollen types. Starting from September, after a slight increase in pollen concentrations, the release of pollen into the atmosphere remains very low until the winter taxa's flowering period begins again during the second fortnight of December or the first fortnight of January.

A pollen calendar was prepared for the city of Lugo using the data obtained during the three-year period. The calendar shows each taxon's average weekly value during the study period, calculated from the weekly averages of each year. It includes the 13 best-represented pollen types in the city's atmosphere: Poaceae, *Pinus*, *Betula*, *Quercus*, Cupressaceae, *Alnus*, *Mercurialis*, Ericaceae, Fabaceae, *Olea*, *Plantago*, *Urtica* and *Castanea*. A different scale was used for the first four due to their high concentrations (Figure 5). In the case of the city of Lugo, the seasonal behaviour patterns of the pollens included in the calendar are similar to those described in nearby localities such as Ourense, Vigo and Santiago de Compostela (Mendez 2000; Rodríguez-Rajo 2000; Dopazo et al. 2001).

A study of the intra-daily variation of pollen (Figure 6) reveals two behaviour patterns. The first is followed by the majority of pollen types studied and shows a single concentration peak throughout the day, while the second is followed by *Castanea* and has two concentration peaks. Generally, the highest values were recorded during the central hours of the day and all afternoon/evening, specifically between 1 pm and 8 pm. Subsequently, these values decreased and remained low during the early morning, gradually increasing again during the morning.

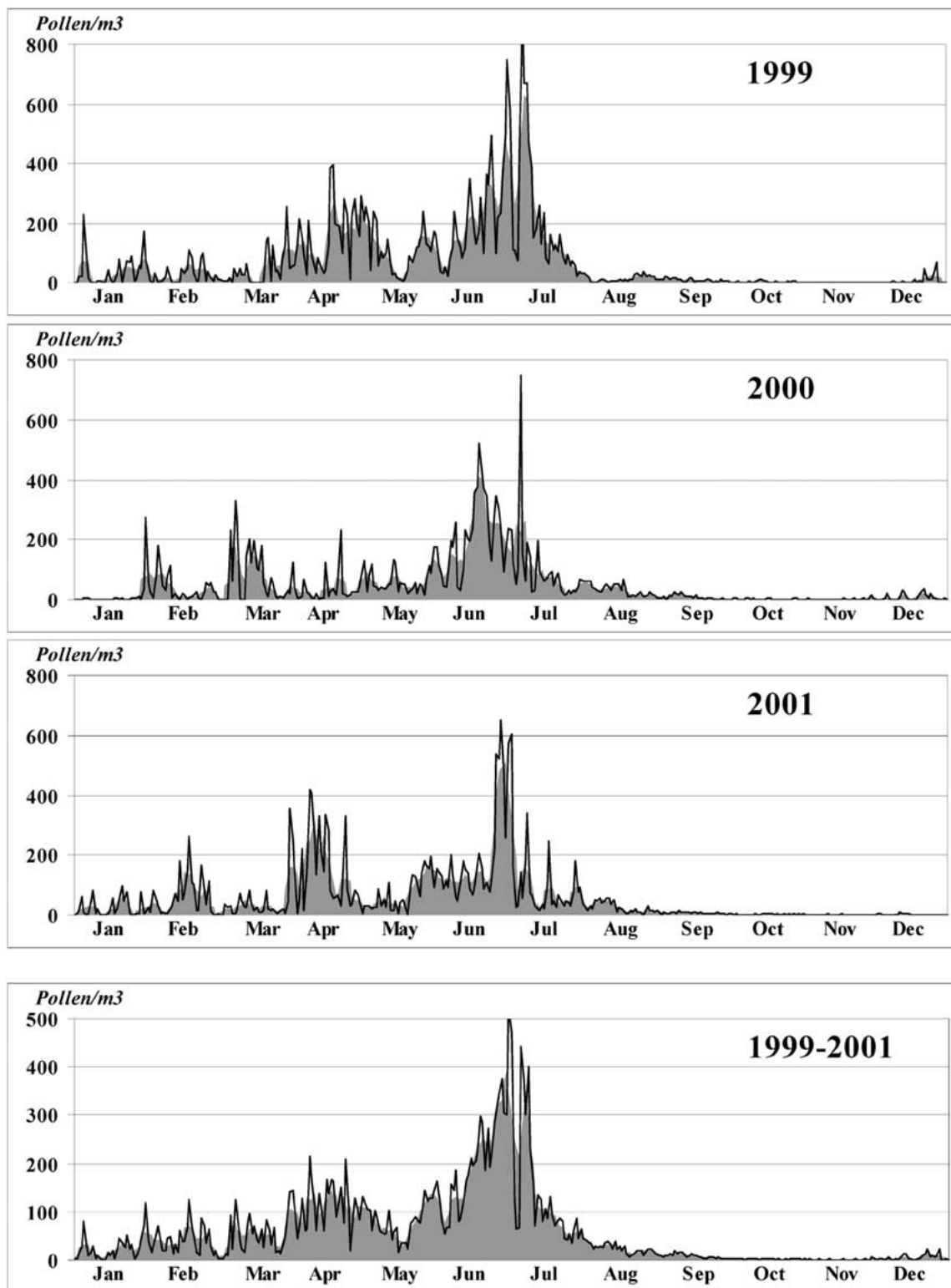


Figure 4. Annual variation of the pollen concentrations and average of the three years 1999–2001.

