

Seasonal fluctuations of the airborne pollen spectrum in Murcia (SE Spain)

Some peculiarities in the pollen calendar

Manuel Munuera Giner¹, José Sebastián Carrión García² & Cristina Navarro Camacho²

¹Universidad Politécnica de Cartagena, Escuela Técnica Superior de Ingeniería Agronómica, Departamento de Producción Agraria, Área de Botánica. Paseo Alfonso XIII, E-30203 Cartagena (Murcia), España (E-mail: Manuel.Munuera@upct.es.); ² Universidad de Murcia, Facultad de Biología, Departamento de Biología Vegetal (Botánica), Campus de Espinardo, E-30100 Espinardo (Murcia), España

Received 17 June 2002; accepted in final form 17 June 2002

Key words: Brassicaceae, Caryophyllaceae, *Casuarina*, Chenopodiaceae, *Corylus*, Poaceae, pollen calendar, *Robinia*, SE Spain, Thymelaeaceae, winter pollen

Abstract

During six consecutive years (1993–1998), a Burkard volumetric pollen trap was continuously operated to sample pollen from the air of the city of Murcia. The aim of the study was to elucidate the spectra of airborne pollen and the variations during the year, and to elaborate a pollen calendar. This time span includes the end of the period with severe drought from 1990–1995, which particularly affected the south-eastern region of Spain.

The total sum of daily average pollen concentrations amounted to 148,645 pollen grains belonging to 93 different taxa. A daily average of 74 pollen grains/m³ and 11 taxa were recorded, with maxima of 1157 and 27 respectively. The total pollen amount registered in a year correlated with yearly rainfall, but there was no relation with mean annual temperature. As for annual fluctuations, there seemed to be no influence by total rainfall or temperature. Spring and winter were the seasons with the highest pollen counts and pollen diversity.

From the 93 identified taxa, 36 are included in the pollen calendar. Noteworthy findings are: (i) the presence of Thymelaeaceae, *Robinia*, *Betula*, *Castanea*, *Zygophyllum*, Caryophyllaceae and *Cannabis*, (ii) a long pollen season of Chenopodiaceae/Amaranthaceae, Urticaceae, Poaceae, Arecaceae and *Plantago*, (iii) the occurrence of summer, autumn and winter flowering of *Artemisia*, (iv) the late appearance of *Corylus* pollen, and (v) the minor presence of *Casuarina* pollen during the mid winter and late spring.

1. Introduction

The province of Murcia is situated in the south-east of the Iberian Peninsula (Figure 1). About 51% of the region is lower than 400 m above sea level, about 40% has an altitude between 400 and 1,000 m, and 9% is above 1,000 m. In the north-west area of the region high mountains of over 1,300 m in altitude work like a natural barrier to east winds and storms, which contributes to an increase in “Föhn” effect after the usually slight precipitations.

The regional climate is warm Mediterranean, with semi-arid rainfall regime (250–300 mm/year), average

relative humidity of 58%, and mean annual temperature of 16.8 °C; being above 18 °C in the sampler’s surrounding area. Summer is dry and hot, and winter is mild. Main rainfall occurs around spring and autumn equinoxes, showing great fluctuations between the years: presenting dramatic droughts and torrential rainfalls provoking floods. Winds are coming mainly from the east, especially during summer, although in winter north-western winds are dominant. Autumn is very irregular in relation to main and mean wind direction.

Murcia is an eminently agricultural region. In both dry and irrigated lands, a great variety of crops grow



Figure 1. Location map, showing main Murcian cities and sampling site, and location of other Spanish cities where comparisons are made: León (L), Palencia (PA), Lleida (LI), Cáceres (CA), Badajoz (Ba), Huelva (H), Sevilla (Se), Córdoba (Co), Málaga (Ma), Granada (G) and Almería (Al).

throughout the year because of the particular climate. In the natural vegetation, woodland and brushwood zones can be distinguished. The former basically coincide with mountainous areas and are dominated by *Pinus halepensis*, and frequently includes evergreen oaks as undergrowth or as small woods. Most of the forested and brushwood areas present *Brachypodium* covering the floor. Bushy grounds are heterogeneous and widespread as rosemary (*Rosmarinus officinalis*), thyme (*Thymus* sp. pl.), esparto (*Stipa tenacissima*) and *Anthyllis cytisoides* communities, which include several species of Poaceae, *Cistus*, *Helianthemum*, *Fumana*, *Sideritis*, *Thymus*, and *Teucrium*, among others. Those communities dominated by *Lygeum spartum* include *Salsola genistoides* and *Limonium* sp. pl. In uncultivated lands, there are very frequent nitrophilous communities rich in Chenopodiaceae, Poaceae, Brassicaceae, *Artemisia* and other Asteraceae, *Parietaria*, and other herbs. Together with Chenopodiaceae and *Lygeum spartum*, *Artemisia* even extends to salty soils.

