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### Annual variation of airborne pollen in the city of Palencia, Spain, 1990-1992

Baudilio Herrero<sup>a</sup> & Carmen Fraile<sup>a</sup>

<sup>a</sup> Departamento de Ciencias Agroforestales, Universidad de Valladolid,  
Avda, Madrid 57, Palencia, E-34004, Spain

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# Annual variation of airborne pollen in the city of Palencia, Spain, 1990–92

BAUDILIO HERRERO and CARMEN FRAILE

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The aim of this work is to present the atmospheric pollen concentrations of Palencia, Spain. Data were collected for three consecutive years (1990–92). An active volumetric pollen trap, type CAP2, was used. During this time, 88 different pollen types were identified, of which 27 occurred at more than 0.15% of the total pollen recorded annually. These types formed the main pollen spectrum of this sampling station. Pollen coming from herbs (Poaceae, Chenopodiaceae, *Plantago*, Urticaceae, etc.) was predominant (53.79%); arboreal pollen (*Quercus*, *Populus*, Cupressaceae, etc.) represented 42.11%, and pollen from shrubs (Ericaceae, *Sambucus*, etc.) only 4.10%.

May and June was the time of the year with maximum pollen emission to the air. This was due to the quantities of pollen coming from Poaceae and *Quercus*, which together represent 47.25% of the pollen recorded over the three-year sampling period. Herbaceous pollen appeared throughout the year with maximum concentrations recorded in the spring, coinciding with the maximum levels of arboreal pollen in the atmosphere.

An analysis of multiple regression and one-way anova test between pollen concentrations and selected meteorological parameters show that relative humidity and average temperature are the meteorological factors most correlated with the concentrations of specific pollen types (*Plantago*, *Ligustrum*, *Sambucus*, *Carex*). In the same way, when the winds are predominantly from the northeast (second quadrant), there are higher pollen concentrations of *Sambucus*, Ericaceae and *Mercurialis*.

B. Herrero & C. Fraile, Departamento de Ciencias Agroforestales, Universidad de Valladolid, Avda. Madrid 57, E-34004 Palencia, Spain.

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Regional atmospheric pollen concentrations have relevance in several situations, including agriculture (Cour & Van Campo 1980), environmental assessment (Doskey & Uroagwu 1992) and medicine (Subiza Martín et al. 1988). This fact has aroused a greater worldwide interest in knowing the pollen content of the atmosphere of some towns or cities.

Knowledge of the local flora, be it native or introduced, enhances the probability of correctly identifying pollen grains which can affect human health. However, pollen originating from plants at some considerable distance from the sampling locality can also be detected. Transport of pollen over 300 km has been recorded, such as in the case of *Ostria carpinifolia* (Mandrioli et al. 1984).

The influence of meteorological factors varies, depending on the plant species and its phenological emission phase (Leuschner & Boehm 1982, Cambon 1983). Precipitation and temperature are the meteorological parameters which have the greatest influence on the atmospheric pollen level. The photoperiod affects the synthesis of flowering and growth regulators; these, plus mechanical processes cause the dehiscence of anthers in the early morning or late evening.

The aim of this work was to gather qualitative and quantitative data of the pollen in the atmosphere of the city of Palencia. This study expands upon the partial work done by other researchers (González Minero et al. 1993, Herrero 1994), and complements those carried out in the cities of Castilla and León (Linares López et al. 1983, Fernández González et al. 1993). The results are for the period between

1990 and 1992, and show the most representative pollen types and the evolution of their mean weekly concentrations.

## MATERIALS AND METHODS

### Area of study

Palencia is located at 42° 0' N 4° 32' W at an elevation of 743 m.a.s.l. It is situated in the south of the province of the same name, in the valley of the river Carrión between two morphostructural units: the Tierra de Campos and the limestone moors. It is in the Duero basin, in the northwest quadrant of the Iberian Peninsula.

The mean annual temperature is 11.7°C, and the area has long winters and short summers with marked thermal contrasts. The mean annual precipitation is low (351 mm), and distributed homogeneously throughout the autumn, winter and spring. The predominant winds are from the Duero basin in the southwest. The vegetation of Palencia belongs biogeographically to the supra-mediterranean stage of the Mediterranean region, Castellano-Maestrazgo-Manchega province, Castellano-Duriense area (Rivas Martínez 1987). It consists mainly of gall-oak woods (*Quercus faginea*) and holm-oak woods (*Quercus rotundifolia*), which occupy approximately 10% of the land surface around Palencia. Agricultural land makes up the other 90%, and this is used to grow extensive cereal crops, and on a small scale, sugar beet and lucerne crops.

### Methods

Pollination and pollen dispersal depend on biological, climatic and physical processes. The influence that meteorological factors have on air pollen concentrations is studied here by two statistical

analyses, multiple regression and one-way anova test. The meteorological parameters considered are: mean temperature, relative humidity, precipitation, wind speed and direction.

