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Original articles

Pollen calendar of the city of Salamanca (Spain). Aeropalynological analysis for 1981-1982 and 1991-1992

M. Hernández Prieto F. Lorente Toledano
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Laffond Yges and A. Calvo Bullón

Palabras clave: Calendario de pólenes.
Salamanca. Palinología.

We report a study on the contents or airborne pollen in the city of Salamanca (Spain) aimed at establishing a pollen calendar for the city for the yearly periods of maximum concentrations, relating these with quantifiable atmospheric variables over two two-year periods with an interval of 10 years between them: 1981-82 and 1991-92. The pollen was captured with Burkard spore-traps, based on Hirst's volumetric method. Determinations were made daily and were used to make preparations, previously stained with basic fuchsin, for study under light microscopy at x 1,000 magnification. 946 preparations were analyzed, corresponding to the same number of days distributed over 150 weeks of the periods studied. The results afforded the identification of 48 different types of pollen grain: Grasses (Poaceae), Olea europea (olive), Quercus rotundifolia (Holm-oak), other Quercus spp. (Q. pyrenaica, Q. suber, Q. faginea, etc.), Cupressaceae (Cupressus sempervivens, C. arizonica, Juniperus communis etc.), Plantago (Plantago lanceolata, Plantago media, etc.), Pinaceae (Pinus communis, Abies alba, etc.), Rumex sp. (osier), Urtica dioica (nettle), Parietaria (Parietaria officinalis, P. judaica), Chenopodio-Amaranthaceae (Chenopodium sp., Amaranthus sp., Salsola kali, etc.), Artemisia vulgaris (Artemisia), other Compositae (Taraxacum officinalis, Helianthus sp. etc.), Castanea sativa (Chestnut), Ligustrum sp. (privet), Betula sp. (birch), Alnus sp. (common alder), Fraxinus sp (ash), Populus sp. (poplar), Salix sp. (willow), Ulmus sp. (elm), Platanus sp. (plantain, plane), Carex sp. (sweet flag), Erica sp. (common heather), Leguminosae or Fabaceae: -

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Papilionaceae (Medicago sp.; Cercis sp., Robina sp.) - Cesalpinoideae Acacia sp. (Acacia),- Mimosoideae: Sophora japonica, Umbelliferae (Foeniculum sp., Cirsium sp., etc.), Centaurea sp., Cistus sp. (rock rose), Typha sp (bulrush), Mirtaceae (Myrtus communis), Juglans regia (Walnut), Galium verum, Filipendula sp. (spirea/drop wort), Rosaceae (Pyrus sp., Prunus sp., etc.), Tilia sp. (Linden), Morus sp. (mulberry), Taxus baccata (yew), Papaveraceae (Papaver rhoeas etc.), Labiata (Lavandula sp.), Cannabaceae (Humulus sp. etc.), Liliaceae (Lilium sp.), Echium sp. (viper's bugloss). The most abundant taxa, detected in the highest quantities (grains/m³ air), by order of counting were as follows: holm-oak, olive, grasses, Plantago and Parietaria. With the data obtained we have established a pollen calendar for Salamanca and report the period in which each type of pollen is found along the years and the periods with the highest airborne concentrations of such pollens. The diversity and the spectrum of the pollen in the city of Salamanca correspond to the typical plant communities found on the dehesas (large ranges of grasslands) of Castile, where Salamanca is located, although the wind directions and the peculiar climatic characteristics of the area govern the peaks of maximum presence of the different taxa. As examples, in the case of olive, which is cultivated at some distance from the city, its maximum presence coincides with south-westerly winds; in the case of grasses, the peaks of maximum counts coincide with a sharp rise in mean temperature, close to or higher than 20° C and between five and six weeks after rainfall equal to or greater than 5 L/m².

Keywords: Pollen calendar. Salamanca. Palynology.

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ORIGINAL ARTICLES

Pollen calendar of the city of Salamanca (Spain). Aeropalynological analysis for 1981-1982 and 1991-1992

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SUMMARY

We report a study on the contents or airborne pollen in the city of Salamanca (Spain) aimed at establishing a pollen calendar for the city for the yearly periods of maximum concentrations, relating these with quantifiable atmospheric variables over two two-year periods with an interval of 10 years

between them: 1981-82 and 1991-92. The pollen was captured with Burkard spore-traps, based on Hirst's volumetric method. Determinations were made daily and were used to make preparations, previously stained with basic fuchsin, for study under light microscopy at x 1,000 magnification. 946 preparations were analyzed, corresponding to the same number of days distributed over 150 weeks of the periods studied. The results afforded the identification of 48 different types of pollen grain:

Grasses (*Poaceae*), *Olea europea* (olive), *Quercus rotundifolia* (Holm-oak), other *Quercus* spp. (*Q. pyrenaica*, *Q. suber*, *Q. faginea*, etc.), *Cupressaceae* (*Cupressus sempervivens*, *C. arizonica*, *Juniperus communis* etc.), *Plantago* (*Plantago lanceolata*, *Plantago media*, etc.), *Pinaceae* (*Pinus communis*, *Abies alba*, etc.), *Rumex* sp. (osier), *Urtica dioica* (nettle), *Parietaria* (*Parietaria officinalis*, *P. judaica*), *Chenopodio-Amaranthaceae* (*Chenopodium* sp., *Amaranthus* sp., *Salsola kali*, etc.), *Artemisia vulgaris* (*Artemisia*), other *Compositae* (*Taraxacum officinalis*, *Hellianthus* sp. etc.), *Castanea sativa* (Chestnut), *Ligustrum* sp. (privet), *Betula* sp. (birch), *Alnus* sp. (common alder), *Fraxinus* sp (ash), *Populus* sp. (poplar), *Salix* sp. (willow), *Ulmus* sp. (elm), *Platanus* sp. (plantain, plane), *Carex* sp. (sweet flag), *Erica* sp. (common heather), *Leguminosae* or *Fabaceae*: - *Papilionaceae* (*Medicago* sp.; *Cercis* sp., *Robina* sp.) - *Cesalpinoideae* *Acacia* sp. (*Acacia*), - *Mimosoideae*: *Sophora japonica*, *Umbelliferae* (*Foeniculum* sp., *Cirsium* sp., etc.), *Centaurea* sp., *Cistus* sp. (rock rose), *Typha* sp (bulrush), *Mirtaceae* (*Myrtus communis*), *Juglans regia* (Walnut), *Galium verum*, *Filipendula* sp. (spirea/drop wort), *Rosaceae* (*Pyrus* sp., *Prunus* sp., etc.), *Tilia* sp. (Linden), *Morus* sp. (mulberry), *Taxus baccata* (yew), *Papaveraceae* (*Papaver rhoeas* etc.), *Labiata* (*Lavandula* sp.), *Cannabaceae* (*Humulus* sp. etc.), *Liliaceae* (*Lilium* sp.), *Echium* sp. (viper's bugloss).

The most abundant taxa, detected in the highest quantities (grains/m³ air), by order of counting were as follows: holm-oak, olive, grasses, *Plantago* and *Parietaria*.

With the data obtained we have established a pollen calendar for Salamanca and report the period in which each type of pollen is found along the years and the periods with the highest airborne concentrations of such pollens.

The diversity and the spectrum of the pollen in the city of Salamanca correspond to the typical plant communities found on the *dehesas* (large ranges of grasslands) of Castile, where Salamanca is located, although the wind directions and the peculiar climatic characteristics of the area govern the peaks of maximum presence of the different taxa. As examples, in the case of olive, which is cultivated at some distance from the city, its maximum presence coincides with south-westerly winds; in the case of grasses, the peaks of maximum counts coincide with a sharp rise in mean temperature, close to or higher than 20° C and between five and six weeks after rainfall equal to or greater than 5 L/m².

Key words: Pollen calendar. Salamanca. Palynology.

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INTRODUCTION

Salamanca (Spain) is located on the Iberian Peninsula in the south-western zone of the southern submeseta on the Duero peniplain. It lies on the banks of the River Tormes on three small hills and the city center has an altitude of 808 m.a.s.l. Its coordinates are 5° 41" W and 40° 58" N. In view of its location and altitude, the climate in Salamanca is strongly continental because its closeness to Atlantic influence is attenuated by the mountainous relief surrounding the Central Meseta. The climate in Salamanca is therefore dry with little rain and extreme temperatures, both as regards summer/winter and day/night differences. The dominant wind is Atlantic, i.e., coming from the SW.

The Castilian landscape is characterized by the presence of what are locally known as *dehesas*. These comprise more or less disperse clumps of trees -- mainly holm-oaks and cork-oaks-- and meadow and scrub. Dehesas are an expression of human activity aimed at farming and livestock raising in the natural environment.

The ornamental vegetation of the city is concentrated in four of five quite large areas such as the *Parque de los Jesuitas*, the *Parque fluvial*, the *Alemedilla*, the *Parque Villar y Macias* and the *Campo de San Francisco*. The rest of the townscape and surrounding, periphery essentially features ruderal vegetation, rupicolous species, areas of cultivatable grasses and other irrigated areas, palustrine vegetation and small copses of trees and bushes.

The present work establishes a pollen calendar of the air in the city of Salamanca, evaluating a sample from two two-year periods separated by an interval of 10 years; 1981-82 and 1991-92. This is the first contribution to the particular study of the content of airborne pollen in the city and its chronological structure with respect to the different seasons and months of the year.

