VARIATIONS IN THE MAIN POLLEN SEASON OF *OLEA EUROPAEA* L. AT SELECTED SITES IN THE IBERIAN PENINSULA

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(Manuscrito recibido el 8 de Octubre 1999, aceptado el 5 de Noviembre1999)

SUMMARY: A comparative analysis of the aerobiological behavior of *Olea europaea* L. pollen at different sites in Spain was made. A Hirst-type suction sampler was used at all sites. The results highlighted the irregular distribution of this taxon in the Iberian Peninsula. The largest olive growing areas are located in Andalucía, mainly in the provinces of Jaén and Córdoba where the highest pollen concentrations were recorded. The area given over to olives decreases further North, where lower pollen concentrations are obtained, with the exception of the Catalan cities where the Mediterranean sea favors olive growing. The main pollen season varied between 30 and 60 days, except in Santiago de Compostela where this lasted for 8 days. This means that allergy patients are exposed to this type of pollen for a very long period. The start of the pollen season was between April and May. The olives flowered first in meridional latitudes and last in the Euro-Siberian region. Maximum pollen concentrations were recorded in May or during the first fortnight of June.
KEY WORDS: Aerobiology, Pollen, *Olea europaea*, Iberian Península.

RESUMEN: En este trabajo se presenta un análisis comparativo sobre el comportamiento aerobiológico del polen de *Olea europaea* L. en distintas ciudades españolas, con una distribución biogeográfica y bioclimatológica diferente. El muestreo se ha realizado durante varios años consecutivos utilizando captadores volumétricos tipo Hirst. Los resultados han demostrado que este taxon presenta una distribución muy irregular en la Península Ibérica. Las mayores extensiones dedicadas a olivar se encuentran en Andalucía, particularmente en las provincias de Jaén y Córdoba. A medida que nos alejamos hacia el Norte los cultivos de olivo son menos frecuentes y, por lo tanto, las concentraciones de granos de polen detectadas en el aire son inferiores, excepto en Cataluña donde la influencia del mar Mediterráneo favorece a este cultivo. La estación principal de polen osciló entre 30 y 60

días, excepto en Santiago de Compostela donde tuvo sólo 8 días de duración. Esto significa que los pacientes de alergia están expuestos a este tipo polínico durante un largo periodo de tiempo en la mayoría de los lugares. El inicio de la estación polínica ocurrió entre abril y mayo. Los olivos que florecieron primero fueron los que crecen en las latitudes meridionales, los últimos en florecer fueron los de la Región Eusiberiana. Las máximas concentraciones diarias se producen generalmente en el mes de mayo o durante la primera quincena de junio.
PALABRAS CLAVE: Aerobiología, polen, *Olea europaea* L., Península Ibérica

INTRODUCTION

Olive growing probably began around five thousand years ago in the Eastern Mediterranean. It spread throughout the West, eventually reaching the Iberian Peninsula. Today, Spain (particularly Andalucia) is the most important olive-oil producer in the world; in some provinces in Andalucia, more than the 40% of the total surface area is given over to olive growing. Olive trees produce a large number of flowers, grouped in elongated panicles (TORMO MOLINA *et al.*, 1996). Pollen spore concentrations in the atmosphere are therefore very high. The area given over to olives decreases as one moves further North.

As in other Mediterranean countries, pollen from *Olea europaea* is considered to be one of the main causes of allergies in Spain (BOUSQUET *et al.*, 1985; D'AMATO & LOBEFALO, 1989; MACCHIA *et al.*, 1991; LICCARDI *et al.*, 1996). This has prompted many aerobiological studies of this species in Spain (CANDAU *et al.*, 1981; DOMÍNGUEZ *et al.*, 1993; DÍAZ DE LA GUARDIA *et al.*, 1993; RECIO *et al.*, 1996; GONZÁLEZ MINERO & CANDAU, 1997; RUIZ *et al.*, 1998), and a preliminary aerobiological comparison between olive cultivated areas in different Mediterranean countries (FORNACIARI *et al.*, 1995)

The aim of this study was to compare the different patterns on pollen season at several sites in the Iberian Peninsula, taking into account the biogeographical and biometeorological characteristics of each.

MATERIAL AND METHODS

The atmosphere was monitored at 15 sites in the Iberian Peninsula. Three of the stations studied - Córdoba, Málaga and Granada - have been operating since 1992, the year in which the Spanish Aerobiology Network was set up. Madrid, Jaén, León, Ourense and Santiago de Compostela joined the network in 1993; Barcelona and Priego de Córdoba in 1994; Vigo and Estepona in 1995; and lastly, Lleida, Girona and Tarragona in 1996.