Within a radius of 15 km around the sampling site, situated 4 km outside the centre of Murcia, the capital city, about 50 towns and villages, belonging to 7 different municipalities, are found having a total population of close to 400,000. Approximately 20%

of this population suffer from pollinosis at some time during the year, but no studies of airborne pollen in Murcia have been done before. Some partial results have been reported previously (Munuera et al., 1995, 1998a, 1998b, 1999; Munuera and Carrión, 1995). Here we present a first pollen calendar, based on a 6-year study, establishing start, severity and length of the pollen season for the main taxa present in Murcia atmosphere, and confirming the particularly long "pollinic spring" lasting most of the year.

2. Material and methods

From 1 March 1993 to 31 December 1998 a Burkard volumetric seven-day recording pollen trap located at about 19 m above ground street level was operated on the exposed flat roof of the Veterinary Faculty (Murcia University, 110 m a.s.l., 38° 01' N, 01° 10' W, 4 km NW of Murcia city centre). There were no higher buildings in the immediate vicinity of this faculty building. From weekly tapes, daily slides were prepared following the standard methods accepted by the Spanish Aerobiology Network (REA, Red Española de Aerobiología; Domínguez et al., 1991), and subsequently examined by light microscopy.

Daily pollen concentrations are expressed as number of pollen grains per cubic metre of air during 24 hours. Main characteristics of pollen records in Murcia are shown in Table 1 and Table 2. Attending to regional flora, pollen Urticaceae, Cupressaceae, Thymelaeaceae and Arecaceae must originate mostly from *Parietaria*, *Cupressus*, *Thymelaea* and *Phoenix* respectively. Detailed information about pollen taxon identification criteria can be found in Munuera (1999).

Main pollen seasons have been established as proposed by Nilsson and Persson (1981), that is the period from which the sum of daily means concentrations reaches 5% of the total sum until the time when the sum reaches 95%. The same has been done for "all-taxa" pollen season, defined by considering all pollen grains as coming from a single taxon. For seasonal studies the astronomical criterion has been adopted. So, spring lasts from 21 March to 20 June, summer from 21 June to 20 September, autumn from 21 September to 20 December, and winter from 21 December to 20 March. All calculations were made by using SPSS 9.0.1 (SPSS Inc., 1989–1999, Chicago), graphs were made by using Excel 97 (Microsoft Corporation, 1985–1997), and the pollen calendar was made by using Tilia 1.12 and Tilia Graph 1.18 (Eric C.

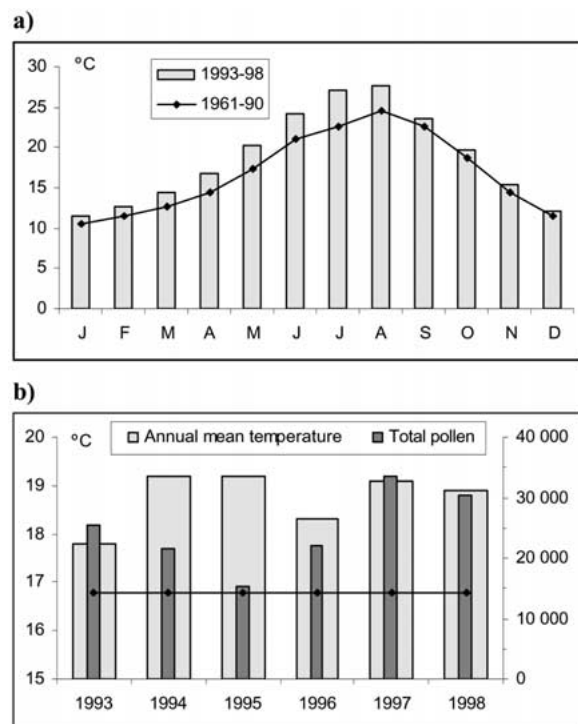


Figure 2. Mean air temperature at Murcia. a) Average monthly temperatures. b) Average year temperatures and annual sums of daily pollen concentrations. Horizontal line indicates annual average of the mean temperature for 1961-1990.

Grimm, 1991-1992, Springfield) and CorelDRAW 8.0 (Corel Corporation, 1997).

3. Results and discussion

3.1 Meteorology

The first half of the observation period was during the severe drought (low precipitation and high temperatures) in Spain during 1990-1995. This period was comparatively much warmer and drier than the average observed in 1961-1990 (Figure 2 and Figure 3). Consequently, water availability was extremely low, and presumably affecting plant phenology and pollen production and release. Attending to the National Institute of Meteorology criteria, the years 1998, 1994 and 1995 were very dry, with less than 85% of the average rainfall registered in the period from 1961 to 1990. The years 1994, 1995, 1997 and 1998 were very hot, that is more than 110% of the mean temperature from 1961 to 1990.