Table 3. Characteristics of the MPP of the most important taxa: start and ending dates, length, maximum value and its date, total pollen and number of days with pollen concentration over an allergenic significantly value

		1999	2000	2001
Poaceae	<i>Pollen season</i>	26May–02Aug	18May–11Aug	10May–13Aug
	<i>Length</i>	68	86	96
	<i>Maximum – Day</i>	835–07Jul	703–05Jul	630–28Jun
	<i>Total pollen</i>	10168	7233	7808
	<i>Days > 25 pollen/m³</i>	42	42	45
	<i>Days > 50 pollen/m³</i>	30	30	33
Pinus	<i>Pollen season</i>	02Mar–27May	27Feb–18May	13Feb–21May
	<i>Length</i>	87	82	98
	<i>Maximum – Day</i>	168–31Mar	306–08Mar	256–01Apr
	<i>Total pollen</i>	2011	2788	2728
	<i>Days > 100 pollen/m³</i>	4	8	7
Betula	<i>Pollen season</i>	04Apr–06May	24Mar–20May	01Apr–08May
	<i>Length</i>	33	58	38
	<i>Maximum – Day</i>	245–19Apr	83–21Apr	248–09Apr
	<i>Total pollen</i>	2922	504	2259
	<i>Days > 30 pollen/m³</i>	26	5	16
	<i>Days > 80 pollen/m³</i>	15	1	10
Quercus	<i>Pollen season</i>	31Mar–01Jun	06Apr–07Jun	02Apr–01Jun
	<i>Length</i>	62	63	61
	<i>Maximum – Day</i>	102–20Jun	87–30May	198–24Apr
	<i>Total pollen</i>	2082	1199	2277
	<i>Days > 50 pollen/m³</i>	13	6	15
Urticaceae	<i>Pollen season</i>	31Mar–09Sep	3May–10Sep	05Mar–18Sep
	<i>Length</i>	162	131	198
	<i>Maximum – Day</i>	102–20Jun	54–02Aug	129–29Jul
	<i>Total pollen</i>	1926	1749	1264
	<i>Days > 80 pollen/m³</i>	1	5	1
Plantago	<i>Pollen season</i>	25Apr–09Sep	03May–13Sep	27Apr–17Sep
	<i>Length</i>	138	134	144
	<i>Maximum – Day</i>	52–27May	42–31May	36–30May
	<i>Total pollen</i>	1287	1008	976
	<i>Days > 50 pollen/m³</i>	1	0	0
Alnus	<i>Pollen season</i>	15Jan–03mar	26Jan–21Feb	19Dec–21Feb
	<i>Length</i>	48	27	65
	<i>Maximum – Day</i>	152–30Jan	152–05Feb	87–21Jan
	<i>Total pollen</i>	1406	650	997
	<i>Days > 50 pollen/m³</i>	16	7	11
Cupressaceae	<i>Pollen season</i>	03Jan–13May	22Dec–18Jun	11Jan–18May
	<i>Length</i>	135	180	128
	<i>Maximum – Day</i>	213–05Jan	192–31Jan	37–24Apr
	<i>Total pollen</i>	684	862	534
	<i>Days > 40 pollen/m³</i>	3	8	2
Castanea	<i>Pollen season</i>	01Jul–28Jul	26Jun–31Jul	25Jun–30Jul
	<i>Length</i>	28	36	36
	<i>Maximum – Day</i>	118–10Jul	42–02Jul	46–06Jul
	<i>Total pollen</i>	1036	469	502
	<i>Days > 50 pollen/m³</i>	4	0	0

