Polen 10:37-47(1999)

AEROPALYNOLOGY OF BIRCH (*BETULA* SP.) IN SPAIN

Jato, V.[1]; Aira, M.J.[2]; Iglésias, M.I.[1]; Alcázar, P.[3]; Cervigón, P.[4]; Fernández, D.[5]; Recio, M.[6]; Ruíz, L.[7] & Sbai, L.[8]

[1] Departamento de Biología Vegetal y Ciencias del Suelo, Universidad de Vigo, Facultad de Ciencias, Campus Universitario As Lagoas, 32004-Ourense, Spain.
[2] Departamento de Biología Vegetal, Facultad de Farmacia, Universidad de Santiago de Compostela, 15706-Santiago de Compostela, Spain.
[3] Departamento de Biología Vegetal, Facultad de Ciencias, Universidad de Córdoba, Avda. San Alberto Magno s/n., 14004-Córdoba, Spain.
[4] Departamento de Biología Vegetal II, Facultad de Farmacia, Universidad Complutense de Madrid, 28040-Madrid, Spain.
[5] Departamento de Biología Vegetal, Facultad de Biología, Universidad de León, 24071-León, Spain.
[6] Departamento de Biología Vegetal, Facultad de Biología, Universidad de Málaga, 29080-Málaga, Spain.
[7] Departamento de Biología Vegetal, Facultad de Ciencias, Universidad de Granada, 18001-Granada,Spain.
[8] Unidad de Botánica, Facultad de Ciencias, Universidad Autónoma de Barcelona, 08193-Bellaterra, Barcelona, Spain.

(Manuscrito recibido el 30 de Junio de 1999, aceptado el 9 de Diciembre de 1999)

SUMMARY**:** The aim of this study was to determine the behavior of birch pollen in 13 Spanish cities, with different bioclimatic and plant characteristics, and to delimit the areas in which important concentrations are reached. Birch pollen is present in Spain's atmosphere from March to the end of May, the highest values being recorded between mid-March and the end of April. Daily mean concentrations greater than 100 pollen grains/m^3 are only found in the northwestern corner of the Iberian Peninsula (Santiago de Compostela, Ourense and Vigo). There is a second zone covering the northern half of the country, excluding the aforementioned area, in which daily mean values of 50 pollen grains/m^3 are rarely exceeded. Lastly, in the rest of the country, Betula pollen levels are very low or practically non-existent. Notable differences in total annual Betula pollen counts are recorded for the same city in different years. Although the differences between the onset of pollination in the same city for different years are generally not very significant, contrasting meteorological conditions recorded from one year to the next may produce differences of up to 30 days.
KEY WORDS: *Betula*, Birch, Spain, Aerobiology

RESUMEN: En el presente trabajo, se realiza un estudio comparativo entre el compartamiento del polen de abedul en 13 localidades de España con características bioclimáticas y biogeográficas diferentes. El polen de abedul está presente en la atmósfera en España durante los meses de marzo a mayo, y alcanza sus concentraciones más elevadas entre la segunda quincena de marzo y final de abril. Unicamente en las localidades situadas en el extremo noroccidental de la Península Ibérica (Santiago de Compostela, Vigo y Ourense), se alcanzan concentraciones medias diarias superiores a 100 granos/m^3. En el resto de la mitad norte los valores medios diarios raramente exceden los 50 granos/m^3, y en las otras localidades, el polen de abedul aparece en concentraciones muy bajas o está

ausente. Para una misma ciudad, existen importantes diferencias entre las cantidades anuales registradas en los diferentes años. En general, las diferencias en el inicio de la estación polínica no son importantes, si bien, en algún año, llega a haber hasta 30 días de diferencia.
PALABRAS CLAVE: *Betula*, Abedul, España, Aerobiología

INTRODUCTION

Birch is represented in Spain by two species: *Betula alba* L. and *Betula pendula* Roth. (MORENO & PEINADO, 1990). The former is more widely distributed, especially in the north, being more abundant towards the west where it is the dominant tree and forms high mountain oro-Cantabrian acidophilic forests, with a clearly Euro-Siberian distribution. They are found at altitudes of over 1,150 meters, as the last tree formations of the altitudinal sequence, with mountain thermo-climates and hyper-humid ombro-climates (IZCO, 1994). Their limit, although the subject of some controversy, is situated in the Galician mountain ranges of Ancares and Caurel (COSTA *et al*., 1990). In this same area, but on siliceous soils and with a greater Mediterranean influence, there are also birch forests in the Galician-Portuguese high mountain layer and the Ourense-Sanabria and supra-Mediterranean layer.