This study was carried out over three consecutive years, from January 1990 until December 1992. An active filtration device, a trap of pollen and spores, CAP2, (Suárez-Cervera & Seoane-Camba 1983) was used. This device consists of a filtration chamber with a vane, a 7 cm diameter filter with a 5 µm pore size. The filters were exposed in the pollen trap for 24 hours during which time 4 m<sup>3</sup> of air was filtered. Afterwards, the filters were placed on slides and prepared for light microscopic observation by using immersion oil. Three preparations were obtained daily from each filter without further manipulation. A full analysis of every filter was recorded, and the results expressed as the number of pollen per m<sup>3</sup>. The collecting device was placed 12 m above ground level on the flat roof of the building of the Agricultural Engineering School, in the southeastern part of the city.

To make the interpretation of the annual results easier we calculated the weekly means of the daily concentrations of the different pollen types and total pollen, dividing the weekly number of pollen grains by the volume of air filtered during that time. The pollen types recorded mainly coincide with those described by Valdés et al. (1987). The taxonomic limits were flexible. Therefore, the defined pollen types can include: pollen of only one species, pollen of one genus, of one family and even pollen of two families (Chenopodiaceae-Amaranthaceae).

The 27 pollen types which form the main pollen spectrum of the

sampling station as well as the pollen group and the total pollen were calculated as daily concentrations of pollen per m<sup>3</sup>.

We calculated daily and weekly concentrations for the three years sampled, daily percentages, weekly percentages per year, weekly mean percentages of the triennium, and accumulated pollen percentages. The accumulated pollen percentages were obtained by summing the daily pollen counts belonging to these types and dividing them by the total pollen collected throughout the year, to establish the principal pollen period (PPP; Nilsson & Persson 1981).

Two statistical analyses were made:

1. A multiple regression analysis in which the dependent variable was the daily concentration of each pollen type considered, total pollen, and concentration of the pollen grouped as trees, shrubs and herbs. The explanatory variables were daily values of mean temperature, precipitation, relative humidity and wind speed. The values of the variables were selected by a stepwise procedure, when all variables were in the model.
2. A one-way analysis of variance was made, where the dependent variable was the concentration of the selected pollen types, and the explanatory variable was wind direction, code 1=N to E, 2=E to S, 3=S to W, 4=W to N, and 5=calm. These codes were chosen to identify the quadrant with the daily dominant wind, direction as a percentage of the day. To establish the wind direction for each day, more than 70% of the wind frequencies must have had the same component. The confidence interval was fixed at 95% and a Duncan multiple range test among means was

Table I. The principal pollen spectrum of Palencia and the distribution of pollen types between trees, shrubs and herbs.

Percentage occurrence, principal pollen period (PPP) and time of maximum pollen emission (TMPE), during the three-year period (1990–92).

| Pollen type                  | Percentage | PPP               | TMPE           |
|------------------------------|------------|-------------------|----------------|
| <i>Acer negundo</i>          | 0.36       | midFeb-midMay     | midMarch       |
| <i>Artemisia vulgaris</i>    | 0.84       | midMay-midSep     | midJuly        |
| <i>Helianthus annuus</i>     | 0.29       | earlyJul-midAug   | earlyJuly      |
| <i>Pinus glutinosa</i>       | 2.02       | earlyJan-earlyApr | earlyMarch     |
| <i>Betula pubescens</i>      | 0.97       | midJan-earlyJun   | midApril       |
| <i>Corylus avellana</i>      | 0.55       | midNov-lateApr    | midFebruary    |
| Brassicaceae                 | 3.85       | midMar-lateJul    | midMay         |
| <i>Sambucus nigra</i>        | 0.63       | midApr-lateMay    | midMay         |
| Chenopodiaceae               | 6.2        | earlyJun-lateSep  | earlySeptember |
| Eupressaceae                 | 4.64       | midJan-midApr     | midFebruary    |
| <i>Carex</i>                 | 0.79       | earlyFeb-midAug   | midJuly        |
| Ericaceae                    | 0.95       | midJan-earlyOct   | midMay         |
| <i>Mercurialis tomentosa</i> | 0.81       | earlyApr-midSep   | midMay         |
| <i>Ononis repens</i>         | 0.88       | midMay-midAug     | earlyJune      |
| <i>Quercus</i>               | 19.45      | midApr-midMay     | earlyJune      |
| <i>Fraxinus angustifolia</i> | 1.35       | earlyJan-lateMar  | midMarch       |
| <i>Ligustrum lucidum</i>     | 0.34       | midMay-lateAug    | earlyAugust    |
| <i>Pinus</i>                 | 4.04       | lateFeb-midSep    | midMay         |
| <i>Plantago coronopus</i>    | 4.06       | midMar-midAug     | lateApril      |
| <i>Platanus hybrida</i>      | 0.31       | midFeb-lateApr    | midMarch       |
| Poaceae                      | 28.8       | lateJan-midNov    | midMay         |
| <i>Polygonum aviculare</i>   | 0.23       | earlyJun-lateAug  | earlyJune      |
| <i>Rumex conglomeratus</i>   | 2.19       | lateFeb-earlyNov  | midMay         |
| <i>Populus alba</i>          | 6.78       | earlyMar-midApr   | midMarch       |
| <i>Salix</i>                 | 1.64       | earlyApr-earlyJun | midApril       |
| <i>Ulmus minor</i>           | 0.92       | lateFeb-midMay    | midMarch       |
| Urticaceae                   | 4.01       | midJan-lateOct    | lateMarch      |
| Other pollen types           | 2.1        |                   |                |
| Arboreal pollen              | 42.11      | earlyMar-lateJun  | earlyJune      |
| Shrub pollen                 | 4.11       | earlyApr-earlyNov | lateMay        |
| Herbaceous pollen            | 53.78      | midFeb-lateOct    | earlyJune      |
| Total pollen                 | 100        | lateJan-earlyNov  | midMay         |

used when the differences among groups were significant. The statistical treatment was by means of SPSS software.

