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Analysis of Chenopodiaceae-Amaranthaceae airborne pollen in Salamanca, Spain

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Abstract: Chenopodiaceae-Amaranthaceae pollen represents an allergenic risk for pollen-sensitive people. The aim of this study was to describe the Chenopodiaceae-Amaranthaceae pollen dynamics in the atmosphere of Salamanca (mid-west Spain) during the years 2000-2007. Measurements were performed by the volumetric method using a Burkard spore trap located in the urban centre at the height of 20 m above ground level. This pollen type was mainly detected in the atmosphere between late spring and late summer, with an Atmospheric Pollen Season (APS) registered between late May and early October and maximum concentrations detected in August. The intradiurnal pattern, calculated by means of 3 different methods, reached a higher hourly concentration percentage in the second half of the day. The correlations obtained between daily pollen counts and different meteorological parameters showed that the airborne presence of this pollen type is associated positively with temperature and negatively with rainfall and relative humidity. In terms of the known threshold (10-15 pollen/m^3), Chenopodiaceae-Amaranthaceae pollen concentrations were found to exceed this threshold on 1 day in the years 2002, 2005, and 2007, and on 12 days in 2006. The results can be utilised to prevent symptoms of allergic reactions to this pollen type and to improve quality of life during seasonal allergic diseases in Chenopodiaceae pollen-sensitive people.

Key words: Chenopodiaceae, Amaranthaceae, pollen, aerobiology, Spain

Introduction

The Chenopodiaceae and Amaranthaceae families are widespread worldwide and constitute the most diverse group of Caryophyllales, with 180 genera and 2500 species. Both families share an important number of features, mostly derived, such as occurs in the case of pollen grains making a stenopalynologic group (Erdtman, 1966). These shared features combine with phylogenetic analyses and support their merge into a single family (Judd et al., 1999). Pollen grains of both families are present in the atmosphere of many cities in Africa (Njokuocha, 2006), America (Rocha-Estrada et al., 2008), Asia (Erkan et al., 2011), and Europe (Weryszko-Chmielewska & Piotrowska, 2004). Many members of these families have been involved in inducing pollinosis (Lombardero, 1991) by playing the orbicules located in the pollen exine, an important role as possible important vectors of allergens (Vinckier & Smets, 2001). Various authors have reported a high degree of cross-reactivity among related pollens of different species belonging to those families (Lombardero et al., 1985) and even among some foods, such as asparagus, garlic, and onion (Anibarro et al., 1997). In Spain, the prevalence of

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sensitisation to Chenopodiaceae-Amaranthaceae pollen is between 30% and 40% in patients with hay fever symptoms (Pola, 2003) and is most notable in the summer (Galán et al., 1989).

The aims of this work were to determine the aerobiological behaviour of Chenopodiaceae-Amaranthaceae pollen in the atmosphere of 1 city located in mid-west Spain (Salamanca) and to evaluate the influence of meteorological parameters in its airborne distribution. The importance of regional studies is increasing these days in order to better our knowledge of daily and seasonal airborne pollen characteristics (Munuera, 2002); this information could allow allergologists to establish the main season of acute sensitivity, with the ultimate aim of preventing pollinosis.

Materials and methods

The study was carried out in the city of Salamanca (40°58′N; 5°40′W), which is located in the mid-west of the Iberian peninsula, 800 m above sea level, and has around 180,000 inhabitants. The climate is Mediterranean continental, characterised by a low annual rainfall level (382 mm) that results in a dry season in the summer period. Flora in the surrounding area include species developed in natural formations, such as pastures with holm oaks [*Quercus ilex* L. subsp. *ballota* (Desf.) Samp.] and forests with oak trees [*Quercus pyrenaica* Willd.], both located to the south and west of the city, whereas in the north and east there are croplands of cereal and leguminous species. In these croplands and other wastelands, nitrophilous species from the families Chenopodiaceae, Lamiaceae, Leguminosae, and Compositae can be found.

The aerobiological monitoring was performed by a Hirst type volumetric spore trap (Burkard 7-day recording volumetric spore trap, Burkard Manufacturing Co. Ltd.) placed on the roof of a central historical building at a height of 20 m a.g.l. Monitoring was done from 1 January 2000 to 31 December 2007. The pollen trap has an air-flow rate of 10 L per minute. The daily average of pollen grains per cubic meter of air was expressed. Methods standardised according to the Spanish Aerobiology Network were used for sampling, slide preparation, pollen counting, and data interpretation (Domínguez et al., 1991).

