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# Aerobiological survey of *Alnus* pollen in Ourense (N.W. Iberian Peninsula), 1993–2000

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*Alnus* pollen is one of the major components of the aeropalynological spectra during winters in Ourense, with maximum values registered in January and February. This work analyses the intra- and interannual variations within the period 1993–2000, when a volumetric Hirst spore-trap (LANZONI VPPS 2000) was in continuous operation. Statistically significant differences between periods 1996/97 (with a few rainy days), 1998/99, and all the others were observed. The relationships between atmosphere pollen content and the most important meteorological parameters within the same period were studied by means of correlation analysis. Temperature was the most important factor explaining the presence of *Alnus* pollen in the air. A Scheffe's test was carried out before the correlation analysis to establish years corresponding to the same statistical population. The results obtained from both tests were used for a regression analysis to establish the prediction patterns for this taxon. Even when a negative correlation coefficient was presented, the influence of this parameter did not decline. Previous temperatures in the main pollination period, however, were a determinant factor predicting the onset and intensity of *Alnus* flowering.

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*Alnus glutinosa* is a common riverside tree in Galicia, Spain. Its airborne concentrations in the atmosphere at Ourense are significant enough to produce pollinosis symptoms. *Alnus* pollen is the main aeroallergen in winter in this area, with 13% of the allergenic population presenting positive to a skin test (Arenas et al. 1996). Ourense is the Galician city where the highest values of this pollen type are collected, owing to its biogeographical situation close to the border between the Mediterranean and Eurosiberian regions.

Authors who have quoted the allergenic potential of *Alnus* pollen include Ekeboom et al. (1996), Hjelmroos (1991) and Norris-Hill & Emberlin (1991). The specific IgE for this pollen type was isolated by Ruffin et al. (1988). This taxon is one of the main causes of allergological diseases in north European countries (Spieksma et al. 1991, 1995) and has therefore been the focus of numerous studies attempting to establish its seasonal and diurnal behaviour (Spieksma et al. 1989, Atkinson & Larsson 1990, Galán et al. 1991, Norris-Hill & Emberlin 1991, Alba 1997). Moreover, correlations between different meteorological parameters and airborne pollen concentrations have been found by Goldberg et al. (1988), Driessen et al. (1989), Spieksma et al. (1989), Caramiello et al. (1990), Frenguelli et al. (1991), Frenguelli & Bricchi (1998) and Larsson (1993). The present study was carried out with the aim of establishing forecast models predicting onset and severity of the pollen season.

## MATERIALS AND METHODS

Ourense is situated in northwest Spain (Fig. 1), where the climate is oceanic with a strong Mediterranean influence. The mean annual

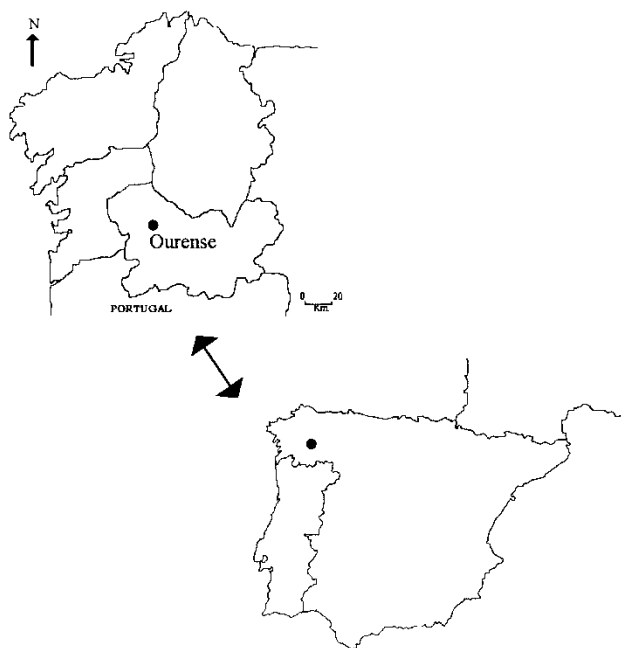


Fig. 1. Location of the study area.

temperature is 14°C, the average maximum temperature 18.9°C and the average minimum temperature 9.2°C. Annual rainfall reaches 772 mm, with an irregular distribution throughout the year and only 29 mm collected in summer (Carballeira et al. 1983).

Ourense lies in a depress area, 130 m above sea level, served by the Loña, Barbaña and Miño rivers (Nespereira 1982). The area

is surrounded by hills reaching 400 m above sea level. The geographical situation is 42°21'N and 7°51'W.