Galicia's mountains and foothills are populated by non-climactic birches, in place of mountain oak groves, which are located on acidic soils and with altitudinal limits between 600 and 1,100 meters.

In the Euro-Siberian region, birch may form part of riparian forests, together with *Alnus glutinosa*, *Salix atrocinera* and *Frangula alnus*. Lastly, in other characteristic forests of the Cantabrian mountain range or Eastern Pyrenees, birch is also found with beech and petiolate oak.

The distribution of *Betula pendula* is more limited, forming part of Pyrenean mountain ash forests and of dense bushes in place of acidophilic Pyrenean fir forests. It can also be found in the center of the peninsula and in the southeastern mountains as a species cultivated in different Spanish areas (RIVAS MARTÍNEZ, 1987).

Birch is an anemophilous tree with high pollen production (MOORE & WEBB, 1978; LEWIS *et al*., 1983), whose allergenic capacity has been described by numerous authors (SPIEKSMA, 1990; NORRIS-HILL & EMBERLIN, 1991; D'AMATO & SPIEKSMA 1992). Its pollen is considered to be the main cause of pollinosis in Northern and Central Europe (WIHL *et al*., 1998; SPIEKSMA *et al*., 1995), not only during its pollen season but even during previous and subsequent periods, since its pollen can be easily transported over long distances (WALLIN *et al*., 1991; HJELMROOS, 1991). In such cases, antigenic activity seems to be linked to allergens characteristic of birch pollen grains that are deposited on dust particles inside houses, triggering the onset of allergic processes, even up to two months after maximum pollen concentrations are recorded (EKEBOM *et al*., 1996; RANTIO-LEHTI-MÁKI *et al*., 1996).

In view of the above (mainly the abundance and allergenic nature of this pollen), several researchers have carried out aeropalynological studies on this taxon, in order to determine the model of seasonal and daily behavior of birch pollen and the influence of the different meteorological parameters on pollen concentrations (SPIEKSMA *et al*., 1989; ATKINSON *et al*., 1990; GALÁN *et al*., 1991; NORRIS-HILL & EMBERLIN, 1991; SPIEKSMA *et al*., 1995). In this way, models

can be established in order to predict both the beginning and severity of the pollen season (RUFFALDI & GREFFIER, 1991; ANDERSEN, 1991; LARSSON, 1993; CARAMIELLO *et al*., 1994; BRICCHI *et al*., 1995).

In Spain, pollen birch data for recent years from different localities forming the Spanish Aerobiology Network (REA) were published in the REA Bulletin. Nevertheless, very few studies have focused exclusively on the aeropalynological aspects of *Betula*; in Spain, this has only been studied by AIRA *et al.* (1998) in Santiago de Compostela. The aim of the present study was to determine the behavior of this pollen, which is of such great allergenic importance, in several parts of Spain with different bioclimatic and plant characteristics, and to delimit the areas in which significant concentrations are reached.

MATERIAL AND METHODS

The periods studied differed according to the individual sampling stations: Ourense, Santiago, Cordoba and Granada have the most extensive records (1993-1998); León, Barcelona, Málaga and Madrid (1994-1998); Vigo (1995-1998); Estepona (1995-1997); and Lleida, Tarragona and Girona (1996-1998).

All of the stations used Hirst pollen traps, situated at approximately 25 meters above the ground. The methodology recommended by the Spanish Network of Aerobiology (REA) was used to process and interpret the samples (DOMÍNGUEZ, 1995). In order to establish the beginning of the pollen season, the criterion proposed by MULLENDERS *et al.* (1972) was adopted, according to which the season begins when the running five-day average reaches or exceeds 1% of the annual total. In terms of the application of this criterion, although this study does not cover a large number of years, the authors followed the same criterion as that used by SPIEKSMA *et al.* (1998), whereby the annual total is deemed to be the average value of the years studied. The advantage of this criterion is that it enables the beginning of the season to be predicted with the same threshold. It can therefore be calculated without having to wait for the total results recorded in each specific year. In those cities and/or years in which the annual total *Betula* pollen count failed to reach 100 pollen grains, the date of the beginning of the pollen season was taken as the first of two consecutive days on which at least 1 pollen grain/m^3 was recorded.

RESULTS

Table 1 shows, for each sampling station, the annual daily maximum and the date on which this was recorded, the date of the beginning of the pollination period and the concentration of birch pollen recorded on that day. It also shows the average annual total for each city and the number of days on which more than 50 pollen grains/m^3 were recorded.

