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An aerobiological study of Urticaceae pollen in the city of Granada (S. Spain): correlation with meteorological parameters

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An aerobiological study was made of Urticaceae pollen in the city of Granada, relating the mean values of the daily counts to meteorological parameters. Sampling was carried out with a Burkard seven-day-recording spore trap from October 1992 to September 1997. This pollen type has an extremely long main pollen season (MPS), with maximum counts in (January) February, March and April, causing numerous cases of human pollinosis throughout the entire Mediterranean region, including Granada. A highly constant intradiurnal variation pattern was obtained showing that the maximum peaks usually occur between 12.00 and 20.00. According to Spearman's correlation coefficient, during the pre-peak period the parameters which have the greatest effect on the levels of this type of pollen are daily and accumulated temperature and sunshine, accumulated rainfall, and wind direction from the third quadrant; during the post-peak period these same variables presented significantly negative coefficients. Daily rainfall and relative humidity presented negative coefficients during the entire MPS. The maximum daily temperature was the variable which provided the closest match with the theoretical predictive pattern presented here.

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Although several species of the genera *Urtica* and *Parietaria* are distributed throughout south-western Europe, in the urban area sampled *P. judaica* is the most widely represented taxon, as well as the most significant, since its pollen is considered to be the cause of a large number of cases of allergy in the Mediterranean region (Bousquet et al. 1986, D'Amato et al. 1991, 1992; Ariano et al. 1994). Insofar as the allergenic capacity of this pollen is concerned, many authors have studied the characterisation, location and purification of its allergenic proteins (e.g. Corbi et al. 1985, 1986; Ford et al. 1986, Ayuso et al. 1995, Panzani et al. 1996, Casas et al. 1996), while others have examined its aerobiological behaviour in various European cities (e.g. Mañas Martínez et al. 1990, Emberlin & Norris-Hill 1991, Arobba et al. 1992, Fornaciari et al. 1992, Trigo et al. 1996, González Minero et al. 1997).

The frequent presence of this pollen in the atmosphere of Granada (Alba 1997, Alba & Díaz de la Guardia 1996) and its effect on the allergic population (Díaz de la Guardia et al. 1991) led us to study its seasonal and intradiurnal behaviour correlating variations in its concentration with the main meteorological parameters, in order to devise a predictive model of the seasonal behaviour of this pollen type.

The city of Granada is located in the SSE of the Iberian Peninsula (37°11'N, 3°35'W) at the western end of the Genil Basin (altitude: 685 m), surrounded by the mountains of the Betic and Sub-Betic ranges (Fig. 1). According to Elias Castillo & Ruiz Beltrán (1977), the city's climate is contin-

ental Mediterranean, with large daily and seasonal temperature ranges. The mean annual temperature during the study period was 12.7°C the mean maximum temperature in the hottest month (July) was 34.9°C, and the mean minimum temperature in the coldest month (January) ranged between 4.3°C in 1993 and 5.9°C in 1996. Total annual rainfall ranged between 244.9 mm in 1995 (a year of major drought) and 786.8 mm in 1996. The urban area, besides presenting a very humid and nitrified environment, which favours an abundance of such species as *Urtica urens*, *U. membranacea* and

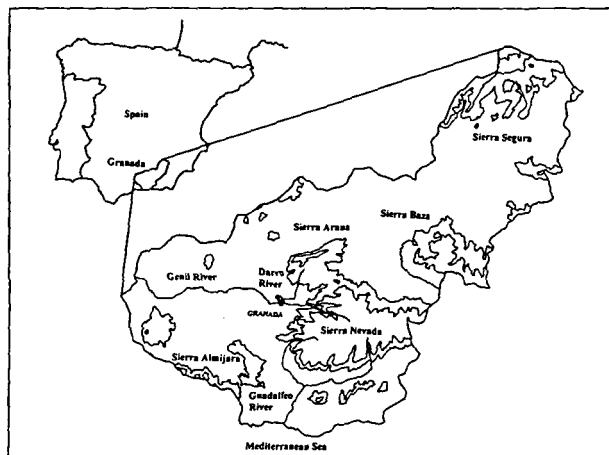


Fig. 1. Location of sampling site, in Granada, Spain.

