Zeitschrift: Botanica Helvetica
Herausgeber: Schweizerische Botanische Gesellschaft
Band: 107 (1997)
Heft: 2

Artikel: Study on pollen content in the air of Seville (SW Spain) : the pollen spectrum and its relation with vegetation and anthropogenic activity

Autor: González Minero, Francisco José / Candau Fdez.-Mensaque, Pilar

DOI: https://doi.org/10.5169/seals-72646

Bot Helv 107 (1997): 221–237
0253-1453/97/020221-17 $ 1.50+0.20/0

Botanica Helvetica

Study on pollen content in the air of Seville (SW Spain): The pollen spectrum and its relation with vegetation and anthropogenic activity

Francisco José González Minero and Pilar Candau Fdez.-Mensaque

Dpto. Biología Vegetal y Ecología (Botánica). Facultad de Farmacia. 874. E-41012 Sevilla (Spain).
E-mail: Candau@fafar.us.es

Manuscript accepted May 15, 1997

Abstract

González Minero F. J., and Candau Fdez.-Mensaque P. 1997. Study on pollen content in the air of Seville (SW Spain): The pollen spectrum and its relation with vegetation and anthropogenic activity. Bot. Helv. 107: 221–227.

We present a study on pollen content in the air of Seville. It has been carried out during eight consecutive years using a Cour trap. Pollen from trees is dominant over that from herbaceous and shrub origin in the pollen spectrum of the city. Fifty-nine different types (with a representation higher than 0.01% in the total pollen collected) have been identified, belonging to 48 different plant families. The most abundant types are *Quercus*, *Olea europaea*, Cupressaceae, *Platanus hispanica*, Poaceae, Urticaceae, Myrtaceae and Pinaceae.

The collection of the greatest part of the pollen was between February and August, with maxima in May. The pollen spectrum can be divided into twelve groups of taxa characterised by a similar pollen curve, that is, one appearing at the same time of the year, and their weekly concentrations within a determined range. These groups have been established from a cluster analysis of the pollen spectrum. Its composition reflects the vegetation: the Mediterranean forest (*Quercus*), the ornamental flora of the city (*Platanus hispanica* and Cupressaceae), crops (*Olea europaea*), introduced forest areas (Pinaceae and Myrtaceae) and the nitrophilous weeds (Poaceae, Urticaceae, *Plantago*, *Rumex*, Asteroideae, etc.) are very well represented. There are also small amounts of pollen coming from communities of riverside plants (*Fraxinus*, *Ulmus*, Salicaceae), wetland vegetation (Typhaceae, Cyperaceae) and also from the regional and interregional vegetation (*Castanea sativa* and *Betula*). Finally, human activities are also registered in the spectrum, as with the harvest of sunflowers (*Helianthus annus*), olives (*Olea europaea*), grapes (*Vitis vinifera*) and opium (*Papaver somniferum*).

Key words: Palynology, pollen spectrum, Seville, vegetation.

Introduction

The city of Seville is located in the Guadalquivir basin (37°23′N and 5°58′W). The city has a population of over a million inhabitants, and is one of the most populated in Spain. The altitude of the city ranges between 0 and 28 m above sea level. The Guadalquivir basin is an extensive plain with an average altitude not exceeding 200 metres in 60% of its area.

The city has a Mediterranean climate characterised by mild winters and prolonged hot summers. The mean annual temperature is 18.1 °C, the mean of the annual maximum temperature is 24 °C and the mean of the minima is 11 °C. The hottest months are July and August and the coldest are December and January. The mean annual rainfall is 606.2 mm, irregularly distributed throughout the year (Rivas Martinez 1987) and year-to-year, with recurrent droughts periods when annual rainfall is lower than the mean values. The mean annual shinshine is 2877 hours.

The vegetation of the area potentially affecting the pollen spectrum is made up of the following groups: ornamental flora of the city, nitrophilous weeds, crop areas, introduced forest, wetland vegetation, communities of riverside plants and native forest.

The ornamental flora of Seville comprises approximately 800 different species, coming from the five continents and belonging to 47 different families. They are distributed in four large green areas and eighteen small gardens (1,374,644 m^2) (Elías Bonells 1983; Andrés Camacho 1991). The best-represented families are Pinaceae, Cupressaceae, Moraceae, Ulmaceae, Salicaceae, Platanaceae, Leguminosae, Myrtaceae, Euphorbiaceae, Anacardiaceae, Rutaceae, Solanaceae, Oleaceae, Caprifoliaceae, Asteraceae, Liliaceae, and Palmae.

The nitrophilous weed communities comprise nitrophilous species present in building sites, dumps, and near houses and walls: *Amaranthus*, Boraginaceae (*Anchusa*, *Borago*, *Echium*), *Chenopodium*, Compositae (*Calendula*, *Carduus*, *Chamaemelum*, *Senecio*, *Sonchus*), Cruciferae (*Capsella*, *Diplotaxis*, *Raphanus*), *Ecballium*, Euphorbiaceae (*Euphorbia*, *Mercurialis*), Leguminosae (*Latyrus*, *Medicago*, *Vicia*), *Galium*, *Plantago*, Poaceae (*Avena*, *Bromus*, *Poa*), Polygonaceae (*Polygonum*, *Rumex*), Umbelliferae (*Amni*, *Daucus*) and Urticaceae (*Parietaria* and *Urtica*).

The crop areas (64% of the land), have substituted the native forests in areas where the soil richness has made them potentially more profitable. For this reason, large areas of perennial crops (*Olea europaea*, *Citrus*, *Prunus*) and annual herbaceous crops (*Avena*, *Triticum*, *Helianthus annus*, *Brassica oleraceae*, *Papaver somniferum*, *Beta vulgaris*, *Zea mays*, *Gossypium*, *Oryza sativa*) are found. Weeds are also present with these crops: *Amaranthus*, *Euphorbia*, *Heliotropium*, Poaceae (*Echinochloa*, *Eragrostis*, *Paspalum*) and *Solanum*.

The introduced forest areas constitute 6% of the land, located mainly to the north of the city where one can find chestnut (*Castanea sativa*), pine (*Pinus pinaster*) and eucalyptus (*Eucalyptus globulus* and *E. camaldulensis*) trees; the latter have spread extensively in the province.

The riverside areas were originally constituted by *Fraxinus*, *Ulmus minor*, *Populus*, *Corylus avellana* and *Salix*. These areas are very deteriorated and have been substituted by *Eucalyptus* and by crop areas. At the sides of the streams appear herbaceous representatives (*Scirpus*, *Carex*, *Cyperus*, Poaceae, *Ranunculus*) and elements from the wetland vegetation (Typhaceae, *Phragmites*); the latter appear at the sides of slow water floods.

In the south of the province there are marsh zones where elements from the halophyte vegetation are present (Chenopodiaceae, Poaceae, Polygonaceae).

The holm oak (*Quercus rotundifolia*) would have occupied a large area if it had not been substituted by agricultural or forest sites, or transformed for exploitation as pastures (Poaceae, Compositae, Leguminosae, etc.) for cattle or as acorns. Quite frequently the pastures have been abandoned and shrubs have colonised them: Cistaceae, *Daphne gnidium*, *Genista hirsuta*, *Lavandula stoechas*, *Teucrium fruticans*, *Thymus mastichina*, *Astragalus lusitanicus*, *Rhamnus alaternus*, *Myrtus communis*, *Pistacia lentiscus*, *Quercus coccifera*, *Olea europaea* var. *sylvestris*.

The cork oak (*Quercus suber*) appears on those siliceous soils where annual rainfall exceeds 600 nm. It exists in a good state of conservation at numerous sites in the north of the province, where it can coexist with or be substituted by pine and eucalyptus trees, shrubs (*Phyllirea angustifolia*, *Viburnum tinus*, *Halimium*, *Arbutus unedo*, *Calluna vulgaris* and *Erica arborea*) and oaks (*Quercus pyrenaica* and *Quercus faginea*). Cork oaks can also be found as small islands on sandy soils bordering the Guadalquivir marshes in the south of the province.