From a biogeographical point of view, Ourense is located at the confluence of the Eurosiberian and Mediterranean regions (Izco 1988). The predominant natural vegetation consists of oak (*Quercus robur*) intermixed with *Q. pyrenaica* and *Q. suber* in the lowest areas or with *Betula alba* in the highest areas. Forest fires and inadequate management of the forest have greatly decreased wooded areas, and bushes of *Cytisus*, *Ulex*, *Adenocarpus*, Ericaceae, etc., have replaced the trees. *Alnus glutinosa* and different species of *Salix* and *Fraxinus angustifolia* can also be found. The main cultivated crops are potatoes, cereals, corn and barley, turnips and grapes.

During the study period, a Hirst-spore trap (Lanzoni VPPS 2000) was operating at about 25 m above ground level on the roof of the Cristal-Piñor Hospital, which is located in a semi-urban part of the city. The *Alnus* pollen was monitored continuously from 1 January 1993 to 31 December 2000.

The methodology used for sampling and processing the aerobiological data was that proposed by the Spanish Aerobiology Network (R.E.A; Domínguez et al. 1991). Delimitation of the main pollination period was fixed at 95% of the annual period (Andersen 1991). The meteorological data were obtained from the Area Meteorological Service of Ourense, just 20 m in front of the sampling point.

STATISTICA V4.5 was used for statistical processing of the data. Before computing any statistical analysis, the normal distribution of the data set was tested. The results revealed abnormal distributions in a large number of cases. In carrying out the different analyses of the pollen count, we calculated Napierian logarithms, and added a unit to the original value, i.e.  $\ln(x+1)$ , to avoid the problems caused by null values. The modified variable was then tested using the Kruskal-Wallis test and could be adjusted to a normal distribution. An ANOVA test was done to establish the differences among the different years of sampling. Afterwards, a