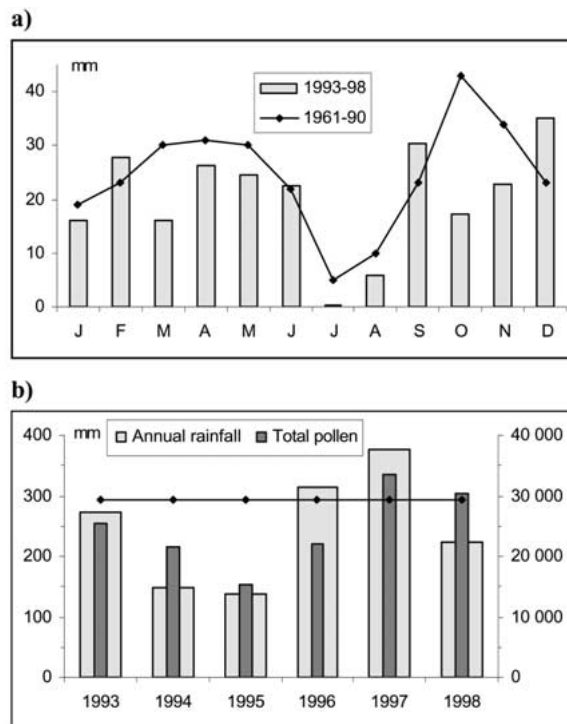


Figure 3. Mean precipitation rates and pollen concentrations. a) Average monthly amount of rain. b) Annual amounts of rain and annual sums of daily pollen concentrations. Horizontal line indicates average of annual rainfall for 1961-1990.

3.2 Pollen concentrations

During 1993-1998, pollen grains were observed every day in the samples from the atmosphere of Murcia (Figure 4) and a total of 283,181 pollen grains were counted, resulting in a total sum of daily average concentrations of 148,645. The highest overall pollen amounts occurred at the beginning of the "all-taxa" pollen season, which extended on average for 268 days from early February to early November (Table 1). From mid February to mid June, two major pollen periods were observed every year (Figure 4), separated by a significant drop in daily concentrations in about April, most clearly observed in the years 1993, 1994 and 1997, but less significant in the other years. Dates and amounts of maxima varied notably from year to year (Table 1), but as a mean they occurred in 26 March (552 grains/m³) and 23 May (625 grains/m³). A maximum of 1,157 grains/m³ was reached by 5 May 1997.

The annual daily average of pollen concentration varied from 47 in 1995 to 97 grains/m³ in 1997, with an overall mean of 74 grains/m³ day (Figure 5a).