MATERIALS AND METHODS

A Burkard spor-trap was used to collect the pollen; this is based on the volumetric method of Hirst (16). Such traps are mounted on weather vanes to ensure that they will always be facing the oncoming wind. The suction mechanism works by a simple turbine principle with an intake of up to 10L air/min. For the present study, the trap was placed on the terrace of a building in the centre of the city at a height of more than 20 m, with few nearby obstacles to prevent air flow. Determinations were made daily and were used to elaborate preparations for observation under light microscopy at x 1000 magnification. Prior to study the preparations were stained with basic fuchsin (15). A total of 946 preparations was analyzed, corresponding to the same number of days, distributed along 150 weeks of the period studied. Weekly arithmetic means were obtained from all the daily determinations made. Likewise, quantifiable atmospheric variables such as maximum and minimum

temperatures, relative air humidity, atmospheric pressure, precipitation and wind speed and direction were taken into account during the same periods.

RESULTS FOR THE FOUR YEARS ANALYZED

Pollen concentrations

Quercus rotundifolia

The highest holm-oak pollen counts were found in 1991, with weekly means of up to 1,195 grains/m³ between 25 and 31 May; this means that during that year the pollen counts were much higher than those recorded during the other years studied. In 1981 the weekly means did not surpass 125 grains/m³ and the week with the highest counts was that of 4-10 June. In 1982, a figure of 161 grains/m³ was reached between 9 and 15 April and in 1992 a figure of 194 grains/m³ was recorded between 25 and 31 May.

The interannual period with the highest holm-oak pollen counts in Salamanca along the four years studied ranged between 9 April and 10 June (Chart 1), the most frequent period having the maximum pollen counts being the last week of may (Fig. 1).

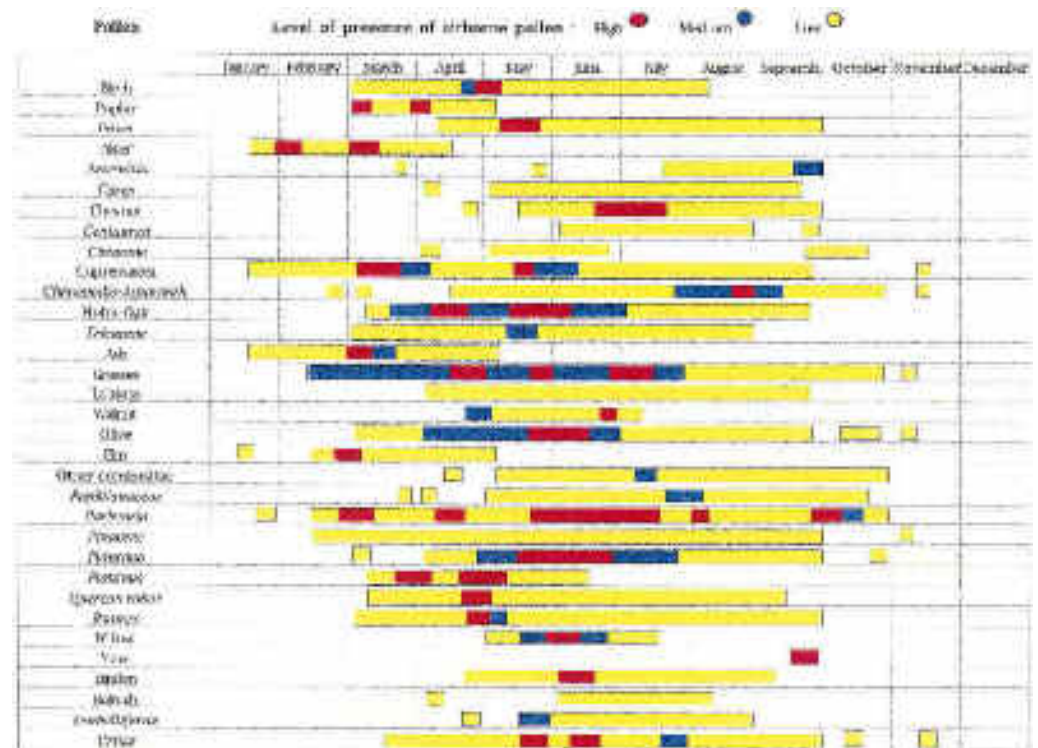


Chart 1.--Pollen calendar with grading in pollen intensity observed in Salamanca for the two two-year periods of 1981-82 and 1991-92.

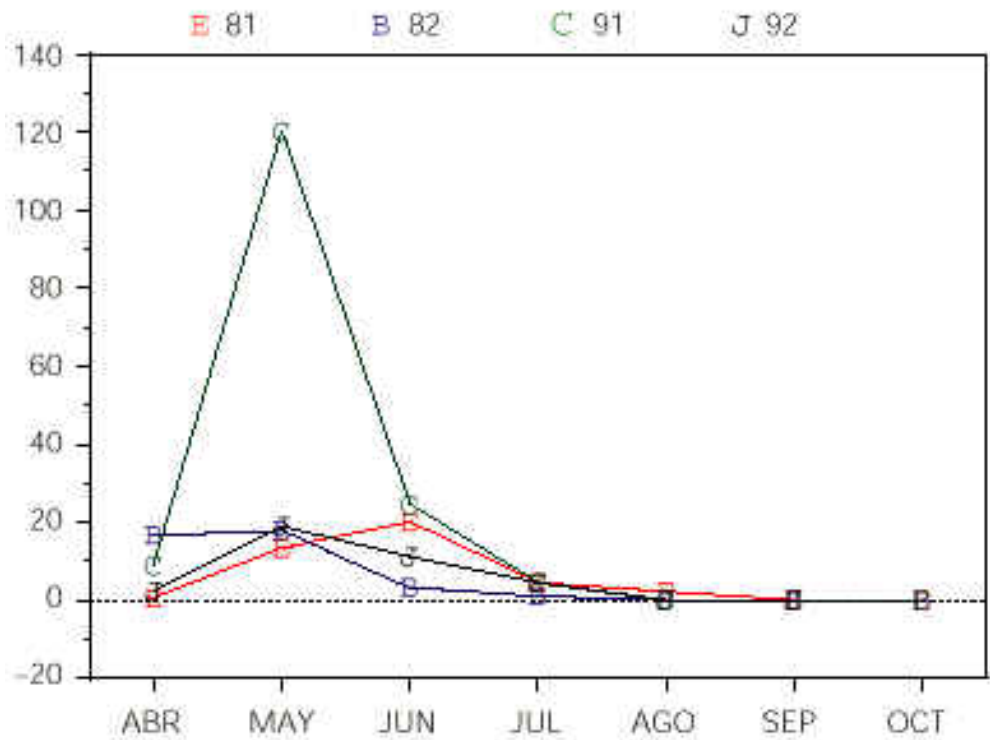


Figure 1.--Monthly *Quercus rotundifolia* (holm-oak) pollen concentration in grains/m³ of air along the four years studied.

Olea europea

In 1981, the week 4-10 June had the highest counts of olive pollen whereas in 1982 the week 21-27 May had the highest counts. During the two-year period between 1991 and 1992 the highest figures were obtained between 8 and 14 June and between 11 and 17 May, respectively.

The interannual period with the highest presence of olive pollen in Salamanca during the two two-year periods studied ranged between 11 May and 14 June (Chart 1).

The highest figures corresponded to 1991, with weekly means of up to 223 grains/m³. In 1981, the value for the week with the highest counts was seven-fold higher than that of the previous week. In 1982, the increase in the most important week was forty-fold higher than the previous week and occurred in May. However, this was followed by a drop in the counts between the end of that month and the beginning of June, after which they rose a few days later.

In 1991, the year with the highest figures, there was a high point with 87 grains/m³ from 13 to 19 April. Following this, counts dropped but then rose again several weeks later, reaching a maximum during the first days in June. In 1992, the highest counts were recorded in May with 198 grains/m³ as the weekly mean, implying an increase of 33-fold over the figure for the previous week. The other data collected over the four years as from July were fairly low and hence of little interest from the perspective of allergology.

In comparative terms for the four years analyzed, olive flowering followed a

fairly stable inter annual behaviour within fairly well defined periods of time (Fig. 2).

