Airborne Ericaceae Pollen Grains in the Atmosphere of Vigo (Northwest Spain) and Its Relationship with Meteorological Factors

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Abstract: Several species of the Erica genus are broadly represented in northwest Spain, being among the shrubs that form the substitution stage following forest degradation as a result of human activity, caused mainly by fire or other anthropogenic causes. Therefore airborne pollen from Erica is frequent. From 1995 to 2002, an aerobiological study of Ericaceae family pollen was undertaken in the atmosphere of the city of Vigo (Northwest Spain) using a Lanzoni VPPS 2000 (Lanzoni srl, Bologna, Italy) sampler placed in the left margin of the Vigo fiord (42°14'15'' N, 8°43'30'' W). Despite being a taxon of eminently entomophilous pollination, the pollen of Ericaceae was well represented in the atmosphere above the study zone. Erica arborea L. is the main species represented in the annual pollen curve. This taxon shows a long main pollen season and higher pollen concentrations were recorded during the months of April and May, which is why beekeepers place their beehives at specific locations in April to ensure a considerable contribution from this pollen to the composition of the honey. The maximum daily average concentration was detected in 1997, with a concentration of 156 grains/m³. Throughout the day, maximum values occur at 5/6 h and between 17:00 and 18:00 h. Finally, correlation statistical analyses were developed in order to determine the degree of association between the daily average of meteorological parameters and daily mean airborne pollen concentrations. Rainfall exerts a clear influence on Ericaceae pollen season characteristics, with precipitation registered in March being responsible for the decrease in total annual pollen values.

Key words: Erica arborea; Ericaceae; meteorology; pollen; pollen calendar; Spearman correlations; Vigo.

The Ericaceae family is found throughout Galicia (Northwest Spain) in the brushwood and undergrowth of pinegroves. It is widely spread in the study area among the shrubs that form the substitution stage following forest degradation as a result of human activity, mainly associated with fire. The species most commonly found in the city of Vigo and its surrounds are Arbutus unedo L., Daboecia cantabrica (Hudson) C. Koch, Erica australis L., E. arborea L., E. cinerea L., E. umbellata L., E. tetralix L., E. ciliaris L., and Calluna vulgaris L. (Fraga 1983). Over recent years, these species have increasingly been grown as ornamentals and they are also a mainstay for beekeeping as sources of pollen and nectar.

The genus Erica is of particular aerobiological and apicultural interest in view of its long flowering period, which extends from late March (E. australis) to August (E. cinerea). E. arborea flowers after E. australis, in April and May, whereas E. umbellata flowers slightly later, in May and June (Seijo 1994). Finally, C. vulgaris and A. unedo are responsible for the appearance of airborne pollen grains in late summer and autumn.

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Because this family of plants is mainly entomophilous and pollen is dispersed in large tetrads, airborne pollen concentrations tend to be very low. In addition, the *Erica* genus displays a certain amount of anemophilous pollination. *Calluna* pollination is initially entomophilous, but once nectar secretion ceases, stamen filaments are elongated until anthers become exerts, at which point pollination is anemophilous (Lewis et al. 1983). This accounts for the routine inclusion of Ericaceae in pollen calendars and its current classification as an airborne pollen. Although its importance as an allergen is not easily determined, there is evidence of pollen allergy symptoms in areas where Ericaceae are widespread and common. *Erica* has been reported as allergenic by Domínguez et al. (1984), *Calluna* has been reported as allergenic by Halse (1984), and *Rhododendrum* has been reported as allergenic by Lewis et al. (1983).

Measurement of airborne pollen counts provides a general idea of the phenological status of plants over a wide area; thus, charting of airborne Ericaceae pollen is of great interest for beekeeping, in that it tells us exactly when plants are in full flower and enables beekeepers to place hives. Given the paucity of aerobiological research into this pollen type, the present study sought to chart pollen count peaks over the year and determine at what stage of the day maximum dispersion takes place. Patterns of onset of Ericaceae flowering were also studied and the effect of major weather factors on airborne pollen counts was analysed using a statistical correlation test.