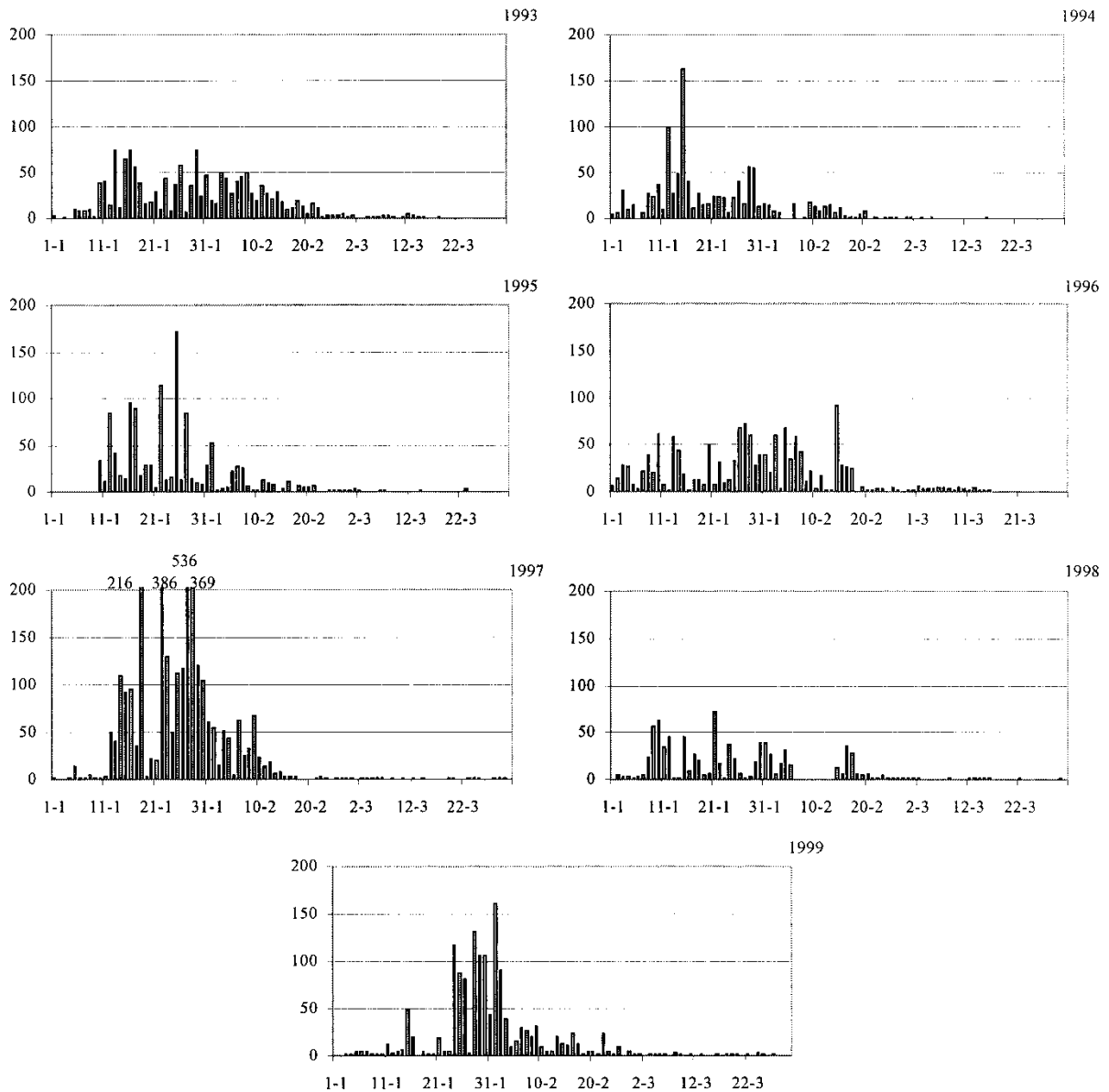


Fig. 2. Annual variation of *Alnus* pollen release. The X-axis represents the daily dates and the Y-axis the concentration reached (expressed in pollen grains/m<sup>2</sup>).

Pearson correlation analysis was carried out to establish the relationship between the different meteorological parameters and the pollen concentration in the previous 7 days. A linear regression analysis was also carried out with the years belonging to the same statistical population and with the most significant parameters.

*Alnus*, along with a great number of other arboreal species in warm regions, falls into dormancy when darkness prevails over the photoperiod, that is, at the end of summer. These trees have to undergo a cold period in winter that, in our case, takes place in the last weeks of autumn and in the coldest days of the year. From this moment on they begin to accumulate temperatures over a threshold value, and flower when they reach the required total. A similar model (Frenguelli et al. 1991) was based on the existence of a chilling period, and in the case of Italy 9°C was established as the threshold temperature, not just for the chilling period but also as the beginning for heat accumulation.

For our region we have varied the temperature threshold slightly, establishing it at 10°C for the cold period. When this period ends and temperatures are higher, an increasing heat accumulation effect takes place until a critical point is reached, which establishes the beginning of the main pollination period.

## RESULTS

*Alnus* pollen appears in the atmosphere around Ourense in December, and is therefore the first pollen type to be collected. It remains present until the end of March or the beginning of April, but reaches its highest daily values in the second half of January, except in 1996, when it was delayed until 14 February, although there was a previous period of high airborne concentrations when values around 70 p/m<sup>3</sup> were reached, representing secondary peaks. The highest values oscillated between 75 p/m<sup>3</sup> in the first year of the study and 534 p/m<sup>3</sup> on 27 January 1997. It was observed that the highest concentrations coincided with the warm days, low relative humidity, lots of sunshine hours and no rain (Figs. 2 & 3).

Despite the interannual variations registered in every year of the study, important amounts of *Alnus* pollen were collected, representing percentages of total annual pollen counts of up to 15% in 1997, although this averaged about 5% in other years. The highest absolute amount of *Alnus* pollen was also collected in 1997 a much higher value than in the remaining years. This was due to the special conditions of this year; the few rainy days during the main pollination period had a powerful influence on the concentrations of *Alnus* pollen in the air.

There were also variations in the length and intensity of the main pollination period. In the 1992/93, 1995/96, 1998–99 and 1999–2000 periods, length was 62, 64, 63 and 61 days, respectively, compared to the 49, 41 and 47 days registered in the 1993/94, 1995/96 and 1997/98 periods. The shortest pollination period was recorded in 1996/97, with a main pollination period of only 38 days (Table I).

## Statistical analysis

The ANOVA results indicate that there were significant differences between years ( $F = 6.0676$ ,  $p < 0.0000$ ). A Scheffe's test showed significant differences between the 1996/97, 1998–99 periods and the remaining pollen seasons (Table II).

## Correlation analyses

The Pearson correlation coefficients between *Alnus* pollen and meteorological parameters were calculated, but the values obtained were not consistent along the different years of the study. The average temperature was the parameter reflecting the highest number of significant results (Table III). When a single analysis, using all the different years at the same time, was computed, significant positive values (at 95% and 99%) with relative humidity and negative significant values with maximum, mean or minimum temperatures and sunshine hours were found. It must be borne in mind that the 1996–97 and 1998–99 periods were not taken into account in this last correlation analysis, because, as we saw in the ANOVA analysis, it belonged to a statistically different group, and this caused major discrepancies in the results.

However, on studying each year separately we obtain significant values with maximum, mean and minimum temperatures during the periods 1992/93, 1993/94 and 1997/98, having the last one negative value. During the 1995/96 period, with mean and minimum temperature and with the maximum temperature in 1996/97, significant results were obtained.

Relative humidity is only significant during 1994/95 and 1996/97, so although temperature is the most significant parameter along the different periods, the sign of the correlation coefficient is different during certain periods.