We have illustrated the eight most abundant pollen types using the weekly concentrations for each of the three years sampled. The figures also show the pollen grouped according to trees, shrubs and herbs.

The meteorological data were gathered from the Meteorological Centre of the Duero basin, at the Autilla-Palencia station, located 1 km from the airborne particle sampling station.

## RESULTS AND DISCUSSION

For the three years sampled, the average temperature was 10.6°C, the annual mean precipitation 315 mm (range=384–240 mm), and the predominant wind direction from the west.

88 pollen types were recorded, 27 of which exceeded 0.15% of the total pollen. These types defined the main pollen spectrum of Palencia city, and represented 97% of total pollen recorded. The other pollen types represented 3%.

In Table I, the 27 most representative pollen types are presented in alphabetical order by family. The airborne pollen reflects the local vegetation present in the city. The most abundant types are: Poaceae (28.80%), *Quercus* (19.45%) and *Populus alba* (6.78%).

Under-represented pollen types include: *Polygonum aviculare* (0.23%), *Helianthus annuus* (0.29%) and *Ligustrum lucidum* (0.34%).

Using the principal pollen period of the various types recorded, three groups can be established:

- Pollen with a short principal pollen period, <10 weeks. These pollen types belong to a few species with a short flowering season. The following plants are included in this group: *Helianthus annuus*, *Sambucus nigra*, *Quercus* spp., *Platanus hybrida*, *Populus alba* and *Salix* spp.
- Pollen with a medium principal pollen period, between 10 and 15 weeks. This type includes: *Acer negundo*, *Alnus glutinosa*, Cupressaceae, *Fraxinus angustifolia*, *Polygonum aviculare* and *Ulmus minor*.
- Pollen with a long pollen period, >15 weeks: *Artemisia vulgaris*, *Betula pubescens*, *Corylus avellana*, Brassicaceae, Chenopodiaceae, *Carex* spp., Ericaceae, *Mercurialis tomentosa*, *Ononis repens*, *Ligustrum lucidum*, *Pinus* spp., *Plantago coronopus*, Poaceae, *Rumex conglomeratus* and Urticaceae. The pollen curves of these taxa vary annually since the pollen types are either a family or genera compris-

ing many taxa with differing flowering seasons, or come from plants which liberate pollen intermittently and in small quantities.

Seasonal frequency per type indicates that: 19 pollen types have their maximum concentrations in spring (March–May); 5 mostly in summer and only 3 have their maximum emissions in winter.

This spring pollen explosion is such that most pollen appears during the months from March to June (Fig. 1). Maximum values are recorded in the 21st week of the year, in the middle of May. These values are twice as high as in the winter. The highest concentrations come mostly from arboreal species, coinciding with high emissions of *Quercus*

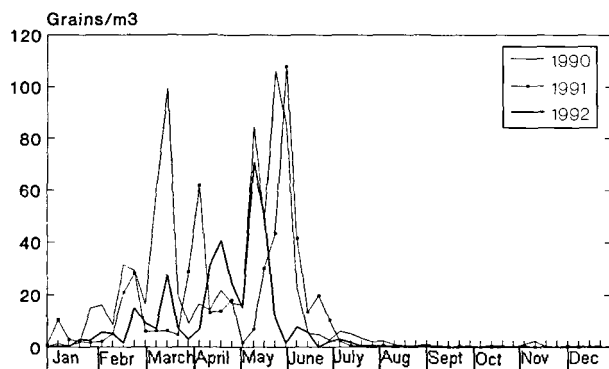


Fig. 2. Variation in weekly arboreal pollen concentrations, 1990–92.

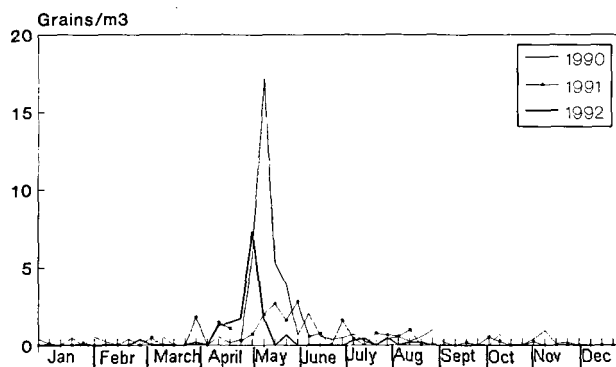


Fig. 3. Variation in weekly shrub pollen concentrations, 1990–92.