We present the results of a study on the airborne pollen content of Seville, including a list of the most quantitatively significant types. The pollen spectrum of the city is determined out and conclusions are drawn on how the pollen spectrum reflects the vegetation and human activities. These results can be considered as a further element of other partial works previously published by the authors (Candau and González Minero 1992, Gonzalez Romano 1992, 1993).

Materials and methods

The aeropalynological sampling was carried out during eight consecutive years (1987–1994) with a Cour trap located at a height of 20 metres on the flat roof of the School of Pharmacy of Seville University. The methodology used in the processing and later microscopical analysis of the samples is that described by Cour (Cour 1974). The filters are interconnected gauzes of 400 cm^2 arranged in a plastic frame, turned to the direction of the wind by a vane. They were changed weekly. Processing consisted of a complex chemical treatment to give semifluid samples of acetolysed pollen (Erdtman 1960). With the help of data from an anemometer located next to the trap, pollen concentrations can be worked out and expressed as weekly pollen in grains/m^3 air.

Pollen types were identified following the works of Wodehouse (1935), Plà Dalmau (1957), Nilsson et al. (1977), Valdés et al. (1987a). We also used our own collection of microscopical samples, which includes a large number of pollens from the ornamental flora of the city.

The pollen spectrum was interpreted according to results obtained from the cluster analysis with a matrix of data. This matrix includes the pollen types considered in our analysis. To each type 52 variables were assigned coinciding with the values of the 52 weekly pollen concentrations corresponding to each week of the year (these values of concentration were calculated from the concentrations recorded during the eight years of sampling: 1987–1994). This analysis was performed using the CSS program. The Euclidean distances were calculated using Ward's method as rule of amalgamation (Statsoft 1991).

In addition, the variation, throughout the year, of the weekly pollen concentrations of some of the types identified (mean of the eight years of sampling: 1987–1994) was represented graphically, with the abscissa as weeks and months and the ordinate as pollen concentrations (each type on the most appropriate scale).

Finally, the main pollination period (MPP) of each pollen type was calculated according to the criterion of Nilsson and Persson (1981): this is the period of the year when between 5 and 95% of the annual pollen of a particular type is collected.

Results and discussion

The pollen spectrum

The foremost characteristic of the aeropalynology of Seville is the collection of weekly concentrations of pollen higher than 100 grains of total pollen/m^3 during 30 weeks, between January and August. May is the month with highest pollen emission, with several weeks exceeding 1000 grains/m^3 (Fig. 1).

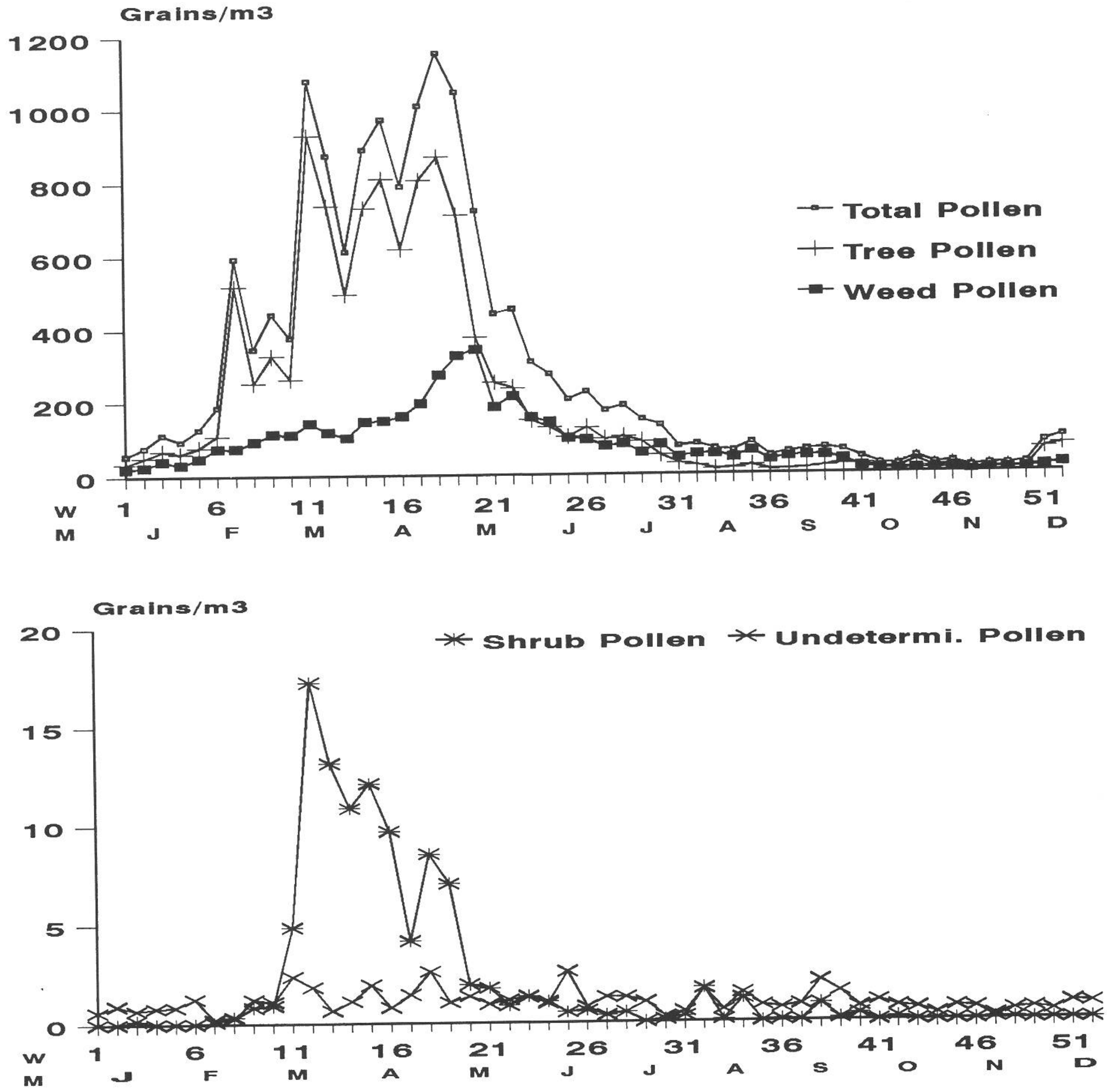


Fig. 1. Variation of weekly pollen concentrations during the year of total pollen, tree pollen, shrub pollen, herbaceous pollen and undetermined pollen. Average data from the eight years of sampling (1987–1994).

Three pollen is approximately 70% of the total pollen collected. Its presence is especially high during the first months of the year, but decreases during the summer when pollen from herbs is dominant (30% of the total pollen collected). Most of the shrub pollen appears between March and May, though at very low concentrations (Fig. 1).

Arboreal types are dominant in the spectrum even though they are quantitatively less numerous than the herbaceous types. This over-representation of tree pollen is a consequence of the greater height of the emission sources (flowers), which are better exposed to the effect of the wind (Faegri and Iversen 1975). There is also a fraction of unidentified pollen (between 0.1 and 2 weekly grains/m^3) resulting from the deformation and breaking caused by the processing of samples (Fig. 1). This problem is largely countered by the easiness of pollen identification when working with acetolysed pollen (Cambon 1981).