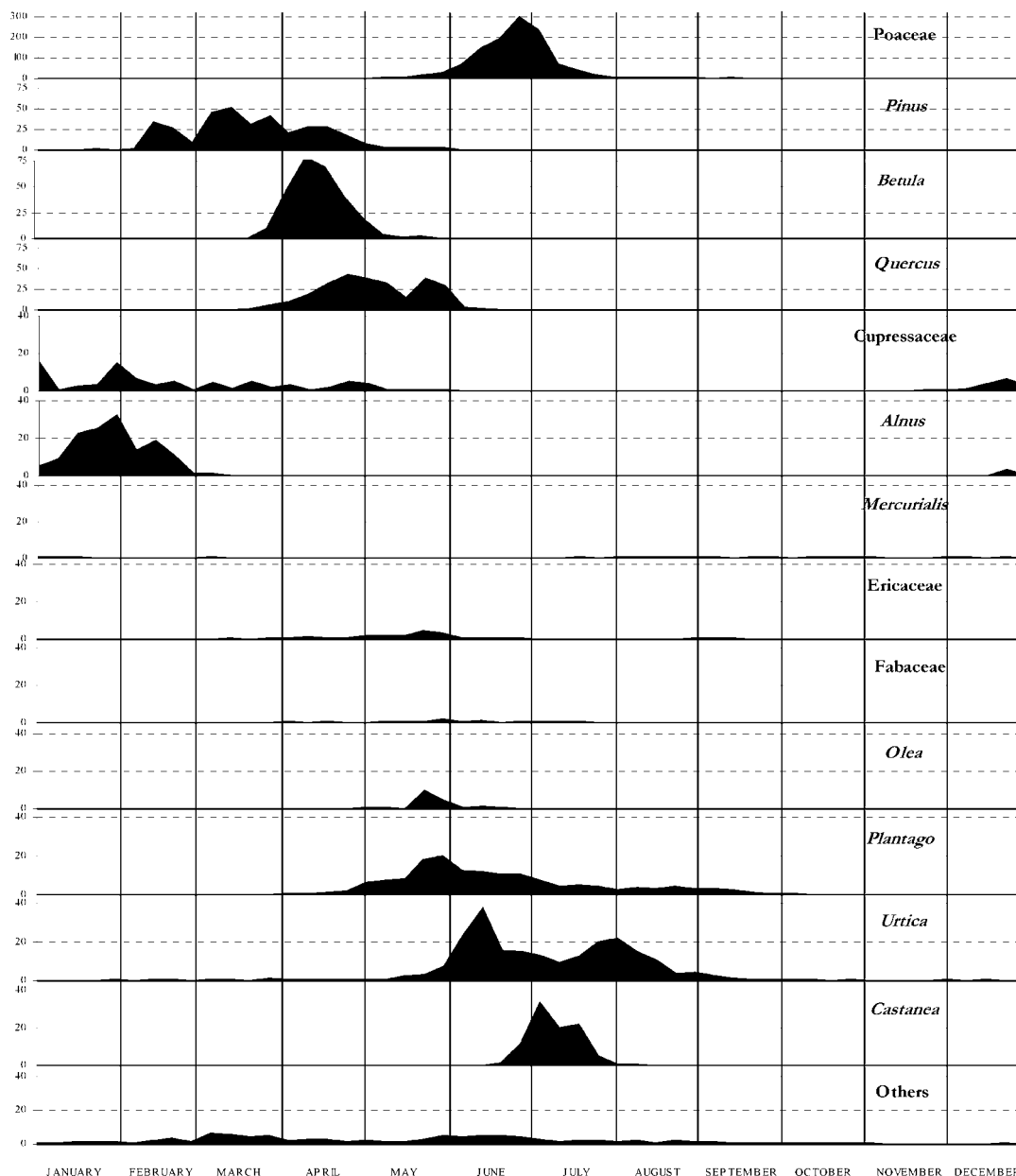


Figure 5. Pollen calendar of the city of Lugo.

Finally, the correlation between pollen concentrations during the main pollinization period and the main meteorological parameters was significant in a large number of cases (Table 4). In view of the results, the parameters that have the greatest positive influence on the city of Lugo's atmospheric pollen are maximum temperature, sunshine and wind distance, while the greatest negative influence is exerted by rainfall, humidity and south-westerly winds.

4. Discussion

During the study period, we attained an average of almost 21,000 pollen grains per year, which is similar to the value recorded in other areas in northwest Spain (Méndez 2000; Dopazo et al. 2000; Fernández-González et al. 1998). This concentration is far lower than the ones attained in other Spanish areas, which record very high quantities of a certain pollen type

