VARIATIONS IN THE *QUERCUS* SP. POLLEN SEASON AT SELECTED SITES IN SPAIN

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SUMMARY: This is a preliminary study of *Quercus* pollen levels in the air at 15 Spanish sites which was carried out over 6 consecutive years (1993-1998). Pollen levels increased significantly in the last three years of this period, probably due to the recovery following the severe drought in Spain between 1993 and 1995. Nevertheless, a biennial cyclic pattern of pollen production could still be observed at most of the sites studied. The duration of the pollen season varied with the local climate. Important differences were therefore detected between Mediterranean and Euro-Siberian regions. However, as regards pollen season start dates, these varied mainly depending on the pre-season temperatures in each year, and no significant differences were detected between the individual sites.
KEY WORDS: Aerobiology, *Quercus*, pollen season, annual trends.

RESUMEN: En este trabajo se ha realizado un estudio preliminar sobre los niveles de granos de polen de *Quercus* presentes en el aire en 15 localidades españolas. El trabajo analiza datos polínicos de 6 años consecutivos (1993-1998). Los niveles de este tipo polínico se incrementan considerablemente en los últimos años del periodo analizado debido probablemente a la recuperación tras la sequía de 1993-1995. Aún así fue posible observar un ciclo de producción polínica bianual en muchas de las zonas estudiadas. La duración de la estación polínica varió dependiendo del clima, así se detectan diferencias significativas entre la región Mediterránea, y la Eurosiberiana. Por el contrario, respecto a las fechas de inicio de la floración, estas variaron fundamentalmente dependiendo de las temperaturas preestacionales de cada año no detectándose variaciones considerables entre los diferentes sitios.
PALABRAS CLAVE: Aerobiología, *Quercus*, estación polínica, tendencia anual.

INTRODUCTION

Quercus genus is represented in the Iberian Peninsula by 10 tree species commonly known as oaks (cork-oaks, holm-oaks, galloaks, etc). They are well distributed all over the country, being dominant species in all types of Iberian woodland.

These are perennial monoecious species and most are evergreens. Male flowers are borne on long catkins, which develop in the axils of scale leaves. The flowering period normally lasts from March until June, or even early July. Since all of them are wind-pollinated or anemophilous species, they require the production and dissemination of very large amounts of pollen (PROCTOR & YEO 1973, TORMO *et al.*, 1996).

The different species of *Quercus* have estenopalinos pollen grains, presenting only slight differences in size; all of them have therefore been classified as *Quercus* pollen types (SAENZ DE RIVAS, 1973, MOORE & WEBB 1978, VALDES *et al.*, 1987).

Allergic sensitization in the population has yet to be fully clarified. Recent research has reported an increase in hayfever in the UK and *Quercus* pollen has been identified as one of the main causes (ROSS *et al.*, 1996, BUTLAND *et al.*, 1997). FARNHAM (1990) showed a 29% positive skin prick test to *Quercus* pollen. SUBIZA (1987) and BELMONTE *et al.* (1998) in Spain and NEGRINI & AROBBA (1992) in Italy, reported up to 13% - 15% positive prick tests. In contrast, low results - around 4% - have been reported by GERGEN(1987) and LUSCRI *et al.* (1996) in USA, and IGLESIAS *et al.* (1997) and PRADOS (1995) in Spain. However, in most these studies, a minimal clinical significance of pollen was noted (BOUSQUET *et al.*, 1984, 1991). This may be the reason for the reduced number of studies on the aerobiology of this taxon, despite the fact that high quantities of pollen grains are recorded in most European countries (CORDEN & MILLINGTON 1998, NORRIS-HILL 1998). The *Quercus* pollen season has been basically studied in both pollen calendars and airborne tree pollen analysis (EMBERLIN *et al.*, 1990, ATKINSON & LARSSON 1990).

This study analises *Quercus* pollen data collected over a six year period (1993-1998) at 15 selected sites in Spain with different local climates. The aim of this paper was to make a comparative study in order to define the *Quercus* pollen season in those zones of the Iberian Peninsula with different biogeographical and bioclimatological characteristics. This type of study is interesting insofar as it helps to determine the influence of climate and location in the pre-season and season period of wind-pollinated species (GONZÁLEZ-MINERO *et al.*, 1993, CANDAU *et al.*, 1993, EMBERLIN *et al.*, 1994, GALÁN *et al.*, 1995).

MATERIALS AND METHODS

The 15 studied sites belong to the Spanish Aerobiology Network. All of them have different local climates, topography and vegetation and can be grouped into four main geographical areas (Tab. 1). Most were in operation over the whole of the six year period (1993-1998), although, as shown in Table 2, some started monitoring at later dates. Estepona data are only available from 1995 to 1997. Tarragona, Lerida and Gerona data only available from 1996 to 1998.