U. dioica, includes the Darro and Genil rivers, close to which there are large populations of *Parietaria judaica* accompanied by *P. mauritanica*, causing an abundance of this pollen in the human-influenced habitats of the area.

MATERIAL AND METHODS

Pollen monitoring was performed from October 1992 to September 1997 using a Burkard 7-day-recording volumetric spore-trap sampler (Hirst 1952), located at approximately 23 m above ground level on the roof of the University of Granada Faculty of Sciences in the city centre. For the pollen count four longitudinal sweeps per slide were made with a $\times 40$ -magnification objective; the hourly count was made with the aid of a small ruler impressed in acetate paper stuck to the reverse of the slide, following the method recommended by the Red Española de Aerobiología (Dominguez et al. 1991). The data used correspond to the mean daily values expressed as number of pollen grains per cubic metre of air.

For graphic presentation of the 5-day running mean and also for the calculation of the Main Pollen Season (MPS) October was taken as the starting point and September the end point, since although *Urticaceae* pollen is present throughout the year, the counts recorded fall during the summer, with September being the month presenting the lowest percentage values (<2% of the total annual pollen).

MPS was determined by taking 95% of the annual sum, using cumulative values (Pathirane 1975). The beginning of the season was the first day of a period of five consecutive days on which pollen grains were observed. The initial and final 2.5% of the annual variation curve were eliminated to avoid lengthy tail-offs.

Spearman's correlation of the mean daily values was used to establish the relationship between the pollen count and the main meteorological parameters (rainfall, mean, maximum and minimum temperature, sunshine, relative humidity, mean wind speed and wind direction, and frequency of calms). When establishing the relationship between the pollen count and the different meteorological parameters, the principal pollination period was divided into two periods (pre-peak and post-peak), corresponding to the periods before and after the day of maximum pollen counts. Accumulative temperature, sunshine and rainfall values were used from the month of September. For the accumulated temperature a base temperature of 5°C was chosen; according to some other authors (e.g. Dennis 1984), this is the starting point from which flowering is activated.

In order to obtain a theoretical predictive pattern that provided the best fit with our data, various linear and polynomial regression analyses were carried out using one or more variables from the pollen data from five MPSs and the meteorological variables studied. The equation which provides the best fit is second-degree polynomial, with maximum daily temperature as the only variable. The regression analyses were made using the mean pollen count transformed into $Lg [(No. \text{ pollen grains}/m^3) + 1]$ as the dependent variable and the daily values of meteorological parameters as independent variables.

The intradiurnal variation patterns were obtained by referring to rain-free days on which the daily mean count was equal to or higher than the daily average of the MPS.

The meteorological data used were supplied by Estación Agrometeorológica No. 5 of the Centro de Investigación y Fomento Agrario (CIFA), located five kilometres south of the sampling station.

RESULTS

Most species of the genera *Urtica* and *Parietaria* present a long flowering season in the study area; *P. judaica* is in flower throughout the year, coinciding in the spring with the other species sharing the same pollen type. The aerobiological study shows the presence of airborne *Urticaceae* pollen throughout the year in Granada, although the seasonal

pattern (Fig. 2) reveals that the highest values are recorded in (January) February, March and April, and the lowest levels occur in August, September and October, with the pollen season always characterised by major daily fluctuations.

The MPS data varied over the years studied (Table I), although the degree of variation was not very great. The start of the season varied between late October and mid-November, except in 1995–96, when it was delayed until December. The season always ended in July (occasionally in early August). The length of the MPS was fairly uniform, ranging between 282 d and 217 d; however, the annual total amount of pollen, the peak date and the number of grains on the peak date varied significantly from one year to the next.

The intradiurnal variation pattern was very similar for each of the years studied (Fig. 3), with *Urticaceae* pollen reaching the highest hourly levels between 12.00 and 20.00 (75% of the daily total pollen), with maximum counts occurring between 14.00 and 16.00; the lowest amounts were recorded during the night and early morning (24.00–10.00).

Correlation analysis shows that during the pre-peak period (Table II) both daily and accumulated temperatures and sunshine were the parameters which generally presented a positive relationship with *Urticaceae* pollen levels. Daily rainfall and humidity invariably presented negative correlation coefficients, although the level of significance was low. However, significant positive indices were obtained with accumulated rainfall for most of the years studied. There was generally a positive relationship between wind direction from the third quadrant and the pollen levels recorded, whereas wind directions from the first and fourth quadrants presented negative correlation coefficients. The mean wind speed presented significantly negative correlation indices during the first years of the study.