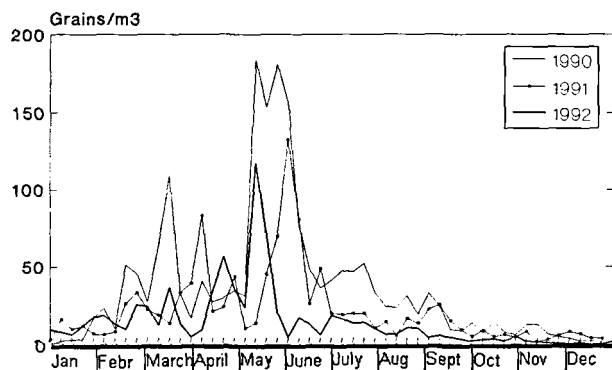


Fig. 1. Variation in weekly pollen concentrations, 1990–92.

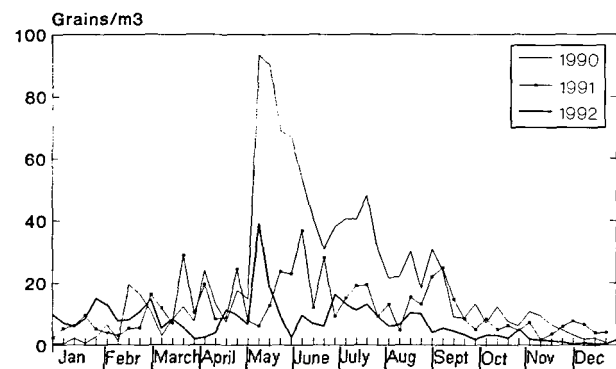


Fig. 4. Variation in weekly herbaceous pollen concentrations, 1990–92.

pollen into the atmosphere. The pollen concentration rises sharply at the end of the spring, in contrast to the spectrum of more southerly cities in the Iberian Peninsula, such as Seville (González Romano et al. 1992). These cities have high pollen concentrations from the beginning of February.

The concentrations recorded in 1990 were higher than in the other two years. This may be due to a periodicity in pollen production of certain arboreal species (Nilsson & Persson 1981, Troise et al. 1992). Poaceae and *Quercus* jointly emitted 47.25% of the total pollen recorded during the sampling period.

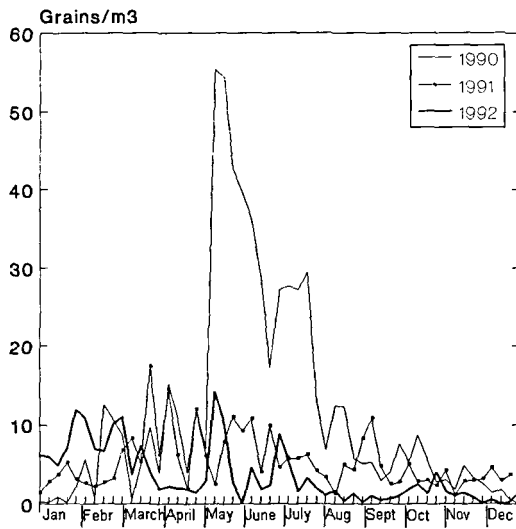
The arboreal pollen (Fig. 2) has 2 peaks of maximum weekly mean concentration, one in March due to pollen

from *Populus* and Cupressaceae and another one in May, which is the result of *Quercus* pollination. Its percentage of occurrence is lower than that of the herbaceous pollen. These figures differ from those provided by González Minero (1993) for Huelva, where the percentage of herbaceous pollen was 10% higher.

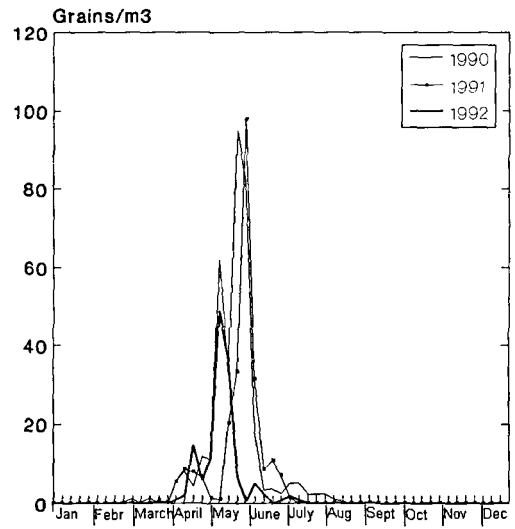
Pollen from shrub species (Fig. 3) was 4.11% of total, which is similar to the figures recorded by Belmonte (1988) in Barcelona. Maximum concentrations were recorded at the end of May, due to the flowerings of *Salix*, *Sambucus* and Ericaceae. This last pollen type (Ericaceae) appears intermittently throughout the year.

Herbaceous pollen is present throughout the year (Fig. 4).