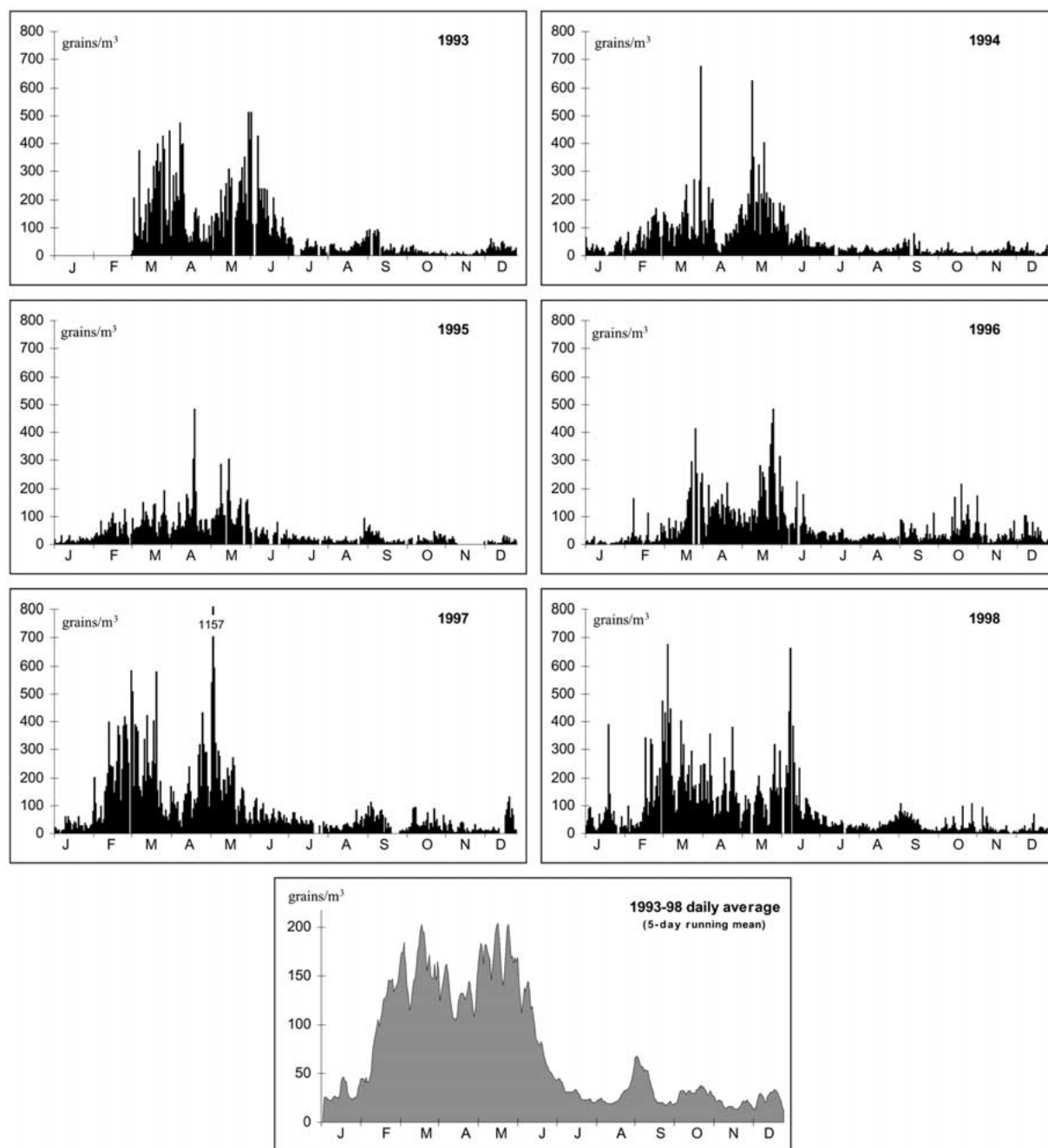


Figure 4. Daily variation of total pollen recorded in Murcia (Spain) from 1 March 1993 to 31 December 1998.

Table 1. Main characteristics of total pollen records (DFS = Days from start; * With regard to total pollen recorded during 1993–1998; For the “all taxa” pollen season means, 1993 data have been not taken into account because records started on 1 March)

	“All-taxa” pollen season				1st peak day			2nd peak day			Annual	
	Start	End	Days	grains/m ³	Date	DFS	grains/m ³	Date	DFS	grains/m ³	grains/m ³	%*
1993	< 13-mar	14-oct	> 215	> 22 952	9-apr	27	473	4-jun	83	514	> 25 431	17.12
1994	9-feb	7-nov	272	19 563	1-apr	52	676	11-may	92	625	21 677	14.58
1995	8-feb	26-oct	261	13 849	20-apr	72	483	18-may	100	307	15 330	10.31
1996	1-mar	1-dec	275	19 965	27-mar	26	416	28-may	88	484	22 136	14.89
1997	10-feb	27-oct	260	30 332	1-mar	20	584	5-may	85	1157	33 567	22.58
1998	22-jan	19-oct	271	27 522	6-mar	44	679	11-jun	141	664	30 504	20.52
Mean	9-feb	3-nov	268	22 246	26-mar	40	552	23-may	98	625	24 643	–

These variations closely resemble the pattern of the annual rainfall, as can be shown in Figure 3b. By seasons, daily pollen concentrations were highest in spring, with an average of 149 grains/m³ (Figure 5b). It is noticeable that winter showed a mean daily pollen concentration of 81 grains/m³, which is twice as much as in summer (38 grains/m³), and becomes four times as high as in autumn (24 grains/m³). Concerning the monthly variation, March and May showed the highest daily average concentration, with values above 160 pollen grains/m³ (Figure 5c).

3.3 Variation in the number of pollen taxa

A total of 93 different pollen taxa were identified between March 1993 and December 1998, from which 89 were angiosperms and 3 were gymnosperms. Indeterminatae represented about 2.4% of the total. For the interannual variation, a minimum of 65 taxa in 1996 and a maximum of 82 in 1993 (with a mean of 71 taxa per year) were registered (Figure 5a).

The seasonal variation in the number of pollen taxa correlates well with the seasonal average of daily concentration (Figure 5b), and shows a maximum of 71 and a minimum of 55 taxa during spring.

Also monthly, there is correspondence between daily mean concentration and number of taxa; except for April, when the highest diversity (up to 50 taxa) is associated with a remarkable decline in the pollen concentration (Figure 5c). This phenomenon occurs just during the transition from winter-flowering taxa to spring-flowering taxa, i.e., in April, when pollen of winter-flowering taxa are still present in the air (but with decreasing pollen quantities), and simultaneously the pollen of spring-flowering taxa are beginning to appear (with still low, but increasing pollen quantities).

3.4 Pollen calendar

The climate in Murcia allows many plants to grow, flower, produce and release pollen grains into the atmosphere at any time of the year. To show this particular situation graphically, a pollen calendar (Figure 5) has been constructed presenting 36 of the main taxa. Usually, pollen calendars show the sum of 10-day periods pollen counts averaged over the years under consideration and subsequently placed in exponential classes (Stix and Ferretti, 1974), making both low and high concentrations visible. Unlike these authors, in Figure 6 we show 10-day average pollen concentrations instead of 10-day pollen sums. In this way maxima are diminished but, in return, trivial presences are avoided, and “artificially” long pollen seasons are not presented, doing values more representatives of actual airborne pollen concentrations in an area where many plants are flowering and releasing low quantities of pollen for long periods “outside the main pollen season”.

In the Murcia pollen calendar, the timing of airborne pollen of most taxa is simultaneous with that found in other European regions and reaches similar levels. On the other hand, there are a number of regional peculiarities, such as the presence of taxa rarely found or totally absent in other localities, and extraordinary long pollen periods. From pollen taxa included in the pollen calendar (Figure 6) only those which show more originalities or peculiarities with respect to other Spanish and European calendars are commented upon hereafter. These comments are done in order of seasonal appearance, with special attention to comparison with reported pollen records from other Spanish pollen monitoring stations.