By basing the date of the beginning of the pollen season on a different average value for each city, the number of pollen grains/m^3 marking the beginning of the period varied. Thus, in the case of Santiago, this begins when the running five-day average reaches 23 grains/m^3; in Vigo, this value is 9 grains/m^3; and in Ourense, 11 grains/m^3. After applying this criterion, virtually no differences were observed between the dates of the beginning of the period calculated using other criteria (LEJOLY GABRIEL & LEUCHSNER, 1983; PATHIRANE, 1975; MULLENDERS *et al*.,

Sites	Years	Peak (date)	Beginning of pollination season	First day season concentration (grains/m^3)	Mean of annual total	Days number >50
Ourense	1993	66 (19/4)	9/4	8	1121	1
	1994	254 (29/4)	24/3	39		14
	1995	146(4/4)	31/3	17		14
	1996	123(17/4)	11/4	14		5
	1997	152(29/3)	14/3	29		8
	1998	37(27/3)	21/3	32		0
Santiago de Compostela	1993	160 (15/4)	27/3	45	2332	8
	1994	368 (13/4)	28/3	16		12 and 13
	1995	327 (12/4)	30/3	62		19
	1996	192 (29/4)	16/4	57		5
	1997	561 (28/3)	17/3	33		22
	1998	171 (27/3)	25/3	39		6
Vigo	1995	204 (14/4)	29/3	12	876	13
	1996	73 (15/4)	14/4	32		3
	1997	172 (28/3)	14/3	43		7
	1998	29 (27/3)	24/3	19		0
León	1994	38 (2/5)	24/3	8	209	0
	1995	23 (3/4)	3/4	23		0
	1996	27 (16/4)	12/4	3		0
	1997	59 (18/3)	11/3	19		1
	1998	5 (27/3)	24/3	1		0
Barcelona	1994	39 (2/5)	26/3	9	165	0
	1995	32 (14/4)	9/4	11		0
	1996	3 (15 y 25/4)	17/4	1		0
	1997	48 (2/4)	18/3	1		0
	1998	4 (8 y 24/4)	7/4	1		0
Tarragona	1996	1	11/2	1	110	0
	1997	27 (29/3)	23/3	4		0
	1998	2(18/5)	11/5	1		0
Girona	1996	18 (26/4)	13/4	13	232	0
	1997	88 (2/4)	23/3	4		3
	1998	6 (16/4)	31/3	1		0
Lleida	1996	4 (26/4)	28/3	1	91	0
	1997	25 (4/4)	19/3	2		0
	1998	3 (19/5)	8/4	1		0
Madrid	1994	11 (30/4)	11/3	2	43	0
	1995	15 (14/4)	3/4	1		0
	1996	3 (15/4)	13/4	1		0
	1997	7 (15/4)	16/3	1		0
	1998	6 (8/5)	26/4	2		0
Estepona	1995	11 (14/4)	8/4	1	21	0
	1996	2 (29 v 30/3)	27/3	1		0
	1997	5 (8/4)	27/2	1		0
Málaga	1994	12 (30/4)	26/3	1	29	0
	1995	13 (15/4)	11/4	1		0
	1996	3 (26/4)	26/3	1		0
	1997	6 (30/3)	27/2	2		0
	1998	2 (19 y 20/5)	17/4	1		0

TABLE 1. Maximum birch pollen concentrations and dates on which these were registered in each locality and year, dates of the beginning of pollen seasons, first day season concentrations, means of annual total birch pollen counts and number of the days with concentrations of over 50 pollen grains/m^3.

1972; DRIESSEN *et al*., 1989; NILSSON & PERSSON, 1981) and the criterion obtained in this case (in most years and cities the differences ranged between 1 and 4 days), with the exception of 1993 in Ourense, when the start date was put back up to 13 days according to the criterion employed.

Figure 1a shows the evolution of annual birch pollen grain counts during the study period in Santiago, Ourense and Vigo. These localities presented the highest values. In all the years studied, Santiago was the station with the highest pollen concentrations, with values ranging between 4,608 pollen grains in 1997 and 966 in 1996. The evolution in the other localities is shown in Figure 1b.

Figures 2a and 2b show, in addition to the average daily means for the years studied, the trend line obtained with the running five-day averages. In all of the stations studied, the pollination periods last from the middle or end of March to the end of April or beginning of May.

DISCUSSION

In view of these results, it can observed that, in Spain, *Betula* pollen only reaches high concentrations in the North, the highest concentrations being recorded in the North West. Within the Euro-Siberian region, these areas correspond to those with the greatest distribution of birch.