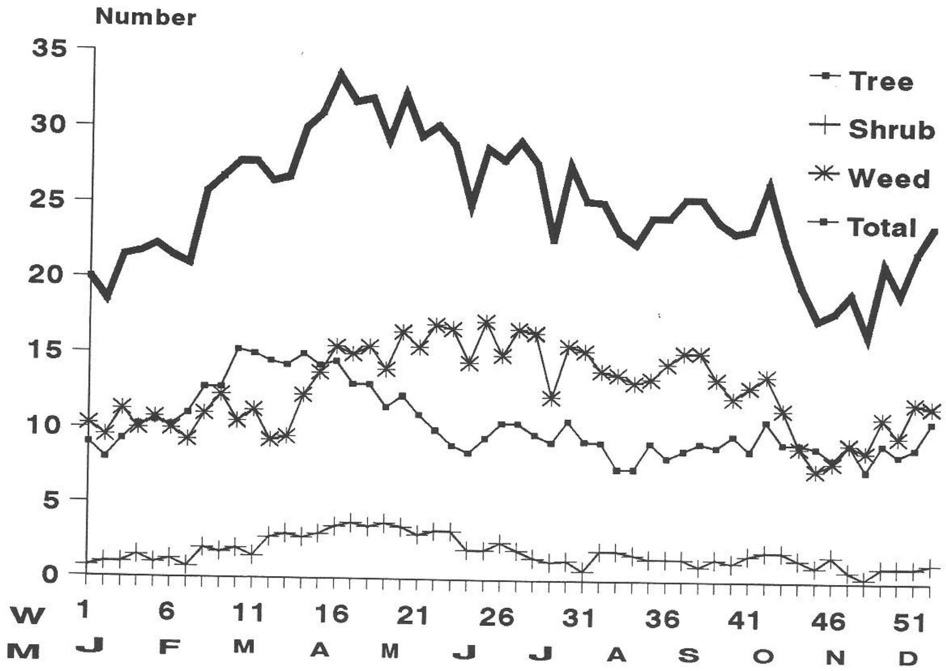


Fig. 2. Variation of number of weekly identified types: Total, Tree, Weed, Shrub. Average data from the eight years of sampling (1987–1994).

The number of pollen types identified weekly varies between 17 (Week 48 – December) and 35 (Week 17 – April) (Fig. 2). This variation in pollen variety is not parallel with the variation in concentration, since during a few months a large number of pollen types at very low concentrations was identified. This is a result of the flowering tails (and pollination) of the numerous taxa (Poaceae, Urticaceae, Cupressaceae, *Quercus*, Amaranthaceae/Chenopodiaceae, etc.) and, as will be explained later, from the phenomenon of pollen reflotation (*Olea europaea*, *Helianthus annuus*, *Vitis vinifera*, etc.). Between February and April, approximately 15 different arboreal types were collected each week. During those months the diversity of arboreal types found in the air is greater than that of herbaceous types. The latter predominate in the spectrum from May to October, with 10 to 17 different types being identified during that period, depending on the week. The number of shrub types is lower than five during all the weeks of the year (Fig. 2).

A total of 59 different pollen types was identified (which appeared in all the years of sampling), each with a representation higher than 0.01% in the total pollen collected and belonging to 48 different plant families (Table 1). These types represent 1157 species (Valdés et al. 1987a). The collection of this large amount of pollen types (many of which are entomophilous), is possibly a consequence of the dryness of Seville's air (a result of high temperatures and scarce rainfall), a situation that helps pollen dispersion (Keynan et al. 1991).

During the mean year 15 486.96 grains/m^3 are collected. The most abundant types are *Quercus* (3018.31 grains/m^3), *Olea europaea* (2848.11 grains/m^3), Cupressaceae (1838,93 grains/m^3), Poaceae (1704.39 grains/m^3), *Platanus hispanica* (1304.79 grains/m^3), Urticaceae (938.37 grains/m^3), Myrtaceae (456.46 grains/m^3), and Pinaceae (371.41 grains/m^3), (mean values for the period 1987–94). Table 2 details the annual concentrations, established year by year, of total pollen and of the eight most- and least-abundant types. In the table it can be seen that the greatest collection was obtained in 1991 (30 216 grains/m^3), and

Table 1. Types with a representation higher than 0.01% in the total pollen collected. Annual concentration in grains/m^3 (arithmetic mean of eight years, 1987–94) and standard deviation of the arithmetic means. The number of species included in each type also appears in the table.

Type	Family	Grains/m^3 Annual (Aver. 8 years)	Standard Deviation	Species Number
Acacia	Mimosaceae	7.09	2.24	8
Acer	Aceraceae	52.33	33.99	2
Alnus glutinosa	Betulaceae	15.59	9.68	1
Amar	Chenopodiaceae	250.66	100.63	43
Artemisia	Compositae	25.85	15.58	4
Asteroideae	Compositae	169.44	61.64	75
Betula	Betulaceae	1.98	1.30	1
Boraginaceae	Boraginaceae	33.99	19.37	36
Brachychiton	Sterculiaceae	8.21	5.22	1
Caryophyllaceae	Caryophyllaceae	6.48	6	73
Castanea sativa	Fagaceae	17.09	3.59	1
Casuarina	Casuarinaceae	56.64	26.90	2
Cistus	Cistaceae	12.49	1.95	3
Citrus	Rutaceae	36.89	18.51	3
Cocculus laurifolius	Menispermiaceae	10.68	2.74	1
Corylus avellana	Betulaceae	0.61	0.49	1
Cruciferae	Cruciferae	119.23	49.46	55
Cupressaceae	Cupressaceae	1838.93	1675.94	12
Cyperaceae	Cyperaceae	48.99	31.14	14
Daphne	Thymeleaceae	1.96	1.26	7
Ericaceae	Ericaceae	86.62	61.34	11
Euphorbia	Euphorbiaceae	7.29	4.69	26
Fraxinus	Oleaceae	182.56	149.99	5
Galium	Rubiaceae	2.27	0.97	19
Helianthus annuus	Compositae	99.55	59.66	1
Juglans	Juglandaceae	2.92	2.36	2
Lactucoideae	Compositae	46.63	21.96	130
Leguminosae	Leguminosae	9.78	7.96	140
Ligustrum	Oleaceae	6.70	3.16	3
Liliaceae	Liliaceae	15.17	9.05	46
Mercurialis	Euphorbiaceae	161.37	127.82	4
Moraceae	Moraceae	234.05	87.42	10
Myrtus-Eucalyptus	Myrtaceae	456.50	195	4
Olea europaea	Oleaceae	2848.11	1161	1
Palmae	Palmae	345.01	365.14	7
Papaver	Papaveraceae	9.98	4.53	11
Pinus-Cedrus	Pinaceae	371.41	187.21	7
Pistacia	Anacardiaceae	56.38	33.28	2
Plantago	Plantaginaceae	360.15	129.63	11
Platanus hispanica	Platanaceae	1304.59	421	1
Poaceae	Poaceae	1704.39	526	224
Polygonum	Polygonaceae	11.98	4.7	6
Quercus	Fagaceae	3018.31	1920	6
Rhamnus	Rhamnaceae	4.58	62	2
Ricinus communis	Euphorbiaceae	2.51	0.61	1

Table 1. (Fortsetzung)

Type	Family	Grains/m^3 Annual (Aver. 8 years)	Standard Deviation	Species Number
Rosaceae	Rosaceae	2.52	1.32	28
Rosmarinus	Labiatae	1.78	1.62	14
Rumex	Polygonaceae	224	113.74	9
Salix-Populus	Salicaceae	58.54	27.11	8
Scrophularia	Scrophulariaceae	11.75	6.21	7
Solanum	Solanaceae	3.69	2.2	4
Tilia	Tiliaceae	2.04	1.64	2
Typhaceae	Typhaceae	55.33	36.10	2
Ulmus	Ulmaceae	45.50	26.27	4
Umbelliferae	Umbelliferae	20.05	14.28	58
Urticaceae	Urticaceae	983.37	641	5
Viburnum	Caprifoliaceae	16.93	8.97	7
Vitis vinifera	Vitaceae	4.59	3.87	1
Xanthium	Compositae	3.68	3.12	2
		15486.96		1157

Table 2. Annual concentrations of total pollen and of the eight most- and least-abundant types.