The term Atmospheric Pollen Season (APS) can be used to delimit the period during which most pollen is recorded and it is analogous to other classical terms as Main Pollen Season (MPS) or Principal Pollination Period (PPP). APS appears to be the term best suited to describe this concept (Jato et al., 2006) and it was defined using the methodology proposed by Andersen (1991) as the period of the year that accounts for 95% of the total annual Chenopodiaceae-Amaranthaceae pollen count. The pre-peak period (PRE) includes the period between the starting date of the APS and the date on which the highest concentration is reached. A 5-day running mean was calculated during the studied period and plotted in order to assess the seasonal trend.

In addition, the intradiurnal variations recorded during the APS for the 2005-2007 period have been studied, taking into account 3 different models described by authors (Galán et al., 1991; Sánchez Reyes et al., 2009). In the first model, the value registered each hour is represented by the average of the values of that hour, while in the second model, an ideal day was calculated by dividing the sum of the values of each hour by the number of days in which Chenopodiaceae-Amaranthaceae pollen was present. In both cases, the values for each hour are expressed as a percentage of the daily total. In the third model, it is important whether rainfall occurred or not. The daily average of the pollen type was calculated using the total number of days of the APS period as the denominator. After that, we selected just the dry days with a daily value equal to or higher than the average previously calculated. In this model, the value obtained for each hour is represented as described in the first model, with the aim to compare the 3 models. For the graphical representation we used a 3-hour running mean to smooth the tendency, expressed as bi-hourly concentration.

Meteorological data were supplied by the Agencia Estatal de Meteorología (AEMET, Spanish State Meteorological Agency), located 10 km east of the pollen sampling site. Non-parametric statistical correlation analyses (Spearman's test) were carried out between meteorological parameters (temperature, total hours of sunshine, rainfall, relative humidity, wind speed, frequency of calms, and winds from the first, second, third, and fourth quadrant) and pollen data (daily average of pollen grains/m^3 of air) during the whole period and each year was analysed with its APS-PRE defined periods. The non-parametric Spearman's coefficient was chosen because daily pollen counts are not normally distributed. Statistical analysis was carried out using the SPSS v. 12 software package.

Results

The study on Chenopodiaceae-Amaranthaceae pollen indicated variation in annual pollen indexes (Figure 1). The lowest pollen index was recorded

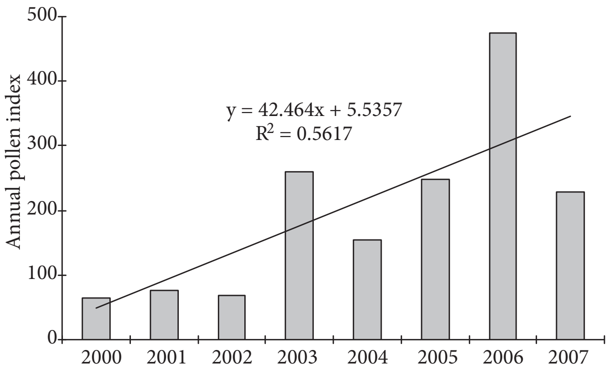

Figure 1. Chenopodiaceae-Amaranthaceae annual pollen indexes in the city of Salamanca from 2000 to 2007 and their evolution, as analysed by means of regression analysis.

in 2000 and the highest in 2006, with 197 being the mean value. The years 2002 and 2001 also displayed lower pollen indexes. The percentage of these pollen indexes with respect to the total pollen count ranged from 0.6% in 2000 to 3.1% in 2003, with 1.2% as the mean value. This interannual variation meant an increase in the levels of this pollen type, reflected by the index of regression analysis (R^2 = 0.56), and which also occurred for the length and ending date of APS (R^2 = 0.56 and R^2 = 0.84, respectively) (Figure 2).