This study includes three provinces in Galicia, a region in the northwest of the Iberian Peninsula, characterised by a rainy and warm climate. Vigo and Santiago de Compostela are the only two provinces from the Euro-Siberian Region. Ourense belongs to the Mediterranean region, with its drier climate similar to that of the other sampling sites. Barcelona, Tarragona, Lleida and Girona are located in the northeastern part of the Iberian Peninsula, and form the region of Cataluña. The first three are included in the meso-mediterranean belt. Tarragona has a drier and warmer climate and belongs to the thermo-mediterranean belt. León forms part of the region of Castille-Leon in the North West. Although this province belongs to the Mediterranean Region, it is influenced by Euro-Siberian regional characteristics.

Moreover, it is located in a Supra-Mediterranean belt. It is probably the most continental site of all the sampling points studied here. Madrid is located in the center of the Iberian Peninsula and belongs to the Autonomous Community of Madrid. It forms part of the mesomediterranean belt. The other provinces are located in Andalucía in the South; Granada and Jaén are included in the mesomediterranean belt; Córdoba and Málaga belong to the thermomediterranean belt; Córdoba and Priego de Córdoba, given their inland locations, have certain continental features; Málaga is located on the coast and has a mild climate.

A Hirst-type seven-day spore trap suction sampler was used at all sites (HIRST, 1952). These traps were located in the roofs of the buildings, 20-25 m above ground level, thus ensuring that there were no obstacles to air flows. Daily pollen counts were obtained using the methodology proposed by the Spanish Aerobiology Network (REA) (DOMÍNGUEZ *et al.*, 1991). Daily mean data are expressed in terms of pollen concentration per cubic metre of air (grains/m^3).

The main pollen season (MPS) has been defined as the period of the year that accounts for 95% of the total annual catch, in accordance with the methodology proposed by NILSSON & PERSSON (1981), which is the most suitable procedure for a taxon with such a short pollen season. The characteristic MPS data for each of the stations was used to draw up tables showing the start and end dates, maximum counts and the date on which maximums were recorded, mean counts during the MPS and the number of days on which the count exceeded 50 grains/m^3. The tables also include annual absolute values for *Olea* pollen for each of the cities. Graphs have also been plotted to show the annual total for each year studied, together with the mean daily count for all the years analyzed at each station.

RESULTS

The results show that in most of the cities the MPS of *Olea* lasts from April to June (Fig. 1). In coastal cities like Málaga, Estepona and Vigo and thermomediterranean areas like Córdoba and Priego de Córdoba, the pollen season starts in late April and lasts until the middle-to-end of June. In cities such as Barcelona and Madrid, the MPS may, under exceptional circumstances, last until July. The day of maximum pollen concentration was usually recorded in May. Very occasionally, the peak day in Córdoba, Estepona and Málaga occurred in April and in Ourense, Girona and Madrid in June. Maximum pollen concentrations were recorded in Córdoba, Priego de Córdoba and Jaén. The highest average concentrations during the MPS were also recorded in Priego de Córdoba and Jaén, with values of over 500 grains/m^3, followed by Córdoba and Granada (150 grains/m^3). In general, the MPS lasted for more than 30 days in the southern cities, with values of over 50 grains/m^3. The other cities presented MPS of between 1–20 days, when the pollen count was below 50 grains/m^3 (Tab. 1).

Although the pollen index is included in a column in Table 1, these data are also presented in Figure 2 to illustrate the evolution of total annual counts. These data show that the highest annual pollen index usually occurred in Jaén (67,107 grains in 1997) and Priego de Córdoba (56,367 grains in 1994). Santiago de Compostela and Ourense were invariably the stations where the lowest pollen counts were detected. The city of León