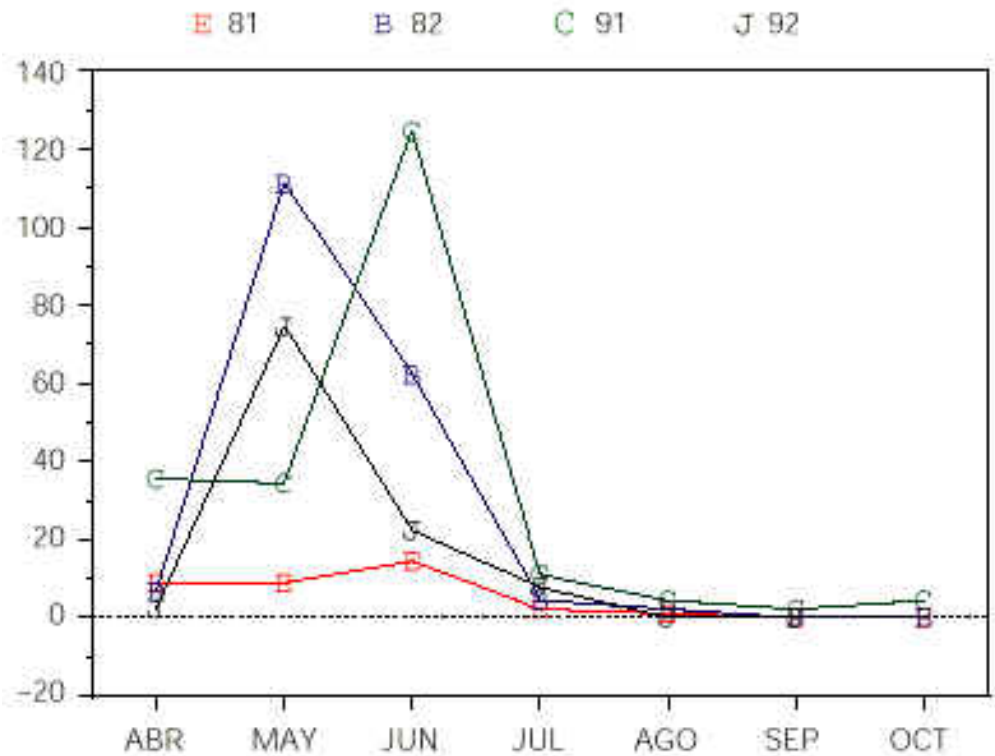


Figure 2.--Monthly *Olea europaea* (olive) pollen concentration in grains/m³ of air along the four years studied.

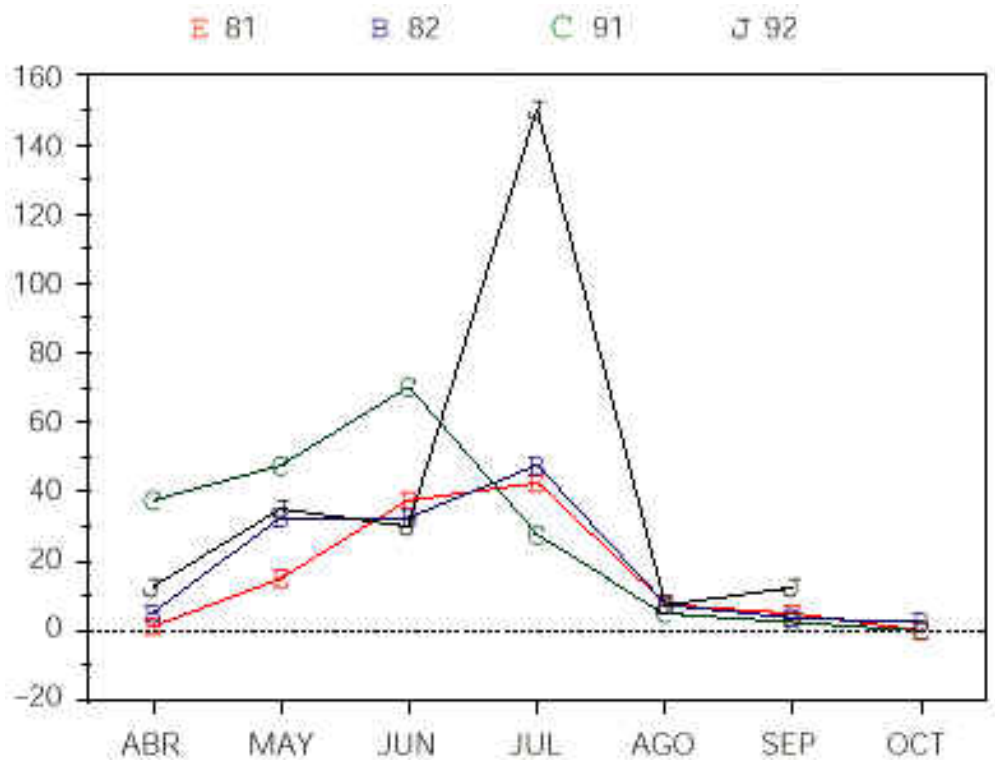


Figure 3.--Monthly *Poaceae* (grass) pollen concentration in grains/m³ of air along the four years studied.

Poaceae

Grass pollen was present uninterruptedly in Salamanca from half way through January to the end of October and was sometime found on a few days in November. The time of maximum intensity coincided in 1981 and 1982 with the week 2-8 July; in 1991 with the week 22-28 June, and in 1992 with the week 13-19 June. Accordingly, the interannual period of maximum counts in the two two-year periods studied ranged between the last week in June and the first two weeks in July. The year with the highest counts was 1992.

Along the four years studied, substantial elevations in the counts were observed in April and the end of May, respectively (Chart 1).

With the exception of the days of maximum incidence, the mean values of the counts in grain/m³ occurred between February and July, being reduced as from August. During 1981 and 1982, the period of predominant inflorescence corresponded to what is known as the "short-cycle" since elevations in the counts were sharp with respect to the days immediately before and were fairly strongly linked to an increase in summer temperatures.

For example, in 1981 the count rose from 23 grains/m³ as the weekly mean to 118 grains/m³ in just a few days, meaning that the maximum counts were five-fold higher than those recorded during the previous week. In 1982, the highest mean value was 83 grains/m³; 62% higher than that obtained the previous week. In both years, the week with the highest pollen counts was 2-8 July.

During the two-year period between 1991 and 1992, the periods of predominant inflorescence were both "short-cycle" and "long-cycle". That is, during 1991 there were two clear elevations in the counts of grass pollen in spring, with peaks between 30 March and 5 April and 25-31 May, respectively. The true maximum occurred between 22-28 June, with a weekly mean of 120 grains/m³, pointing to a sharp rise of 42% with respect to the previous week.

In 1992 the maximum weekly mean was 190 grains/m³ between 13-19 July, although this figure was reached progressively, starting from 117 and 134 grains/m³ in the previous two weeks. This year had the highest counts of all four analyzed.

Another feature observed was a descriptive phenomenon present along the four years studied. To appreciate this it was necessary to relate the grass count curves of each year to the temperature and rainfall values. The conclusion was that the peaks of maximum counts of grass pollen occur between five and six weeks after rainfall values close to or above 5 L/m².

These peaks of maximum counts also coincided with a sharp rise in temperature; close to or more than 20° C. This means that along the four years studied the three parameters (the highest pollen counts, elevations in temperature and rainfall) were always related, in good agreement with the behaviour of the vegetative cycle of certain types of grasses.

Plantago

The presence of *Plantago* pollen in the air of Salamanca was detected in the first days of March. It then disappeared but later returned in April, after which, with different fluctuations, it persisted in the air up to the end of September and a few days in October. The highest counts were found between May and June, and although some elevations were seen in July (Fig. 4) they normally fall after that time and disappeared at the end of the summer.

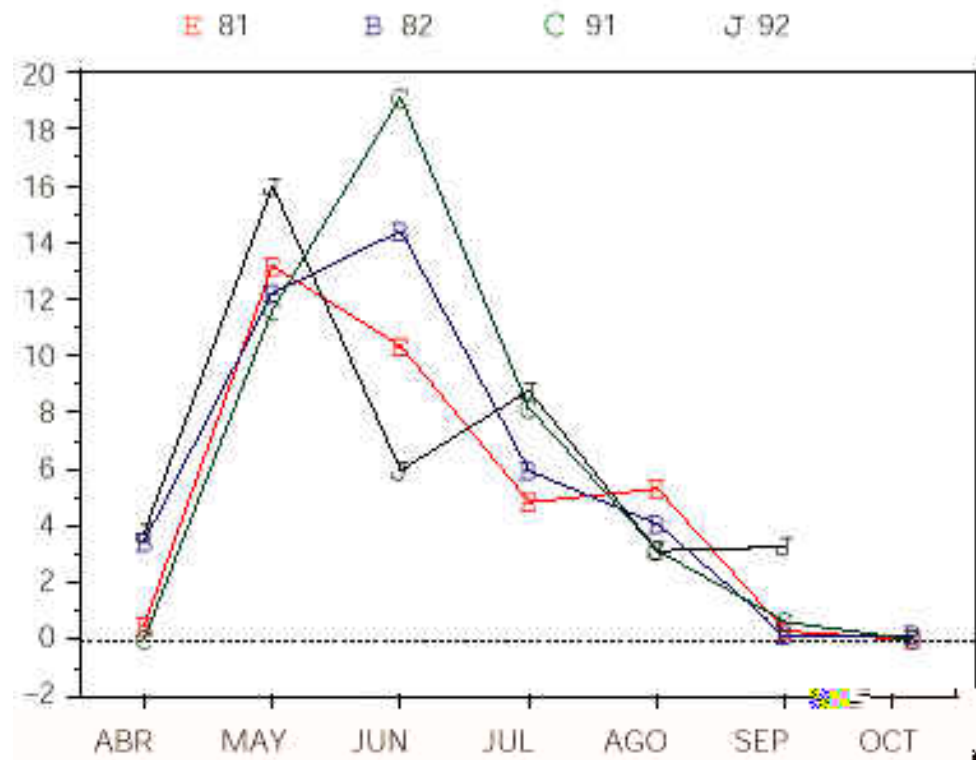


Figure 4.--Monthly *Plantago* pollen concentration in grains/m³ of air along the four years studied.

Along the period studied the highest amounts of pollen grains were collected in 1991, with 33 grains/m³ between 25-31 May. The counts for the other years analyzed evolved as follows: in 1981 the most representative week was between 28 May and 3 June, with 32 grains/m³; in 1982, it was between 18-24 June, with 27 grains/m³; finally, in 1992 it was between 11-17 May, with 31 grains/m³.