Seven-day Mistrap volumetric spore traps (HIRST, 1952) were used at the selected sites. The traps were located 15-20 m above

the ground and all of them were adapted to the standard sampling procedures proposed by the Spanish Aerobiology Network (DOMÍNGUEZ *et al.*, 1991). Daily mean data are expressed in terms of pollen concentrations per cubic metre of air.

The start of the pollen season was defined as the day on which 1 pollen grain/m^3 was reached and when subsequent days contained 1 or more pollen grains/m^3. The end of the season was as the last day on which 1 pollen grain/m^3 was recorded and when subsequent days presented concentrations below this level.

As regards meteorology and vegetation, although every site has its own local characteristics, these were grouped into four areas with similar climatological characteristics: NE, NW, Central and South. The NW is generally a mild and rainy area. Deciduous woodlands with a large population of *Quercus* species are the predominant forms of vegetation. The cities of Vigo and Santiago in this Euro-Siberian region (RIVAS MARTÍNEZ 1987) have similar weather and vegetation conditions. The oak - *Q. robur* L. - is the most common species of the *Quercus* genus in the forests in this area. Ourense belongs to the Mediterranean area and has a drier and warmer climate. Mediterranean species, such as *Q. suber* L. (cork oak), *Q. pyrenaica* Wild. and *Q. robur* L. are also found in this area.

The sampling sites located in the NE of the Iberian Peninsula —Barcelona, Tarragona, Lleida and Girona— have Mediterranean climate. The first two cities are influenced by the proximity of the sea. The temperature is warm and annual rainfall scarce. The landscape is typically Mediterranean, with extensive areas of holm oak (*Q. ilex* L.), and cork oak. Kermes oak (*Q. coccifera* L.) woodland appears on most impoverished soils.

The Central area has a dry continental climate with significant inter-seasonal variations in temperature and rainfall. In the local countryside around Madrid, the dominant *Quercus* specie is *Q. rotundifolia* Lamk., also known as holm oak. It forms large areas or meadows used for livestock farming known as *dehesas*. León, located to the north of Madrid, is influenced by the Euro-Siberian region. Its landscape is also characterised by *dehesas*, although woodland populated by *Q. robur* L. can also be found.

Zone	Site	Altitude	Position	Mean temp.(°C)	Annual rainfal (mm)
North-West	Santiago	270	42°53'N, 8°32'W	12'9	1288
	Vigo	50	42°14'N, 8°43'W	14'9	1412
	Orense	130	42°21'N, 7°51'W	14	772
North-East	Barcelona	245	41°24'N, 2°9'E	16'5	595
	Gerona	125	41°54'N, 2°46'E	15	740
	Lérida	202	41°37'N, 0°38'E	14'8	414
	Tarragona	48	41°7'N, 1°15'E	16'7	482
Center	León	830	42°34'N, 5°35'W	10	550
	Madrid	600	40°27'N, 3°45'W	14	440
South	Córdoba	123	37°50'N, 4°45'W	18	600
	Priego de Córdoba	650	37°26', 4°11'W	14,4	650
	Jaen	560	37°46'N, 3°47'W	17	592
	Granada	685	37°11'N, 3°35'W	15'1	400
	Málaga	5	36°47'N, 4°19'W	18	575
	Estepona	Sea level	36°25'N,5°9'W	16'8	556

TABLE 1. Characteristics of site locations.

Lastly, the southern region has a very warm and dry Mediterranean climate. Typical vegetation includes *dehesas* populated by *Q. rotundifolia* Lamk., kermes oaks in the impoverished areas and cork oaks in the most humid areas with acid soils. Gall oak —*Quercus faginea* Lamk.— can be found at high altitudes, with basic pH soils and no human alteration

RESULTS

Table 2 shows, as the Pollen Index, the annual sum of *Quercus* pollen grains at each site, the dates that define the PPP (Principal Pollination Period) and its duration, the maximum diurnal value recorded and the date of the maximum value. As can be seen, the