Figure 3 shows the seasonal variations in the average of the daily pollen concentrations of Chenopodiaceae during the studied years and the 5-day running means of 8 years, analysed from 1 April to 30 November. This pollen type appears already in late April, increasing its daily levels from

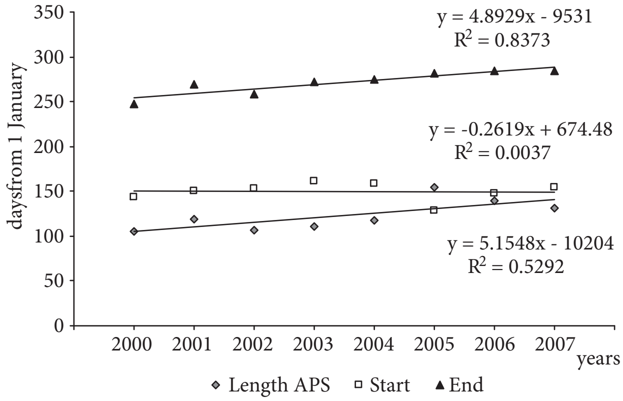

Figure 2. Evaluation of Atmospheric Pollen Season (APS) length and starting and ending dates (from 1 January) during the studied period by means of regression analysis.

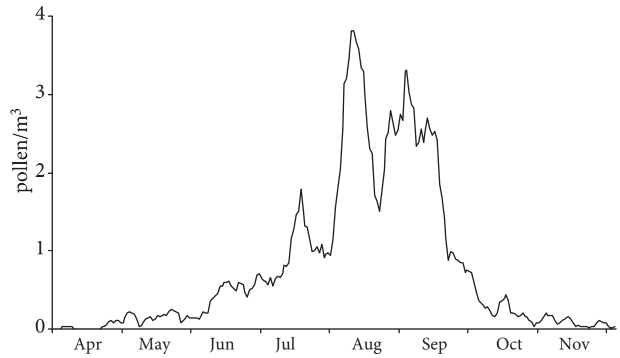

Figure 3. Average seasonal variation of Chenopodiaceae-Amaranthaceae during the period 2000-2007 (5-day running mean).

early June until the first week of August, when it reaches the highest mean daily value (Figure 3). The highest daily counts usually occurred between late July and mid August, with the highest value being on 9 August 2006 and the lowest on 17 June 2000 and 24 July 2001; the earliest peak recorded was on 17 June 2000 and the latest was on 8 September 2004 (Table 1).

The duration of the APS was 123 days on average and it ranged between 105 and 155 days (Table 1). The earliest APS starting date was on 24 May 2000 and the latest was on 11 June 2003, with 29 May as a mean value. On average, the APS ended on 9 June, with values ranging between 5 September 2000 and 12 October in the last 2 years studied.

Known threshold daily values of Chenopodiaceae-Amaranthaceae pollen (10-15 pollen/m^3), which provoke allergy symptoms when surpassed, have

Table 1. Seasonal behaviour of airborne Chenopodiaceae/Amaranthaceae pollen.

	2000	2001	2002	2003	2004	2005	2006	2007	Mean
Annual Pollen Index	64	77	68	260	154	248	474	228	197
% total	0.6	0.8	0.9	3.1	0.8	1.1	1.8	0.7	1.2
Peak value	4	4	12	8	5	12	22	10	5
Peak day	17 Jun	24 Jul	6 Aug	20 Aug	8 Sep	28 Aug	9 Aug	18 Aug	4 Aug
Days >10 p/m^3	0	0	1	0	0	1	12	1	2
APS length	105	119	107	111	118	155	139	131	123
Start APS	24 May	31 May	2 Jun	11 Jun	7 Jun	8 May	27 May	4 Jun	29 May
End APS	5 Sep	26 Sep	16 Sep	29 Sep	2 Oct	9 Oct	12 Oct	12 Oct	28 Sep
PRE length	25	55	66	71	94	113	75	76	67

APS = Atmospheric Pollen Season; PRE = Pre-peak period

been described by Feo Brito et al. (1998). According to these figures, the number of days exceeding this threshold were low (Table 1), except in the year 2006, which featured 11 days in August and 1 day in September. In this investigation, half of the studied years (2000, 2001, 2003, and 2004) did not present any daily concentrations higher than the stated threshold.

The hourly distribution of this pollen type in the atmosphere had a clear pattern with the first and third model: pollen levels increased from 1000 to 1400 hours, at which point concentrations reached maximum percentages over the average total counts of the day. After this time, the values decreased until 2000, with a slight increase from 2100 to midnight (Figure 4).