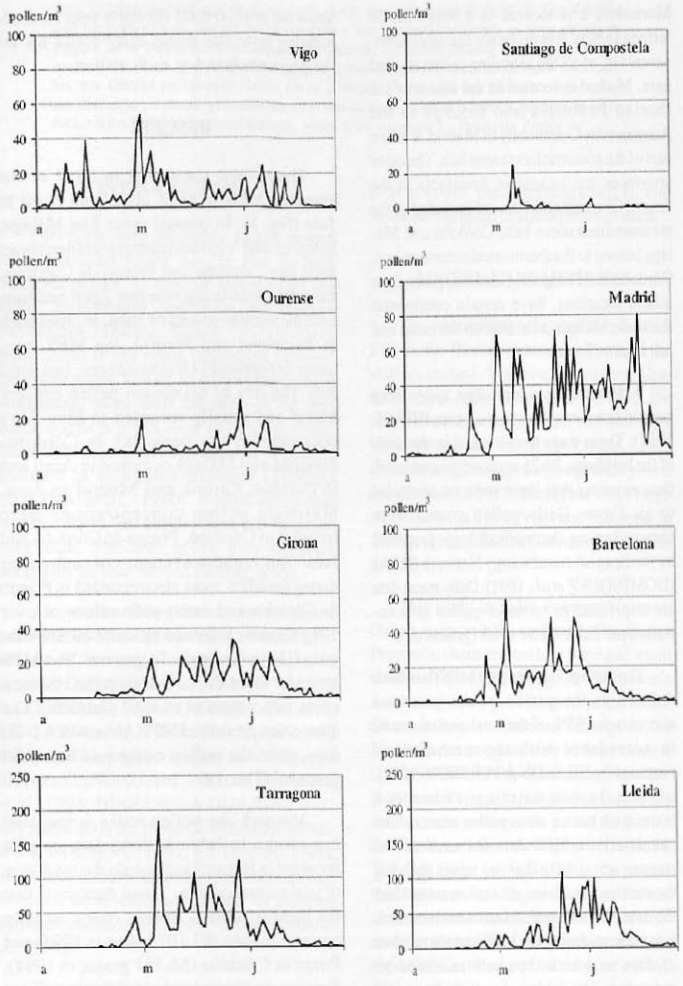

FIGURE 1. Evolution of the mean daily Olea-pollen counts; representation of the daily average considering all the years studied and all the sampling stations.

has not registered *Olea* pollen. The other cities presented significant variations, with years in which the pollen count was high and others when this was low.

DISCUSSION

The study of a high number of years at sites such as Córdoba, Granada, Málaga, Ourense, Madrid and Jaén enabled the seasonal behavior of olive trees to be examined in depth. It also provides sufficient data for carrying out future research into pollen emission and transport using meteorological factors, which will facilitate the obtainment of forecast formulas in different climates and vegetation areas in Spain.

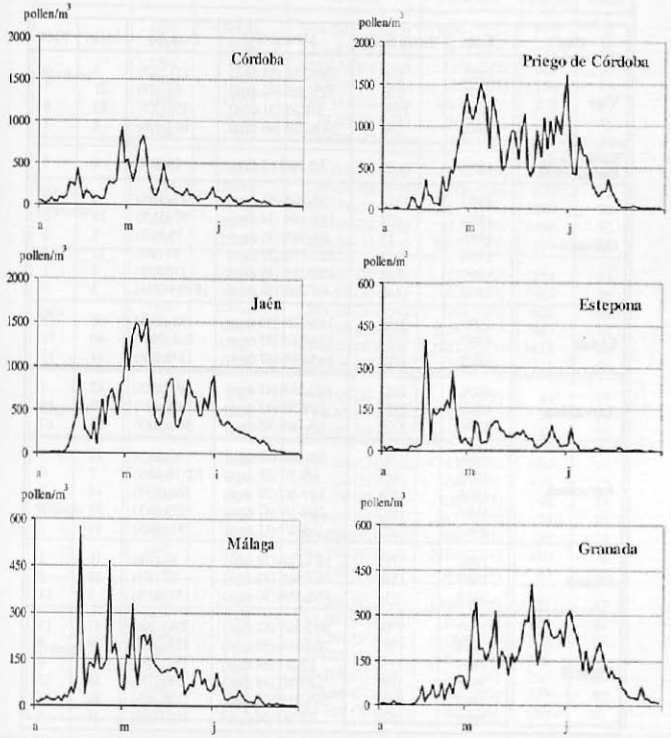

FIGURE 1 (Cont.). Evolution of the mean daily Olea-pollen counts; representation of the daily average considering all the years studied and all the sampling stations.