Precipitation has an important effect on atmospheric cleaning, and pollen grains are not exempt; however, no significant results were obtained for the correlation coefficients. In this way, we can see that during some years when we collected large amounts of pollen, such as 1996–97, only 88 mm of precipitation was registered. On the other hand, during 1993–94 only 1089 pollen grains were collected, and the level of precipitation was around 224 mm. But the distribution of rain is not regular during the *Alnus* pollination period, and parameters such as rain intensity and duration are important and difficult to consider. This could be the reason why the rainfall does not have a major effect on *Alnus* pollen dispersion. The highest values of rainfall do not coincide with the lowest pollen values, since significant rainfall can be registered at night, when pollen concentrations are low, and cannot produce the aforementioned effect.

On the other hand, the 1997–98 period registered a low level of rainfall, and the amount of pollen collected was also low, probably due to the minor pollen production during this year or to the influence parameters not tested in this work.

In this work, we analysed the relationship of meteorology with the previous day's concentrations. Correlation coefficient values were always significant between the pollen concentration and the previous day values, except in 1994–95, while in the case of the two previous days' concentration, the 1992–93, 1995–96, 1996–97 season values were significant. From this moment on, the coefficient value was lower, except in 1992–93 and 1998–99. This influential parameter is important if we analyse the post-peak period, when pollen production is less, because it is the

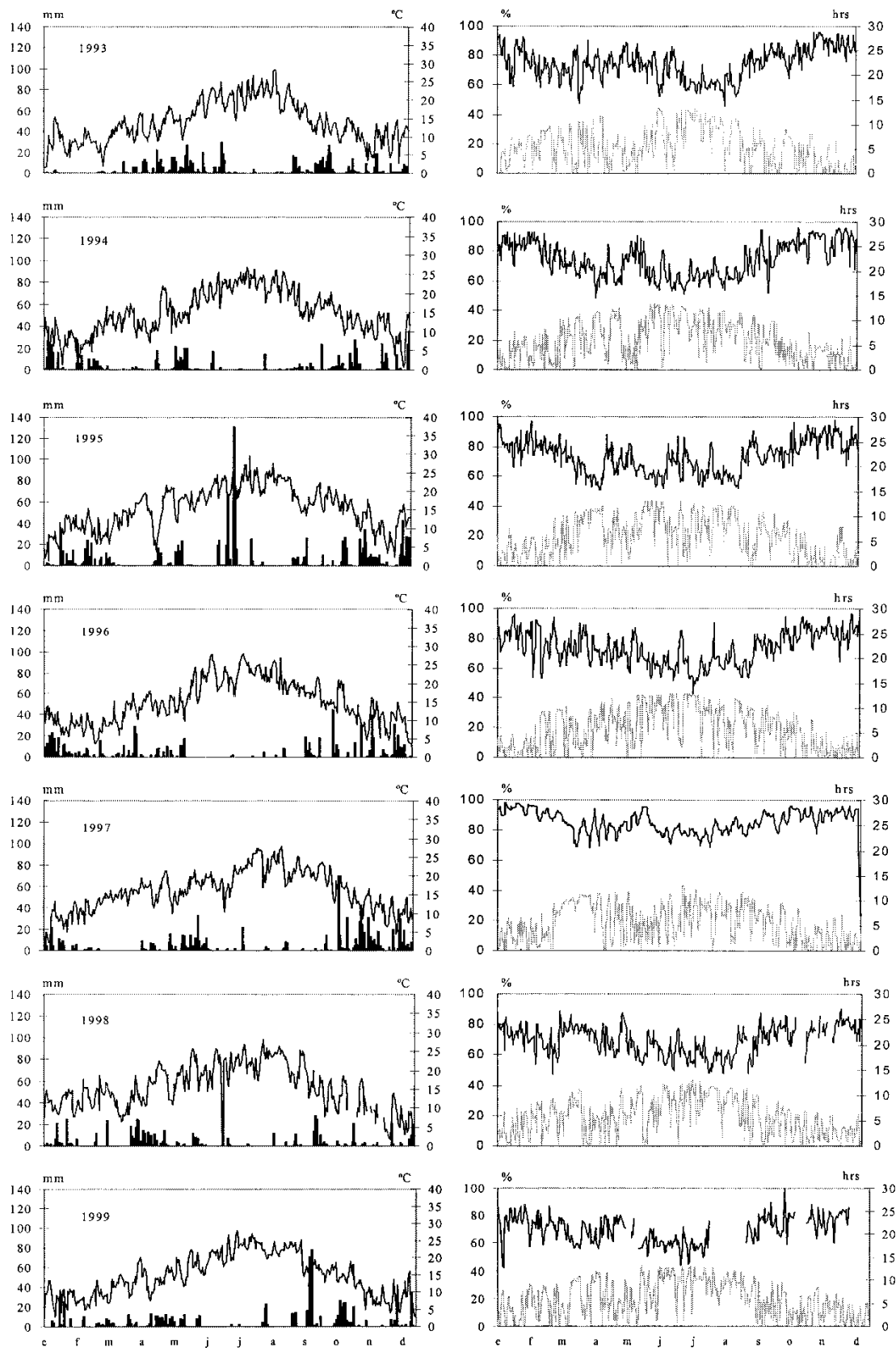


Fig. 3. Variations of different meteorological patterns during the period of study. The graphics on the left represent the average temperature (°C) in lines; the rain (mm) in bars. The graphics on the right show the relative humidity (black line) and the sunny hours (grey line).