Site	Year	PI	PPP	Range	Peak	Date of Peak	N>50
Santiago de Compostela	1993	712	23/3-9/5	48	100	24/3	1
	1994	827	16/3-3/5	49	113	29/3	6
	1995	2152	19/3-23/5	66	333	12/4	13
	1996	366	3/4-14/5	43	54	16/4	0
	1997	1975	8/3-4/5	58	154	28/3	12
	1998	199	17/3-5/4	20	18	28/3	0
Vigo	1995	3884	6/3-23/5	86	433	14/4	23
	1996	794	20/3-12/5	53	166	15/4	2
	1997	4530	27/2-5/5	67	205	17/3	37
	1998	720	24/2-26/5	92	38	27/3	1
Orense	1993	1702	8/3- 27/6	112	134	19/4	6
	1994	1535	9/3-21/6	105	114	30/3	8
	1995	3332	20/3-11/6	83	194	14/4	26
	1996	2382	18/3-13/6	88	215	16/4	15
	1997	2941	3/3-5/6	95	151	6/4	27
	1998	1345	4/3-23/6	112	77	21/3	6
Barcelona	1994	1652	19/3-19/7	123	88	31/5	7
	1995	2858	19/3-13/7	117	149	12/5	25
	1996	4645	10/4-5/7	86	279	28/5	51
	1997	6460	10/3-22/7	103	457	6/5	52
	1998	5787	24/3-29-7	97	417	15/5	37
Gerona	1996	18647	10/4-12/9	155	1772	24/5	52
	1997	11189	10/3-11/8	154	844	30/4	52
	1998	12791	30/3-3/8	126	769	23/5	52
Lérida	1996	3812	10/4-10/8	123	356	25/5	23
	1997	3819	9/3-31/5	84	533	27/4	21
	1998	6048	22/3-3/8	134	247	18/5	38
Tarragona	1996	3350	14/4-15/7	93	230	27/5	23
	1997	3447	13/3-26/6	104	228	27/4	20
	1998	5014	28/3-30/7	125	365	15/5	30
León	1994	462	29/4-19/6	52	84	6/5	1
	1995	385	30/4-24/6	56	33	6/5	0
	1996	2214	15/4-23/6	70	258	30/5	14
	1997	634	18/3-30/5	62	133	29/4	10
	1998	1514	30/3-30/6	55	404	4/6	32

TABLE 2. Characteristics of *Quercus* pollen season in the selected sites for the six years period (1993-1998).

PPP usually started in the second or third week of March, although, in some cases, this period was delayed even late April. The average duration of the PPP was about 80 days, and varied according to the annual climatological conditions at each site. The same table also shows the number of days on which more than 50 grains/m^3 were recorded; the average was approximately 20 days with more than 50 grains/ m^3, although this number varied depending from year to year.

An analysis of the data obtained reveals the inter-annual and inter-regional differences between the pollen season start and end dates at each site. The variations in pollen

Site	Year	PI	PPP	Range	Peak	Date of Peak	N>50
Madrid	1993	6973	16/4-9/7	85	523	16/4	38
	1994	2659	27/3-26/6	92	254	3/5	20
	1995	4531	1/4-6/8	126	372	18/4	26
	1996	4564	28/3-25/6	92	346	26/5	34
	1997	9778	10/3-5/6	89	630	17/4	36
	1998	16438	27/3-29/7	125	3091	26/4	68
Córdoba	1993	7962	21/3-20/6	92	1135	9/4	23
	1994	1953	23/3-12/5	51	207	10/4	11
	1995	5588	14/3-18/6	87	503	5/4	25
	1996	2544	22/3-14/7	115	480	17/4	14
	1997	19749	26/2-10/6	105	343	25/3	53
	1998	9196	1/3-28/6	120	576	24/3	47
Priego	1994	3675	16/3-19/5	65	311	1/4	22
	1995	6657	22/3-11/7	112	666	9/5	33
	1996	1174	1/4-9/6	70	116	14/4	4
	1997	15524	8/3-24/5	78	1262	21/3	38
	1998	3376	3/3-20/5	79	273	21/4	18
Jaén	1996	1247	4/4-16/6	74	148	17/4	5
	1997	8132	12/3-24/5	74	1567	25/3	31
	1998	4702	17/3-22/6	98	374	8/4	31
Granada	1993	3835	23/3-6/7	106	305	11/4	23
	1994	4270	12/3-4/7	115	380	10/4	22
	1995	2890	11/3-10/6	92	194	29/3	18
	1996	1950	22/3-16/6	87	360	25/3	9
	1997	3778	13/3-16/6	96	368	21/3	20
	1998	3865	21/3-6/7	108	247	8/4	26
Málaga	1993	3073	21/3-30/6	102	346	9/4	12
	1994	3216	16/3-20/6	98	261	7/4	19
	1995	3257	16/3-26/6	103	409	20/4	21
	1996	1663	25/3-27/6	95	225	17/4	5
	1997	8024	4/3-21/6	110	1578	25/3	26
	1998	4891	7/3-4/7	120	419	8/4	30
Estepona	1995	3617	27/3-16/7	112	242	19/3	21
	1996	1357	10/3-6/7	110	125	17/4	3
	1997	8133	13/3-6/7	116	1106	25/3	33

TABLE 2 (Cont.). Characteristics of *Quercus* pollen season in the selected sites for the six years period (1993-1998).