Thymelaeaceae pollen (type including mainly *Thymelaea* pollen grains) occurs in Murcia throughout

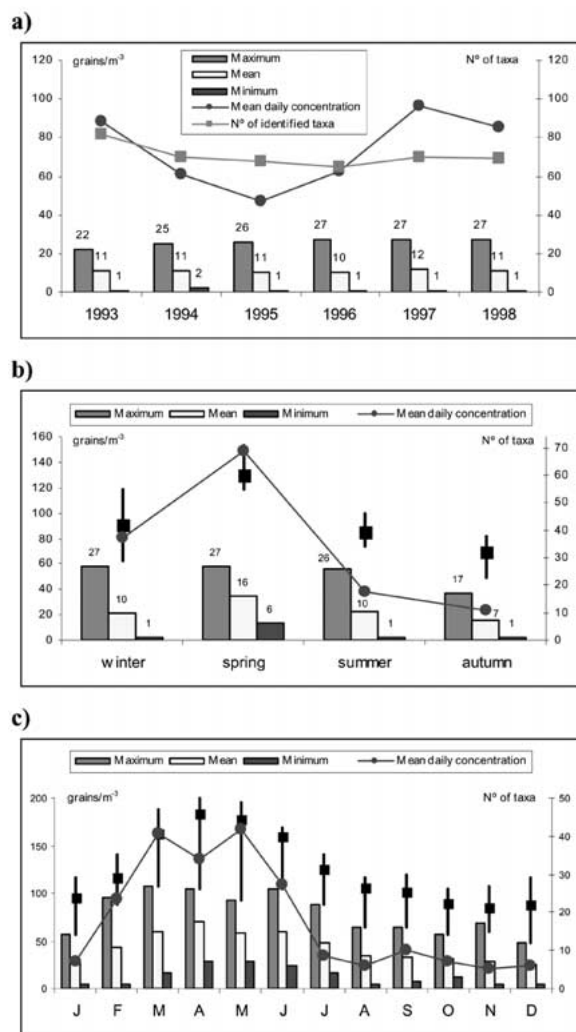


Figure 5. Annual (a), seasonal (b) and monthly (c) variations in pollen concentration and diversity. Columns are always daily number of taxa. Vertical lines show maximum, average and minimum of the seasonal (b), and monthly (c) number of taxa.

the year, with concentrations high enough to be included in the calendar only in winter. Thymelaeaceae pollen has only been recorded, but at lower levels, in the near city of Cartagena (SE Spain; Moreno-Grau et al., 1998) and León (NW Spain; Fernández-González and Valencia-Barrera, 1995).

Chenopodiaceae/Amaranthaceae represent in Murcia about 12% of the total pollen recorded in a year (Table 2). This type include mostly Chenopodiaceae, and approximately 49.5% of pollen-allergic people in the region are sensitised to their pollen grains (García-Sellés and Munuera, 1996), which is 5–6 times higher than in other Spanish