Type	1987 G/m^3	1988 G/m^3	1989 G/m^3	1990 G/m^3	1991 G/m^3	1992 G/m^3	1993 G/m^3	1994 G/m^3
Total pollen	15201	8885	23896	7494	30216	23208	6523	8267
Quercus	1575	1419	2518	2389	7643	3903	1617	3296
Olea europaea	2277	1354	3244	1471	4361	2251	1064	1089
Cupressaceae	829	512	1512	425	2893	5868	1582	1408
Platanus hispanica	1599	1163	1575	820	1043	2120	811	1122
Poaceae	2497	1928	1330	1141	2272	1967	882	1616
Urticaceae	779	1118	1370	573	1696	2003	104	219
Myrtaceae	441	592	480	100	495	204	639	700
Pinaceae	185	636	624	141	292	503	403	190
Corylus avellana	1.36	0.93	0.36	0.12	0.05	0.20	1.28	0.59
Rosmarinus	1.10	0.10	0.23	1.40	1.70	3.50	0.98	5.20
Daphne	0.45	0.11	2.93	3.10	1.99	1.67	4.01	1.30
Betula	2.31	0.41	0.37	2.60	1.27	4.71	2.17	2.00
Tilia	0.40	1.17	0.10	3.25	1.57	2.40	5.56	1.86
Galium	1.29	1.23	3.87	1.12	2.57	2.12	2.59	3.47
Ricinus communis	2.30	3.12	3.10	2.67	1.70	3.20	1.45	2.51
Rosaceae	0.47	4.50	2.34	3.11	4.11	2.63	0.81	2.30

the lowest in 1993 (6523 grains/m^3). Analysis of Table 2 shows that the variation in concentrations from year to year can be very great, so that the data for a pollen-rich year are overvalued with respect to those for lesser ones (1991 supplied almost 25% of the total pollen of the eight years). These differences in concentration between different years explain the high

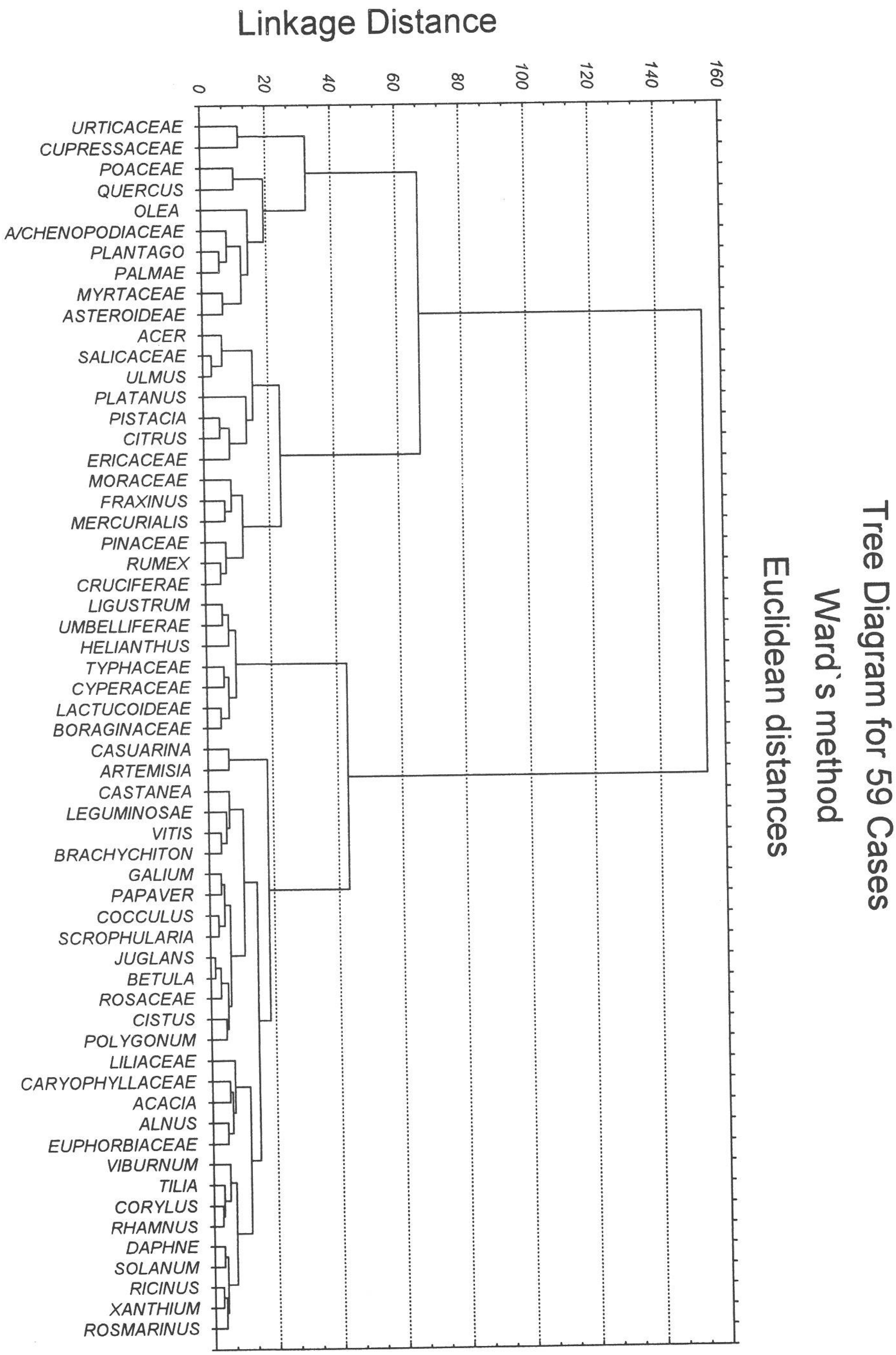


Fig. 3. Cluster analysis of the pollen spectrum in Seville.

standard deviations for the arithmetic means of the annual concentrations for most types (Table 1). It can also be seen that the variation with time in the annual concentrations of total pollen depends on the annual total amounts of *Quercus* and *Olea europaea* (the two most abundant types in the spectrum). In *Olea europaea* a biennial rhythm can be observed in the collection of pollen (although broken in 1993) characterised by one year of high collection followed by another of low collection (Table 2). This alternation in pollen production and collection has been reported previously *Olea europaea* by Macchia et al. (1991) and Domínguez Vilches et al. (1993).

The pollen types identified in the air of Seville have been allocated to twelve groups using cluster analysis (Fig. 3). The groups were established from a distance of amalgamation lower than 13. If the value 6.5 had been chosen, the number of groups would be considerably higher and the presentation of the results extremely long; in contrast, with a value of 20, the number of different groups would be very small, and only very general characteristics would be contributed for each one. This type of analysis enables the pollen types to be gathered in function of the similarity of their pollen curves – the main characteristic when considering a pollen calendar, and which is determined by the pollen concentrations (in this case weekly) and the time of the year in which they are produced. The use of cluster analysis in studies on atmospheric pollen is interesting from various points of view: a statistical method of presenting the results and grouping different pollen types is brief, synthetic, and readily understandable; it may be of interest when studying simultaneous allergies to diverse pollens (e.g., if an individual presents allergy symptoms in winter, it is useful to study the sensitivity to both Urticaceae and Cupressaceae, found in the same group, as detailed below).

Comtois and Sherknies (1991) carried out this type of analysis with the pollen counts of the air of Montreal (Canada). They present a cluster analysis with the mean values for three years of sampling, and consider that such is a good basis for getting a overall idea of the pollen spectrum of a particular region. We are of the same opinion, although we think that for more detailed interpretations, it is better to have available the cluster analysis for each year.

Figure 3 is completed with Figures 4 and 5. Figure 4 shows the pollen curves of the pollen types of each group established by cluster analysis. For a better graphical representation, a maximum of three types has been used in the case of a group formed by more than three. Figure 5 shows the main pollination periods of each type, listed by starting date.