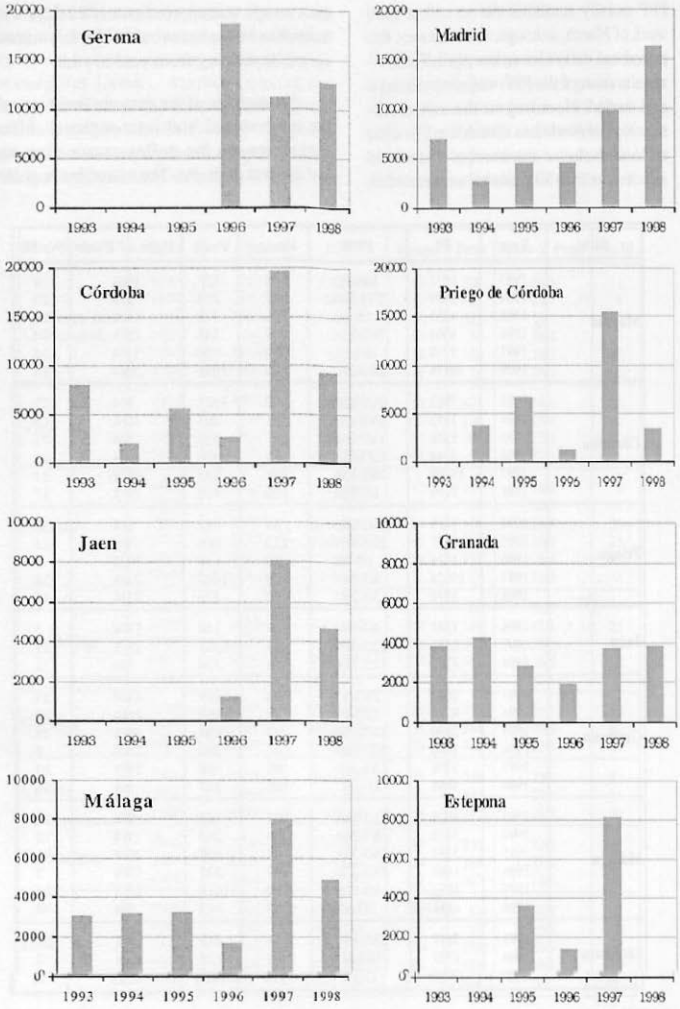

FIGURE 1. Pollen Index variation among the years.

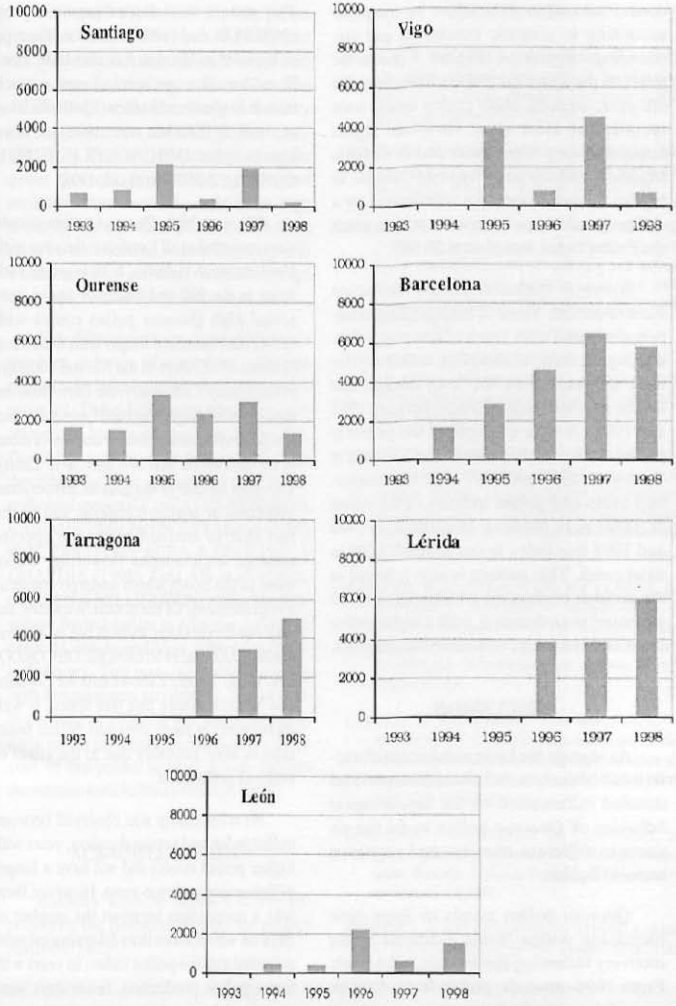

FIGURE 1 (Cont.). Pollen Index variation among the years.