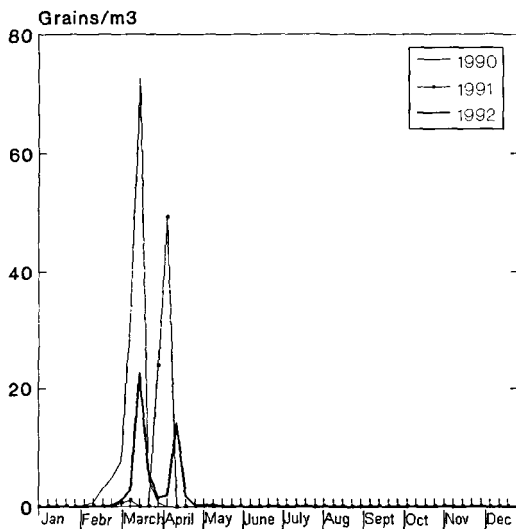
### Poaceae



### Quercus



### Populus alba



### Chenopodiaceae-Amaranthaceae

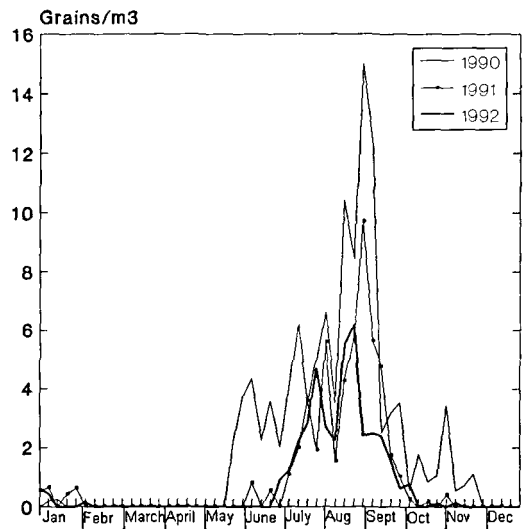


Fig. 5. Variation in weekly pollen concentrations of the following types: Poaceae, *Quercus*, *Populus alba* and Chenopodiaceae-Amaranthaceae, 1990-92.

Its maximum peak is between May and August, with a 53.78% of occurrence. The decrease in pollen concentrations during the three-year sampling period could be due to the drought suffered between 1990–92, which directly affected herbaceous plants. The dominance of herbaceous pollen over arboreal pollen is typical for inland towns. On the other hand, seaside places, such as Barcelona or Huelva, have a predominantly arboreal spectrum (Belmonte 1988, González Minero 1993).

Pollen types comprising the principal pollen spectrum are represented by 8 types, with a percentages of  $\geq 4\%$ .

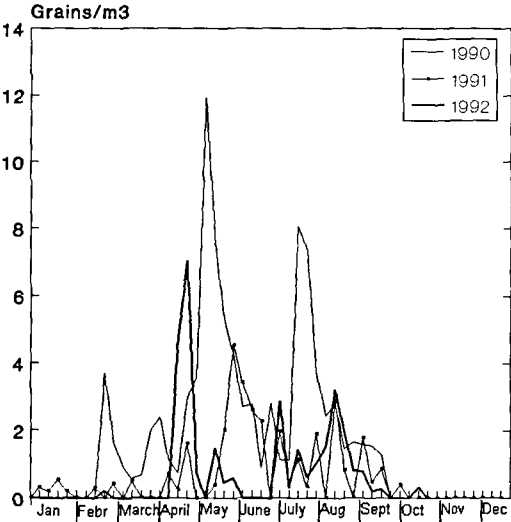
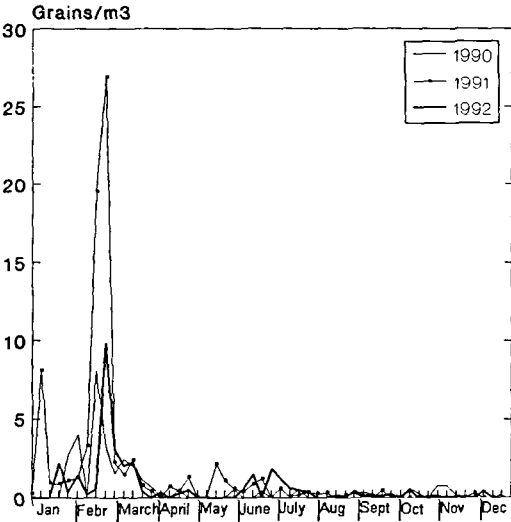
Poaceae is one of the most prominent groups, with a high

percentage (28.80%). This is due to the anemophilous character of the plants, the great number of species, and the variability in habitat. Poaceae pollen is present in the atmosphere throughout the year, reaching maximum concentrations between April and July (Fig. 5). Pollen concentration varied greatly during the sampling period, probably due to the drought (Buck & Levetin 1985). Throughout the Mediterranean, Poaceae is the most important pollen type, with its maximum peak coinciding with the harvest season of cereals.

*Quercus* is the second most important pollen type, at 19.45% of total. It is in the atmosphere between April and