The spectrum shows twelve groups of taxa with common aeropalynological characteristics, which have been established from the results of the cluster analysis (Fig. 3):

1. Urticaceae and Cupressaceae, appearing preferentially in winter months, and whose weekly pollen concentrations frequently exceed 20 grains/m^3 (Fig. 4a). Both types have a main pollination period longer than 35 weeks, with the starting date in week 3 of the year (Fig. 5).
2. *Quercus* and Poaceae, appearing mostly between March and June with weekly pollen concentrations often exceeding 100 grains/m^3 (Fig. 4b). Both types have a main pollination period longer than 15 weeks, with the starting date in week 12 of the year (Fig. 5). These two anemophilous types include numerous species with simultaneous and spaced out flowering at various times of the year (Valdés et al. 1987b), and are generally the most abundant in the pollen spectra of many Spanish cities (Belmonte and Roure 1991).
3. *Olea europaea*, characterised by a short main pollination period (Fig. 5) and by weekly pollen concentrations often exceeding 100 grains/m^3 between April and the beginning of June (Fig. 4c).
4. Amaranthaceae/Chenopodiaceae, *Plantago*, *Palmae*, Myrtaceae and Asteroideae, characterised by types appearing between March and September with weekly pollen concen-

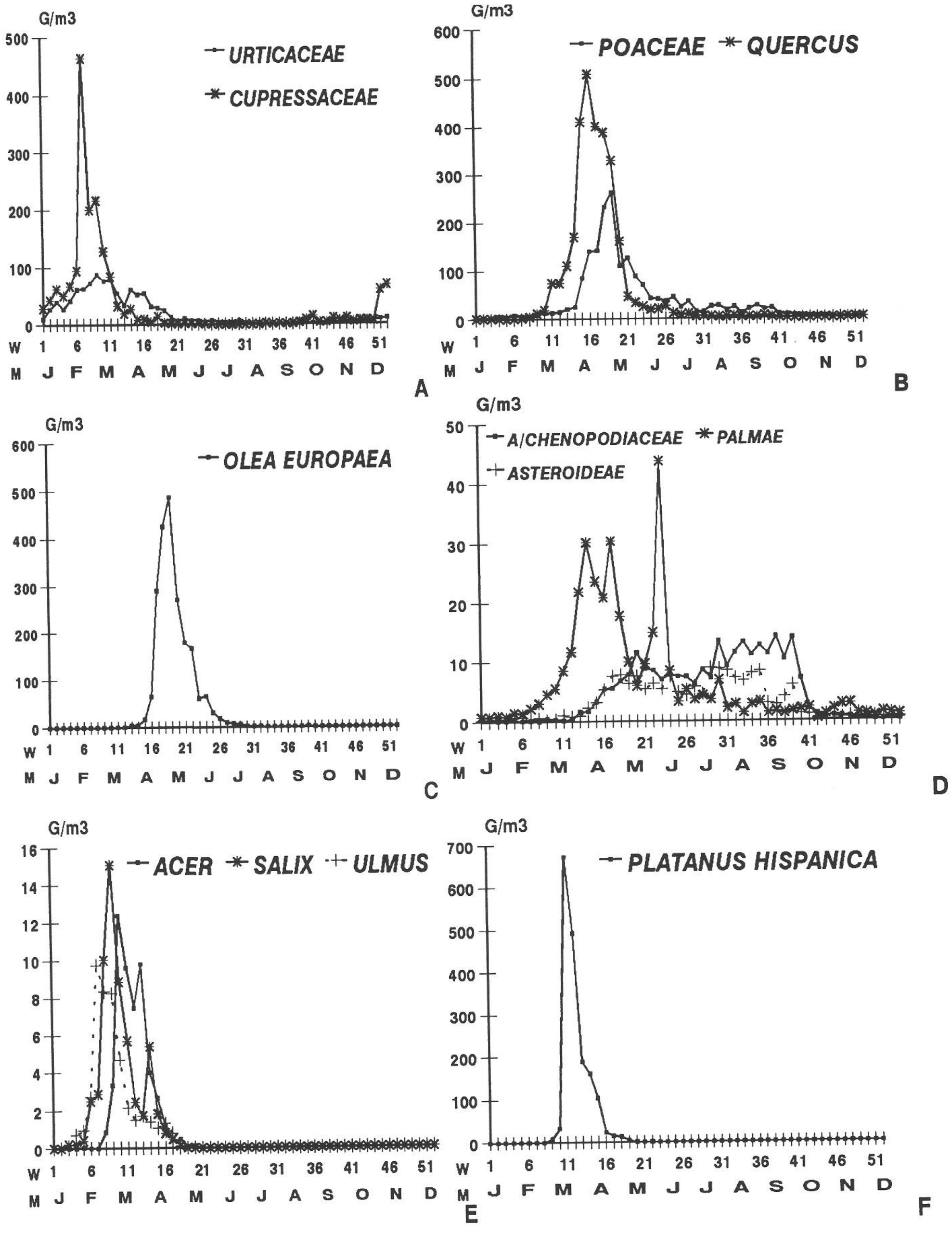
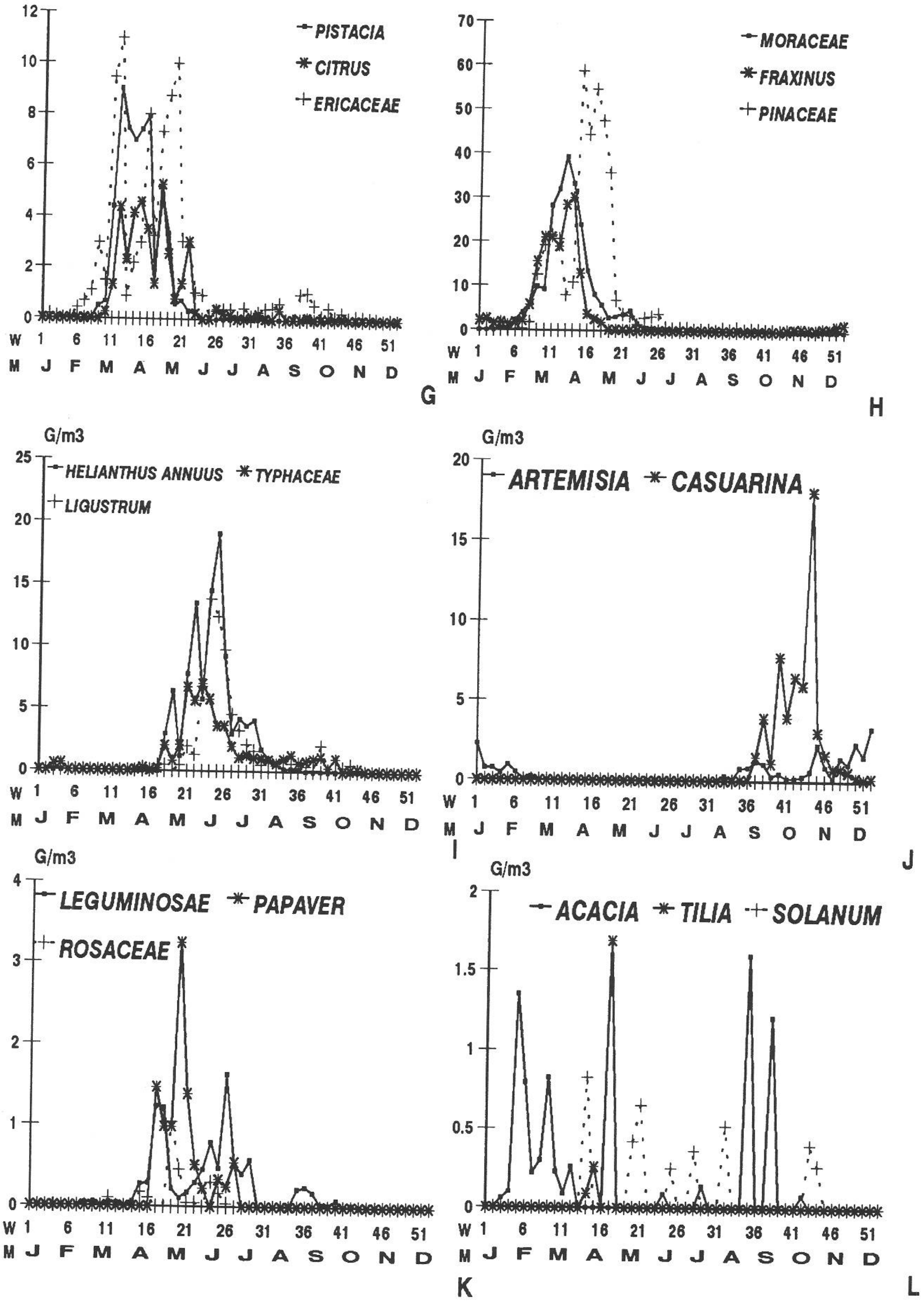


Fig. 4. Variation during the year of the weekly pollen concentrations for the pollen types identified in the air of Seville (mean of period 1987–1994). The types are grouped in accord with the result of the cluster analysis.



trations that often exceed 10 grains/m^3 (Fig. 4d). All these have a main pollination period longer than 20 weeks (Fig. 5).