concentrations can therefore be compared according to climatic conditions and surrounding vegetation. Figure 1 shows the trend of the *Quercus* Pollen Index over the six years studied. High pollen counts were recorded at most sites. However, higher concentrations were recorded in Gerona, Madrid, Córdoba and Priego de Córdoba. In Figure 1, these sites are represented by a different scale since there were years in which the Pollen Index was almost 20.000.

Biennial cycles of pollen production were observed. Years of high pollen production alternated with years of low production, although at some of sampling sites the cycles were interrupted by the long drought that hit the southern half of Spain between 1993 and 1995. A clear example of this pattern is evidenced by all the cities in the NW area; at these sites, 1995 and 1997 were high production years and pollen indexes in the region of 3,000 were reached. In contrast, in 1996 and 1998 this index failed to reach 1,000 in most cases. This pattern is also reflected in the number of days on which more than 50 grains/m^3 were detected, with a higher pollen index and more days with more than 50 grains.

DISCUSSION

As regards the large number and characteristics of the selected sites, these provided detailed information on the aerobiological behavior of *Quercus* pollen in the last six years in different climates and vegetation areas of Spain.

Quercus pollen trends in Spain show increasing pollen levels prompted by the recovery following the drought in the South. From 1996 onwards, pollen levels have increased dramatically. It is important to highlight the biennial cyclic pattern of *Quercus* pollen. This pattern was studied previously by EMBERLIN *et al.* (1990) in London. This type of biennial production has also been mentioned for other tree species, such as birch trees in England and Leiden (EMBERLIN *et al.*, 1993, SPIEKSMA *et al.*, 1995) and olive trees in Spain (DOMÍNGUEZ *et al.*, 1993, GONZÁLEZ-MINERO *et al.*, 1998).

Although high *Quercus* pollen counts were recorded at all locations, the sites with Mediterranean climates, both together with those in the NE and South of Spain, presented high *Quercus* pollen counts with earlier start dates and longer season duration (a mean of 123 days in the NE and 100 days in the South). Conversely, the Euro-Siberian regions of Santiago, Vigo and León presented low pollen counts and shorter seasons (a mean of 67 days in the first two and 59 in León). This may be due to the greater temperature variations at southern regions, and to the fact that in northen zones the species undergo simultaneous flowering, unlike those in the South which undergo consecutive pollination. Of the southern species, the cork oak flowers later, even as late as Autumn (CEBALLOS and FERNÁNDEZ DE CÓRDOBA, 1979). Figure 2 shows data for Córdoba and Málaga; where this tree specie is well represented at these sites and pollen peaks later in May, probably due to the effect of cork oak pollination.

No relationship was observed between pollen index and season duration; years with higher pollen counts did not have a longer pollen season and vice-versa. However, there was a connection between the number of days on which more than 50 grains/m^3 were recorded and the pollen index; in years with lower pollen production, fewer days were registered despite the season maintaining its normal duration.

As regards the definition of the pollen season or PPP, as described in the chapter on "Materials and methods", a new approach was adopted excluding a % method. The disadvantage of these methods is that they are dependent on the total pollen catch (EMBERLIN *et al.*, 1994). In the case of the genus *Quercus*, high pollen counts were recorded. Thus, even 1% would be too high to use for that start date. However, this taxon shows a well-defined season in spring with a sudden start. As a result, long ties are not often observed in the pollen curve.

Few differences were observed between the sites in terms of start dates, although significant inter-annual variations were recorded. These differences may have been influenced by the temperature in the pre-flowering months as it has already been described by other authors for most wind-pollinated species (GONZÁLEZ-MINERO & CANDAU (1998), FRENGUELLI *et al.* (1998), PEETERS (1998), ALBA & DÍAZ DE LA GUARDIA (1998), GALÁN *et al.* (1998), CORDEN & MILLINGTON (1998). The 1997 season started earlier in all areas, being the earliest Córdoba and Vigo, where this began in February. This was due to the unusually high temperatures recorded in that month. In contrast, in 1996 the low temperatures in early spring prompted a general delay in the start of the pollen season, which did not commence until halfway through April.

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