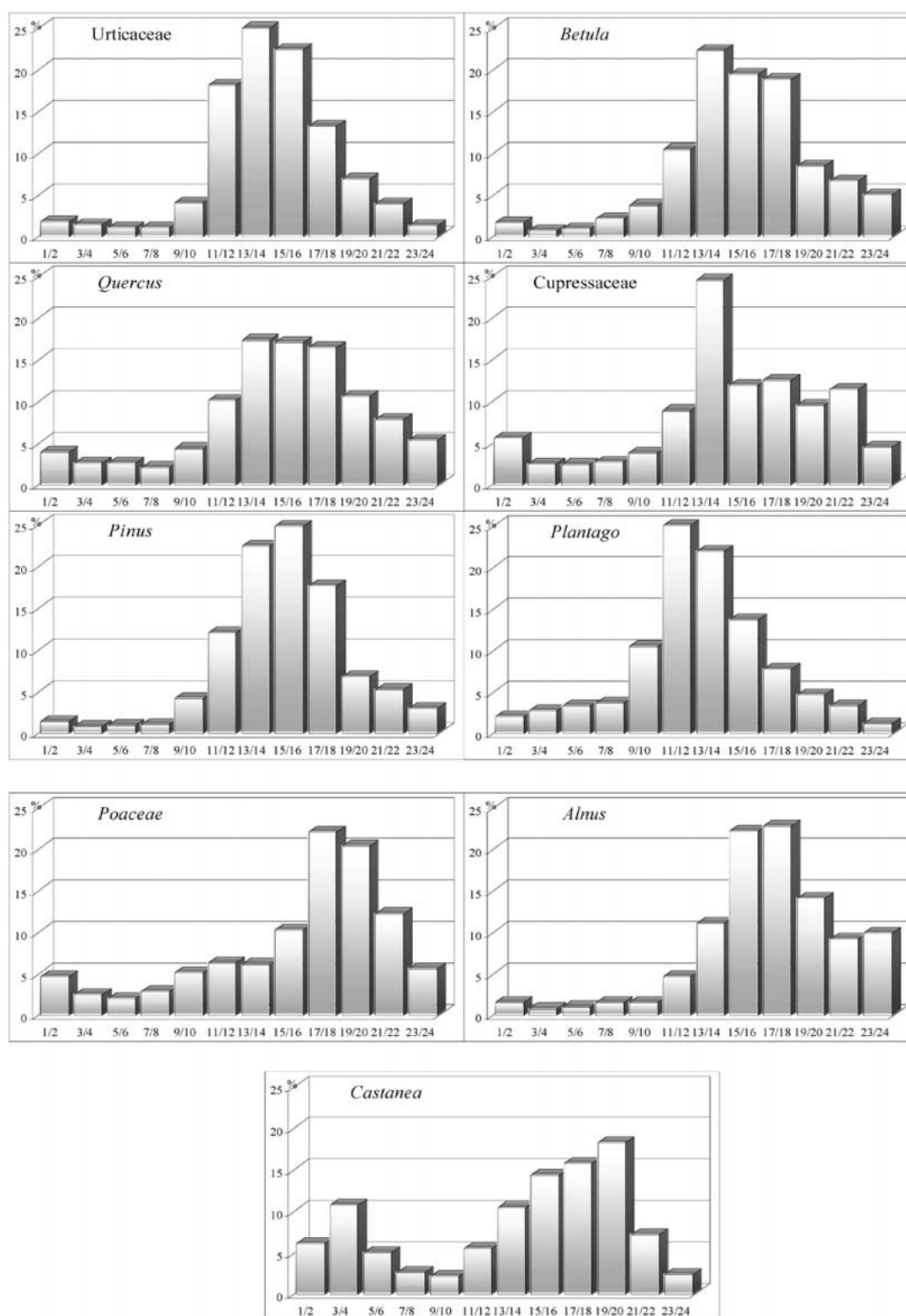


Figure 6. Intradial variation of the most important pollen types (average of the three years, 1999 to 2001).

Table 4. Coefficients of correlation between the pollen concentration and the main meteorological parameters by using the Spearman correlation test (*95%, **99% of signification)

	<i>Alnus</i>	<i>Betula</i>	<i>Castanea</i>	Cupressaceae	<i>Pinus</i>	<i>Plantago</i>	Poaceae	<i>Quercus</i>	Urticaceae
Rainfall	-0,234**	-0,261**	-0,062	0,063	-0,161*	-0,171**	-0,235**	-0,259**	-0,375**
Humidity	-0,181*	0,049	0,295**	-0,111*	-0,209**	0,008	0,030	-0,213**	-0,069
Maximum temp.	0,379**	0,387**	0,151	0,163**	0,113	0,053	0,331**	0,459**	0,486**
Minimum temp.	0,118	0,097	0,069	0,156**	-0,137*	0,036	0,106	0,326**	0,421**
Mean temp.	0,294**	0,290**	0,143	0,180**	-0,001	0,047	0,282**	0,453**	0,512**
Sun hours	0,026	0,498**	0,282**	-0,036	0,190**	0,055	0,261**	0,276**	0,202**
Wind calm	-0,059	-0,052	-0,171	-0,179**	0,020	-0,092	0,073	0,167*	0,027
Wind N-NE	-0,058	0,086	0,128	-0,288**	-0,011	0,042	0,048	0,066	0,262**
Wind NE-S	0,124	0,026	-0,186	0,248**	0,139*	-0,035	-0,089	-0,060	-0,272**
Wind S-SW	0,036	-0,117	-0,141	0,256**	-0,051	-0,019	-0,048	-0,062	-0,224**
Wind SW-N	-0,044	-0,188*	-0,010	-0,281**	-0,177**	-0,053	0,111	-0,083	0,224**
Wind speed	0,162	0,195*	0,223*	0,247**	0,099	0,143**	-0,022	-0,028	-0,131**

that usually represents more than half of the pollen obtained during an entire year. This is the case of Jaén (Ruiz et al. 1998) or Cordoba (Cariñanos et al. 1999), where the olive attains very high concentrations, Extremadura (Tormo et al. 1999) with very high values of Poaceae or *Quercus* pollen, and Madrid and Barcelona, where the ornamental use of *Platanus* is widespread, resulting in high pollen concentrations during flowering (Gutierrez et al. 1999; Belmonte et al. 2000).