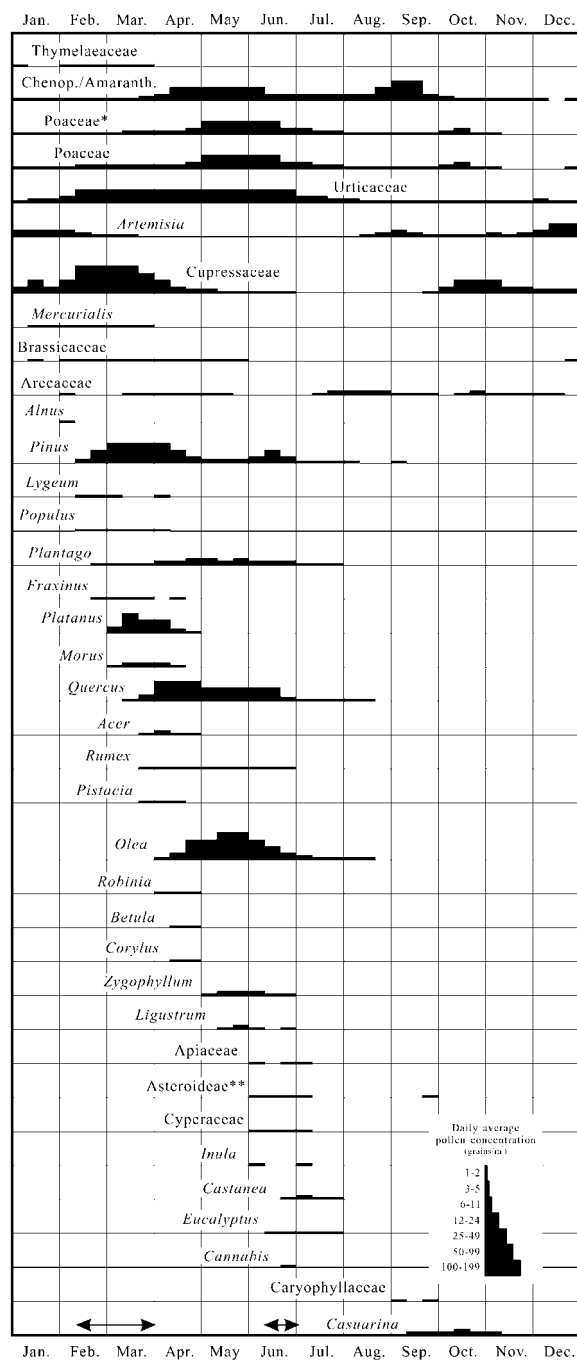


Figure 6. Pollen calendar for Murcia city. *Excludes *Lygeum*. **Excludes *Artemisia*. Arrows in *Casuarina* graphs show original pollination periods, during which pollen concentrations are not high enough to be plotted by using the proposed 10-day average pollen concentration method instead of the 10-day sum as proposed by Stix & Ferretti (1974).

Table 2. Main characteristics of main taxa pollen records. Data corresponds to the 1993–1998 mean (DFS = Days from start; * Mean value with regards to the total pollen recorded during 1993–1998)

	Pollen season				1st peak day			2nd peak day			Annual	
	Start	End	Days	grains/m ³	Date	DFS	grains/m ³	Date	DFS	grains/m ³	grains/m ³	%*
<i>Artemisia</i>	3-sep	17-feb	167	> 917	5-sep	2	21	18-dec	106	47	> 1015	4.04
<i>Chenop.</i>	26-mar	28-sep	186	> 2547	2-may	37	51	7-sep	165	72	> 2820	11.75
<i>Cupress.</i>	7-nov	12-apr	157	> 4086	24-nov	17	55	8-mar	121	268	> 4503	18.84
<i>Pinus</i>	27-feb	14-jun	108	2156	19-mar	21	174	2-jun	96	63	2368	9.66
<i>Poaceae</i>	3-mar	14-oct	225	1363	21-may	74	72	10-oct	221	23	1555	6.11

	Pollen season				Peak day			Annual	
	Start	End	Days	grains/m ³	Date	DFS	grains/m ³	grains/m ³	%*
<i>Brassicaceae</i>	1-nov	25-may	208	> 181	25-feb	115	9	> 203	0.71
<i>Olea</i>	28-apr	17-jun	50	2419	19-may	21	363	2656	11.07
<i>Urticaceae</i>	16-dec	10-jul	206	> 2662	1-apr	107	67	> 2992	12.22
<i>Plantago</i>	21-mar	14-jul	114	462	27-apr	37	32	514	2.03
<i>Platanus</i>	13-mar	11-apr	29	755	21-mar	8	99	833	3.14
<i>Quercus</i>	3-apr	17-jun	75	1918	14-apr	11	279	2099	9.03
<i>Zygophyllum</i>	6-may	14-jul	70	149	24-may	18	11	165	0.65

localities: 10.2% in Málaga (García González, 1994), 8.4% in Córdoba (Galán et al., 1989). Chenopods flower all year round and have an extraordinarily long pollen season with two main periods, and maximum concentrations during September, occurring in Europe only in other south-eastern Spanish cities, such as Almería (Ruíz-García et al., 1998), Cartagena (Moreno-Grau et al., 1998) and Málaga (Recio et al., 1998b). Nevertheless, Murcia records are higher.

Airborne pollen of grasses (*Poaceae*), which affect 55% of the Murcian pollen-allergic population (García-Sellés and Munuera 1996), has a very long presence (Table 2), with a pattern similar to other European mediterranean cities (Spiekma et al., 1989; Spiekma 1991) with the highest quantities in May and June. There is a second minor peak in October, which was first reported in 1995 (Munuera et al., 1995) and to our knowledge did not occur previously. In Lleida (NE Spain), a similar peak has been recently reported for September (Fernández-González et al., 1999).

Parietaria is the more abundant *Urticaceae* in Murcia region. Its pollen affects 41% of the allergics in Murcia (García-Sellés and Munuera, 1996). Together with *Urtica* pollen (*Urticaceae* type), it represents more than 12% of the average annual total and is the most abundant airborne pollen in Murcia after *Cupressaceae* (Table 2). *Urticaceae* pollen has a very long

season, with maxima between February and June. Its pattern is similar to that in Málaga (Trigo et al., 1997), Granada (Alba, 1997) and Cartagena (Moreno-Grau et al., 1998).

Artemisia affects 23.5% of the pollen-allergic population in Murcia (García-Sellés and Munuera, 1996). There is a typical summer appearance (Spiekma, 1991), in Murcia related to *A. campestris* (Munuera et al., 1998a, 1999). In addition, there is also a small autumn peak related to *A. herba-alba* (Munuera et al., 1995, 1998a), and a main winter period corresponding to the flowering of *A. barrelieri* (Munuera et al., 1998a, 1999). In other south-eastern Spanish cities, such as Almería (Ruíz García et al., 1998), Granada (Alba, 1997) and Cartagena (Moreno-Grau et al., 1998), winter flowering of *Artemisia* has been also reported, although showing considerably lower concentrations than in Murcia.