The sampling stations can be divided into 3 groups. The first group includes the cities in which the annual counts exceeded 1,000 pollen grains, with daily average occasionally exceeding 100 pollen grains/m^3. The cities in this group —Santiago de Compostela, Ourense and Vigo— are located in the northwestern corner of the Iberian Peninsula. The highest values were recorded in Santiago de Compostela, with a maximum annual total of 4,608 pollen grains in 1997. In Ourense, the maximum annual total was 1,979 pollen grains in 1994 and in Vigo the maximum annual total of 1,540 pollen grains was recorded in 1995. Daily maximum counts were 561 pollen grains/m^3 in Santiago in 1997, 254 pollen grains/m^3 in Ourense in 1994 and 204 pollen grains/m^3 in Vigo in 1995. This is therefore the area of greatest risk in Spain; the population is sensitive to this pollen since concentrations above 80 pollen grains/m^3, considered to be sufficient to produce symptoms in all clinically sensitive individuals (DETANDT & NOLARD, 1996), are normally reached every year.

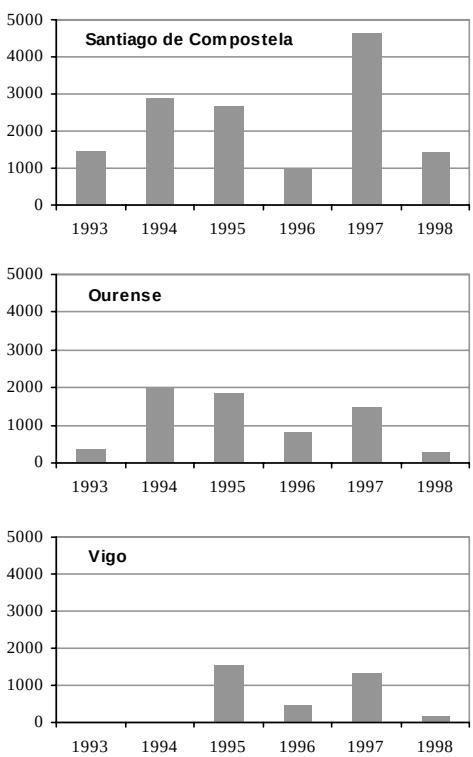

FIGURE 1a. Evolution of the annual quantity of birch pollen grains in Vigo, Santiago and Ourense.

The second group includes the cities in which total annual *Betula* pollen counts were greater than 100 pollen grains in some years and daily averages rarely exceeded 50 pollen grains/m^3. This group includes Barcelona (maximum annual total of 522 pollen grains), Girona (510 pollen grains), León (436 pollen grains), Tarragona (303 pollen grains) and Lleida (246 pollen grains). In all these cities, the maximum annual totals were recorded in the same year (1997). Nevertheless, it is worth highlighting that the number of years for which data are available differed; although 5 years (1994 to 1998) were studied in León and Barcelona, in the other three stations data were only available for the last three years.

The third group includes Madrid together with the two southernmost stations: Malaga and Estepona. In these three cities the