Table I. Principal values for *Alnus* pollen during the period under study.

The average temperature during the Main Pollination Period (MPP) is expressed in degrees Celsius and the precipitation in mm.

|                          | 1992–93  | 1993–94   | 1994–95   | 1995–96  | 1996–97   | 1997–98  | 1998–99  | 1999–00   |
|--------------------------|----------|-----------|-----------|----------|-----------|----------|----------|-----------|
| Total pollen count       | 1545     | 1089      | 1181      | 1516     | 3186      | 845      | 1445     | 862       |
| Annual percentage        | 6.6      | 4.6       | 5.2       | 5.4      | 15.3      | 4.6      | 10.4     | 4.9       |
| Dates start-end of PPP   | 4–1/8–3  | 2–1/19–2  | 11–1/20–2 | 3–1/4–3  | 5–1/12–2  | 7–1/22–2 | 9–1/13–3 | 11–1/11–3 |
| Maximum value and date   | 75(16–1) | 163(15–1) | 95(16–1)  | 91(14–2) | 534(27–1) | 72(21–1) | 161(1–2) | 113(30–1) |
| Duration                 | 62       | 49        | 41        | 64       | 47        | 38       | 63       | 61        |
| Average T° during MPP    | 8.4      | 7.8       | 10.3      | 8.7      | 9.1       | 11.9     | 8.4      | 9.5       |
| Precipitation during MPP | 12       | 244       | 188       | 230      | 88        | 91       | 123      | 43        |

Table II. Scheffe’s test for the modified pollen count during the study period.

|         | 1992–93  | 1993–94  | 1994–95  | 1995–96  | 1996–97  | 1997–98  |
|---------|----------|----------|----------|----------|----------|----------|
| 1993–94 | 0.832442 |          |          |          |          |          |
| 1994–95 | 0.946664 | 0.800295 |          |          |          |          |
| 1995–96 | 0.564483 | 0.743558 | 0.564247 |          |          |          |
| 1996–97 | 0.000592 | 0.000587 | 0.002171 | 0.000095 |          |          |
| 1997–98 | 0.051692 | 0.101896 | 0.069969 | 0.160110 | 0.000001 |          |
| 1998–99 | 0.017354 | 0.044735 | 0.029966 | 0.073586 | 0.000000 | 0.804758 |

Table III. Correlation coefficient values between the main meteorological parameters and the Napierian logarithm of the pollen concentration.

The marked values are significant (\*\* $p < 0.01$  and \* $p < 0.05$ ). The previous day’s pollen concentrations corresponding to the *Alnus* variables *Alnus* 1–*Alnus* 7.

| Years               | 1992–93  | 1993–94  | 1994–95   | 1995–96  | 1996–97   | 1997–98   | 1998–99  | Total years |
|---------------------|----------|----------|-----------|----------|-----------|-----------|----------|-------------|
| Rain                | –0.1175  | –.0871   | 0.0076    | 0.0107   | –0.2923   | –0.2472   | –0.0614  | –0.0584     |
| Relative humidity   | 0.1993   | –.2411   | –0.5384** | –0.2476* | –0.3236** | 0.2600    | –0.0313  | –0.0197     |
| Sunside hours       | –0.2249  | .0787    | –0.0080   | –0.1109  | 0.3077    | –0.1184   | 0.3529** | –0.0795     |
| Maximum temperature | 0.2566*  | 0.3836** | –0.0818   | 0.0925   | 0.3718**  | –0.3580** | 0.1318   | –0.0108     |
| Average temperature | 0.3870   | 0.4463** | –0.1187   | 0.2901*  | 0.1314    | –0.4921** | –0.0827  | 0.0376      |
| Minimum temperature | 0.3096   | 0.3281*  | –0.0995   | 0.3248** | –0.1212   | –0.3514** | –0.2293  | 0.0645      |
| <i>Alnus</i> 1      | 0.5176** | 0.3666** | 0.1709    | 0.4378** | 0.4306**  | 0.4372**  | 0.6006** | 0.3715**    |
| <i>Alnus</i> 2      | 0.5679** | 0.2565   | 0.2329    | 0.3922** | 0.3533**  | 0.0716    | 0.4917** | 0.3085**    |
| <i>Alnus</i> 3      | 0.5997** | 0.3351*  | 0.2255    | 0.2975*  | 0.2983    | 0.1265    | 0.4376** | 0.3146**    |
| <i>Alnus</i> 4      | 0.4382** | 0.1993   | 0.0980    | 0.2352*  | 0.3172*   | –0.0292   | 0.5426** | 0.1958**    |
| <i>Alnus</i> 5      | 0.5355** | 0.1218   | 0.3070*   | 0.2821*  | 0.2663    | –0.0587   | 0.4651** | 0.2510**    |
| <i>Alnus</i> 6      | 0.4213** | 0.1294   | 0.2004    | 0.0664   | 0.1878    | –0.0286   | 0.4189** | 0.1684**    |
| <i>Alnus</i> 7      | 0.3267** | 0.0082   | 0.1144    | 0.1597   | 0.1987    | –0.0971   | 0.3848** | 0.1222*     |