Cupressaceae

*Plantago coronopus*



*Pinus*

Urticaceae

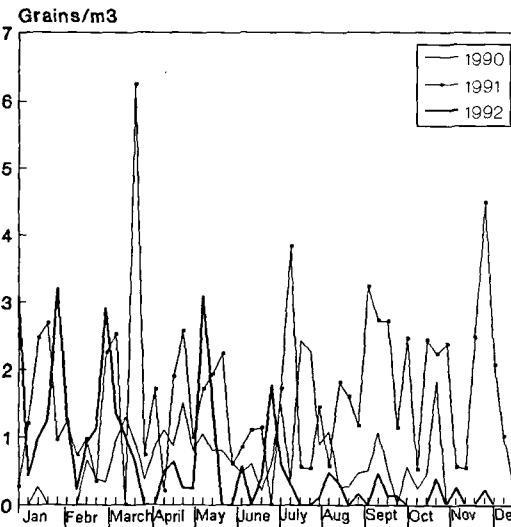
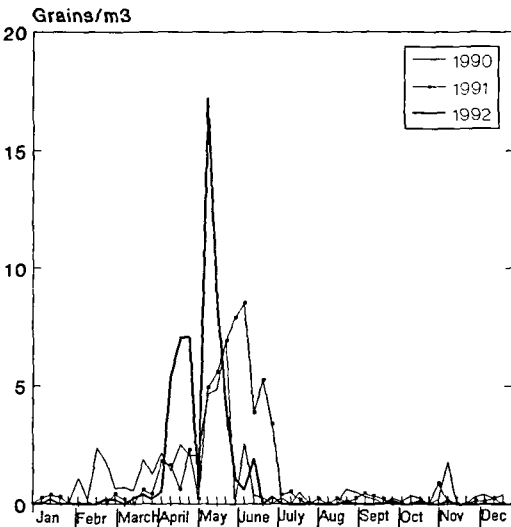


Fig. 6. Variation in weekly pollen concentrations of the following types: Cupressaceae, *Plantago coronopus*, *Pinus* and Urticaceae, 1990–92.

July, with maximum concentrations recorded in the middle of June (Fig. 5). Its flowering season appears prolonged since there are two consecutively flowering species. It is said that *Quercus* has rhythms of pollen production of 2 or 5 years (Emberlin et al. 1990, Hyde 1952), however, we cannot confirm this fact with our results.

*Populus alba* pollen appears mostly between February and April, with highest concentrations at the end of March. The actual quantity of pollen is much higher than in nearby cities such as León and Orense (Fernández González et al. 1993, Iglesias et al. 1993). This is due the extensive areas where poplars are grown on the banks of Pisuerga and Carrión rivers. *Populus* pollination is of the explosive type (emitting a great quantity of pollen in a very short time), which is the consequence of an extreme continental climate.

Chenopodiaceae is the 4th most predominant pollen type and is present throughout most of the year. Its maximum concentrations occur at the beginning of September, and reach higher levels than in the northern cities of the Iberian Peninsula, but lower than in southern regions like Almería (Belmonte & Roure 1991) or Huelva (González Minero 1993).

Fig. 6 presents data for: Cupressaceae, *Plantago coronopus*, *Pinus* and Urticaceae. Cupressaceae appears mostly between

January and March. The oscillations recorded over the three years sampled are probably due to the different taxa this pollen group includes.

*Plantago coronopus* is present in the atmosphere for a long time, at concentrations similar to those recorded in nearby cities such as Valladolid (Linares López et al. 1983).

*Pinus* is the sixth most abundant kind of pollen in the area. It flowers from April to June although refloitation extends its atmospheric presence.

Urticaceae appears in the atmosphere throughout the year, but in low concentrations. The absence of a maximum spring peak due to the flowering of *Urtica* makes us think that *Parietaria*, which has an almost continuous flowering throughout the year, is the genus most frequently recorded.

Table II contains the results of the multiple regression analysis. We have found a correlation between temperature and pollen concentration for: Chenopodiaceae, *Carex*, *Mercurialis tomentosa*, *Ligustrum lucidum*, *Plantago coronopus* and herbaceous pollen. Other researchers have observed a correlation between mean temperature and: *Platanus* and *Urtica* (Hamilton 1959) in London, with *Platanus* (Cepeda & Candau 1990) in Seville and with *Parietaria* (Mandrioli 1987) in Italy.

Precipitation was positively correlated with the concentra-

Table II. Effect of meteorological factors on pollen concentrations.

Mean T.=daily mean temperature, Prec.=daily precipitation, R. Hum.=relative humidity, Speed W.=wind speed, \*significance of  $\alpha$ ,  $P < 0.05$ .