The Interannual period of highest counts along the four years analyzed ranged between 11 May and 24 June (Chart 1).

Parietaria

The weeks with the highest counts of *Parietaria* pollen were 28 May-3 June in 1981; 26 February-4 March in 1982; 25-31 May in 1991, and 29 June-5 July in 1992 (Fig. 5). This indicates that the interannual period of maximum counts along the four years studied was very broad, ranging from 26 February to 5 July (Chart 1).

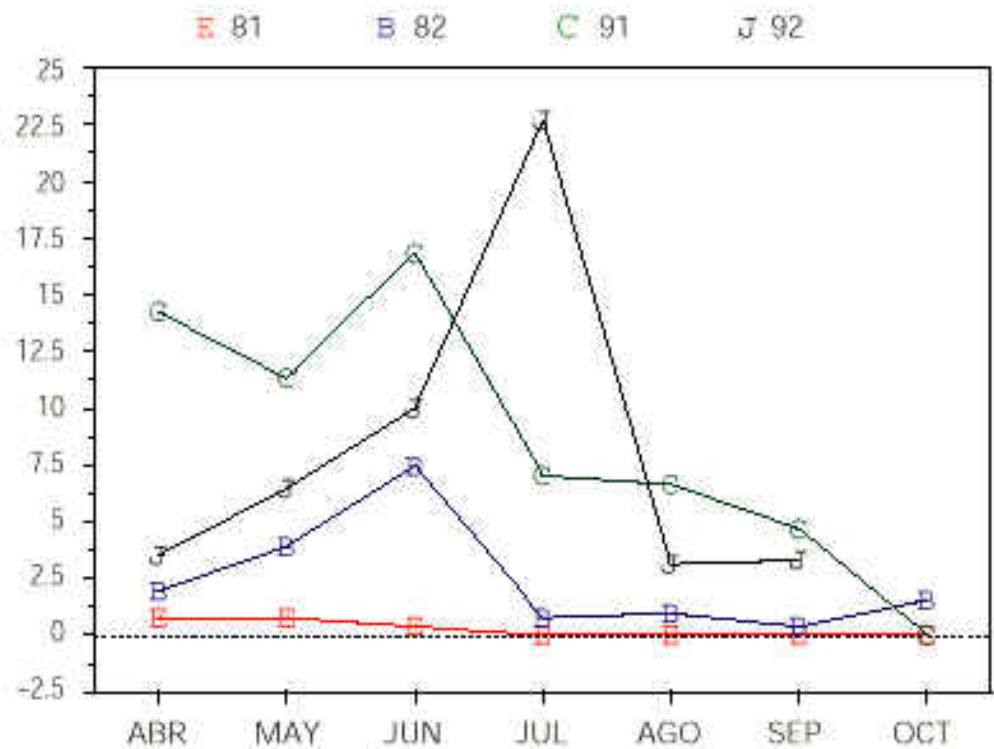


Figure 5.--Monthly *Parietaria* pollen concentration in grains/m³ of air along the four years studied.

Chenopodio-Amaranthaceae

The pollen of *Chenopodio-Amaranthaceae* was present from April to October, but increased significantly during the central months of the summer from July to September, with figures not exceeding 40 grains/m³ as the weekly mean. The allergological importance of this type of pollen in Salamanca is relative (Fig. 6).

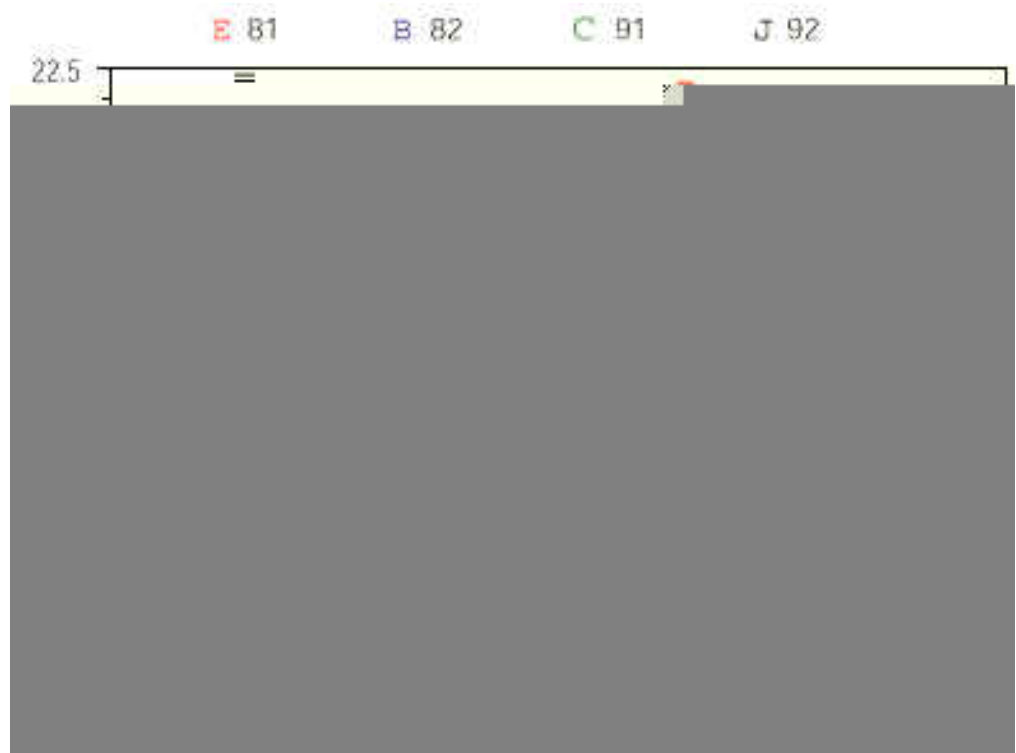


Figure 6.--Monthly *Chenopodio-Amaranthaceae* pollen concentration in grains/m³ of air along the four years studied.

Cupressaceae

The pollen from *Cupressaceae* was present from half way through January to the end of September along the four years studied, March and April being the months with the highest counts. The figures were highest in 1991 almost above 200 grains/m³ as the weekly mean in March. During the rest of the seasons studied the figures ranged between 4 and 69 grains/m³ as the weekly mean. A rise in the values was observed in the months of May in 1991-92 with respect to 81-82 (Fig. 7).

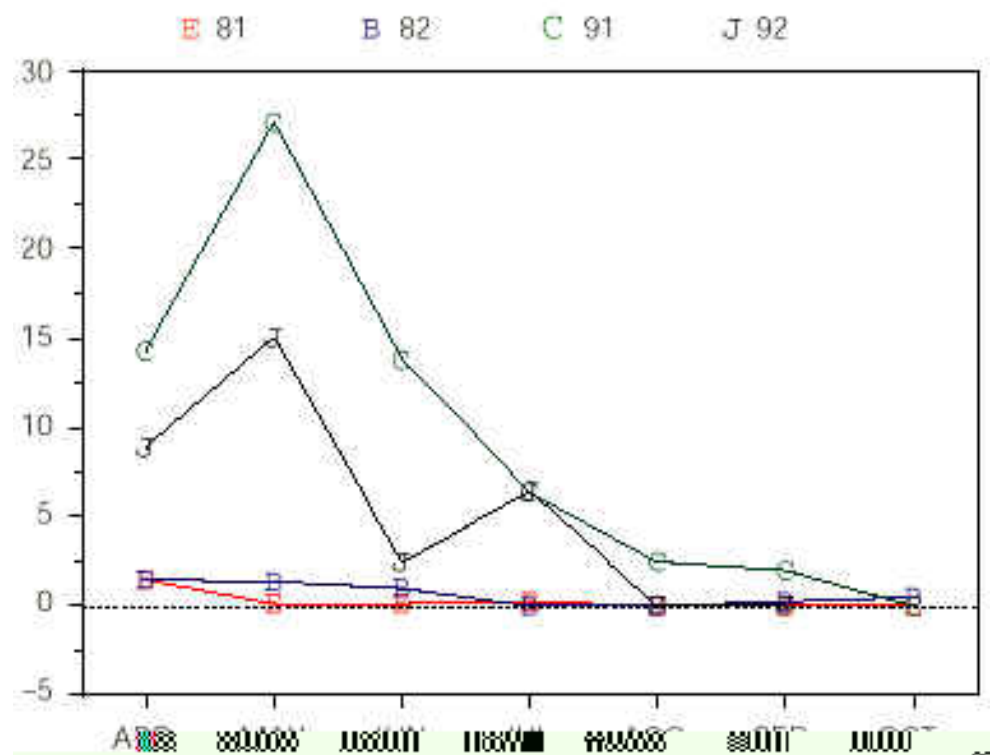


Figure 7.--Monthly *Cupressaceae* pollen concentration in grains/m³ of air along the four years studied.

Artemisia

The weekly counts of *Artemisia* pollen did not surpass 13 grains/m³ between 14-20 September, 1991. The dates on which pollen grains in suspension were detected along the four years studied covered a maximum period ranging from the end of July to the last days in September (Fig. 8).

Figure 8.--Monthly *Artemisia* pollen concentration in grains/m³ of air along the four years studied.