Cupressaceae (pollen type including mostly *Cupressus*) is the most abundant pollen source in Murcia (> 19% of the annual pollen total; Table 2), occurring almost every day from late September to early July. The main pollen period extends from February to April and is related to *C. sempervirens* and native *Juniperus* species, which flower from mid January. There is an autumn peak possibly due to *Cupressus arizonica*.

Brassicaceae is a taxon seldom referred in to pollen calendars and, when present in other Spanish cities, is only for periods no longer than one month. In the region of Murcia, this family includes 52 genera and 95 species with different phenologies. Some of them are widespread and flower continuously throughout the year. As a consequence, Brassicaceae pollen is present in the Murcia atmosphere continuously from the later part of December to the later part of May, similar to the situation described in Spain for Palencia (Herrero and Fraile, 1997) and Sevilla (González-Minero et al., 1998).

Although less important, and for shorter periods, Arecaceae pollen is recorded in other Spanish cities such as Málaga (Toro et al., 1996; Recio et al., 1998a), Barcelona (Belmonte et al., 1998) and Huelva (González-Minero and Candau, 1994). Different Arecaceae species are probably involved in Murcia, but we suspect these are mainly *Phoenix canariensis* and *Ph. dactilifera*, which flower repeatedly after cutting of inflorescences to favour growth of palm trees cultivated on the University Campus where the sampler is situated.

Lygeum belongs to the Poaceae, and its pollen grains can be easily distinguished from other grasses because of its size (equatorial diameter: 50–70 μm), form (elliptic) and pore position (lateral). To our knowledge, this pollen type has been not reported before. Allergologically *Lygeum* must not be relevant on its own because of its coincidence in flowering time, and because of the high cross-reactivity between Poaceae species.

As in other Spanish and Mediterranean sites (Roses-Codinachs et al., 1992; Ruíz García et al., 1998; Spieksma 1991), pollen of *Pinus* peaks in Murcia twice a year. Maxima occur earlier than in other countries but simultaneously with other Spanish calendars. We have no information on species involved in other places, but in Murcia, the main pollen period occurring in March–April corresponds to the flowering of *P. halepensis* and *P. canariensis*, whereas *P. pinea* and *P. pinaster* flower in May–June.

Plantago pollen affects 18% of the pollen-allergic population in Murcia region (García-Sellés and Munuera, 1996) and can reach maximum concentrations of 47 grains/ m^3 as a daily average over its season. The pollination period is long (Table 2) as a consequence of the high number of species included (13, of which 6 widespread). Such a long season is also found in many places throughout Europe (Spieksma, 1991; Gutiérrez et al., 1999).

Table 3. *Corylus*' last month and year of occurrence in the atmosphere of several Andalusian localities

	April	May	June
Almería			1998 ¹
El Cabril			1998 ²
Chirivel		1995 ³	1996 ³
Córdoba	1995 ⁴	1996 ⁴	
	1997 ⁵	1998 ⁶	
Huelva	1998 ⁷		
Priego	1995 ⁸		
	1997 ⁹		
Sevilla	1995 ¹⁰		

¹Sabariego et al., 1999; ²García et al., 1999; ³Cariñanos et al., 1998; ⁴Galán et al., 1998a; ⁵Galán et al., 1998b; ⁶Cariñanos et al., 1999; ⁷González-Minero et al., 1999; ⁸Alcázar et al., 1998a; ⁹Alcázar et al., 1998b; ¹⁰Candau et al., 1998.

Robinia is an entomophilous taxon which, under certain conditions, can also release pollen into the atmosphere (Faegri and van der Pijl, 1966; Proctor and Yeo, 1979). Nevertheless, it is very rare in pollen calendars, being referred for the first time as airborne in Palestine by Gutmann (1950). To our knowledge, in Europe it has been reported only from Vienna (Jäger, 1989), Murcia (Munuera et al., 1995) and Cartagena (Moreno-Grau et al., 1995a). In the last study, *Robinia* pollen grains reported for July might correspond to *Quercus*, whose pollen looks quite similar to *Robinia* pollen when observed in light microscopy at 400x (and even at 1000x), the usual magnification in aerobiological counts in España. Also, it should be taken into account that *Robinia* trees flower for only a short time (no more than a month) from the end of March.

Betula and *Castanea* trees are not present in an area of 200–250 km around the city of Murcia. In a year-to-year comparison, great differences can be found in *Betula* pollen amounts, but not in the time of occurrence, suggesting long-range transport instead of resuspension of "old pollen". Long-range transport of pollen of these two taxa has been described by Hjelmroos (1991), Mandrioli et al. (1977), Peeters and Zoller (1988) and Comtois (1997). Both *Betula* and *Castanea* pollen appear in Murcia simultaneously to their occurrences elsewhere in Europe (Spieksma, 1991), in late April and late June and July respectively.