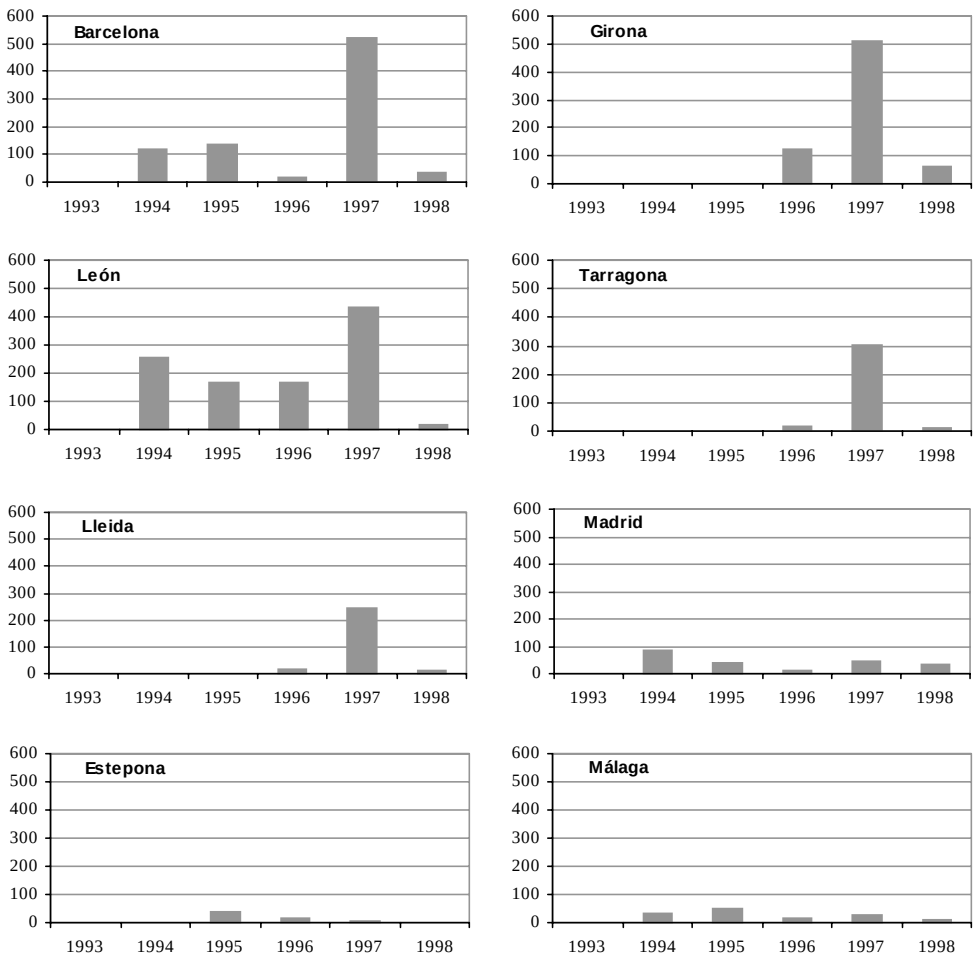

FIGURE 1b. Evolution of annual birch pollen grain counts in the other cities.

pollen levels were very low, never exceeding an annual total of 100 pollen grains and with maximum daily averages of 15 pollen grains/m^3.

Lastly, in Cordoba and Granada birch pollen was only detected on isolated days and always with testimonial values.

In the other aerobiological stations included in the Spanish Network of Aerobiology, Betula pollen was only recorded in Zaragoza, with annual total values of 220 pollen grains in 1995 and 101 pollen grains in 1996 (BERMEJO *et al*., 1998). These results would place this city in the second group.

Significant differences exist in terms of the total birch pollen grain counts recorded in the years studied in each city. In those for which more years of data are available, 1995 and especially 1997 were generally deemed to be the years with the highest pollen production, as compared with 1996 and 1998 when concentrations were very low. There is no absolute agreement in terms of the year in which maximum total annual quantities were recorded. Thus, while in Santiago, León and Barcelona this was 1997, in Ourense and Madrid it was 1994 and in Vigo and Málaga it was 1995. Apart from possible factors inherent to the species that cause variations in pollen production in specific years, the presence of abundant and frequent rainfall during the pollination periods in 1993 and 1998 undoubtedly helped to clean the atmosphere and thus reduce pollen concentration. An overall tendency towards maintaining an alternate rhythm of high and low concentrations was observed. This alternation generally occurred in all the cities in the final three years of the study period (1996-1998).

In the years in which the annual concentrations exceeded 100 pollen grains, no significant differences were observed in terms of the pollination start dates in the different cities. The most significant was in 1997, with a 12-day difference between the start of pollination in the earliest station (León) and the latest (Lleida). The northwestern stations (Santiago, Vigo and Ourense) were generally the ones with the earliest onset of pollination, with small differences between them (from 1 to 5 days), whereas the Catalan stations presented the latest onset of pollination.

In order to study the differences in the onset of pollination in a city during the years studied, the authors took into account the stations included in group 1, since these presented the highest concentrations and more years of data for analysis. The differences in

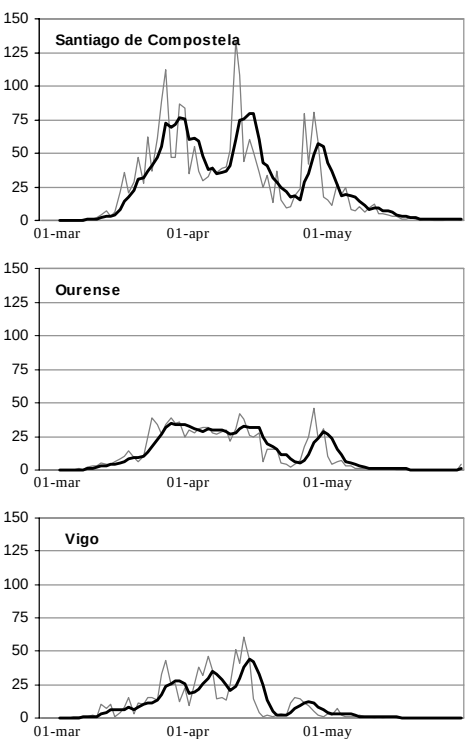

FIGURE 2a. Average of the daily mean concentrations of birch pollen in Vigo, Santiago and Ourense.