| Pollen type                  | R <sup>2</sup> | n   | Source/t-Student<br>Mean T. | Prec.  | R. Hum. | Speed W. |
|------------------------------|----------------|-----|-----------------------------|--------|---------|----------|
| <i>Acer negundo</i>          | 0.146          | 19  | 1.188                       | -0.343 | 1.084   | 0.913    |
| <i>Artemisia vulgaris</i>    | 0.017          | 56  | 0.089                       | 0.723  | -0.356  | -0.592   |
| <i>Helianthus annuus</i>     | 0.140          | 24  | 0.229                       | -0.799 | 0.748   | 0.560    |
| <i>Ainus glutinosa</i>       | 0.066          | 91  | 0.888                       | 0.046  | 0.981   | 0.860    |
| <i>Betula pubescens</i>      | 0.107          | 44  | -0.200                      | -0.259 | -1.732  | -0.013   |
| <i>Corylus avellana</i>      | 0.030          | 36  | -0.067                      | -0.232 | -0.036  | 0.230    |
| Brassicaceae                 | 0.098          | 107 | -0.753                      | 0.547  | -3.104* | 0.241    |
| <i>Sambucus nigra</i>        | 0.339          | 22  | -0.404                      | -1.694 | 2.004*  | 0.910    |
| Chenopodiaceae               | 0.149          | 196 | 1.026*                      | -0.473 | -0.420  | -0.103   |
| Cupressaceae                 | 0.030          | 167 | -0.467                      | -0.285 | -0.996  | -0.670   |
| <i>Carex</i>                 | 0.066          | 67  | 1.909*                      | 0.179  | 0.527   | 0.516    |
| Ericaceae                    | 0.072          | 76  | 0.460                       | 2.333* | -0.099  | 0.314    |
| <i>Mercurialis tomentosa</i> | 0.068          | 60  | 1.588*                      | 0.049  | -0.350  | 0.052    |
| <i>Ononis repens</i>         | 0.053          | 52  | -1.475                      | 0.089  | -0.121  | -0.163   |
| <i>Quercus</i>               | 0.011          | 143 | -0.074                      | -0.173 | 0.530   | -0.517   |
| <i>Fraxinus angustifolia</i> | 0.296          | 44  | 0.021                       | -0.738 | -1.563  | -1.394   |
| <i>Ligustrum lucidum</i>     | 0.194          | 30  | -2.386*                     | -0.500 | -1.095  | -1.361   |
| <i>Pinus</i>                 | 0.056          | 185 | 0.257                       | 0.577  | -1.508  | 1.121    |
| <i>Plantago coronopus</i>    | 0.062          | 183 | 2.322*                      | 1.625  | 0.931   | -1.781   |
| <i>Platanus hybrida</i>      | 0.225          | 27  | -0.369                      | -0.188 | -1.618  | -0.121   |
| Poaceae                      | 0.056          | 536 | -0.191                      | 1.152  | -1.766  | -1.366   |
| <i>Polygonum aviculare</i>   | 0.025          | 23  | 0.122                       | -0.469 | 0.545   | 0.254    |
| <i>Rumex conglomeratus</i>   | 0.064          | 161 | 0.721                       | 1.482  | -1.826  | -0.268   |
| <i>Populus alba</i>          | 0.070          | 58  | 0.963                       | -0.454 | -0.090  | 0.021    |
| <i>Salix</i>                 | 0.048          | 40  | -0.281                      | -1.295 | 0.653   | -0.648   |
| <i>Ulmus minor</i>           | 0.117          | 33  | -0.305                      | -0.119 | -1.286  | -1.265   |
| Urticaceae                   | 0.021          | 260 | -1.394                      | 0.181  | -1.868  | 1.152    |
| Arboreal pollen              | 0.015          | 378 | 0.478                       | 0.236  | -0.976  | 0.500    |
| Shrub pollen                 | 0.015          | 121 | -0.419                      | 0.633  | 0.046   | -0.750   |
| Herbaceous pollen            | 0.126          | 587 | 0.071*                      | 0.924  | -2.840* | -0.862   |
| Total pollen                 | 0.055          | 594 | 0.672                       | 0.728  | -2.278* | 0.148    |

tions of Ericaceae, in such a way that higher precipitation increases the concentration of this pollen type. According to Suárez-Cervera & Seoane-Camba (1983), rainfall produces an increase in pollen concentration immediately after the rain starts. Later the pollen concentration decreases.

Relative humidity was negatively correlated with concentrations of total pollen, herbaceous pollen and Brassicaceae pollen, and positively correlated with *Sambucus*. A negative correlation with total pollen has also been observed by Hamilton (1959) and Leuschner & Boehm (1982).

No correlation was found between wind speed and daily pollen concentration. Defining the relationship with wind is complex and wind speed and the degree of turbulences need to be considered.

Table III shows the values calculated by means of analyses of variance between pollen concentrations and wind direction, and Table IV represents the significant results of Duncan's test. We found differences between the pollen concentrations and the predominant wind directions. The concentrations of herbaceous pollen and Poaceae are higher if the wind blows from the northeast rather than the southwest, the latter being associated with lower concentrations of these pollen types. When the winds come mostly from the southeast quadrant, higher concentrations of *Sambucus nigra*, Ericaceae, *Mercurialis tomentosa*, *Pinus* and shrub pollen are

expected. Winds coming from the southwest transport greater quantities of *Betula pubescens* and *Ulmus minor* pollen than those blowing from the northeast and southeast. In the same way, the northwest is associated with high concentrations of *Betula pubescens*. These data correspond with the location of these vegetation types, and can be used to locate focal areas which emit allergenic pollen.

CONCLUSION

The three year study in Palencia shows that pollen from Poaceae, *Quercus* and *Populus alba* were the most abundant, comprising more than 55% of the total studied. These pollen together with another 24 types form the main pollen spectrum.

*Quercus* and *Populus alba* have a short period of pollination, <10 weeks, although they produce great quantities of pollen. *Quercus* pollination mostly occurs between May and June.

*Populus alba* pollen is registered earlier, between February and April. Its predominant presence in Palencia is due to the extensive areas where poplars are grown.

Poaceae pollen is present throughout the year, being the most frequent pollen type. This is in agreement with other studies carried out in some northern cities of the Iberian Peninsula.

By means of multiple regression analysis, we observed that

Table III. One-way analysis of variance for pollen concentrations versus wind direction.