As regard as the pollen index, this can be divided into three categories; the first corresponds to cities with a pollen index of more than 4000, and includes all the Andalusian cities excluding Estepona, which was only over this figure in 1997; the second category includes sites with pollen indexes between 500-2500, and includes all the Catalan cities, Vigo and Madrid; the third category includes sites where values below 500 were recorded, such as Santiago de Compostela and Orense. Notably, non-*Olea* pollen was detected in the atmosphere of León. This confirms the close relationship that exists between *Olea* cultivation and ambient pollen concentration. The largest olive plantations can be found in Andalucia, mainly in the provinces of Jaén and Córdoba, where the highest pollen concentrations were recorded. The area given over to olives

City	Year	Pollen Index	MPS 95%	Peak day	Mean	N>50
Vigo	1995	598	23/4-27/6 (66 days)	121 (5/5)	3	8
	1996	916	20/5-30/6 (42 days)	94 (6/6)	21	7
	1997	1134	2/4-2/5 (31 days)	195 (2/5)	35	8
	1998	536	24/4-22/6 (60 days)	66 (19/6)	8	3
Santiago de Compostela	1998	66	7/5-14/5 (8 days)	24 (8/5)	6	0
Ourense	1993	241	17/5-26/6 (41 days)	43 (31/5)	5	0
	1994	469	23/5-15/6 (24 days)	97 (31/5)	16	1
	1995	83	6/5-19/6 (45 days)	19 30/5)	2	0
	1996	374	22/5-17/6 (27 days)	93 (6/6)	13	2
	1997	342	13/4-28/5 (46 days)	113 (2/5)	7	1
	1998	149	6/5-20/6 (46 days)	19 (9/5-17/6)	3	0
Lleida	1996	2135	24/5-22/6 (30 days)	185 (29/5)	66	15
	1997	1559	25/4-31/5 (37 days)	224 (23/5)	40	11
	1998	1710	14/5-29/6 (47 days)	272 (3/6)	34	12
Tarragona	1996	2033	10/5-23/6 (45 days)	349 (28/5)	42	9
	1997	2473	26/4-7/6 (43 days)	539 (5/5)	55	11
	1998	2219	8/5-16/6 (40 days)	306 (16/5)	52	10
Barcelona	1994	782	9/5-26/6 (49 days)	76 (29/5)	14	1
	1995	457	5/5-3/7 (60 days)	32 (16-18/5)	7	0
	1996	848	12/5-8/7 (58 days)	166 (27/5)	14	2
	1997	1633	22/4-7/6 (47 days)	271 (5/5)	33	8
	1998	685	3/5-2/7 (61 days)	92 (20/5)	10	1
Girona	1996	771	15/5-21/6 (38 days)	66 (7/6)	19	2
	1997	846	18/4-30/5 (43 days)	67 (4/5)	18	2
	1998	533	17/5-15/6 (30 days)	51 (23/5)	1	14
Madrid	1993	2700	20/5-20/7 (62 days)	304 (18/6)	41	15
	1994	1907	28/4-25/6 (59 days)	275 /27/5)	30	9
	1995	1394	1/5-3/7 (64 days)	150 (22/5)	21	8
	1996	1898	22/5-8/7 (48 days)	199 (7/6)	34	13
	1997	3291	23/4-31/5 (39 days)	356 (8/5)	80	17
	1998	1678	9/5-5/7 (58 days)	105 (10/6)	28	9

TABLE 1. Total pollen index of *Olea* counts and characteristics of the MPS for each of the sampling stations every year.

gradually decreased further North. Consequently, lower pollen concentrations were noted, in the Norta with the exception of the Catalan cities, where the proximity to the Mediterranean favors olive growing.

All the sites presented significant interannual variations (Fig. 2). However, the biannual pattern reported by some authors for arboreal species (GALÁN *et al.*, 1988; EMBERLIN *et al.*, 1990) was not observed here. At the sites where more years were monitored, two general trends were observed in pollen production: firstly, a decrease from 1992 to 1995 that concurred with a dry period; and, secondly, an increase from 1996 to 1998 that coincided with a rainy period. These results