1 Materials and Methods

The city of Vigo lies in Northwest Spain (Fig. 1) in the left margin of the Vigo estuary (42°14'15'' N, 8°43'30'' W) 50 m a.s.l. One Hirst-type (Hirst 1952) volumetric sampler (VPPS 2000; Lanzoni srl, Bologna, Italy) was used for the collection of airborne pollen and the sampler was located on the terrace of the town hall 15 m above ground level. The annual mean temperature in Vigo is 14.9 °C, with an average maximum temperature of 18.8 °C and a minimum of 11.0 °C. The average annual precipitation is 1412 mm, following an irregular pattern throughout the year. July and August are normally fairly dry, with rainfall < 40 mm.

Biogeographically, Vigo is located in the Atlantic Province of the Eurosiberian region. The *Quercus robur* deciduous forest is the characteristic vegetation formation and, as a consequence of human activity, the autochthonous forest has been markedly reduced and substitutive communities of species of Leguminosae (*Cytisus scoparius, C. striatus, Ulex spp., Genista spp.* etc.) and Ericaceae (*C. vulgaris, Erica spp.* etc.) have become widespread. For the past 40 yr, fast-growing species like *Pinus pinaster, P. radiata*, and *Eucalyptus globulus* have been used for re-afforestation (Rivas-Martínez 1987).

A Nikon Optiphot II microscope with a 40×/0.95 objective was used for the identification of pollen grains. Pollen counting was done following the model proposed by the REA (Red Española de Aerobiología-Spanish...
Aerobiology Network) of four longitudinal continuous traverses along the slide and daily values are represented as the number of pollen grains per m$^3$ of air. Specific identification of pollen grains was based on the Valdés et al. (1987) and Grant Smith (1990), as well as a collection of slides prepared directly from plants.

To determine the pollination period, we have taken into account the period that includes 95% of the annual airborne total pollen registered, eliminating the initial period until 2.5% of the total annual pollen grains is attained and the final period once 97.5% total annual pollen has been attained (Andersen 1991).

In order to obtain a model reflecting the fluctuation of pollen concentration throughout the day, we followed the model proposed by Galán et al. (1991), which selects the days on which the pollen concentration is greater than the mean of the main pollen season and, within such, days without rainfall. The resulting days were used to calculate the mean concentration every two hours, thereafter expressing the data as percentages (Galán et al. 1991).

Finally, Spearman’s correlation test was used to find a possible correlation between Ericaceae pollen concentrations and the main meteorological factors of rainfall (mm), relative humidity (%), hours of sunshine, maximum, minimum, and mean temperatures, thermal oscillation (°C), and wind direction (%). Correlations were established by taking into account the main pollen season and the months of maximum Ericaceae flowering (March to May). Meteorological data were supplied by the Spanish National Institute of Meteorology.

The taxa included in the pollen calendar reached, in at least a week, more than one pollen grain/m$^3$ as a mean 7-d concentration.

2 Results

The main pollen season generally started during the second half of March, with an average date of 24 March. Total annual pollen counts fluctuated considerably, from a maximum of 520 grains in 1995 to a minimum of less than 100 grains in 1999. Although counts were low, airborne Ericaceae pollen was recorded in Vigo in both spring and summer; however, the highest counts were generally recorded in April and May, and the maximum daily concentration was observed on 14 April 1995 (156 grains/m$^3$). Over the study, as a whole, a slight trend towards a later onset and earlier ending of the pollen season could be detected, with a consequently positive slope for the length of the main pollen season indicating a gradual increase in the number of days of the pollen season (Fig. 2). There appeared to be an overall drop in both total pollen counts and peak daily mean counts over different consecutive seasons.