5. *Acer*, Salicaceae and *Ulmus*, formed exclusively by arboreal types with early flowering, appearing in the air between February and April, and with weekly pollen concentrations frequently exceeding 2 grains/m^3 (Fig. 4e). The main pollination period of these types lasts between 8 and 10 weeks (Fig. 5).

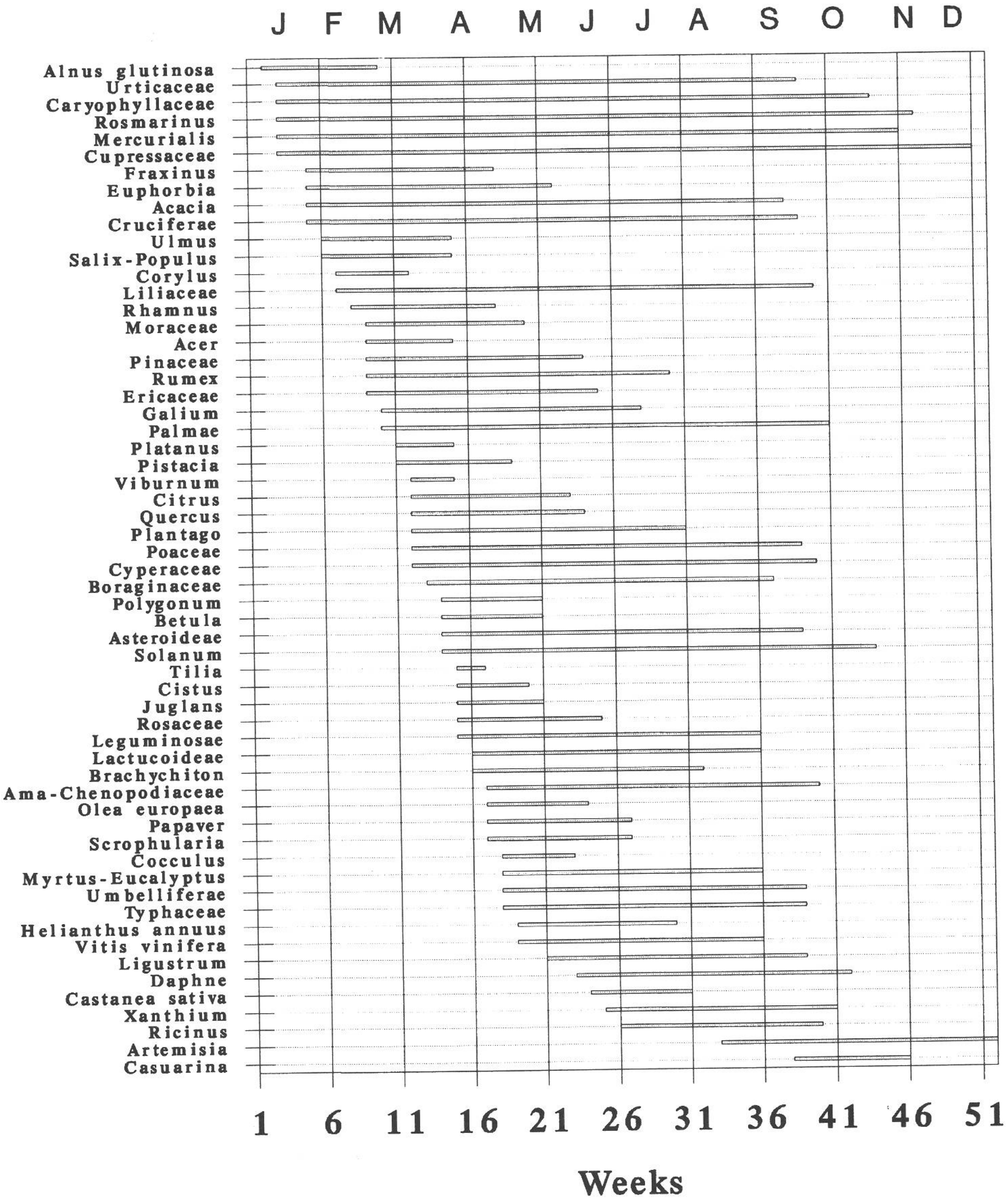


Fig. 5. Main pollination period (MPP) (mean of the period 1987–1994).

6. *Platanus hispanica*, a monospecific type with a very short main pollination period (4 weeks) (Fig. 5), and which appears in the air in March and April, with weekly pollen concentrations frequently exceeding 100 grains/m^3 (Fig. 4f).
7. *Pistacia*, *Citrus* and Ericaceae, entomophilous types of arboreal-shrub character, appearing between March and May with weekly pollen concentrations frequently exceeding 2 grains/m^3 (Fig. 4g).

8. Moraceae, *Fraxinus*, *Mercurialis*, Pinaceae, *Rumex* and Cruciferae, appearing between February and June with weekly pollen concentrations frequently exceeding 10 grains/m^3 (Fig. 4h), and whose main pollination period is longer than 10 weeks (trees) and 20 weeks (grasses) Fig. 5).
9. *Ligustrum*, Umbelliferae, *Helianthus annuus*, Typhaceae, Cyperaceae, Lactucoideae, and Boraginaceae, comprising almost exclusively grasses, and appearing between April and September with weekly pollen concentrations frequently exceeding 1 grain/m^3 (Fig. 4i), and whose main pollination period is longer than 15 weeks (Fig. 5).
10. *Artemisia* and *Casuarina*, two types appearing in autumn (Fig. 4j), whose main pollination periods are the latest of the spectrum (Fig. 5).
11. *Castanea*, Leguminosae, *Vitis*, *Brachychiton*, *Galium*, *Papaver*, *Cocculus*, *Scrophularia*, *Juglans*, *Betula*, Rosaceae, *Cistus* and *Polygonum*, types appearing between March and September with weekly pollen concentrations often not exceeding 1–2 grains/m^3 (Fig. 4k) and whose main pollination periods vary between 5 and 20 weeks in length (Fig. 5).
12. Liliaceae, Caryophyllaceae, *Acacia*, *Alnus*, *Euphorbia*, *Viburnum*, *Tilia*, *Corylus*, *Solanum Ricinus*, Xanthium and *Rosmarinus*, appearing irregularly at different times of the year, with weekly pollen concentrations not exceeding 1–2 grains/m^3 (Fig. 4l), and main pollination periods ranging between 2 and 44 weeks in length depending on type (Fig. 5).

Relationship between pollen spectrum and vegetation

The ornamental flora of Seville is highly represented in the pollen spectrum. This situation is somewhat unusual in aeropalynological studies (Negrini et al. 1987), since the proximity to the trap counters the effect of the buildings which act as screens that make it difficult for the pollen to be carried around urban sites (Donini and Sutra 1987). Types with an anemophilous origin (Cupressaceae, *Platanus*, Palmae, Moraceae, *Casuarina*, etc.) are those that reach the highest concentrations of pollen. The particular case of *Platanus hispanica* gives the highest weekly pollen concentration found for all pollen types (Fig. 4f). Types with an entomophilous origin (*Acacia*, *Citrus*, *Viburnum*, *Tilia*, *Juglans*, Rosaceae, *Brachychiton*, *Cocculus laurifolius*, etc.), even though at low concentrations, contribute to the enrichment of the spectrum from a taxonomical point of view, and make known the flower richness of the ornamental flora in Seville.

One of the properties of the pollen spectrum of Seville is the high representation of herbaceous nitrophilous weeds (Urticaceae, *Mercurialis*, *Plantago*, *Rumex*, Poaceae, Brassicaceae, Amaranthaceae-Chenopodiaceae, Asteroideae, Lactucoideae, Umbelliferae, *Artemisia*, *Xanthium*, Caryophyllaceae, Scrophulariaceae, *Euphorbia*, *Galium*, *Solanum*, *Polygonum*) (Table 1). They are characterised by a poor dispersion of those pollen types which are deposited mainly close to the plant (Faegri and Iversen 1975).

Introduced forest sites and crop areas are equally represented in the pollen spectrum: Pinaceae and Myrtaceae (forest areas resulting from reforestation by human activity), olive groves (*Olea europaea*), vineyards (*Vitis vinifera*), fruit orchards (*Citrus* and Rosaceae), and herbaceous areas (*Helianthus annuus*, Leguminosae, Cruciferae, and *Papaver*). This makes it possible to forecast in groves based on atmospheric pollen count (Candau et al. 1991; González Minero and Candau 1995a). With the exception of the type Pinaceae, all types have entomophilous or mixed pollination. Their appearance in the spectrum constitutes once again an example of the transformation of the natural environment into economically more-profitable sites.