During the year, pollen concentrations in the city of Lugo gradually increase starting from March, attaining a summer maximum peak in July due to high concentrations of Poaceae (the highest in North Spain) (Aira et al. 1998; Fernández-González et al. 1998). This behaviour pattern, in which the summer peak is much higher than the spring one, is a characteristic that makes Lugo different from other nearby points. The high degree of stockbreeding in the province, conditions the use of much of its surface area as pastureland, in which gramineae are dominant. This results in an increase in the concentrations of Poaceae pollen at the beginning of summer, coinciding with its flowering and harvesting, which favours the dispersion of its pollen grains. Contrary to what happens in Lugo, in other nearby cities the summer peak is less important and the maximum total concentration is attained in spring, due to the flowering of *Pinus* and *Quercus* in the case of Ourense (Mendez 2000), *Betula* and *Platanus* in Santiago (Dopazo 2000) and Urticaceae and *Pinus* in Vigo (Rodríguez-Rajo 2000).

The oscillations in pollen concentrations throughout the study period were largely determined by meteorological differences during the flowering periods of the sampled years. In relation to maximum and mean temperature, positive and 99% significant values were obtained in the cases of the main pollinization periods of *Alnus*, *Betula*, Cupressaceae, Poaceae, *Quercus* and Urticaceae. In some cases, such as *Pinus*, the lack of a significant correlation with maximum and mean temperature may be explained by the clear temperature increase that usually takes place from the second half of April onwards. Consequently, the source of pollen has practically been exhausted due to the longer duration of its post-peak period in relation to other taxa. Correlation with sunlight is 99% significant in the cases of *Betula*, *Castanea*, *Pinus*, Poaceae, *Quercus* and Urticaceae, all of which are spring/summer-flowering taxa.

Rainfall, wind direction and speed and turbulences are the most influential meteorological parameters once the pollen is airborne. Rainfall had a negative significant correlation for most of the taxa (Table 4). *Betula* flowering decreased in 2000 due to the great quantity of rainfall during the second fortnight of March and the first few days of April (more than 300 mm), at the beginning of its pollinization period. The high concentration of *Pinus* in the same year was due to the fact that its flowering took place before precipitation. For its part, the increase in Urticaceae pollen in the atmosphere was favoured by the presence of N-NE winds, in the case of Cupressaceae by NE-S

and S-SW winds (which come from the city centre) and of *Pinus* by winds from the NE-S, where there are large expanses of vegetation belonging to this family. In relation to wind speed, the correlation was significant and positive in the cases of *Betula*, *Castanea*, Cupressaceae and *Plantago*, whose pollen grains are easily transportable over large distances (Wallin et al. 1991; Hjelmroos 1991; Peeters and Zoller 1988; Frei 1997; Levetin 1998). For this same factor, the correlation was significant and negative in the case of Urticaceae, which shows that the recorded pollen came mainly from plants near the trap.

Despite the limited number of years included in this study, we observed an alternation in the total annual pollen of *Alnus*, *Betula* and *Quercus*. This biannual behaviour applies to different tree species and is explained by alternation in the mobilisation of nutrient reserves towards the vegetative growth of the tree or towards the reproductive structures, according to the year. This pattern has been described in the cases of *Alnus* (Andersen 1980; Rodríguez-Rajo 2000), *Betula* (Nilsson and Persson 1981; Emberlin et al. 1993; Rodríguez-Rajo 2000) and *Quercus* (Andersen 1980; Spieksma et al. 1995; Rodríguez-Rajo 2000).