During the post-peak period (Table III) both daily and accumulated temperatures were negatively linked to the pollen levels recorded, except in 1996–97, when positive coefficients with maximum and mean temperatures were obtained. Similar results were obtained for accumulated sunshine, although the correlation was less regular for daily sunshine, with both positive and negative indices being obtained. The effect of daily and accumulated rainfall and humidity was generally negative, with an association of 99% for most periods. Wind speed presented negative coefficients, generally with a higher level of significance than during the pre-peak period, whereas there was a positive link between calms and daily pollen counts. The wind-direction results were the opposite of those obtained for the pre-peak period, with winds from the first, second and fourth quadrants presenting a positive link with pollen counts, while those from the third quadrant were negative.

DISCUSSION

Seasonal and intradiurnal variation

Airborne *Urticaceae* pollen is constantly present throughout the year in the daily samples for Granada, although the

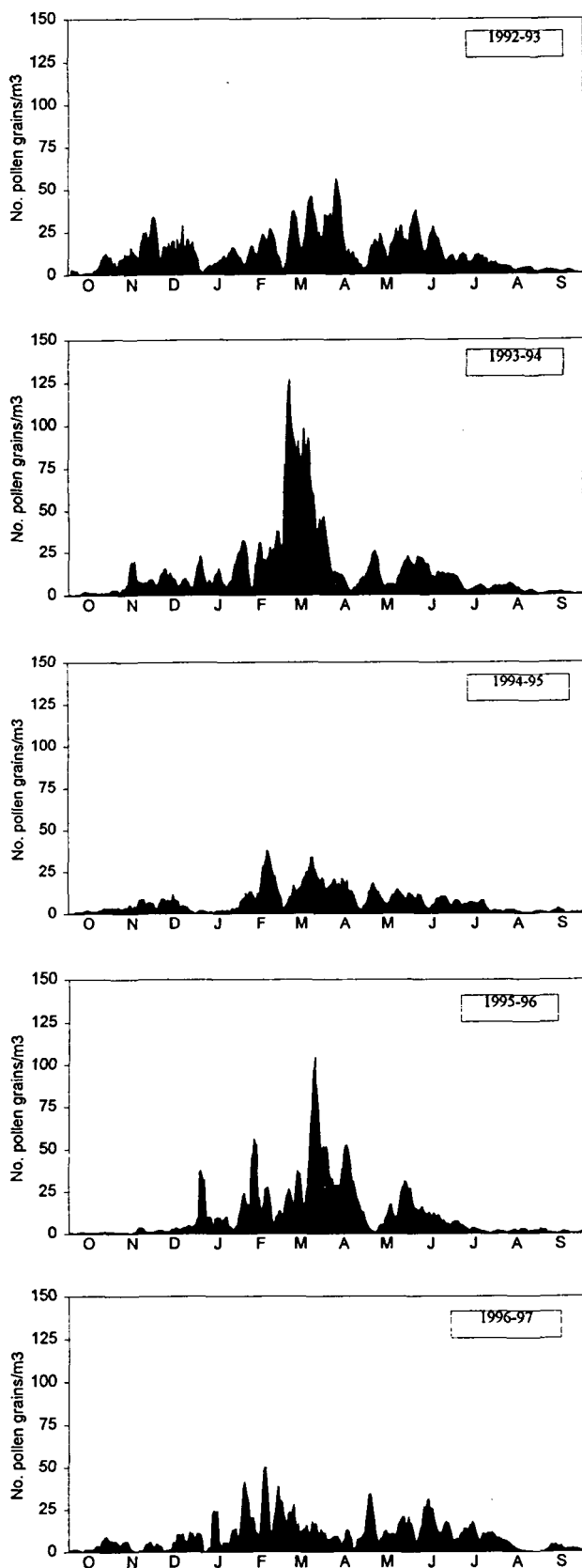


Fig. 2. Annual variation in five-day running mean of Urticaceae pollen (1992–1997).