Ericaceae was among the 12 major airborne pollen types in Vigo. Data recorded over the 8-yr study were used to prepare a pollen calendar showing average weekly values for the predominant pollen types: Urtica, Pinus, Quercus, Poaceae, Cupressaceae, Alnus, Platanus, Ericaceae, Myrtaceae, Betula, Olea,
Fig. 3. Pollen callendar for the city of Vigo (1995–2002).
Plantago, and Castanea. A different scale was used for the first four taxa in view of the high concentrations recorded (Fig. 3). These taxa are widespread on the city’s outskirts and the pollen concentration in the months of March and April accounted for more than 40% of total annual pollen. In March, a sharp temperature increase favored the flowering of *Betula*, *Pinus*, *Platanus*, and *Quercus*, herbaceous plants of the Urticaceae family and shrub species of Ericaceae. Pollen concentrations declined in May, thereafter increasing again with the onset of the flowering of the herbaceous species. The amount of pollen released into the atmosphere increased again during June and July, with a secondary summer peak accounting for 27% of total annual pollen. This increase was due to the flowering of the herbaceous species, particularly Poaceae and *Plantago*; *Castanea sativa* was the only tree species attaining high airborne pollen concentrations. A gradual decrease in pollen counts was observed in August, coinciding with the end of the flowering period for the species indicated. From September onwards, after a slight increase in pollen concentrations, the release of pollen into the atmosphere remained very low until the onset of the flowering period of the winter taxa, during the latter half of December or in the first fortnight in January.

Figure 4 charts Ericaceae pollen behaviour throughout the day, using the mean hourly value from the 8-yr study. A general model is presented, because the behaviour pattern was fairly constant throughout the study period; pollen counts peaked twice during the day, once at morning between 03:00 and 06:00 h, and again in the afternoon from 13:00 to 18:00 h.

Spearman’s correlation test was applied to mean daily values in order to determine the relationship between Ericaceae pollen counts and major weather parameters. The results are summarised in Table 1, which shows correlation coefficients calculated using data for the entire pollination period and for the months of maximum concentrations, respectively. A non-parametric statistical test was chosen because pollen data did not display normal distribution. Correlations were significant in a large number of cases: a highly significant (*P* < 0.01) positive correlation was found for temperature, whereas a significant negative correlation was noted with hours of sunlight during the main pollen season. When analysis was limited to the months displaying maximum pollen counts, a positive correlation was observed with temperature and with a south-southwesterly wind.

### 3 Discussion

Ericaceae pollen is present in the air of Vigo for most of the year, albeit at low concentrations. The pollination period lasts over 100 d and peaks in the spring and summer. Some studies suggest that spring-flowering species tend to delay the onset of the main pollen season (Corden and Millington 1999; Emberlin *et al.* 2002; García-Mozo *et al.* 2002). The same behaviour was noted in Vigo, where flowering has tended to start increasingly later in recent years and to last a shorter period of time.

As in most of NW Spain, the highest airborne pollen counts were generally recorded in May (Méndez 2000; Dopazo 2001; Vega *et al.* 2002; Dacosta 2003); however, in Vigo in years with higher overall airborne pollen counts, owing to a lack of rainfall in March, the highest values of airborne pollen were observed in April (Fig. 2). Similar findings have been reported for locations with lower rainfall, where pollen counts peak in April (González-Minero *et al.* 2002; Recio *et al.* 2002). In other areas of northern Spain, maximum concentrations of airborne pollen have been recorded
in March (Belmonte et al. 2002). These variations may be due to climate differences, as well as to the varying quantitative and qualitative composition of the Ericaceae species.