Betula

Along the four years studied, the presence of *Betula* pollen was detected from the end of March and beginning of April up to the middle of July. Counts were not very high, although the maximum values were centred around April and May. The year with the highest weekly mean values was 1992, with figures surpassing 25 grains/m³ (Fig. 9). The presence of alder pollen in Salamanca, was detected from January to April with 23 grains/m³ as the highest weekly mean being recorded in the week 5-11 February 1982.

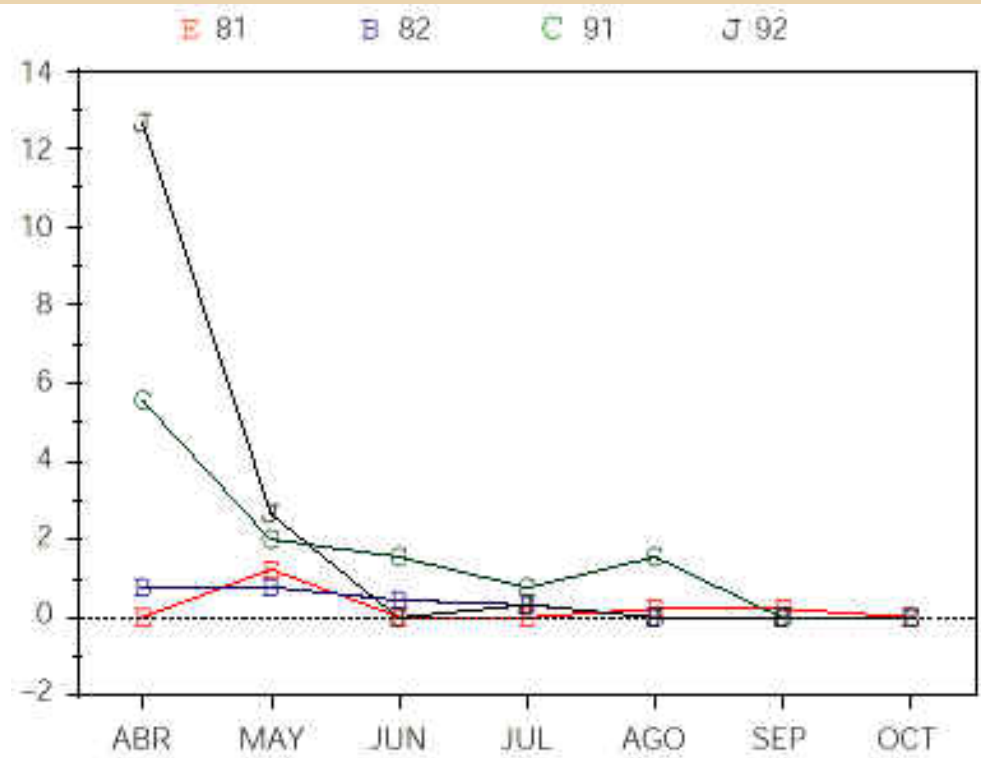


Figure 9.--Monthly *Betula* pollen concentration in grains/m³ of air along the four years studied.

Fraxinus

Fraxinus pollinates between mid February and the first days of May, especially in February and March. The highest counts were recorded during the week 2-8 March with figures reaching 18 grains/m³, thereafter decreasing significantly during April (Fig. 10).

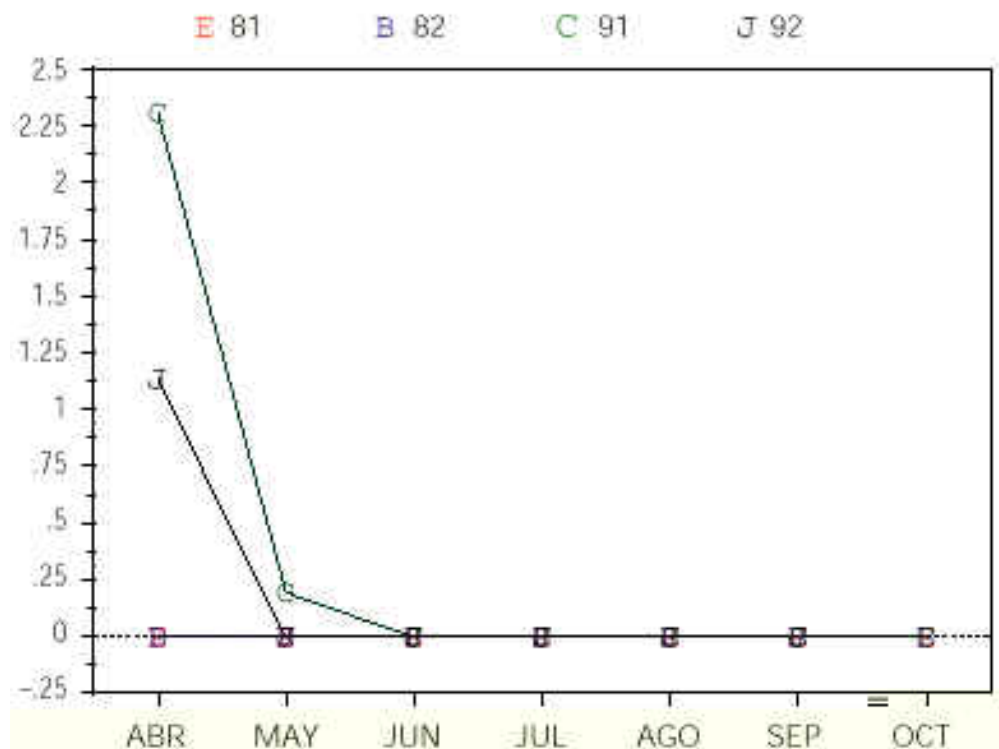


Figure 10.--Monthly *Fraxinus* pollen concentration in grains/m³ of air along

the four years studied.

Populus

Populus pollinates from the beginning of March to mid May. In 1992, weekly mean concentrations of 246 grains/m³ were attained, as happened in the week 16-22 March; in 1982, 100 grains/m³ were recorded for the week 2-8 April (Fig. 11).

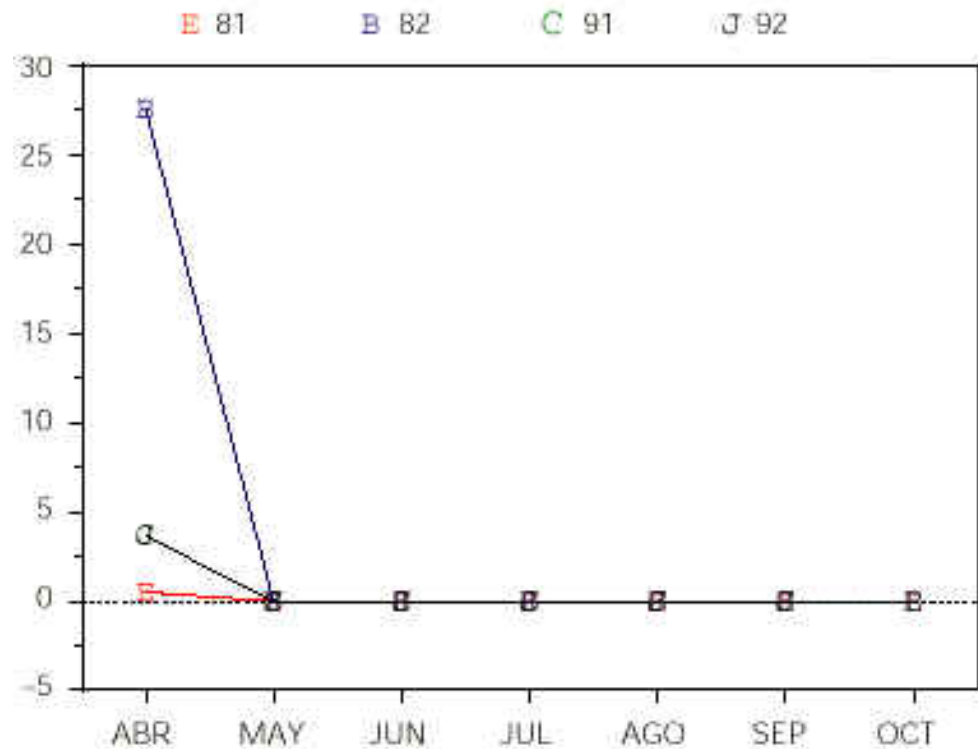


Figure 11.--Monthly *Populus* pollen concentration in grains/m³ of air along the four years studied.

Platanaceae

Platanaceae pollinate from March to May, April being the months with the highest weekly concentrations; this was reflected in the 119 grains/m³ recorded for the week 13-19 April 1992 (Fig. 12).