Statistically significant positive correlations between daily pollen counts and the main meteorological parameters ($P < 0.01$) were found in a large number of cases during the period 2000-2007; these factors included average temperature, maximum and minimum temperature, sunshine hours, and winds coming from the first, second, and fourth quadrants (Table 2). Figure 5 displays the influence of mean temperature on airborne pollen levels between May and October during the studied

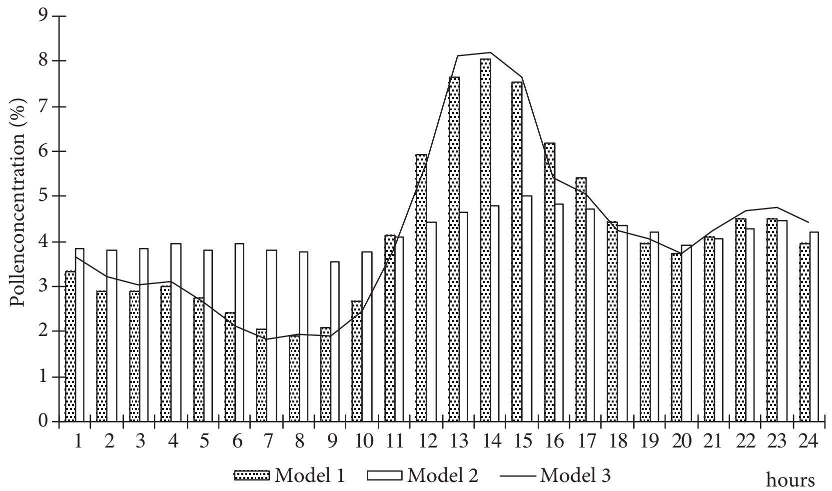

Figure 4. Chenopodiaceae-Amaranthaceae intradiurnal patterns from 2005 to 2007.

Table 2. Spearman correlation coefficients established for airborne Chenopodiaceae/Amaranthaceae pollen concentrations and meteorological parameters within the Atmospheric Pollen Season (APS) and pre-peak (PRE) periods.

Chenopodiaceae		Tmean	Tmax	Tmin	Sunshine	Rainfall	RH	Wspeed	CF	Wind NW	Wind NE	Wind SE	Wind SW
2000	Annual	0.323**	0.343**	0.260**	0.325**	−0.182**	−0.307**	−0.120**	0.083	0.130*	0.039	−0.174**	0.082
95%	APS	0.007	0.056	−0.102	0.095	−0.129	−0.028	−0.075	0.056	0.084	0.116	−0.171	−0.049
	PRE	0.245	0.206	0.163	0.078	−0.087	−0.118	−0.007	0.131	−0.166	0.188	−0.155	0.025
2001	Annual	0.446**	0.449**	0.400**	0.253**	−0.037	−0.293**	−0.121*	0.055	0.119*	0.047	−0.123*	0.121*
95%	APS	0.144	0.100	0.151	−0.152	0.182*	0.143	0.019	−0.133	0.231*	0.121	−0.141	−0.178
	PRE	0.493**	0.448**	0.427**	0.032	0.074	−0.150	−0.201	0.108	0.181	0.265	0.005	−0.114
2002	Annual	0.269**	0.269**	0.239**	0.219**	−0.143**	−0.133**	−0.035	0.020	0.147**	−0.029	−0.175**	0.093
95%	APS	−0.25**	−0.23**	−0.183	−0.144	−0.173	0.248*	−0.041	0.039	0.204*	0.047	−0.243*	−0.079
	PRE	−0.043	−0.027	−0.009	0.043	−0.195	−0.015	−0.096	0.105	0.136	−0.056	−0.261*	−0.094
2003	Annual	0.632**	0.624**	0.609**	0.349**	−0.189**	−0.414**	−0.17**	0.098	0.079	0.013	−0.092	0.240**
95%	APS	0.132	0.138	0.099	−0.235*	−0.089	0.108	−0.193*	0.110	0.283**	0.285**	−0.318**	−0.086
	PRE	0.489**	0.495**	0.416**	−0.319**	−0.112	−0.116	−0.248*	0.186	0.295*	0.435**	−0.328**	−0.089
2004	Annual	0.616**	0.613**	0.584**	0.370**	−0.132*	−0.445**	0.135**	0.099	−0.071	0.107*	0.048	0.199**
95%	APS	0.068	0.071	0.033	−0.205*	0.006	0.042	0.072	0.098	0.056	0.205*	−0.051	−0.011
	PRE	0.086	0.073	0.083	−0.222*	0.021	0.011	0.086	0.062	0.043	0.175	−0.029	0.008
2005	Annual	0.627**	0.633**	0.562**	0.426**	−0.165**	−0.545**	−0.082	0.065	0.127*	0.001	−0.062	0.054
95%	APS	0.271**	0.351**	0.130	−0.010	−0.124	−0.215**	−0.107	0.194*	0.286*	0.143	−0.204*	−0.279**
	PRE	0.270**	0.357**	0.144	−0.002	−0.131	−0.253**	−0.064	0.140	0.350**	0.149	−0.253**	−0.383**
2006	Annual	0.702**	0.704**	0.640**	−0.021	−0.182**	−0.532**	−0.045	−0.020	0.161**	0.117*	−0.125*	0.106
95%	APS	0.361**	0.468**	0.151	-	−0.237**	−0.158	0.021	0.126	0.406**	0.201*	−0.386**	−0.142
	PRE	0.408**	0.457**	0.197	-	−0.008	0.259*	−0.199	0.020	0.247*	0.195	−0.177	−0.173
2007	Annual	0.664**	0.677**	0.592**	0.502**	−0.138**	−0.548**	−0.043	0.102	0.141**	−0.115*	−0.071	0.059
95%	APS	0.509**	0.537**	0.218*	0.276**	−0.199*	−0.503**	−0.057	−0.012	0.321**	0.052	−0.254**	−0.001
	PRE	0.452**	0.497**	0.196	0.199	−0.259*	−0.489**	−0.273*	0.144	0.502**	0.116	−0.449**	−0.007
Total	Annual	0.548**	0.548**	0.501**	0.364**	−0.148**	−0.382**	−0.15**	0.041*	0.116**	0.053**	−0.102**	0.138**