highest levels are recorded between late winter and late spring (Fig. 2), with the longest MPS of all the pollen types studied. The seasonal behaviour of this pollen is very similar to that recorded in other cities in the southern Iberian Peninsula, such as Málaga (Trigo et al. 1996), Seville (González Minero et al. 1997) and Córdoba (Domínguez et al. 1995); however, in locations with different climates, such as London (Emberlin & Norris-Hill 1991) or Perugia (Fornaciari et al. 1992), the maximum counts are obtained in the summer. Although the start, end and duration of the MPS was very similar over all the years sampled, the mean annual and daily values varied considerably, ranging from 2590 grains/m³ in 1994–95 to 5227 grains/m³ in 1993–94, as a result of differences in the meteorological conditions (Fig. 4), particularly accumulated rainfall. Although Granada is located inland (Fig. 1), the humidity associated with the Darro and Genil rivers gives rise to numerous daily counts of >100 grains/m³ (Fig. 2), i.e. considerably higher levels than those found in nearby cities. These daily pollen figures are significant if we consider the sensitivity thresholds given by Negrini et al. (1992), who reported that when the count exceeded 80 grains/m³ over 90% of sensitive subjects presented maximum symptoms. The allergenic capacity of this pollen is very clear for the entire Granada region, where it is considered to be the third most common cause of pollinosis allergies (Díaz de la Guardia et al. 1991). These authors considered 9.5% of the region's population to be allergic to *Parietaria* pollen reaching 47.2% in certain areas of the coast.

The intradiurnal pattern obtained (Fig. 2) shows that Urticaceae pollen levels peak between 12.00 and 20.00 hours, with the lowest levels at other times of day. This pattern is similar to that found in nearby cities such as Córdoba (Galán et al. 1991) and Málaga (Trigo et al. 1996), although in Granada the maximum values appear two hours later, owing to the city's low early-morning temperatures. In this respect the Granada pattern more closely resembles that of other European cities such as London (Emberlin & Norris-Hill 1991) or Perugia (Fornaciari et al. 1992). This would indicate that the intradiurnal pattern of this pollen type is extremely constant, with a daily peak lasting several hours and occurring when the temperature reaches its maximum for the day, thus varying according to the time when the intradiurnal maximum temperature occurs.

Spearman's correlations with meteorological parameters

The results obtained for temperatures during the pre-peak period show that maximum temperatures of 15–28°C and mean temperatures of 9–15°C significantly favour the release of airborne pollen, as does an accumulated temperature of 1700–2400°C. The positive effect of temperature on the levels of this pollen type has been reported by authors studying other areas (Corden & Millington 1991, Emberlin & Norris-Hill 1991, González Minero et al. 1997). The lack of any link between these two variables during 1996–97 was because the peak date of the MPS fell early, which meant that the number of pre-peak days was very low, thus making it impossible for a statistically significant relationship to be established.

Table I. Characteristic data for airborne *Urticaceae* pollen in Granada during the MPS.

	1992-93	1993-94	1994-95	1995-96	1996-97
Date start/end of MPS	30 Oct/7 Aug	13 Nov/31 Jul	5 Nov/21 Jul	18 Dec/21 Jul	27 Oct/12 Jul
Length of MPS	282	261	273	217	259
Total grains	4710	5227	2590	4157	3309
No. grains/m ³ of peak day	73	183	53	161	92
Date of peak day	8 Apr	3 Mar	16 Feb	8 Feb	11 Jan
No. of days with 1-10 grains/m ³	105	114	165	98	127
No. of days with 11-50 grains/m ³	153	109	92	93	104
No. of days with 51-100 grains/m ³	7	17	1	13	7
No. of days with > 100 grains/m ³	0	8	0	4	0

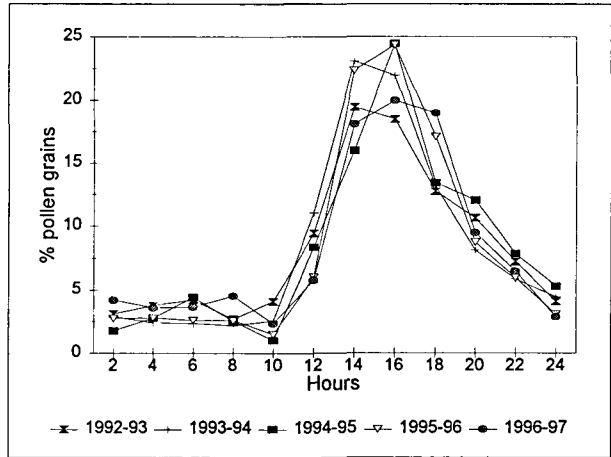


Fig. 3. Intradiurnal pattern of airborne *Urticaceae* pollen during the MPS.