this case are important, since between 1996 (the year with the latest pollination) and 1997 (the year with the earliest pollination), differences of 28 days in Ourense, 30 in San-

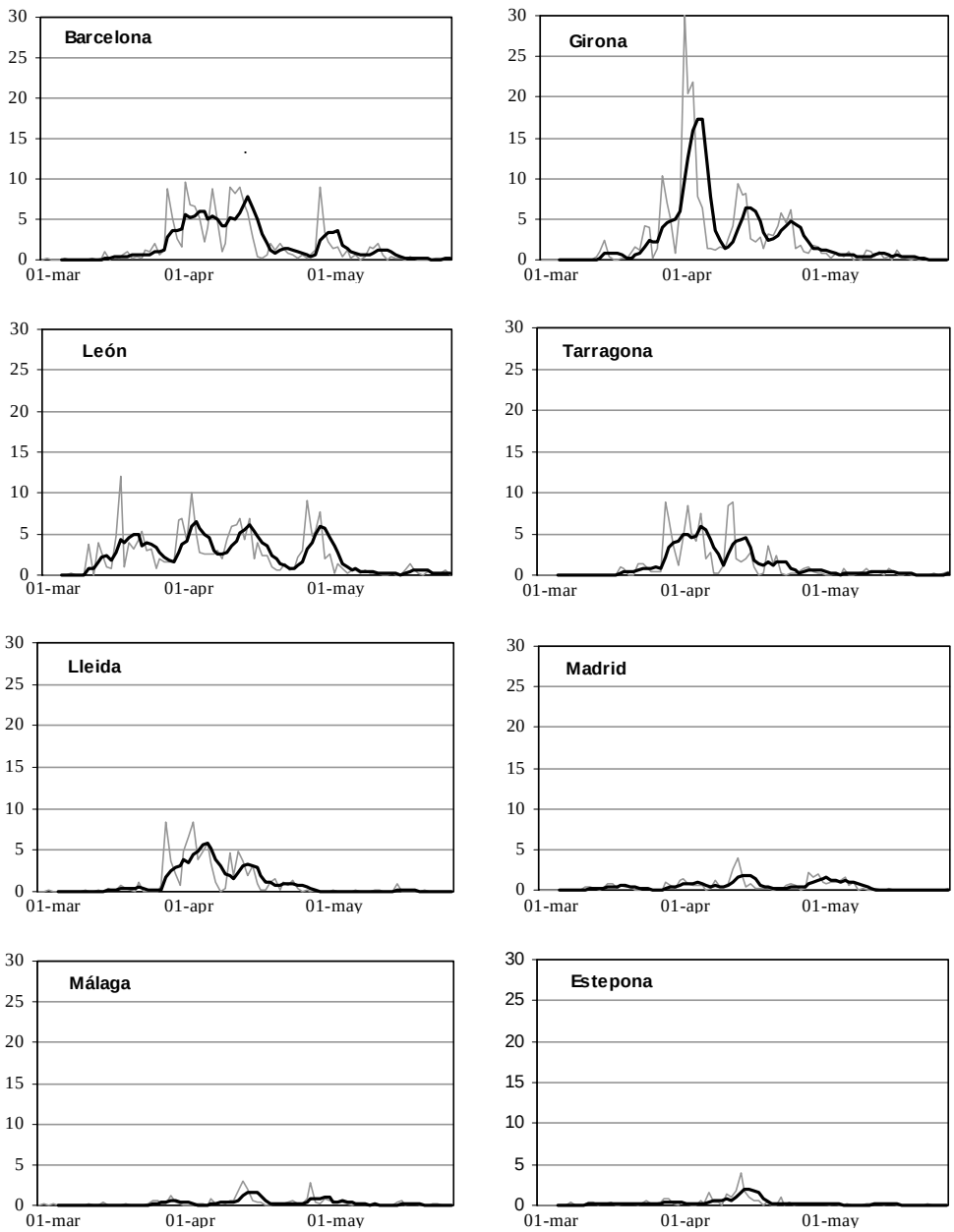

FIGURE 2b. Average of the daily mean concentrations of birch pollen in the others localities.