Table 1  Correlation coefficients between Ericaceae pollen concentrations and the main meteorological parameters during the pollen season and the months of March, April, and May

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<tbody>
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<td>Rainfall</td>
<td>0.060*</td>
<td>0.279*</td>
<td>0.044</td>
<td>0.060</td>
<td>−0.056</td>
<td>0.097</td>
<td>0.144</td>
<td>0.175*</td>
<td>−0.194*</td>
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<tr>
<td>Humidity</td>
<td>0.050</td>
<td>−0.053</td>
<td>0.132</td>
<td>0.196*</td>
<td>0.029</td>
<td>0.006</td>
<td>0.158</td>
<td>0.025</td>
<td>0.046</td>
</tr>
<tr>
<td>Maximum temp</td>
<td>0.093*</td>
<td>0.330**</td>
<td>−0.101</td>
<td>0.102</td>
<td>−0.017</td>
<td>−0.020</td>
<td>0.007</td>
<td>−0.126</td>
<td>0.290**</td>
</tr>
<tr>
<td>Minimum temp</td>
<td>0.159**</td>
<td>0.367**</td>
<td>0.033</td>
<td>0.327**</td>
<td>0.060</td>
<td>−0.018</td>
<td>0.052</td>
<td>−0.062</td>
<td>0.119</td>
</tr>
<tr>
<td>Mean temp</td>
<td>0.133**</td>
<td>0.376**</td>
<td>−0.031</td>
<td>0.207*</td>
<td>0.019</td>
<td>−0.020</td>
<td>0.020</td>
<td>−0.124</td>
<td>0.222*</td>
</tr>
<tr>
<td>Sun hours</td>
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<td>0.015</td>
<td>−0.104</td>
<td>−0.071</td>
<td>−0.090</td>
<td>0.017</td>
<td>−0.118</td>
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</tr>
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<td>−0.030</td>
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<td>−0.147*</td>
<td>0.106</td>
<td>0.143</td>
<td>−0.226*</td>
<td>0.127</td>
</tr>
<tr>
<td>Wind N-NE</td>
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<td>0.016</td>
<td>−0.101</td>
<td>−0.122</td>
<td>−0.068</td>
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<td>0.030</td>
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<tr>
<td>Wind NE-S</td>
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<td>−0.151*</td>
<td>0.045</td>
<td>0.099</td>
<td>−0.022</td>
<td>0.226*</td>
<td>−0.293**</td>
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<td>0.008</td>
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<td>0.014</td>
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<td>0.243*</td>
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<tr>
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<td>0.169*</td>
<td>0.223*</td>
<td>−0.013</td>
<td>−0.058</td>
<td>0.018</td>
<td>−0.252*</td>
<td>0.120</td>
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<td>Wind speed</td>
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<td>0.006</td>
<td>−0.050</td>
<td>0.087</td>
<td>−0.026</td>
<td>−0.221*</td>
<td>0.185*</td>
<td>−0.170*</td>
</tr>
</tbody>
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March, April, and May