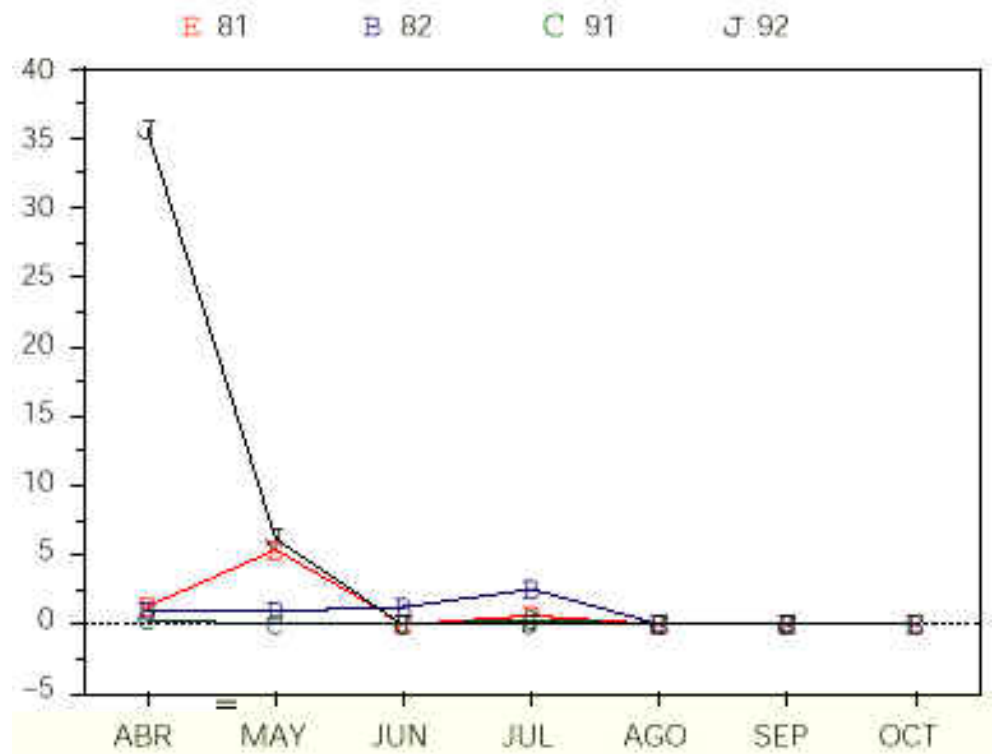


Figure 12.--Monthly *Platanus* pollen concentration in grains/m³ of air along the four years studied.

Rumex

In Salamanca, *Rumex* pollen was captured from mid-March to Mid-September, with 58 grains/m³ as the highest weekly mean being recorded in the week 25-31 May, 1991 (Fig. 13).

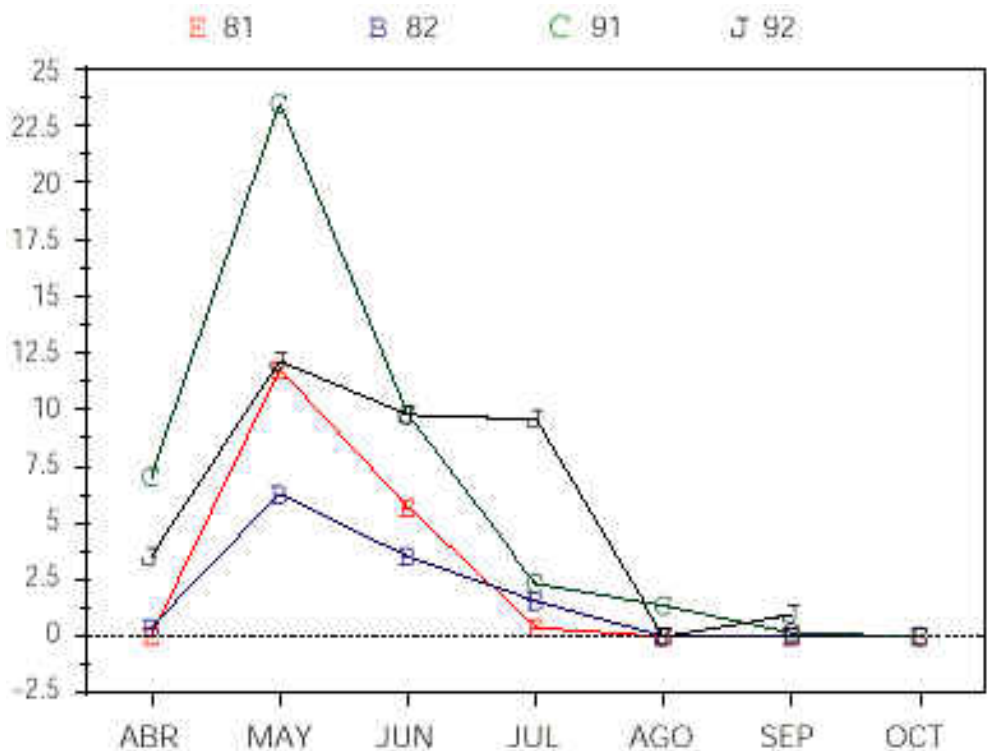


Figure 13.--Monthly *Rumex* pollen concentration in grains/m³ of air along the four years studied.

Urticaceae

The pollen of *Urtica spp.* is present in the air from mid-March to the first days in November (Chart 1) owing to their two possible flowering periods, depending on the circumstances. The highest mean counts were recorded in 1991 with 33 grains/m³ in the week 25-31 May (Fig. 14). In general the summer months had the highest counts.

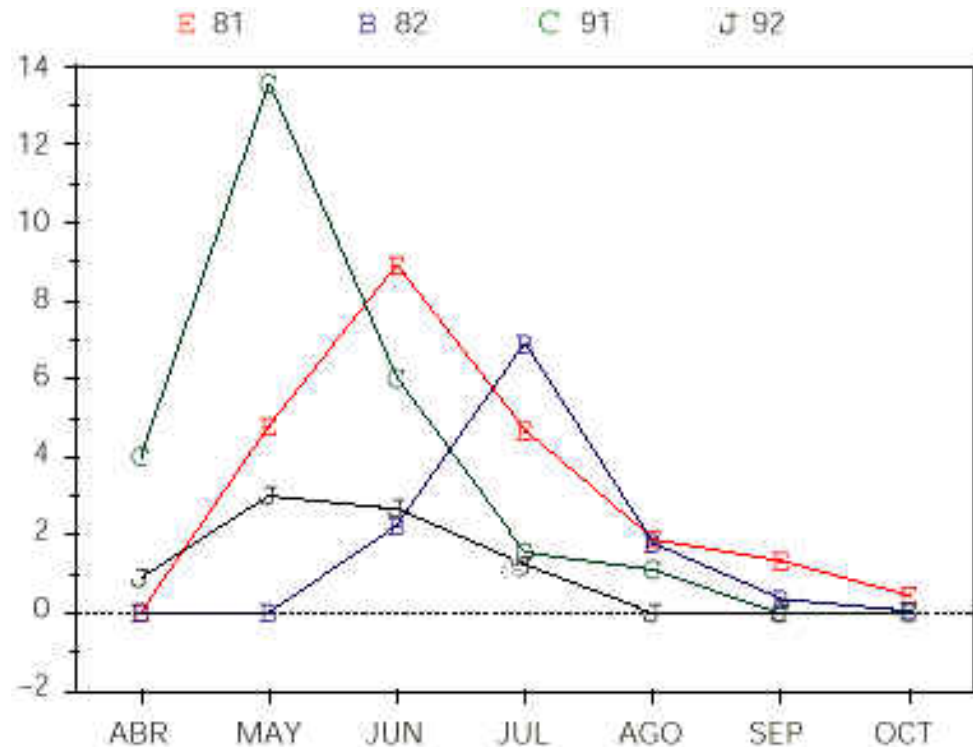


Figure 14.--Monthly *Urtica* pollen concentration in grains/m³ of air along the four years studied.

Atmospheric variables

1) Temperature

For this periods studied, annual mean temperatures were as follows: 1981, 14.5° C; 1982, 11.9° C; 1991, 16.3° C; 1992, 16.1° C. The hottest month was July and the coldest one December.

The mean annual temperature during spring, summer and the beginning of autumn was always around 15° C.

2) Relative air humidity

In general, the lowest mean weekly values coincided with the summer and the highest ones with autumn and winter. In 1981, a maximum mean weekly value of 82% was recorded in the month of December, while the minimum was 42% in June. In 1982, the highest value was again recorded in December, with 95%, and the lowest was in May, with 42%. In 1991, the

highest relative humidity was observed in March, with 70% and the lowest was recorded in July, with 42%. Finally, in 1992 the maximum value was found in spring, with 71% in April and the lowest in summer, with 43% in July.

3) Atmospheric pressure

The highest pressures along the four years studied coincided with the hottest seasons, surpassing 925 millibars from the end of May to September. As from half-way through spring to the end of the summer, mean weekly values ranged from 924 to 930 mb. The lowest pressures were recorded during the spring and autumn, with a few exceptions such as the autumn of 1981, when the values increased as from half-way through October.

4) Precipitation in the form of rainfall

Unlike central Europe, where summer is the rainiest season, in the Mediterranean area the rain mainly falls in spring and autumn.

This holds for Salamanca, despite the dryness due to the continental climate that brakes the humidifying effects of Atlantic winds.

The amounts recorded in L/m² along the four years studied never surpassed the weekly mean of 8.5 L/m². Accordingly, in absolute values all the years studied were dry, 1991 being the driest of all and 1982 having the highest rainfall figures.

5) Wind speed and direction

In general, wind speeds were weak to moderate, with values that did not surpass 25 km/h. Within these moderate values, wind speeds were faster in spring, autumn and the beginning of winter.

During the four years analyzed, the predominant wind directions were, first SW and, second, NE. Although along the years studied the winds changed direction considerably over the different weeks, it was possible to appreciate a moderate trend for them to blow from the W and SW in summer and from the NE during the spring.