Corylus pollen appears continuously from late December to early May, with concentrations high enough to be present in the pollen calendar only in April. This relatively late presence is noticeable because of its delay compared to other southern Spanish cities such as Granada (Alba, 1997), Córdoba

(Domínguez et al., 1984) and Cáceres (Tavira et al., 1998), and because of its coincidence with Corylaceae patterns described for other European countries (Spiexma, 1991). Such late occurrences, but at much lower counts, have been also reported in several localities of Andalucía (Table 3). Detailed studies on phenology of *Corylus avellana* in Murcia region should be done before explaining the original presence of its pollen in Murcia atmosphere as a consequence of resuspension and long-range transport.

The presence of *Zygophyllum* pollen, amounting to 0.62% of the total airborne pollen in Murcia, is interesting because it had been previously reported only in the near city of Cartagena (Moreno-Grau et al., 1995b, 1998). Unidentified Zygophyllaceae were reported previously in Kuwait (Halwagy, 1988).

Cannabis pollen occurs mainly in Murcia during June, but scant quantities can be found from April to August. Some pollen could originate from North Africa, as demonstrated in other Mediterranean localities as Málaga (Cabezudo et al., 1997). Another possibility is that its origin lies in locally naturalised plants growing in dumps and wastelands and even illegal planting for the “production” of marihuana.

Caryophyllaceae is a rare airborne taxon. It occurs in Murcia from April to November, but mainly in September. The airborne pollen concentration is low, with daily maxima of 8 grains/m³, and representing 0.15% of the annual amount of pollen. Caryophyllaceae pollen has been reported as airborne in Italy (Frenguelli and Mandrioli, 1990) and Badajoz (Silva et al., 1994), but in lower quantities that represent solely the 0.004% and 0.05% of total pollen amount.

Casuarina has its main pollen season in early autumn. This airborne pollen presence is related to the flowering of *C. cunninghamiana*, which is simultaneous with other Spanish sites (Trigo et al., 1997; Trigo et al., 1999). A minor flowering period, not high enough to be included in pollen calendar as 10-day bars when using the proposed variation of Stix & Ferretti method, occurs from mid winter to spring (Feb.–Apr.) because of the flowering of *C. cunninghamiana* (mainly in autumn), and because of the flowering of the scarce *C. equisetifolia* trees present in Murcia. This mid winter to spring presence has not been reported previously in Spain, but it was described and related to the same species, albeit in higher quantities, in Florida (Bucholtz et al., 1991) and Buenos Aires (Majas and Romero, 1992). In June 2001, a third minor flowering period has been detected for *C. cunninghamiana*, mainly affecting male trees.

4. Conclusions

- Murcia is an area with a special airborne community because of a favourable climate, which allows many species to flower also in winter leading to long pollination periods.
- A mean annual sum of daily pollen concentrations of about 25,000 is recorded in the atmosphere of the regions of Murcia, with a mean daily concentration of 74 grains/m³, which can be 149 during the spring and more than 600 in peak days (exceptionally more than 1,000).
- The total number of pollen taxa found in the Murcia atmosphere amount to 93.
- During spring, up to 71 different pollen types can be found in Murcia, with a daily maximum of 27 and a daily average of 11.
- After spring, winter is the season with highest diversity and pollen concentrations.
- From year to year, diversity hardly varies, with a mean of 71 different taxa.
- Because of the change from late-winter to spring-flowering taxa, a dip in concentrations and a peak in diversity occurs simultaneously in April.
- Annual pollen records seem to be highly dependant on total precipitation, and affected by severe drought.
- Noteworthy findings are:
 - The presence of pollen from Thymelaeaceae, *Robinia*, *Betula*, *Castanea*, *Zygophyllum*, Caryophyllaceae and *Cannabis*;
 - The constant presence of Chenopodiaceae/ Amaranthaceae (peaking twice and reaching maxima in September) and Urticaceae (with maxima between February and June);
 - Poaceae shows an additional pollen season in October, which has not been mentioned before;
 - Brassicaceae pollen presence lasts more than five months;
 - Arecaceae and *Plantago* pollen show relatively long presence;
 - The winter presence of *Artemisia* pollen, corresponds to the flowering of *A. barrelieri*, and occurs exclusively in SE Spain. It follows from summer flowering of *A. campestris* and autumn flowering of *A. herba-alba*;
 - The autumn presence of Cupressaceae pollen corresponds to the flowering of *C. arizonica*;
 - The late occurrence of *Corylus* pollen peaks;

- The presence of *Casuarina* pollen not only in autumn but also from mid winter to spring and in late spring.

Acknowledgements

Authors are especially grateful to Dr. F. Th. M. Spijksma for reviewing the first and second draft of the manuscript and for providing helpful corrections, comments and suggestions which have clearly improved the text. Authors also thank *Fundación Séneca (Comunidad Autónoma de Murcia)* and *FEDER* for financial support throughout projects PLP/3/FS/97 and 1FD97-0898 respectively. Manuel Munuera Giner thanks *Fundación Séneca* for a grant to study airborne pollen in the city of Murcia (00266/CV/97).

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