Tmean = mean daily average temperature (°C); Tmax = maximum daily average temperature (°C); Tmin = minimum daily average temperature (°C); Sunshine = daily average sunshine (hours); Rainfall = total daily rainfall (mm); RelHum = daily average relative humidity (%); WSpeed = daily average wind speed (km/h); Wind NE = daily average frequency of north-easterly winds (%); Wind SE = south-easterly winds (%); Wind SW = south-westerly winds (%); Wind NW = north-westerly winds (%); CF = daily average frequency of calms (%).
Significance levels: * indicates a significance of 95%; ** indicates a significance of 99%

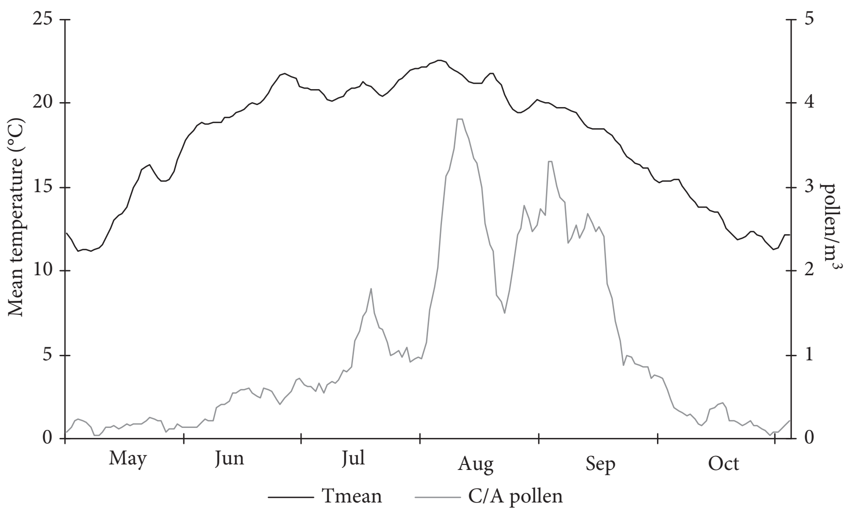

Figure 5. Mean temperature between May and October during the studied years and its influence on Chenopodiaceae-Amaranthaceae pollen concentrations. The lines show the 5-day running means.

period. On the other hand, rainfall, relative humidity, wind speed, and winds coming from the third quadrant were shown to have a significant negative correlation. If the analysis is only limited to the APS and PRE periods during some of studied years (2003, 2005, 2006, and 2007), winds coming from the first and third quadrants presented higher values in terms of their coefficients.

Discussion

The annual pollen index in the air of Salamanca during the studied years registered an increase, probably linked to a longer APS, as shown in Figure 2; this increase was reflected by the regression analyses and their indexes for the length ($R^2 = 0.56$) and the ending date of APS ($R^2 = 0.84$). In airborne grass pollen in different places in the United Kingdom, rainfall amount in periods close to anthesis induced a delay in the date of APS (Emberlin et al., 1994), as also occurred with August and September rainfall and Chenopodiaceae-Amaranthaceae pollen during the period 2000-2007 (Figure 6). The increase in the length of APS could be also related to the known effect of climate change on longer pollination periods (Shea et al., 2008) and, subsequently, a great number of allergic symptoms, but further studies featuring longer observation and more aerobiological stations are necessary to obtain better information about that effect.