COMMENTS

The results obtained over the two two-year periods reveal that the most abundant pollen species in absolute values are holm-oak, in first place, followed by olive, grasses, *Plantago* and *Parietaria*, in that order.

This order in the number of grains counted per cubic meter of air contrasts with the order that could be given to them as a function of their allergenic capacity; in this sense, grasses would occupy first place, followed by olive, which additionally is the primary allergenic tree in our area, and then *Plantago* and *Parietaria*, in that order.

Quercus rotundifolia

The family *Fagaceae* is presented by three highly characteristic genera in Europe. Owing to their abundance, its pollen grains may generate manifestations of allergic sensitization in some pollen sensitive individuals; *Fagus*, *Quercus* and *Castanea*.

These trees are very homogeneously distributed above all in the southern part of Europe (6). Within the genus *Quercus*, on the Iberian Peninsula the dominant form is *Quercus rotundifolia*, generally known as the holm-oak. Holm-oaks are found in nearly all regions of Spain and especially in Castile. Extremadura and Andalusia. Owing to their robustness, their ability to grow on mineral-depleted soils and their capacity to survive under an extreme temperature regime they may live for many years and thrive in thick sopses on the *dehesas*. They mainly flower between April and May (11). In Salamanca, holm-oak pollen was by far the most abundant type seen during the four years studied. However, although it is the most abundant, its properties are of little allergological interest.

In the city, holm-oak pollen is present in the air from March to September, beginning with discrete values and thereafter rising during April, as occurred in 1982 when the maximum counts were recorded.

Despite this, the highest values are usually recorded in May and the beginning of June. As from July, the presence of holm-oak pollen falls considerably, until it disappears in September (Chart 1).

The atmospheric conditions coinciding with the weeks with the highest counts were as follows:

- A mean temperature between 11° and 18.9° C.
- A relative air humidity between 53% and 59%.
- Precipitation in the form of rainfall not surpassing 5.2 L/m².
- An atmospheric pressure between 919 and 927 millibars.
- A wind speed between 9 and 14 km/h.
- A wind direction of SW or NE.

Olea europea

In our environment, the olive is considered to be of primary allergological importance (3) (44). In Spain as a whole, it has been calculated to be responsible for between 15 and 20% of all hypersensitivity reactions to pollen. *Oliva europea* is a rustic evergreen tree, with whoel, leathery leaves and small, generally hermaphrodite flowers. It flowers mainly in April, May

and June or before or after these months depending on the prevailing climatic conditions. Above all, its flowering depends on the climatic conditions of the previous autumn. Although its pollinization is mainly carried out by insects, the olive displays a second type of anemophilous pollination, undoubtedly due to its high production of flowers. The fact that olive cultivations are characterized by huge numbers of specimens over very large tracts of land leads to pollen concentrations far higher than those of other species, at least in our experience, with the possible exception of some Fagaceae such as the holm-oak.

Olive pollen is present in Salamanca from the beginning of March to the end of September, small amounts sometimes being found in October and November. Counts begin to rise as from April and, in particular, the weeks from mid-May to mid-June were those with the highest counts (Chart 1).

The climatic conditions associated with increases in this type of pollen along the two two-years periods studied were as follows:

- A mean temperature of between 18.3° and 20° C.
- A low relative air humidity of between 48% and 59%.
- Rainfall values between 0 and 3.6 L/m².
- Atmospheric pressure between 930 and 927 millibars.
- Wind speed between 9 and 11 km/h.
- Wind direction SW (with the exception of the week of maximum pollination in 1991, in which the winds changed direction constantly and although they did blow from the W their main component was from the NW).

The relationship between the location of the main olive fields in Spain (W. Andalusia and Jaen, La Mancha and Extremadura), the olive groves of the south of Portugal, limiting with the province of Badajoz, the olive groves of the NW quadrant of the province of Salamanca (known as the *Arribes del Duero*) and the geographic situation of the city of Salamanca explains why wind directions from the SW and NW bring about massive influxes of pollen from these areas to the city.

The pattern followed by olive pollen counts in the city of Salamanca along the four years studied reveals that even though in 1981 the weekly mean of 40 grains/m³ was not attained, in the rest of the years studied values of 200 and even 220 grains/m³ were reached; these values alone are of allergological interest.

Poaceae

In terms of allergological importance, *Poaceae* (grasses) are considered to be

the foremost cause of pollinosis in the world, especially in temperate regions, not only because of their abundance (almost 20% of the plant cover of the planer) but also owing to their ubiquity. In southern Europe, the period in which grasses flower is very long and covers almost the whole year (38). Advances or delays in the flowering of each species and the number of individual specimens doing this at the same time depend on the meteorological characteristics of each year and this has different epidemiological and clinical repercussions. From the point of view of their vegetative development, grasses can be divided into two types: "short cycle" and "long cycle" (40). The former comprise plants subjected to higher summer temperatures but favoured by a good supply of water and show a massive cycle of inflorescence over a short period of time (days or a week). Examples of these are the genera *Sorghum*, *Cynodon*, *Panicum*, etc. The second type --"long cycle"-- are adapted to temperate zones and flower mainly in spring. Examples are *Lolium*, *Dactylis*, *Phleum*, *Agrostis*, *Festuca*, etc. Despite this, there is a third group that follows an early development pattern and that includes elements whose flowering under propitious climatic conditions occurs throughout autumn and even in winter; this is the case of *Poa annua*.

The species with the greatest allergenic potential known belong to the genera *Poa*, *Lolium*, *Dactyles* and *Phleum*. The counts in southern Europe do not reach mean values above 300 grains/m³ during May.

As in the rest of Europe, in Spain grasses are the primary cause of pollinosis, accounting for between 40% and 80% of cases.

The pattern of the pollination cycles of grasses in southern Europe covers a broad period from the end of February to the end of August, peak periods ranging from the last weeks in May to the first weeks in July. In central Europe, the period of maximum pollination occurs in June. However, in the North of the continent this occurs between July and the first half of August (36).

Along the four years analyzed it was observed that the maximum pollination of grasses in Salamanca coincided with certain climatic characteristics. From the descriptive point of view, these were:

- A mean temperature between 19.9° and 25.7° C.
- A fairly low relative air humidity: between 43 and 57%.
- A somewhat elevated air pressure: between 925 and 930 millibars.
- A wind speed between 8 and 14 km/h.
- A predominantly westerly or southwesterly wind direction.

Plantago

The genus *Plantago* has 250 different species distributed throughout the temperate zones of both hemispheres. They are plants found on cultivated soils and on land subjected to human activity. Although *Plantago* pollen may be present in the air throughout almost the whole year, significant amounts are only attained in the period between the beginning of spring and autumn (36). The commonest species are *Plantago lanceolata*, *Plantago major* and *Plantago media*.

Most species flower in summer (Chart 1). Their importance as a cause of pollinosis throughout the Mediterranean area may account for up to 35% of cases, although it is not known as from which aerial pollen concentrations symptoms begin to appear. In Spain, depending on the different zones of Spanish territory, *Plantago* may occupy the third or fourth position in allergological importance as a cause of pollinosis. Its distribution is especially frequent as an element present on oligotrophic grasslands, on *dehesas*, on shrubland and on enclaves of nitrified soils. The environmental conditions of the weeks with maximum pollen counts along the four years studied coincided with the following atmospheric values:

- A weekly mean temperature of between 16.1° and 20° C.
- A relative air humidity between 45 and 65%.
- An atmospheric pressure between 924 and 930 millibars.
- A rainfall of between 0 and 5.2 L/m².
- A wind speed of between 9 and 15 km/h (This was the case in all four years analyzed, in which the wind blew from the SW, with the exception of 1991, when it had a NE direction).

Parietaria

Parietaria is a native Mediterranean plant and hence very common in regions close to the sea, especially the south of Italy, Liguria and the eastern coast of Spain. The most representative species are *P. judaica*, *P. lusitanica*, *P. mauritanica*, *P. officinalis*, *P. difusa* and *P. cretica*. The first three species are the most prevalent. *P. judaica* requires warm climates and longer insolation times to develop and is more typical of the Mediterranean coast (22). *P. officinalis* is more prevalent in mountainous areas above 1000 m.a.s.l. in the interior of the Iberian Peninsula. The plants are neutrophilous and occur on shrubland, abandoned land, and on fenced-off areas and are significantly present in urban ecosystems. They flower mainly from March to June, with a further period of flowering in autumn. Their flowering season is long and hence the presence of their pollen in the air is also seen throughout summer (Chart 1). *Parietaria* pollinates mainly under calm atmospheric conditions without wind. Owing to their small size, the pollen grains readily navigate the air currents they encounter (17). In Salamanca, *Parietaria* pollen has been observed in aerial suspension even in January, and it is detected uninterruptedly from February to almost October, coinciding at that time with

the inflorescence typical of autumn in the Mediterranean region.

The environmental conditions of the weeks with the highest counts of *Parietaria* pollen grains along the four years analyzed coincided with the following atmospheric variables:

- A weekly mean temperature of between 9.3° and 19.4° C.
- A relative air humidity of between 45% and 69%.
- An atmospheric pressure of between 924 and 933 millibars.
- Rainfall between 0 and 5.2 L/m².
- A wind speed of between 8 and 18 km/h (The wind blew from different directions although with a clear western component: SW, W, NW and NE).