City	Year	Pollen Index	MPS 95%	Peak day	Mean	N>50
Córdoba	1992	18530	25/4-20/5 (26 days)	3006 (28/4)	712	26
	1993	8766	2/5-2/7 ((62 days)	613 (8/5)	141	38
	1994	8845	25/4-4/6 (41 days)	1479 (6/5)	216	17
	1995	11257	16/4-1/6 (47 days)	1526 (5/5)	239	35
	1996	13352	28/4-14/6 (48 days)	1028 (30/5)	278	43
	1997	24183	2/4-8/5 (37 days)	3890 (1/5)	653	36
	1998	17697	19/4-5/6 (48 days)	3460 (7/5)	352	34
Priego de Córdoba	1994	56367	3/5-11/6 (40 days)	3852 (6/5)	1343	40
	1995	30949	21/4-5/6 (45 days)	2706 (9/5)	675	41
	1996	45780	14/5-13/6 (30 days)	4287 (30/5)	1420	30
	1997	55037	13/4-18/5 (35 days)	6321 (1/5)	1496	32
	1998	27291	26/4-3/6 (38 days)	3494 (19/5)	673	35
Jaén	1993	31187	11/5-2/7 (53 days)	2259 (1/6)	558	45
	1994	39518	2/5-9/6 (39 days)	4926 (6/5)	963	38
	1995	23766	30/4-4/6 (36 days)	3266 (9/5)	626	36
	1996	32515	13/5-13/6 (32 days)	2738 (24/5)	967	32
	1997	67107	13/4-22/5 (40 days)	5451 (16/4)	1612	40
	1998	41784	26/4-21/6 (57 days)	4329 (8/5)	711	56
Estepona	1995	2580	16/4-14/6 (60 days)	186 (9/5)	41	17
	1996	2264	19/4-4/7 (77 days)	248 (27/5)	28	14
	1997	8637	1/4-19/5 (49 days)	1116 (17/4)	167	25
Málaga	1992	4442	15/4-6/6 (53 days)	627 (2/5)	80	19
	1993	9014	29/4-22/6 (55 days)	745 (9/5)	156	42
	1994	6636	4/4-7/6 (65 days)	1060 (8/5)	98	34
	1995	4167	16/4-8/6 (54 days)	387 (10/5)	73	28
	1996	4558	16/4-29/6 (75 days)	506 (27/5)	58	24
	1997	21625	01/4-19/5 (49 days)	2819 (27/4)	419	36
	1998	5758	12/4-16/6 (66 days)	803 (5/5)	83	32
Granada	1992	11533	9/5-20/6 (43 days)	1306 (22/5)	257	37
	1993	11006	13/5-30/7 (79 days)	683 (5/6)	133	42
	1994	18210	4/5-26/6 (54 days)	1519 (22/5)	323	39
	1995	7335	20/4-6/6 (48 days)	630 (22/5)	145	32
	1996	9336	16/5-19/6 (35 days)	846 (2/6)	254	29
	1997	18829	17/4-6/6 (51 days)	1884 (5/5)	353	42
	1998	11231	20/4-28/6 (70 days)	594 (2/6)	153	47

TABLE 1 (Cont.). Total pollen index of *Olea* counts and characteristics of the MPS for each of the sampling stations every year.

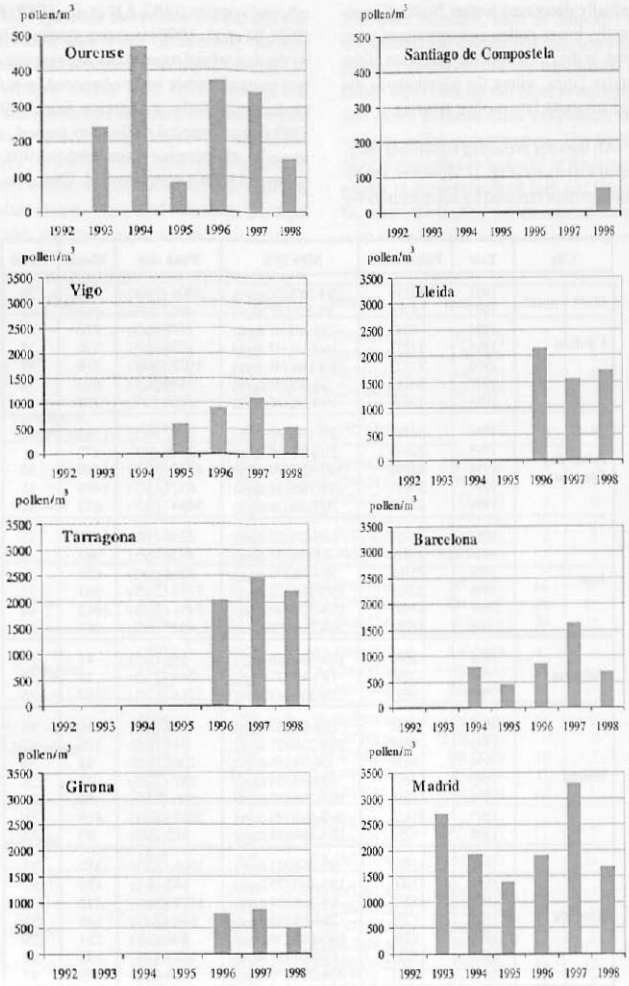

FIGURE 2. Evolution of the total pollen index of *Olea* counts for each of the sampling stations in the studied years.

coincide with the findings of various authors, who confirm that precipitation during the vegetative period of this species has a positive effect on pollen production (ANTÉPARA *et al.*, 1994; CANDAU *et al.*, 1994; FORNACIARI *et al.*, 1997). The highest pollen concentrations were recorded in 1997 at all the sites, with the exception of Ourense and Lleida; the lowest concentrations were recorded in 1995, except in Córdoba and Estepona.