This situation is clearer in the case of olive groves, which occupy great areas of land in a monocultivation regime. Thus, high concentrations of *Olea europaea* pollen can be collected in the air of Seville (2848.11 grains/m^3) (Table 1). They are comparable only to those found in other regions of southern Spain (Dominguez Vilches et al. 1993) and southern Italy (Macchia et al. 1991). The enormous dispersion of this pollen type is an additional factor, since the pollen can be transported kilometres when the wind direction and speed are appropriate (Michel et al. 1979). The amount of *Eucalyptus* pollen (456.50 grains/m^3) (Table 1) is one of the highest established for Mediterranean Europe. It is comparable only to that established for nearby cities (González Minero and Candau 1995b) and is a product of the extensive plantations of this forest genus that was undertaken during the 40s and 50s to obtain wood pulp for paper. In contrast, the relatively low concentration of Pinaceae (371.41 grains/m^3) (Table 1) is notable, especially if the high potential aerovagancy conferred by the air vesicles is taken into account. This contradiction should be attributed to the large size of this pollen type, which makes it poorly represented in the sampling compared with other anemophilous types, all being smaller. The concentrations of Pinaceae established for Seville are similar to those found in other Mediterranean locations in the south of France (Bousquet et al. 1984), Greece (Giuolekas et al. 1991) and Israel (Geller-Berstein et al. 1991).

The arboreal genera of the Mediterranean forest (*Quercus*) are those best represented in the pollen spectrum. The type *Quercus* is the most abundant with 3018.31 grains/m^3. This situation is repeated for the rest of the Iberian Peninsula (Belmonte and Roure 1991) and for other Mediterranean regions (Bousquet et al. 1984), in spite of the recession that these forests have traditionally suffered, degraded by shrubs or substituted by economically more-profitable areas.

The Mediterranean shrubs are qualitatively represented in the spectrum by entomophilous types (*Cistus*, Ericaceae, *Pistacia*, *Rhamnus*, *Viburnum*, *Rosmarinus*, Leguminosae) (Table 1), which at the same time constitute an example of the degradation and abandonment of large areas of holm oaks (*Q. rotundifolia*) and cork oaks (*Q. suber*).

The low amounts of pollen coming from the riverside areas (*Alnus*, *Fraxinus*, *Ulmus*, *Salix*, *Corylus avellana*) and from elements of the wetland vegetation (Typhaceae, Cyperaceae), all of them anemophilous types, are a direct consequence of the enormous pressure to which these units of vegetation are submitted and to their constant disappearance.

Finally, the appearance in the pollen spectrum of pollen transported from long distances (marker pollen) – *Castanea sativa* and *Betula* – should be commented upon. The collection of pollen from chestnut is a case of pollen transport at a regional scale; it possibly comes from places located at more than 100 kms in the northern part of the province. A similar case has been described for Huelva (SW Spain) (González Minero and Candau 1995b) and in the north of Italy (Caramiello and Siniscalco 1990). The collection of pollen from birches is a case of pollen transport on an interregional scale. It comes possibly from the nearest birch forests, located at several hundred kilometres in the centre and north-east of the Peninsula (Castroviejo et al. 1990), although it may also come from those situated thousands of kilometres further north, in central and northern Europe. This possibility is in accord with the data of the wind direction for each annual period of *Betula* pollen collection. The sum of the percentages of duration of north wind (NNE+WNW) is as follows: 53.18% (87), 43.33% (88), 32.52% (89), 54.99% (90), 57.08% (91), 87.01% (92), 50.16% (93) and 52.27% (94). The common denominator of these data is that the wind values exceed 50% for all the years except 1988 and 1989 (when it was greater than 30%). At the same time, if we compare the wind data with the pollen concentrations for *Betula* (Table 2), it can be seen that the year with highest concentration (4.71 grains/m^3 in 1992) coincides with the highest value for north wind (87.01%), while in those years with less than 50% north wind (1988 and 1989), the pollen concentration for *Betula* was lower than 1 grain/m^3. Similar phenomena have been reported by Wallin et al. (1991), Hejlmroos (1992), and González Minero and Candau (1996). A knowledge of such circumstances should be taken into account when making reconstructions of the vegetation from fossil pollen (Cour and Duzer 1976).

Relationship between pollen spectrum and anthropogenic activity

In this paragraph we aim to demonstrate the possibility of obtaining information about certain anthropogenic activities whose effects are seen in the pollen curves of certain taxa, and that the composition of the pollen spectrum is a register of the changes occurring in the natural environment, most of them induced by man (Keynan et al. 1991):

– The presence of pollen from *Helianthus annuus* is particularly interesting, since despite its weight and volume, it is present at concentrations of up to 20 grains weekly/m^3 in the urban atmosphere, in periods not coinciding with the flowering of any of the varieties of this plant (Fig. 4i). This allows the deduction that this pollen is deposited on the surface of the plant by the effect of gravity when flowering occurs, and is passively transported by the air during the summer, wen removed by the turbulence of harvesters. The plant has not taken part in this latter process, but has been dependent on human activity together with the meteorological conditions of the summer, which favour the dispersion of this pollen far from the sunflower plantations on the outskirts of the city (Candau et al. 1994).

– Similar reasoning can be applied in the case *Papaver* pollen (Fig. 6), most of which comes from opium plantations (*Papaver somniferum*) located in the surroundings of Seville. The harvest of the capsules from *Papaver* is basically the same as that of sunflower capitula. For this reason these entomophilous taxa are also reflected in the pollen spectrum of the city during the periods of flowering (April) and harvested (beginning of June) (Fig. 6).

– Finally we will note the collection of small amounts of *Olea europaea* (Fig. 4c) and *Vitis vinifera* (Fig. 6) pollen in the summer and the beginning of autumn, outside their respec-

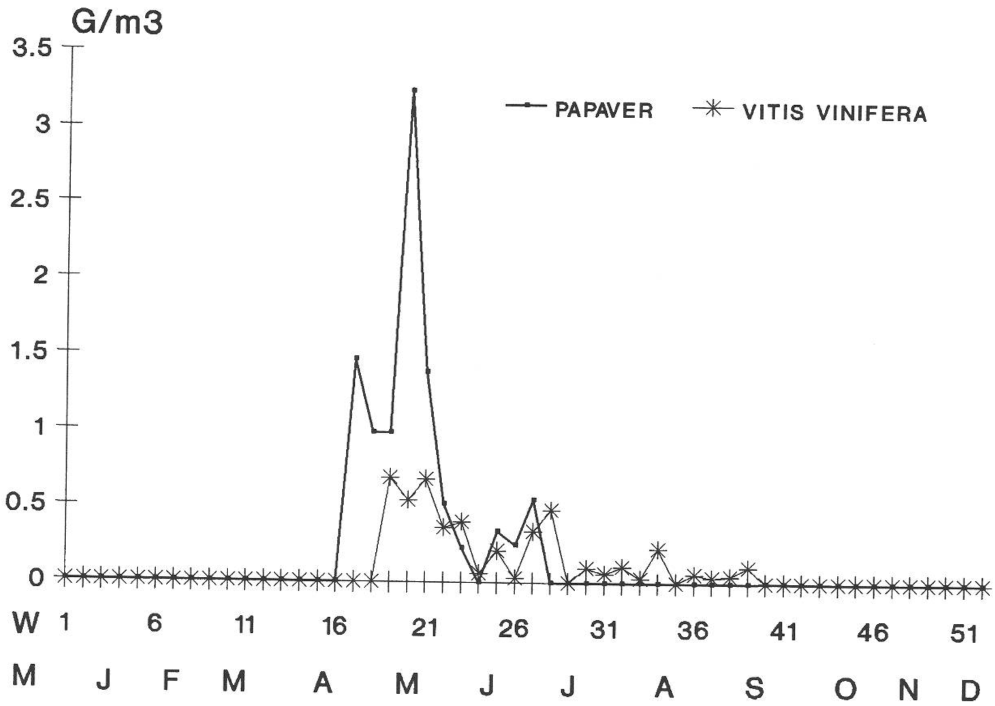


Fig. 6. Variation during the year of the weekly pollen concentrations for *Papaver* and *Vitis vinifera* (mean of period 1987–1994).

tive periods of flowering and pollination of all the varieties of olive and grape (Mary and June). This double situation derives from the manipulation of the crops at the moment of harvest of grapes (August, September and October) and olives (September). In the particular case of olive trees, the possibility of the pollen's being resuspended in the air by the wind in a natural process should be added, as this has an effect on the large amounts of pollen deposited on the trees' leaves. The same effect has been observed in *Quercus* by Subiza et al. (1988) and Keynan et al. (1989).