only significant parameter in the order of 99% except in 1994–95.

The meteorological parameter that shows the most stable correlation with airborne pollen concentration is temperature, which we selected when carrying out the subsequent regression analysis, along with the previous day’s concentration.

Regression analysis

A regression analysis was done using independent variables such as concentration logarithm of the previous day’s amount of pollen and mean diary temperature to explain and predict the behaviour of *Alnus* pollen in the atmosphere. In this way we arrived at a polynomial equation with three terms reflecting the relation between the variables and which allowed the pollen concentrations to be estimated. These equations are given in Table IV.

In all cases studied, the different parameters included in the regression models were highly significant in the equations for the different years. R<sup>2</sup> values were very high too, which meant that the equation could explain a large percentage of the variability of the different values, because 30% was overcome except in 1994–95 with 20% each. The maximum value was obtained in 1992–93 with 47%. If we calculate an equation using values for the years that were statistically similar, the values drop to 26% because of the introduction of bigger variability in the matrix of the initial values.

Predicting onset of flowering

The results show that there is great variability in the parameters examined. The main oscillations were registered in the cold period. In some years (1992–93) there were no

Table IV. Regression summary and equations obtained for the different years.

Column F gives the value reached by Snedecor F, column *p* the probability value for F. Column *r* represents the regression coefficients. Column *r*<sup>2</sup> gives the value of the square of the regression coefficient.

|         | F value | P value | r value | r <sup>2</sup> value | Equation                                                              |
|---------|---------|---------|---------|----------------------|-----------------------------------------------------------------------|
| 1992–93 | 29.556  | 0.0000  | 0.7015  | 0.4921               | Ln <i>Alnus</i> =0.2094+0.1028 (Mean temp)+0.5939 (Ln <i>Alnus</i> 1) |
| 1993–94 | 11.860  | 0.0000  | 0.5833  | 0.3402               | Ln <i>Alnus</i> =0.4801+0.0528 (Mean temp)+0.3844 (Ln <i>Alnus</i> 1) |
| 1994–95 | 2.3556  | 0.1085  | 0.3321  | 0.1103               | Ln <i>Alnus</i> =2.3430–0.0506 (Mean temp)+0.3106 (Ln <i>Alnus</i> 1) |
| 1995–96 | 8.5672  | 0.0005  | 0.4744  | 0.2250               | Ln <i>Alnus</i> =0.7609+0.0803 (Mean temp)+0.4111 (Ln <i>Alnus</i> 1) |
| 1996–97 | 9.8625  | 0.0003  | 0.5949  | 0.3540               | Ln <i>Alnus</i> =1.2265+0.0421 (Mean temp)+0.5557 (Ln <i>Alnus</i> 1) |
| 1997–98 | 13.131  | 0.0000  | 0.6114  | 0.3738               | Ln <i>Alnus</i> =3.2517–0.1677 (Mean temp)+0.4152 (Ln <i>Alnus</i> 1) |
| 1997–98 | 19.436  | 0.0000  | 0.6239  | 0.3892               | Ln <i>Alnus</i> =0.6730+0.0117 (Mean temp)+0.6292 (Ln <i>Alnus</i> 1) |
| Total   | 47.708  | 0.0000  | 0.5181  | 0.2684               | Ln <i>Alnus</i> =1.0409+0.0183 (Mean temp)+0.5158 (Ln <i>Alnus</i> 1) |

cold days, in others, such as 1993–94 and 1995–96, there were 49 cold days.

The heat accumulation period is more regular, the average accumulated heat being 289°C. The average duration of this period was 26 days, but in some years it went up to 49. There were some periods, such as 1992/93 or 1996/97, when the sum of the accumulated temperatures increased because there were periods of low temperatures in between that disturbed the accumulative effect. These cold periods should break the accumulation effect, which then started again. This is the reason the number of days required is higher. When there was a clear cold period, the main pollination period was short and the values for *Alnus* pollen were high, as in 1996/97. During this pollen season there was a previous period to the MPP, when the pollen concentrations achieved significant values, but a fall in temperatures delayed anthesis.