The start of the pollen season occurred between April and May. The olives that flowered first were those that grew in the Meridional latitudes, namely those located

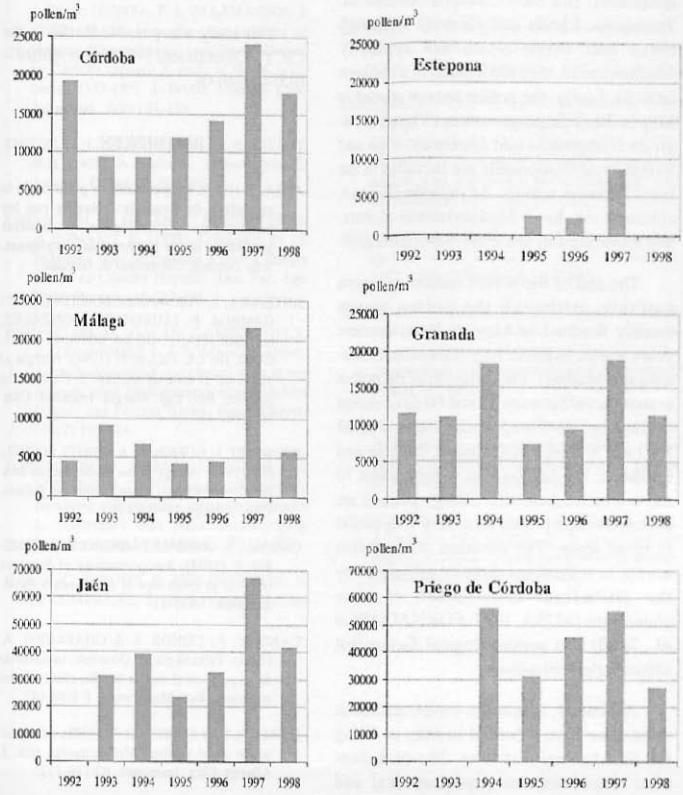

FIGURE 2 (Cont.). Evolution of the total pollen index of *Olea* counts for each of the sampling stations in the studied years.

in the thermomediterranean belt (Málaga, Estepona, Priego de Córdoba and Córdoba). A short delay was observed in those growing in the mesomediterranean belt, and occasionally in the Supra-mediterranean; firstly, Jaén and Granada with certain continental characteristics, followed by Madrid (more continental with less Mediterranean influence), and then Cataluña (Barcelona, Tarragona, Lleida and Girona). Although these last three cities are typically Mediterranean, they are located in a northern latitude. Lastly, the pollen season started in May in the Galician provinces (Vigo, Santiago de Compostela and Ourense). Vigo and Santiago de Compostela are included in the Euro-Siberian region. As regards Ourense, although this has a Mediterranean climate, it is influenced by the Euro-Siberian region.

The end of the pollen season was more variable. Although the pollen season usually finished in May or June, in some years it concluded in July (Granada, Barcelona and Madrid). The duration of the pollen season varied between 30 and 60 days, except in Santiago de Compostela where it lasted for only 8 days. In Granada, Málaga and Estepona, the season was longer, about 70 days, which means that allergy patients are exposed to this pollen for a very long period in these areas. The duration of the pollen season is sometimes directly influenced by the altitudinal distribution of olive plantations (ALBA, 1997; FORNACIARI *et al.*, 2000) and meteorological factors that affect pollen emissions.

In general, maximum concentrations at most sites were recorded in May or during the first fortnight of June. The peak dates also depended on topographical and climatological conditions, as well as on the start and end of the season.

Average pollen concentrations were higher in Granada, Jaén, Priego de Córdoba and Córdoba, reaching over 150 grains/m^3 in all years. At the same time, these sites, together with Málaga, usually had more than 30 days with more than 50 grains/m^3.

ACKNOWLEDGMENTS

This study was possible thanks to the CICYT Co-ordinated I+D Project AMB97-0457-CO7-01-04.

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