Chenopodio-Amaranthaceae

These are geographically widespread wild brambles of allergological importance owing to their seasonality. The families belong to the order *Charyophyllales* and the different wild species are commonly known as white goosefoot (oidium) and amaranth.

Most of these plants flower between June and September. Owing to their abundance in certain areas they make a significant contribution to aerial spore-pollen contents (10). In the family *Chenopodiaceae* the most important genera are *Salsola*, *Chenopodium*, *Atriplex* and *Beta*. The genus *Chenopodium* encompasses up to 100 different species; among them *C. album* is outstanding in our environment.

Species such as *Salsola kali* and *S. pestifer* are important from the point of view of allergology in southern Europe and on the Mediterranean coast and the Balearic Islands in Spain. They pollinate in particular zones with few individuals that pollinate intensely and are responsible for many cases of allergic rhinitis. *Beta vulgaris* (beet) is a cultivatable species and owing to its abundant concentrations is now becoming implicated in cases of hay fever. Among the representatives of the family *Amaranthaceae*, the genus *Amaranthus*, with the species *A. retroflexus*, is important. The high degree of cross reactivity among different white goosefoots and amaranths points to the existence of common antigens (21).

Cupressaceae

The *Cupressaceae* are widely distributed throughout the world, with 16 genera and 140 species. Outstanding among the genera are *Cupressus*, *Juniperus* and *Thuja*, having species as common as cypress, sabine or sandarac, widely used as ornamental bushes for hedges and in parks and gardens. Of considerable importance in the genus *Cupressus*, owing to their abundant presence in the Mediterranean region (29), are *C. sempervivens*

(common cypress) and *C. arizonica*, or Arizona cypress, with plantations in several mountainous zones and areas in Castile.

The *Cupressaceae* pollinate from January to April, although the most representative peak centres around mid-February to mid-March. The amounts of pollen in grains/m³ of air vary considerably. Thus, while sometimes all the counts for a single week together do not surpass 300 grains/m³, on other occasions this figure may increase up to 1,500 grains/m³.

Artemisia

This plant belongs to the family *Compositae* and is known for its allergological importance. Among the most common species are *A. vulgaris*, which is abundant, and *A. velorum* and *A. annua*, the latter predominant in the south of Spain. Their presence is frequent in both urban and industrial areas and in rural zones. *Artemisia* pollinates in summer with several variations and differences in its season: *A. vulgaris* is seen in the last weeks of July and in August and the first days of September while *A. annua* and *A. velorum* flower later, between September and mid-October.

This plant pollinates more readily in the early morning hours, before air turbulence transports the pollen towards higher strata.

Betulaceae

The most representative genera throughout Europe are *Alnus*, *Betula* and *Corylus*. They pollinate early on in northern regions (13). Their allergological importance derives from the fact that they shed much pollen into the air, which is easily displaced and induces rapid allergic sensitization on entering into contact with the mucosa of susceptible subjects. Alder (*Alnus* sp.) is present not only in the north and northeast of Europe (27) but also in different climatic regions and is mainly represented by the species *A. glutinosa* and *A. incana*; i.e., black and grey alder, respectively. In Spain, alders and birch trees are found in mountainous zones and zones in the interior of the Peninsula. They pollinate early on and, in highly favourable climates, airborne pollen grains are found even towards the end of December and the beginning of January, although maximum values are observed as from February and March.

Fraxinus

The ash is a tree from the family *Oleaceae* and is one of the most representative members of that family together with live and privet (*Ligustrum* sp.). It is widely distributed throughout Spain, especially the species *F. angustifolium*, which forms coppices and inhabits meadows, river banks and mountainous areas. In the Central System, it forms thickets and is found on fenced-off, humid and fertile areas.

F. excelsior is mainly found in the north of the Peninsula, in the valleys of the Pyrenees and on the Cantabrian coast. It is a dioic plant that flowers from

February to March and sometimes even in January.

Populus

Poplars form much of the ornamental vegetation of Spanish cities and are found in parks, gardens and boulevards.

Like *Salix*, *Populus* is a genus of the family *Salicaceae*. There are different species, among which outstanding is *P. alba*, or white popular, and *P. nigra*, or black popular. These are riverside trees that may attain considerable heights. They are dioic and pollinate from the end of winter to well into spring. Their emission of pollen is usually massive and concentrated over specific dates (Chart 1), giving rise to a striking presence of pollen in cities. Contrary to popular belief they are of no importance from the allergological point of view.

Platanus

Platanus acerifolia is a representative of the *Platanaceae* and is used in many cities in Europe as a source of shade, especially in France and Spain. It is hybrid that was obtained from England in the seventeenth century from the Levant plane and the Western or Virginia plane. It flowers mainly in April, emitting high concentrations of pollen over short periods of time.

Rumex

Rumex is a genus of *Polygonaceae*, represented by *R. acetosa* and *R. acetosella*, wild plants known as sorrel and osier, respectively, which are distributed throughout almost all Europe in meadows and woods growing on acid soils (36). Under favorable circumstances, they pollinate as from March, although their main inflorescence is seen in May and August.

Urtica

Urtica is a genus of the very extensive family of the *Urticaceae*. These are widespread and are commonly known as nettles. The main species is *U. dioica*. This is found on nitrogen-rich shrubland close to buildings and flowers from June to August. Among the airborne pollens of cities (39), that of *Urtica* is frequent in summer.

RESUMEN

Comunicamos los resultados de un estudio sobre el contenido atmosférico de polen en la ciudad de Salamanca (España). Este estudio fue realizado para establecer un calendario de los pólenes para esta ciudad en que se señalan los períodos del año en que sus concentraciones alcanzan su máximo nivel a un intervalo de 10 años: 1981-82 y 1991-92. El polen se recogió en cepos de Burkhardt para esporas utilizando en el método

volumétrico de Hirst. Se obtuvieron muestras cada día que fueron utilizadas para hacer preparaciones teñidas con fucsina básica para un estudio de microscopio ocular a x 1000 aumentos. Se analizaron 946 preparaciones, correspondientes al mismo número de días distribuidos entre 150 semanas en los períodos estudiados. Se identificaron 48 tipos diferentes de granos de polen: gramíneas (*Poaceae*), *Olea europea* (olivo), *Quercus rotundifolia* (encina), otros *Quercus* spp. (*Q. pyrenaica*, *Q. suber*, *Q. faginea*, etc.), *Cupressaceae* (*Cupressus sempervivens*, *C. arizonica*, *Juniperus communis* etc.), *Plantago* (*P. lanceolata*, *P. media*, etc.), *Pinaceae* (*Pinus communis*, *Abies alba*, etc.), *Rumex* (mimbre), *Urtica dioica* (ortiga), *Parietaria* (*P. officinalis*, *P. judaica*), *Chenopodio-Amaranthaceae* (*Chenopodium* sp., *Amaranthus* sp., *Salsola kali*, etc.), *Artemisia vulgaris* (Artemisia), otros *Compositae* (*Taraxacum officinalis*, *Helianthus* sp., etc.), *Castanea sativa* (castaño), *Ligustrum* sp. (alheña), *Betula* sp. (abedul), *Alnus* sp. (aliso común), *Fraxinus* sp. (fresno), *Populus* sp. (chopo), *Salix* sp. (sauce), *Ulmus* sp. (olmo), *Platanus* sp. (plátano), *Carex* sp. (espadaña), *Erica* sp. (brezo común), *Leguminosae* o *Fabaceae*, *Papilionaceae* (*Medicago* sp.; *Cercis* sp., *Robinia* sp.)-*Cesalpinoideae* *Acacia* sp. (acacia), *Mimosoideae*: *Sophora japonica*, *Umbelliferae* (*Foeniculum* sp., *Cirsium* sp., etc.), *Centaurea* sp., *Cistus* sp. (jara), *Typha* sp. (junco), *Mirtaceae* (*Mirtus communis*), *Juglans regia* (nogal), *Galium verum*, *Filipendula* sp. (espirea), *Rosaceae* (*Pyrus* sp., *Prunus* sp., etc.), *Tilia* sp. (tilo), *Morus* sp. (mora), *Taxus baccata* (tejo), *Papaveraceae* (*Papaver rhoeas* etc.), *Labiata* (*Lavandula* sp.), *Cannabaceae* (*Humulus* sp. etc.), *Liliaceae* (*Lilium* sp.), *Echium* sp. (buglosa).

Los taxones más abundantes, de mayor concentración (gramos/m³ de aire), fueron por orden de frecuencia: encina, olivo, gramíneas, *Plantago* y *Parietaria*.

Con los datos obtenidos elaboramos un calendario de los pólenes de Salamanca que indica los períodos del año en que se encuentra cada tipo de polen, así como los períodos de mayor concentración para cada uno.

La diversidad y el espectro de los pólenes de la ciudad de Salamanca reflejan las comunidades de plantas que se encuentran en las dehesas de Castilla, lugar de emplazamiento de Salamanca. La dirección de los vientos predominantes y las características climáticas particulares de la zona condicionan las concentraciones máximas de los distintos taxones observadas. Por ejemplo, en el caso del olivo, que se cultiva a cierta distancia de la ciudad, su máxima concentración coincide con momentos de viento suroccidental. En el caso de las gramíneas, las concentraciones máximas coinciden con un aumento importante de la temperatura media, a 20° C o más, cinco o seis semanas de haber caído lluvias de 5 L/m² o más.

Palabras clave: Calendario de pólenes. Salamanca. Palinología.

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