tiago and 31 in Vigo were recorded. In Danish cities, ANDERSEN (1991) reports differences of up to 38 days between the beginning of pollination from one year to the next. Temperature and photoperiod have been highlighted by several authors as factors of great importance in the onset of birch pollination (SUTRA, 1992; SPIEKSMA *et al.*, 1989; ANDERSEN, 1991). The beginning of pollination is also controlled by the cooling required by the plant before ending the latency period and the total of accumulated temperatures above a threshold, which EMBERLIN *et al.* (1997) reported to be 5.5ºC. The study of longer series of data will undoubtedly enable a statistical analysis of the causes of these variations. However, in the case of 1997, a combination of two factors was decisive in the early onset of pollination, namely the very low minimum temperatures recorded in January (total temperatures in that month were much lower than in other years) and maximum temperatures higher than those in other years during February. This would, on the one hand, favour an early accumulation of coldness and, on the other, and after this period, the heat required for producing the dehiscence of the anthers would be accumulated earlier.

CONCLUSIONS

Birch pollen is present in Spain's atmosphere from March to the end of May, with the highest values being recorded between mid-March and the end of April. Daily values of over 100 pollen grains/m^3 are only found in the northwestern corner of the Iberian Peninsula (Santiago de Compostela, Ourense and Vigo). In these stations, the presence of rainy days (common in spring) have a great influence on the pollen levels achieved. A second zone, excluding the aforementioned area, covers the northern half of the country, in which daily values of 50 pollen grains/m^3 are rarely exceeded. Lastly, in the rest of the country, *Betula* pollen levels are very low or practically non-existent. The northwestern stations are generally the first to begin pollination, and the Catalan stations present the latest onset of pollination.

For the same city, notable differences are observed in total annual *Betula* pollen counts, and there is a general tendency towards maintaining an alternate rhythm of high and low concentrations.

Although the differences between the onset of pollination in the same city for different years are generally not very significant, different meteorological conditions recorded from one year to the next may give rise to differences of up to 30 days.

ACKNOWLEDGEMENTS

The authors are grateful to the CICYT for the financial support of the project AMB97-1457.C07-03.

REFERENCES

AIRA, M.J.; JATO, V. & IGLESIAS I. (1998). *Alnus* and *Betula* pollen content in the atmosphere of Santiago de Compostela, north-western (1993-1995). **Aerobiol.** 14:135-140.

ANDERSEN T.B. (1991). A model to predict the beginning of the pollen season. **Grana** 30:269-275.

ATKINSON, H. & LARSSON K.A. (1990). A 10 year record of the arboreal pollen in Stockholm, Sweden. **Grana** 29:229-237.

BERMEJO, D.; GARCÍA A.M.; SANCHO, P. & VALERO, C. (1998). Aerobiología de Aragón (1995-96). **Bol. Red Esp. Aerobiol.** 3:45-48.

BRICCHI, E.; FRENGUELLI, G.; MINCIGRUCCI, G.; FORNACIARI, M.; FERRANTI, F. & ROMANO,

B. (1995). Time linkages between pollination onsets of different taxa over an 11-year period in Perugia, Central Italy. **Aerobiol.** 11:57-61.

CARAMIELLO, R.; SINISCALCO, C.; MERCALLI, L. & POTENZA, A. (1994). The relationship between airborne pollen grains and unusual weather conditions in Turin (Italy) in 1989, 1990 and 1991. **Grana** 33:327-332.

COSTA, M.; HIGUERAS, J. & MORLA, C. (1990). Abedulares de la Sierra de San Mamed (Orense, Spain). **Acta Bot. Malacitana** 15:253-265.

D'AMATO, G. & SPIEKSMA, F.TH.M. (1992). European allergenic pollen types. **Aerobiol.** 8:447-450.

DETANDT, M. & NOLARD, N. (1996). The Belgian pollen Phone Service: immediate and direct information to hay fever sufferers. **Aerobiol.** 12(3):201-203.

DOMÍNGUEZ, E. (1995). La Red Española de Aerobiología. **Monograf. REA** 1:1-8.

DRIESSEN, M.N.B.M.; VAN HERPEN, R.M.A.; MOELANDS, R.P.M. & SPIEKSMA, F.TH.M. (1989). Prediction of the start of the grass pollen season for the western part of the Netherlands. **Grana** 28:37-44.

EKEBOM, A.; VERTERBERG, O. & HJELMROOS, M. (1996). Detection and quantification of airborne birch pollen allergens on PVDF membranes immunoblotting and chemi-luminescence. **Grana** 35:113-118.

EMBERLIN, J.; MULLINS, J.; CORDEN, J.; MILLINGTON, W.; BROOKE, M.; SAVAGE, M. & JONES. (1997). The trend to earlier Birch pollen seasons in U.K.: A biotic response to changes in weather conditions?. **Grana** 36(1):29-33.