APS of this pollen type and annual pollen indexes in Salamanca corresponded to those previously described in Madrid (Gutiérrez Bustillo et al., 2002), Cáceres (Paulino et al., 2002), and other points of the Castilla and León Region (Rodríguez de la Cruz et al., 2010; Vega-Maray et al., 2010), also located in the middle of Spain, being longer and higher, respectively, than that of other northern Spanish cities (Vega Maray et al., 2002; Rodríguez-Rajo et al., 2003). However, other sampling points placed in the south of Spain, such as Murcia (Munuera Giner et al., 2002) and Almería (Sabariego et al., 2003), displayed a longer APS and a higher value of annual pollen index, due to an earlier onset and to the great abundance of Mediterranean maquis in the vegetation surroundings (Blanco et al., 1997), where species from Chenopodiaceae predominate.

The highest values recorded during the central hours of the day, specifically between 1000 and 2000, revealed that there was a similar pattern to that reported for Cáceres (Muñoz Rodríguez et al., 2000) and Málaga (Recio et al., 1998) as well as with cities in America, such as La Plata (Nitiu, 2004). This showed agreement with the observed occurrence of anthesis and pollen dispersion during daylight (Latalowa et al., 2005).

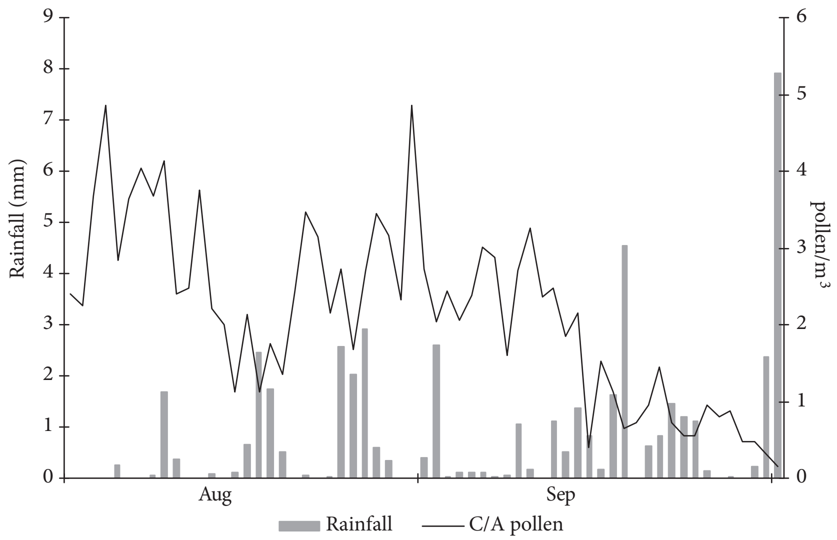

Figure 6. Rainfall occurrence average during August and September in the 2000-2007 period and its effects on Chenopodiaceae-Amaranthaceae airborne pollen.

Taking into account the relationship between meteorological parameters and the airborne pollen concentration, temperature tends to increase the atmospheric pollen content (Rodríguez de la Cruz et al., 2008), as other authors have revealed for Chenopodiaceae-Amaranthaceae airborne pollen (Gónzalez Minero et al., 1997; Cariñanos et al., 2004). Figure 6 shows the 5-day running means of mean temperature and pollen levels between May and October during the studied period. With a correlation of negative influence, rainfall and relative humidity displayed similar results in Toledo (García-Mozo et al., 2006) and Cartagena (Moreno-Grau et al., 2000) due to the known effect of these meteorological parameters on pollen concentrations (Emberlin, 1994). It has been established that any pollen type increases its airborne levels when the wind direction is favourable to the location of the main producing species (Díaz de la Guardia et al., 2003; Damialis et al., 2005). In the city of Salamanca, only south-western winds had a negative effect on the Chenopodiaceae-Amaranthaceae pollen concentration, probably reflecting a lower presence of species belonging to these families in this area compared to the areas included in the other quadrants.

Finally, despite the geographic and temporal limitations of the present study, the findings reported here could contribute to a better knowledge of Chenopodiaceae-Amaranthaceae aerobiological patterns.

Acknowledgements

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