\*significance of  $\alpha$ ,  $P < 0.05$  (D.F. = degrees of freedom, S.S. = Sum of squares, M.S. = Mean squares, F = F Ratio).

| Pollen type                  | Source         | D.F. | Error | S.S.     | M.S.     | F      |
|------------------------------|----------------|------|-------|----------|----------|--------|
| <i>Acer negundo</i>          | Wind direction | 4    | 20    | 3.083    | 0.770    | 0.304  |
| <i>Artemisia vulgaris</i>    | Wind direction | 3    | 58    | 3.734    | 1.244    | 0.796  |
| <i>Helianthus annuus</i>     | Wind direction | 3    | 26    | 1.916    | 0.638    | 0.961  |
| <i>Alnus glutinosa</i>       | Wind direction | 4    | 92    | 77.233   | 19.308   | 1.302  |
| <i>Betula pubescens</i>      | Wind direction | 4    | 45    | 63.814   | 15.953   | 3.248* |
| <i>Corylus avellana</i>      | Wind direction | 4    | 37    | 5.773    | 1.443    | 0.732  |
| Brassicaceae                 | Wind direction | 4    | 108   | 257.261  | 64.315   | 0.768  |
| <i>Sambucus nigra</i>        | Wind direction | 4    | 23    | 49.334   | 12.333   | 2.177* |
| Chenopodiaceae               | Wind direction | 4    | 197   | 84.448   | 21.112   | 1.353  |
| Cupressaceae                 | Wind direction | 4    | 167   | 448.687  | 112.171  | 0.980  |
| <i>Carex</i>                 | Wind direction | 4    | 68    | 8.971    | 2.242    | 1.080  |
| Ericaceae                    | Wind direction | 4    | 77    | 24.538   | 6.134    | 3.093* |
| <i>Mercurialis tomentosa</i> | Wind direction | 4    | 61    | 28.850   | 7.212    | 3.416* |
| <i>Ononis repens</i>         | Wind direction | 4    | 53    | 2.305    | 0.576    | 0.157  |
| <i>Quercus</i>               | Wind direction | 4    | 144   | 2297.147 | 749.286  | 0.853  |
| <i>Fraxinus angustifolia</i> | Wind direction | 4    | 45    | 115.658  | 28.914   | 0.780  |
| <i>Ligustrum lucidum</i>     | Wind direction | 4    | 31    | 2.681    | 0.670    | 1.192  |
| <i>Pinus</i>                 | Wind direction | 4    | 186   | 128.442  | 32.110   | 1.563* |
| <i>Plantago coronopus</i>    | Wind direction | 4    | 184   | 48.695   | 12.173   | 1.370* |
| <i>Platanus hybrida</i>      | Wind direction | 3    | 30    | 1.578    | 0.526    | 1.631  |
| Poaceae                      | Wind direction | 4    | 536   | 732.355  | 183.088  | 1.730* |
| <i>Polygonum aviculare</i>   | Wind direction | 4    | 24    | 1.353    | 0.338    | 0.570  |
| <i>Rumex conglomeratus</i>   | Wind direction | 4    | 162   | 11.120   | 2.780    | 1.454  |
| <i>Populus alba</i>          | Wind direction | 3    | 60    | 1165.894 | 388.631  | 0.521  |
| <i>Salix</i>                 | Wind direction | 4    | 41    | 180.466  | 45.116   | 0.850  |
| <i>Ulmus minor</i>           | Wind direction | 4    | 34    | 91.205   | 22.801   | 3.528* |
| Urticaceae                   | Wind direction | 4    | 261   | 11.903   | 2.975    | 0.951  |
| Arboreal pollen              | Wind direction | 4    | 378   | 963.637  | 240.909  | 0.297  |
| Shrub pollen                 | Wind direction | 4    | 122   | 269.469  | 67.367   | 6.970* |
| Herbaceous pollen            | Wind direction | 4    | 587   | 3452.082 | 863.020  | 3075*  |
| Total pollen                 | Wind direction | 4    | 594   | 6487.702 | 1621.925 | 1.205  |

Table IV. Significant results of Duncan's multiple range test for mean values of pollen concentrations.

| Pollen type/Quadrant         | NE     | SE          | SW   | NW | CALM |
|------------------------------|--------|-------------|------|----|------|
| <i>Betula pubescens</i>      | SW, NW | NW          |      | NW |      |
| <i>Sambucus nigra</i>        | SE     |             | SE   |    |      |
| Ericaceae                    | SE     |             | SE   |    | SE   |
| <i>Mercurialis tomentosa</i> | SE     |             | SE   |    |      |
| <i>Pinus</i>                 |        | SE          |      |    |      |
| <i>Plantago coronopus</i>    | CALM   | CALM        | CALM |    |      |
| Poaceae                      |        | NE          |      |    |      |
| <i>Ulmus minor</i>           | SW     | SW          |      |    |      |
| Shrub pollen                 | SE     |             | SE   | SE | SE   |
| Herbaceous pollen            |        | NE,<br>CALM | CALM |    |      |

mean temperature and relative humidity had a greater influence on the concentration of specified pollen types.

At the same time Duncan's test showed that wind directions significantly determine the concentration level of some pollen types, especially those of *Betula pubescens*, *Mercurialis annua* and *Ulmus minor*.

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