DISCUSSION

Interannual variation

Values registered for *Alnus* in Ourense were higher than those obtained by various authors for others cities in Galicia. Losada (1993) and Aira et al. (1998) in Santiago de Compostela found much lower values. In Vigo, Rodríguez et al. (1998) obtained values that did not reach 800 pollen grains per year and, although total yearly pollen values were higher than in Santiago de Compostela, they were lower than in Ourense. This could be due to where Ourense is situated, crossed as it is by several rivers that cause a wide representation of this tree. As far as other Spanish cities are concerned, e.g. Málaga (Recio 1995) or Sevilla (González-Minero 1993), the annual pollen counts are low because of the smaller representation in these areas.

On the contrary, in other countries in the North of

Europe where the presence of this taxon is greater than in Spain, the MPP for *Alnus* pollen starts later in the season, and remains until mid-April. In these countries, Denmark (Goldberg et al. 1988), Sweden (Atkinson & Larsson 1990) or Holland, higher values are obtained too (Spieksma et al. 1998).

Statistical analyses

The correlation analysis showed that mean temperature is the parameter maintaining the highest correlation with *Alnus* pollen in the atmosphere. It was significant in Santiago de Compostela (Aira et al. 1998b). However, in our situation, this relation between both variables was not constant during the years of the study. In 1994–95, 1996–97 and 1998–99 the correlation coefficient was not significant, while in 1994–95, 1997–98 and 1998–99 it was negative.

This change took place during the hottest years, when the mean temperature of the main pollination period was higher. In 1997–98 it was around 11.9°C (Table I). In these cases the temperature remained high during the last part of the main pollination period, which means the existence of low pollen values changed the correlation coefficient sign. These high temperature values produced points in the scattergram which could be considered as “outliers” in the regression analysis because they had a major influence on the regression curve by causing the change of slope direction (Méndez 2000).

Owing to the poor stability of the meteorological parameters in relation to pollen concentration, the pollen concentration logarithm of the previous day was introduced in the regression lines, along with the mean temperature, in order to optimize the results of the study.

The equations obtained for the different years were similar, although there were some differences. The values obtained for the independent term of each equation

Table V. Values for prediction of onset of *Alnus* flowering.

|                         | 1992–93   | 1993–94   | 1994–95    | 1995–96   | 1996–97   | 1997–98   | 1998–99   |
|-------------------------|-----------|-----------|------------|-----------|-----------|-----------|-----------|
| Cold period             | 0         | 49        | 41         | 49        | 35        | 21        | 18        |
| Date start accumulation | 22/10/92  | 28/11/93  | 30 /11/94  | 16/12/95  | 19/11/96  | 7/12/97   | 9/12/98   |
| Days hot period         | 49        | 24        | 19         | 17        | 25        | 19        | 26        |
| Accumulated heat        | 323       | 275       | 243        | 266       | 319       | 232       | 367       |
| Date start ppp          | 4 January | 2 January | 11 January | 3 January | 5 January | 6 January | 9 January |

happened to be lower in the colder years. So, in periods such as 1994–95 and 1997–98, when the temperature was raised at the end of the period, the value obtained for this term was higher.

The coefficient value that was obtained as representing the mean temperature is also variable. We therefore had negative values in the warmest years, as well as for the independent term, while positive values were obtained for the remaining years. The same behaviour was registered for pollen concentration and previous day coefficient. It could therefore be said that regression line values can vary from one year to the next, with lower values in the hotter years .

To test the use of the equation predictor, we contrasted the years that presented similar data, thus obtaining series from the equation and from *Alnus* pollen during the year 2000. The results are shown in Fig. 4, where we can see how the experimental values follow the same variation model they would had we obtained them from a regression equation; however, maximum values for *Alnus* pollen happened to be higher than those expected from the regression equation.

To check the parallelism of both data series observed and expected, Student’s *t* test was carried out, and the results are indicated in Table VI. The value of *t* was 0.9657; with 60 free degree shows a *p* value of 0.34 and the hypothesis was not useful. We can say that there are no significant differences between the data obtained by the regression equation and those obtained from the experience in the year 2000.

Owing to the lack of stability shown by the meteorological parameters in relation to the pollinic concentration, we decided to use the previous day pollinic concentration logarithm in the regression lines, along with the mean temperature. This was done with the aim of optimizing the results.