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<td>0.180</td>
<td>0.095</td>
<td>−0.103</td>
<td>−0.322*</td>
<td>0.006</td>
<td>0.150</td>
<td>0.134</td>
<td>−0.066</td>
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<tr>
<td>Humidity</td>
<td>0.037</td>
<td>−0.013</td>
<td>0.105</td>
<td>0.251*</td>
<td>−0.064</td>
<td>−0.205*</td>
<td>0.197</td>
<td>−0.117</td>
<td>0.175</td>
</tr>
<tr>
<td>Maximum temp</td>
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<td>0.078</td>
<td>−0.340**</td>
<td>0.405**</td>
<td>−0.099</td>
<td>−0.031</td>
<td>0.033</td>
<td>−0.095</td>
<td>0.251*</td>
</tr>
<tr>
<td>Minimum temp</td>
<td>0.094*</td>
<td>0.189</td>
<td>−0.259**</td>
<td>0.353**</td>
<td>−0.058</td>
<td>−0.157</td>
<td>0.063</td>
<td>−0.102</td>
<td>0.163</td>
</tr>
<tr>
<td>Mean temp</td>
<td>0.092*</td>
<td>0.136</td>
<td>−0.310**</td>
<td>0.407**</td>
<td>−0.078</td>
<td>−0.099</td>
<td>0.041</td>
<td>−0.119</td>
<td>0.223*</td>
</tr>
<tr>
<td>Sun hours</td>
<td>−0.052</td>
<td>−0.134</td>
<td>−0.202</td>
<td>0.099</td>
<td>0.083</td>
<td>0.072</td>
<td>−0.138</td>
<td>−0.150</td>
<td>0.109</td>
</tr>
<tr>
<td>Wind calm</td>
<td>−0.019</td>
<td>−0.222*</td>
<td>−0.047</td>
<td>0.200</td>
<td>−0.165</td>
<td>0.191</td>
<td>0.176</td>
<td>−0.256*</td>
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<tr>
<td>Wind N-NE</td>
<td>−0.030</td>
<td>−0.158</td>
<td>0.092</td>
<td>−0.067</td>
<td>−0.034</td>
<td>0.003</td>
<td>−0.056</td>
<td>−0.029</td>
<td>−0.098</td>
</tr>
<tr>
<td>Wind NE-S</td>
<td>−0.057</td>
<td>0.123</td>
<td>−0.051</td>
<td>−0.329**</td>
<td>−0.161</td>
<td>−0.047</td>
<td>0.001</td>
<td>0.260*</td>
<td>−0.253*</td>
</tr>
<tr>
<td>Wind S-SW</td>
<td>0.091*</td>
<td>0.258*</td>
<td>−0.016</td>
<td>0.289*</td>
<td>−0.088</td>
<td>−0.172</td>
<td>0.091</td>
<td>−0.029</td>
<td>0.231*</td>
</tr>
<tr>
<td>Wind SW-N</td>
<td>0.033</td>
<td>−0.055</td>
<td>−0.017</td>
<td>0.305*</td>
<td>0.052</td>
<td>0.032</td>
<td>0.094</td>
<td>−0.216*</td>
<td>0.017</td>
</tr>
<tr>
<td>Wind speed</td>
<td>0.021</td>
<td>0.236*</td>
<td>0.074</td>
<td>−0.138</td>
<td>0.129</td>
<td>−0.062</td>
<td>−0.272*</td>
<td>0.231*</td>
<td>−0.004</td>
</tr>
</tbody>
</table>

Spearman's coefficient: *, P < 0.05; **, P < 0.001.

Average annual airborne pollen counts for the 8-yr study are shown in Fig. 5. A number of peaks were recorded owing to the diversity of species, flowering following on from one species to another from the end of winter through to autumn. The main pollen season
started in the second fortnight of March, coinciding with the full flowering of *E. australis*. This was followed by *E. arborea*, which, together with *E. australis*, was responsible for the main peak in the annual pollen curve, generally recorded in April. Secondary, peaks were observed in May, owing to flowering of *E. umbellate*. Finally, flowering of *C. vulgaris* prompted a slight increase in pollen counts in late August (Fraga 1983).

In the last year of the present study, Ericaceae pollen types were divided into two groups: (i) the *E. arborea* type, including species with a smaller tetrad; and (ii) the *Erica* type, with larger tetrads. The first group contained a single species, *E. arborea*, the only species present in the area of the sampler with tetrads smaller than 40 µm. *E. arborea* was the main component of the annual Ericaceae pollen curve (Fig. 6), accounting for up to 78% of total pollen counts. The smaller tetrad facilitates pollen grain dispersal by the wind, thus enabling it to outnumber other species in the annual airborne pollen curve.

Intra-year and year-on-year variations in pollen counts were attributable not only to species diversity, but also to weather conditions during the main pollen season (Frenguelli et al. 1992; Dahl and Stradhede 1996; Laadi 2001; Jato et al. 2002), especially rainfall. Spring flowering tended to coincide with heavy rainfall and the resulting atmospheric cleansing considerably reduced airborne Ericaceae pollen concentrations, prompting a marked decline in annual total pollen values; these values, together with total rainfall for March, April, and May, are shown in Fig. 7. High pollen counts in 1995 coincided with low rainfall in March and April; conversely, lower values were recorded in 1999, 2000, and 2001 owing to lower temperatures and frequent, heavy rainfall during the flowering period. Total rainfall for March 2001 was 640 mm, with rain every day of the month. Thus, the declining year-on-year trend recorded for these 3 yr (by 43 grains/m³ for total annual count and 13 grains/m³ for peak value; Fig. 2) was largely attributable to heavy rains. The present study lasted 8 yr and the extension of the study for a longer period of time may modify or confirm these trends.