Observing the values of average daily concentrations of pollen, we can highlight two periods of special importance for people allergic to pollen (Figures 4 and 5). The first corresponds to the spring months in which there is an important presence in the atmosphere of *Betula* and *Quercus*, both of which are highly allergenic. The former, due to its capacity to be transported over large distances, can produce allergic reactions not only during the pollination period but also in the pre- and post-pollination period (Wallin et al. 1991; Hjelmroos 1991). Furthermore, its allergens can remain deposited on dust particles in interiors and induce allergies up to two months after attaining maximum pollen values in the air (Ekebon et al. 1996). Although pollen causes a wide range of reactions in allergy sufferers, different values have been pointed out as thresholds for triggering allergic symptoms. Thus, 30 grains/m³ is considered sufficient to bring on the onset of severe symptoms by Corsico (1993). This value was attained in the atmosphere of Lugo on 26 days during 1999 (Table 3). The value of 80 grains/m³, which produces symptoms in 90% of patients (Viander and Koivikko 1978; Detandt and Nolard 1996), was attained on 15 days during 1999 and 10 days during 2001. Other pollen types that are recorded during this time of the year are of moderate allergenic importance, since their mean daily concentrations are low

or average, which is the case of *Alnus*, *Quercus* and Cupressaceae. The first one surpassed the quantity of 50 grains/m³ on 16 days during 1999, *Quercus* during 15 days in 2001 and Cupressaceae had values above 40 grains/m³ on two to eight days. The moderate allergenic capacity of *Pinus* is due to the fact that allergenic reactions are produced in cases with prolonged exposure to high concentrations, higher than 100 grains/m³ (Fountain and Cornford 1991), which were recorded on four to eight days during the study period. In other nearby areas in Galicia, some patients are mono-sensitive to this pollen type (Marcos et al. 2001).

The months of June and July are the most important for the majority of hay fever sufferers, since in Galicia almost 80% of such patients are sensitive to pollen belonging to the family *Poaceae* (Arenas et al. 1996; Belmonte et al. 1998; Ferreiro et al. 1998). Davies and Smith (1973) and Ong et al. (1997) point out that moderate allergy phenomena are produced when their mean daily concentrations are greater than 25 grains/m³ and these values were attained in Lugo on 42–45 days. Likewise, concentrations greater than 50 grains/m³ are capable of producing clinical symptoms in all allergic patients (Negrini et al. 1992) and this value was exceeded on about 30 days per year. Other pollen types that appear during the summer are *Plantago*, Urticaceae and *Castanea*. Pollen of the genus *Plantago* is present in low concentrations and only attained 50 grains/m³ on one day during the three years of sampling. Despite this, *Plantago* is one of the greatest allergy inducers in Galicia, being the cause of 38–40% of hay fever cases in many areas (Dopazo 2001), which gives us an idea of its allergenic potential. The allergenic nature of the Urticaceae family has been mentioned by many authors (D'Amato and Spieksma 1990; Bass and Bass 1990; Díaz de la Guardia et al. 1998), with *Parietaria* pollen being the frequent cause of hay fever in coastal areas of Northwest Spain (Ferreiro et al. 1998; Belmonte et al. 1998). Negrini et al. (1992) point out that 90% of patients sensitive to the pollen of this family show symptoms when the atmosphere contains concentrations above 80 pollen grains/m³, which was only exceeded in Lugo on one to five days.

A study of the intra-diurnal pollen concentrations variation (Figure 6) shows that the majority of the pollen types follow the same behaviour pattern. Maximum concentrations occur during the day, followed by a gradual decrease until the minimums are reached during the night and then the levels increase again

during the morning. *Plantago* attained its maximum concentrations at 11 am/12 noon. Urticaceae, *Quercus*, Cupressaceae and *Betula* reached their maximum values at 1/2 pm and, finally, *Pinus* and Poaceae recorded their highest values during the afternoon/evening. These curves are similar to those pointed out by Galan et al. (1991) for the south of Spain, where the maximum values are produced when the temperature is highest and the relative humidity is lowest. It is worth highlighting that the behaviour model followed by Poaceae with the highest concentrations during the afternoon/evening is constant in Northwest Spain (Rodríguez-Rajo 2000; Méndez 2000; Dopazo 2001) and in the United Kingdom (Norris-Hill and Emberlin 1991). However, in the south of Spain (Galán et al. 1991), Poaceae concentrations peak during the morning or at midday. These patterns may be due to the fact that this family is made up of a high number of species, whose different concentrations in each area establish the overall behaviour model.

The second pattern is followed by *Castanea*, which includes two concentrations peaks during the day: the first at 3/4 am and the second (most important) at 7/8 pm. This behaviour model is also pointed out by Peeters and Zoller (1988), Frei (1997) and Jato et al. (2001) in areas where expanses of *Castanea* trees are located relatively close to the trap, although the hours in which the first peak is produced vary slightly. This tree is well represented in the surroundings of the city of Lugo, which means that the pattern obtained may accurately reflect its pollen dispersion model. However, in other Galician cities the model shows a single concentration peak during the day (Jato et al. 2001), coinciding with the second one found in our case for Lugo. A possible cause of the different models cited for *Castanea* is the delay from the moment the pollen is released until it is collected by the trap (Jato et al. 2001). This is supported by the medium- and long-distance transportation capacity of the *Castanea* pollen grain has been highlighted by several authors (Peeters and Zoller 1988; Frei 1997).