References

Almarza Mata C. 1984. Fichas hídricas normalizadas y otros parámetros hidrometeorológicos. Instituto Nacional de Meteorología. Madrid.

Andrés Camacho, M. C. 1991. Flora ornamental de Sevilla. Doctoral thesis. Universidad de Sevilla. Sevilla.

Belmonte J. and Roure J. M. 1991. Characteristics of the aeropollen dynamics at several localities. Grana 30: 364–372.

Bousquet J., Cour P., Guerin B. and Michel F. B. 1984. Allergy in the Mediterranean area I. Pollen counts and pollinosis of Montpellier. Clin. Allergy 14: 249–258.

Cambon G. 1981. Relations entre le contenu pollinique de l'atmosphère et le couvert végétal en Mediterranée occidentale à Montpellier (France), Valencia (Espagne) et Oran (Algérie). Doctoral thesis. Montpellier.

Candau P., González Minero F. J. and González Romano M. L. 1991. Polen y productividad. Agricultura 708: 639–641.

Candau P., González Minero F. J. 1992. Relationship between vegetation and pollen spectrum in southwest Spain. Israel Journal of Botany 41: 285–295.

Candau P., González Romano M. L. and González Minero F. J. 1994. Olivo y girasol en el espectro políclinico de Andalucía Occidental. Lagascalia 17: 219–228.

Caramiello R. and Siniscalco C. 1990. Pollen calendar in Northern Italy and its relationship to climate. Aerobiologia 6: 116–121.

Castroviejo S., Laínz S., López González M., Montserrat P., Muñoz Garmandía F., Paiva J. and Villar L. 1990. Flora Ibérica. Vol. II, C.S.I.C. Madrid.

Comtois P. and Sherknies D. 1991. Pollen curves typology. Grana 30: 184–190.

Cour P. and Duzer D. 1976. Persistance d'un climat hyperaride au Sahara Central et Méridional au cours de l'holocene. Rev. de Geographie physique et de géologie dynamique 13 (2–3): 175–190.

Cour P. 1974. Nouvelles techniques de detection des flux et des retombées polliniques: étude de la sédimentation à la surface du sol. Pollen et spores 16: 103–141.

Domínguez-Vilches E., García-Pantaleón F., Galán Soldevilla C., Guerra Posadas F. and Villamandos de la Torre F. 1993. Variations in the concentrations of airborne *Olea* pollen and associated pollinosis in Córdoba (Spain): A study of the 10-year period 1982–1991. J. Invest. Allergol. Clin. Immunol. 3: 121–129.

Donini D. and Sutra J. P. 1987. Recherches aéropalynologiques à Paris et dans sa banlieue: Nouveaux résultats. Grana 28: 37–44.

Elías Bonells J. 1983. Plantas y Jardines de Sevilla. Ayuntamiento de Sevilla y Delegación de Parques y Jardines. Sevilla.

Erdtman G. 1960. The acetolysis method. A revised description. Svensk. Bot. Tidskr. 54: 561–564.

Faegri K. and Iversen J. 1975. Textbook of pollen analysis. 3rd ed. Blackwell Scientific Publications. Oxford, London, Edinburgh, Melbourne.

Geller-Berstein C., Keynan N., Kenett R., Shomer-Ilan A. and Waisel Y. 1991. Aerobiology as a tool for prevention of hay fever. Grana 30: 76–78.

Gioulekas D., Chatzigeorgiou G., Papakosta D., Eleftherochorinos E. and Spieksma F. T. M. 1991. Aerobiological and clinical aspects of *Parietaria officinalis* in the area of Thessaloniki, Greece. Aerobiologia 7: 107–110.

González Minero F. J. and Candau P. 1995a. La aeropalinología aplicada a la previsión de cultivos. I. Los viñedos del Condado de Huelva. Polen 7: 37–44.
González Minero F. J. and Candau P. 1995b. Análisis del contenido polínico de la atmósfera de Huelva. Acta Botanica Malacitana 20: 71–81.
González Minero F. J. and Candau P. 1996. The influence of tree and shrub vegetation composition in the pollen spectrum of SW Spain. Lagascalia 18: 435–441.
González Romano M. L., Candau P. and González Minero F. J. 1992. Pollen callendar of Seville and its relation to allergies. J. Invest. Allergol. Clin. Immunol 2: 323–328.
González Romano M. L., Candau P. and González Minero F. J. 1993. Estudio aeropalinológico de Sevilla. An. Asoc. Palinol. Leng. Esp. 1992, 6: 39–50.
Hjelmroos M. 1992. Long distance transport of *Betula* pollen grains and allergic symptoms. Aerobiologia 8: 231–236.
Keynan N., Waisel Y., Shomer-Ilan A. and Tamir R. 1989. Forecasting pollen pollution: correlation with floral development. Ann. of Allergy 63: 417–420.
Keynan N., Waisel Y., Shomer-Ilan A., Oden A. and Brener S. 1991. Annual variations of airborne pollen in the Coastal Plain of Israel. Grana 30: 447–480.
Macchia L., Caiaffa M. F., D'Amato G. and Trursi A. 1991. Allergenic significance of Oleaceae Pollen. In: D'Amato G., Spieksma F. T. M. and Bonini S. (Eds). Allergenic pollen and pollinosis in Europe. Blackwell Scientific publications. Oxford, London, Edinburgh, Boston, Melbourne, Paris, Berlin, Vienna, pp. 87–93.
Michel F. B., Seignalet C. H. and Cour P. 1979. Contribution palynologique, allergologique, météorologique et climatologique de l'étude des flux polliniques entre la Scandinavie et l'Afrique du Nord, premiers resultats. Les pollinoses. Laboratoires Fisons. Paris.
Negrini A. C., Arobba D., Ebbli A., Troise C. and Voltolini S. 1987. Le calendrier pollinique de Gênes. Rev. Fr. Allergol., 27: 65–70.
Nilsson S., Praglowsky J. and Nilsson L. 1977. Atlas of airborne pollen grains and spores in Northern Europe. Natur och Kultur. Almquist and Wiksell. Stockholm.
Nilsson S. and Persson S. 1981. The pollen spectra in the Stockholm region (Sweden), 1973–1980. Grana 20:179–182.
Plà Dalmau J. M. 1957. Estudios palinológicos y precisiones morfológicas sobre los granos de polen de quinientas especies botánicas del extremo N. E. de España. Doctoral thesis. Barcelona.
Rivas Martínez S. 1987. Memoria del mapa de series de vegetación de España. Madrid.
Statsoft, Inc. 1991. CSS Statistica. Tulsa. U.S.A.
Subsiza Martín E., Subiza Garrido-Lestache F. J. and Jerez Luna M. 1985. Polinosis (I). Palinología. Luzán 5, Madrid, 1988.
Valdés B., Díez M. J. and Fernández I. 1987a. Atlas polínico de Andalucía Occidental. Instituto de Desarrollo Regional (Universidad de Sevilla). Diputación de Cádiz. Sevilla.
Valdés B., Talavera S. and Galiano E. F. 1987b. Flora vascular de Andalucía Occidental. Ed. Ketrés. Barcelona.
Wallin J. E., Segerstrom U., Rosnhall L., Bergmann E. and Hjelmroos M. 1991. Allergic symptoms caused by long-distance transported birch pollen. Grana 30: 265–268.
Wodehouse R. P. 1935. Pollen grains. McGraw-Hill Book Co. Inc. New York & London.