Thus, rainfall exerts a major influence on Ericaceae behaviour in Vigo. Correlation testing was performed to determine the stage of Ericaceae flowering at which rainfall had the greatest effect. The following data were used: total rainfall from February to May, initial, final,

Table 2  Correlation coefficients between the characteristics of the Ericaceae pollen season over the 8 yr of the study (start and final dates, average concentration, total annual pollen grains, peak value and day on which peak value occurred) and total monthly rainfall from February to May

<table>
<thead>
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<th>March</th>
<th>April</th>
<th>May</th>
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<tbody>
<tr>
<td>Start date</td>
<td>0.095</td>
<td>0.357</td>
<td>−0.500</td>
<td>−0.071</td>
</tr>
<tr>
<td>Final date</td>
<td>−0.119</td>
<td>0.262</td>
<td>0.000</td>
<td>−0.667</td>
</tr>
<tr>
<td>Mean concentration</td>
<td>−0.228</td>
<td>−0.731**</td>
<td>−0.659*</td>
<td>0.096</td>
</tr>
<tr>
<td>Total pollen</td>
<td>−0.333</td>
<td>−0.619</td>
<td>−0.405</td>
<td>0.405</td>
</tr>
<tr>
<td>Peak value</td>
<td>−0.500</td>
<td>−0.571</td>
<td>−0.500</td>
<td>0.167</td>
</tr>
<tr>
<td>Peak date</td>
<td>0.238</td>
<td>0.762**</td>
<td>0.048</td>
<td>−0.714**</td>
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</table>

* P < 0.05; ** P < 0.001.
and mean pollen counts for that period, total counts, and maximum pollen concentrations attained during the main pollen season (Table 2). Rainfall in May was found to delay the ending of the main pollen season; March rainfall caused a marked decline in mean Ericaceae pollen concentrations over the main pollen season ($P < 0.001$) and also reduced total annual counts (95% significance).

Average intradiurnal variations in pollen counts proved to be fairly constant, with two notable peaks, one at dawn and the other at 17:00–18:00 (Fig. 4). Similar patterns have been reported by Dopazo (2001) for other areas of NW Spain, including Santiago de Compostela, although there the first peak was not recorded until 09:00. In areas with a marked Mediterranean influence (Mendez 2000), a single peak has been reported at 17:00–18:00 h, coinciding with the main peak in Vigo. Other Mediterranean areas (Galán et al. 1991) also display an irregular pattern, with several peaks throughout the day.

Spearman’s correlation test was performed to determine the influence of weather parameters on airborne pollen concentrations (Table 1). The values obtained disclosed a significant ($P < 0.01$) positive correlation with temperature in the main pollen season. When analysis was limited to the months displaying maximum pollen counts, a less significant positive correlation was observed with temperature and with a south-southwesterly wind. Similar results have been reported for neighbouring areas of NW Spain, including Santiago de Compostela (Dopazo 2001), Ourense (2000), and Trives (Dacosta 2003), where the influence of temperature on pollen counts was stronger during the flowering of spring-summer species. There was no significant correlation with wind speed or wind calm and, in the absence of any evidence regarding airborne transport of this pollen grain, which is hindered by tetrad size, it is assumed that the pollen recorded came from nearby areas of the city. Finally, no significant correlations were established ($P > 0.001$) in 1999, 2000, and 2001, perhaps owing to the low number of data included in the statistical analysis as a result of the lower pollen counts recorded during those years.

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