5. Conclusions

The presence of atmospheric pollen in the city of Lugo throughout the year shows seasonal variability, with a well-defined annual summer maximum. More than half of the total annual pollen is recorded in the months of June and July. The content of the total annual pollen is similar to that of other Galician localities, and the values reached by Poaceae were the highest.

The meteorological parameters that, in general, have a major positive correlation on pollen concentrations are temperature, hours of sunshine and wind distance, while rainfall and relative humidity have a major negative correlation.

During the day, the maximum values are recorded between 11 am and 8 pm when the temperature is highest and the relative humidity is lowest.

Acknowledgements

We would like to thank the Xunta de Galicia's Environment Department for its financing of the R.I.A.G. (Galician Aerobiological Investigation Network) and the Lugo Fire Brigade for its collaboration in the collection of samples.

References

- Andersen T.: 1991, A model to predict the beginning of the pollen season. *Grana* **30**, 269–275.
- Andersen S. Th.: 1980, Influence of climatic variation on pollen season severity in wind-pollinated trees and herbs. *Grana* **19**, 47–52.
- Arenas L., González de la Cuesta C., Tabarés J.M., Iglesias I., Jato V. and Méndez J.: 1996, Sensibilización cutánea a pólenes en pacientes afectos de rinoconjuntivitis-asma en la población de Ourense en el año 1994–1995. Proceedings of the 1st European Symposium on Aerobiology, Santiago, 93–94.
- Bass D.A. and Bass D. J.: 1990, *Parietaria judaica* L. A cause of allergic disease in Sydney. A study of habit and spread of the weed. *Review of Palynology* **64**, 97–101.
- Belmonte J., Roure J.M. and March X.: 1998, Aerobiology of Vigo, North-Western Spain: Atmospheric pollen spectrum and annual dynamics of the most important taxa, and their clinical importance for allergy. *Aerobiologia* **14**, 155–163.
- Belmonte J., Gabarra E. and Roure J.M.: 2000, Aerobiología de Cataluña: Estación de Barcelona (1999). *Rea* **6**, 75–78.
- Benninghoff W.S.: 1991, Aerobiology and its significance to biogeography and ecology. *Grana* **30**, 364–372.
- Carballeira A., Devesa C., Retuerto R., Santillan E. and Uceda E.: 1983, *Bioclimatología de Galicia. Fund. Barrié de la Maza, La Coruña*, 391.
- Cariñanos P., Galán C., Alcázar P., García H. and Domínguez E.: 1999, Aerobiología en Andalucía: Estación de Córdoba (1999). *Rea* **5**, 23–26.
- Chanda S.: 1991, Presidential address: Aerobiology Science in progress. *Grana* **30**, 5–8.
- Corsico R.: 1993, L'asthme allergique en Europe. In: F.T.M. Spieksma, N. Noland, G. Frenguelli and D. Van Moerbeke (eds), *Pollens de l'air en Europe. UCB, Braine-l'Alleud*, pp. 19–29.
- D'Amato G. and Spieksma F.Th.: 1990, Allergenic pollen in Europe. *Grana* **30**, 67–70.
- Davies R.R. and Smith L.P.: 1973, Forecasting the start and severity of the hay fever season. *Clin Allergy* **3**, 263–267.
- Detandt M. and Noland N.: 1996, The Belgian Pollen Service: immediate and direct information to hay fever sufferers. *Aerobiologia* **12**, 197–200.