The lines thus obtained are similar, though there are minor differences between the independent term values and the  $\beta$  values corresponding to the mean temperature and the previous day pollen concentrations. So, the lowest independent terms belong to the coldest years, while the highest values belong to years such as 1995 and 1998, when a high mean temperature during the pollination period was presented (Table IV). The  $\beta$  value in the pollen concentration logarithm also suffers oscillations, and thus, in 1995 and

Table VI. Values for prediction of flowering of *Alnus*.

|           | Mean  | SD    | N  | Diff. | SD diff. | <i>t</i> | df | <i>p</i> |
|-----------|-------|-------|----|-------|----------|----------|----|----------|
| Observed  | 10.85 | 21.43 |    |       |          |          |    |          |
| Predicted | 8.49  | 7.93  | 61 | 23649 | 19.127   | 0.9657   | 60 | 0.3381   |

1998, both representing the highest temperatures, it showed negative values, while in the remaining years it had positive values, though lower when the temperature increased. The same thing happens when we take into account the mean temperature  $\beta$  values, since the lowest values correspond again to 1995 and 1998. It can thus be said that the values or the different parameters of the regression lines are lower in years when the temperature was higher.

To test the predictor value of the equation used for those similar years, we compared the series obtained with this equation and the *Alnus* pollen values in the year 2000. The results are shown in Fig. 4. This figure shows how the values that have been experimentally observed follow the same variation pattern as those expected with the regression equation. However, the maximum values observed for the *Alnus* pollen are higher than those expected for the regression equation.

Student’s *t* test was carried out in order to test the adjustment of both data series. The results are given in Table VI. We obtained a *t* value of 9657 and a *p* value of 0.34 with 60° free. The hypothesis is null with these results. These results confirm that there are no significant differences between the predicted data obtained from the regression equation and those experimentally observed in the year 2000.

Prediction of flowering onset

The results obtained for predicting the onset of flowering vary, although they do explain the beginning and intensity of flowering. Spieksma et al. (1989) state that in Italy and Holland a period between 40 and 50 days prior to heat accumulation is necessary. Once this period is over, temperature accumulation starts. In our case, this previous cold period can last until December, and so heat accumulation starts too late, but the period prior to pollination is warm, and within a very few days the heat accumulation period is complete.

The onset of *Alnus* flowering is uniform but is delayed in some years because of the heat required (Frenguelli et al. 1991, Anderson 1991, Larsson 1993); for this reason flowering starts earlier when temperatures are warmer and constant. Goldberg et al. (1988) and Caramiello et al. (1990), in different cities, state that the main pollination period takes place earlier when the temperature is warmer and its increasing is more precocious. This is the case for the years 1994–95, 1995–96 and 1997–98, when after a few days of temperature accumulation the main pollination period starts.

During the year 2000, the cold period started on 20 November and for 20 days the average temperature was lower than 9°C until 9 December, when the heat accumulation

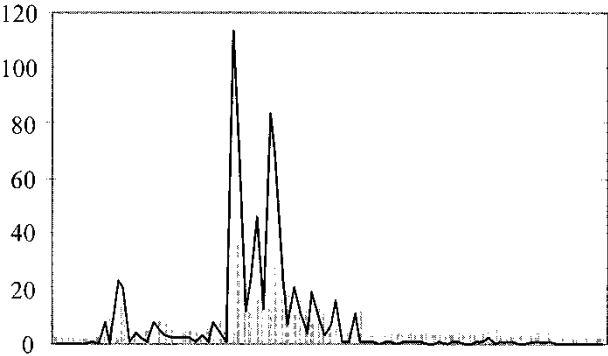


Fig. 4. Comparison between *Alnus* concentration during year 2000 (line) and the expected values for the same period (bars). The dates are represented on the X-axis and the *Alnus* pollen concentration (pollen grains /m<sup>3</sup>) on the Y-axis.

period started. On 11 January, accumulated heat was 286°C, and the main pollination period started.

## CONCLUSIONS

*Alnus* pollen is present in the atmosphere of Ourense during January and February, with the highest values registered in the second half of January. The lowest annual total count was registered in 1997/98, when only 845 pollen grains were collected. However, the highest value was recorded in 1996/97, with a total of 3186 pollen grains collected. In the case of the maximum value, there were important differences. The lowest value was in 1997/98 with 72 pollen grains/m<sup>3</sup>, while the maximum value of 534 pollen grains/m<sup>3</sup> was collected during the 1996/97 pollination period.

*Alnus* pollen concentration and temperature are important parameters predicting *Alnus* concentrations in the atmosphere during the main pollination period. With this parameter, and the previous day pollen concentration, we can predict pollen concentration in the atmosphere fairly accurately.

Previous day pollen concentration is revealed as a good parameter for use in the regression equations, and can be considered like an abstract of the phenological situation of the trees.

Temperature has a double influence on the behaviour of *Alnus* pollen. First, a cold period is needed to break dormancy. Heat accumulation is then the required condition to start the pollination period. Temperature is thus the most important parameter for *Alnus* pollination. In this sense, an increase in temperature is followed by an increase in atmospheric pollen content of *Alnus*.

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