GALÁN, C.; TORMO, R.; CUEVAS, J.; INFANTE, F. & DOMÍNGUEZ, E. (1991). Theoretical daily variation patterns of airborne pollen in southwest of Spain. **Grana** 30:201-209.

HJELMROOS, M. (1991). Evidence of long-distance transport of Betula pollen. **Grana** 30:215-228.

IZCO, J. (1994). O bosque Atlántico. In: C. VALES (ed.). **Os Bosques Atlánticos Europeos,** pp. 13-49. Bahía, La Coruña.

LARSSON, K. (1993). Prediction of the pollen season with a cumulated activity method. **Grana** 32:111-114.

LEJOLY-GABRIEL & LEUCHSNER, (1983). Comparison of airborne pollen at Louvaine-la-Neuve (Belgium) and Basel (Switzerland) during 1979-1980. **Grana** 22:59-64.

LEWIS, W.H.; VINAY, P. & ZENGER, V.E. (1983). **Airborne and allergenic pollen of North America.** The Jones Hopkins Univ. Press. Falta la ciudad

MORENO, G. & PEINADO, M. (1990). *Betula* In: S. CASTROVIEJO (ed.). **Flora Ibérica,** 2:38-43. Real Jardín Botánico. C.S.I.C., Madrid.

MOORE, P.D. & WEBB, J.A. (1978). **An illustrated guide to pollen analysis.** Hodder & Soughton.

MULLENDERS, W.; DIRICKX, M.; VAN DER HAEGEN, D.; BASTIN-SERVAIS, Y & DESAIR, C.(1972). La pluie pollinique à Louvaine-Heverlee en 1971. **Louvain Méd.** 91:159-176.

NILSSON, S. & PERSSON, S. (1981). Tree pollen spectra in the Stockholm region (Sweden), 1973-1980. **Grana** 20:179-182.

NORRIS-HILL, J. & EMBERLIN, J. (1991). Diurnal variation of pollen concentration in the air of north-central London. **Grana** 30:229-234.

PATHIRANE, L. (1975). Aerobiological literature in scientific periodicals. **Grana** 15:145-147.

RANTIO-LEHTIMÄKI, A.; PEHKONEN, E. & YLI PANULA, E. (1996). Pollen allergic symptoms in the off season?. In: M.J. AIRA, V. JATO, I. IGLESIAS, C. GALÁN (ed.). **Compostela Aerobiology 96,** pp. 91-92. Santiago de Compostella

RIVAS-MARTÍNEZ, S. (1987). **Memoria del mapa de series de vegetación de España.** Ministerio de Agricultura, Pesca y Alimentación, Madrid.

RUFFALDI, P. & GREFFIER, F. (1991). Birch (*Betula*) pollen incidence in France (1987-1990). **Grana** 30:248-254.

SPIEKSMA, T.TH.M.; FRENGUELLI, G.; NIKKELS, A.H.; MINCIGRUCCI, G.; SMITHIUS, L.O.M.J.; BRICCHI, E.; DANKAART, W.; ROMANO, B.

(1989). Comparative study of airborne pollen concentrations in central Italy and The Netherlands (1982-1985). **Grana** 28:25-36.

SPIEKSMA; F.Th.M. (1990). Pollinosis in Europe: new observations and developments. **Rev. Paleobot. Palynol.** 64:35-40.

SPIEKSMA, F.TH.M.; EMBERLIN, J.C.; HJELMROOS, M.; JÄGER, S.; LEUSCHNER, R.M. (1995). Atmospheric birch (*Betula*) pollen in Europe: Trends and fluctuations in annual quantities and the starting dates of the seasons. **Grana** 34:51-57.

SPIEKSMA, F.TH.M. & NIKKELS A.H. (1998). Airborne grass pollen in Leiden, The Netherlands: annual variations and trend in quantities and season starts over 26 years. **Aerobiol.** 14(4):347-358.

SUTRA, J.P. (1992). La prévision statistique de la date initiale de pollinisation du bouleau en France. **Climat et Santé** 7:53-84

WALLIN, J.E.; SEGERSTRÖM, V.; ROSENHALL, L.; BERGMANN, E. & HJELMROOS, M. (1991). Allergic symptoms caused by long distance transported birch pollen. **Grana** 30:256-268.

WIHL, J.A.; IPSEN, B.; NÜCHEL, P.B.; MUNCH, E.P.; JANNICHE, E.P. & LÖVENSTEIN, H. (1998). Immunotherapy with partially purified and standardized tree pollen axtracts. **Allergy** 43:363-369.