- Díaz de La Guardia C., Alba F., Girón F. and Sabariego S.: 1998, An aerobiological study of Urticaceae pollen in the city of Granada (Spain): correlation with meteorological parameters. *Grana* **37**, 298–304.
- Domínguez E., Galán C., Villamandos F.E. and Infante F.: 1992, Handling and evaluation of the data from the aerobiological sampling. *Monografías Rea* **1**, 1–18.
- Dopazo A., Jato V. and Aira M.J.: 2000, Allergenic pollen types in the atmosphere of Santiago de Compostela (NW Spain): a pollen calendar for the last six years. *Bot. Hel.* **110**, 51–60.
- Dopazo A.: 2001, Variación estacional y modelos predictivos de polen y esporas aeroalergénicos en Santiago de Compostela. *Universidad de Santiago de Compostela. Tesis doctoral.*
- Ekeboom A., Vesterberg O. and Hjelmroos M.: 1996, Detection and quantification of airborne birch pollen allergens on PVDF membranes by immunoblotting and chemiluminescence. *Grana* **35**, 113–118.
- Emberlin J., Savage M. and Woodman R.: 1993, Annual variations in the concentrations of *Betula* pollen in the London area, 1961–1990. *Grana* **29**, 301–309.
- Fernández-González M. D., Valencia R.M., Vega A. and Sagüés E.: 1998, Aerobiología en Castilla y León (1995–1996): Estación de León. *Rea* **3**, 49–52.
- Ferreiro M., Núñez R., Rico M., Soto T. and López R.: 1998, Pólenes alergénicos y polinosis en el área de La Coruña. *Rev. Esp. de Alerg. e Inmunol. Clin.* **13**, 98–101.
- Fountain D.W. and Cornford C.A.: 1991, Aerobiology and allergenicity of *Pinus radiata* pollen in New Zealand. *Grana* **30**, 71–75.
- Frei T.: 1997, Pollen distribution at high elevation in Switzerland: Evidence for medium range transport. *Grana* **36**, 34–38.
- Galán C., Tormo R., Cuevas J., Infante F. and Domínguez E.: 1991, Theoretical daily variation patterns of airborne pollen in the South-west of Spain. *Grana* **30**, 201–209.
- Gutiérrez M., Cervigón P. and Pertíñez C.: 1999, Aerobiología en Madrid: Estación de Ciudad Universitaria (1998). *Rea* **5**, 131–134.
- Hjelmroos M.: 1991, Evidence of long-distance transport of *Betula* pollen. *Grana* **30**, 215–228.
- Jato M.V., Rodríguez-Rajo F.J. and Seijo M.C.: 2000, *Pinus* pollen in the atmosphere of Vigo and its relationship to meteorological factors. *Int. J. Biometeorol.* **43**, 147–153.
- Jato M.V., Aira M.J., Dopazo A., Iglesias M.I., Méndez J. and Rodríguez-Rajo F.J.: 2001, Aerobiology of *Castanea* pollen in Galicia. *Aerobiologia* **17**, 233–240.
- Leuschner R.M., Christen H., Jordan P. and Vonthein R.: 2000, 30 years of studies of grass pollen in Basel (Switzerland). *Aerobiologia* **16**, 381–391.
- Leventin E.: 1998, A long term study of winter and early spring tree pollen in the Tulsa, Oklahoma atmosphere. *Aerobiologia* **14**, 21–28.
- Marcos C., Rodríguez F.J., Luna I., Jato M.V. and González R.: 2001, Pine pollen aerobiology and clinical sensitization in North-west Spain. *Annals of Allergy* **86**, 39–42.
- Méndez J.: 2000, Modelos de comportamiento estacional e intradiurno de pólenes y esporas de la ciudad de Ourense y su relación con los parámetros meteorológicos. *Tesis doctoral. Universidad de Vigo.*
- Negrini A.C., Voltoni S., Troise C. and Arobba D.: 1992, Comparison between Urticaceae (*Parietaria*) pollen count and hay fever symptoms: assesment of a “threshold-value”. *Aerobiologia* **8**, 325–329.
- Nilsson S. and Persson S.: 1981, Tree pollen spectra in the Stockholm region (Sweden), 1973–1980. *Grana* **20**, 179–182.
- Norris-Hill J. and Emberlin J.: 1991, Diurnal variation of pollen concentration in the air of North-Central London. *Grana* **30**, 229–234.
- Ong E.K., Taylor P.E. and Knox R.B.: 1997, Forecasting the onset of the grass pollen season in Melbourne (Australia). *Aerobiologia* **13**, 43–48.
- Peeters A.G. and Zoller H.: 1988, Long range of transport of *Castanea sativa* pollen. *Grana* **27**, 203–207.
- Rivas Martínez S.: 1987, *Memoria del mapa de series de vegetación de España*, Serie Técnica, ICONA. Madrid.
- Rodríguez-Rajo F.J.: 2000, El polen como fuente de contaminación ambiental en la ciudad de Vigo. *Universidad de Vigo. Tesis doctoral.*
- Rodríguez-Rajo F.J., Méndez J., Díaz M.R., Jato V. and Iglesias I.: 1998, Pollen calendar of the town of Vigo, North-West Spain (1995). *Aerobiologia* **14**, 269–276.
- Ruiz L., Díaz de la Guardia C. and Cano E.: 1998, Aerobiología en Andalucía: estación de Jaén (1995–1996). *Rea* **3**, 29–32.
- Spieksma F. Th., Noland N., Frenguelli G. and Van Moerbeke D.: 1993, *Polen atmosférico en Europa*, UCB, Bruselas, 83.
- Tormo R., Silva I., Muñoz A.F. and Paulino R.: 1999, Aerobiología en Extremadura: Estación de Cáceres. (1998). *Rea* **5**, 115–118.
- Viander M. and Koivikko A.: 1978, The seasonal symptoms of hyposensitized and untreated hay fever patients in relation to birch pollen counts: correlations with nasal sensitivity, prick tests and RAST. *Clin. Allergy* **8**, 387–396.
- Wallin J.E., Segerström U., Rosenhall L., Bergman E. and Hjelmroos M.: 1991, Allergic symptoms caused by long-distance transported birch pollen. *Grana* **30**, 265–268.