Accumulated sunshine of 1300-1580 h also favours pollination, as occurred in the period between 1992 and 1994. Inversely, when the accumulated sunshine is lower (as in 1995-1997), the pollen count decreases considerably (Fig. 3). The negative coefficients with daily temperature (maximum, mean and minimum) and with accumulated temperature and sunshine during the post-peak period indicate that the pollen

count tends to drop after the maximum seasonal peak (Fig. 2), even though temperatures may continue to rise, since after the maximum counts from February to April the high temperature and long hours of sunshine cause the flowers to wither and so reduce their pollen production (Emberlin & Norris-Hill 1991). In 1996-97 positive coefficients were obtained with mean and maximum temperatures because the air temperature was still very mild (15°C) on the peak date (11 January), so these plants continued to release large amounts of pollen. The role of rainfall and the relative humidity of the air in decreasing airborne pollen levels has been documented by numerous authors, such that rainfall during both the pre- and post-peak periods combined with high humidity levels tends to cause airborne pollen levels to be lower. Inversely, accumulated rainfall significantly increased pollination during the pre-peak period during our study; this result is in agreement with the data reported by D'Amato et al. (1983), Fornaciari et al. (1992) and Trigo et al. (1996), who all indicated that the intensity of the release of *Urticaceae* pollen is linked to the rainfall prior to the pollen season, with the effect not being significant if rainfall is low (94 mm in 1994-95); however, during the post-peak period this parameter no longer has a positive effect on the daily counts, since the MPS has ended.

The mean wind speed generally presents significantly negative coefficients during the MPS, since it often causes the

Table II. Spearman's correlation coefficients between daily average pollen count and meteorological parameters during pre-peak period.

**p≤0,01 *p≤0,05.

	1992-93	1993-94	1994-95	1995-96	1996-97
Maximum temperature	0.4969**	0.7201**	0.4725**	0.2132	0.4823**
Mean temperature	0.4714**	0.5620**	0.4154**	0.0653	0.5238**
Minimum temperature	0.2097**	-0.0786	0.3086**	0.0864	0.2390*
Accumulative temperature	0.4197**	0.3406**	0.0770	0.2957*	0.0650
Sunshine hours	0.3137**	0.4074**	0.1726	0.3596**	0.3283**
Accumulative sunshine	0.3254**	0.3338**	0.0501	0.3247*	-0.1021
Rainfall	-0.1319	-0.2269*	-0.0152	-0.2868*	-0.1845
Accumulative rainfall	0.2951**	0.3211**	0.0415	0.3244*	-0.1117
Humidity	-0.1328	-0.4229**	-0.0815	-0.2834*	-0.3311**
Wind speed	-0.1704*	-0.2343*	-0.2078*	0.1363	0.0381
Calm	-0.0362	0.1161	0.0987	0.0306	0.0212
1st Quadrant	0.0544	-0.3217**	-0.2560**	0.0270	0.0513
2nd Quadrant	-0.0681	0.2279*	0.1441	0.0213	0.1084
3rd Quadrant	0.1968*	0.3752**	0.2809**	-0.0355	0.0934
4th Quadrant	0.2002*	-0.2327*	-0.2466*	0.0671	-0.3422**

Table III. Spearman's correlation coefficients between daily average pollen count and meteorological parameters during the post-peak period.

**p≤0,01 *p≤0,05.

	1992-93	1993-94	1994-95	1995-96	1996-97
Maximum temperature	-0.0814	-0.1937*	-0.1827*	-0.1155	0.3375**
Mean temperature	-0.1384	-0.2632**	-0.2739**	-0.2399**	0.1838*
Minimum temperature	-0.2949**	-0.3725**	-0.3957**	-0.4275**	0.0246
Accumulative temperature	-0.2985**	-0.6209**	-0.4967**	-0.4580**	0.0235
Sunshine hours	0.2047*	-0.3378**	0.3070**	-0.1995*	0.0367
Accumulative sunshine	-0.3159**	-0.6111**	-0.5468**	-0.4582**	0.0382
Rainfall	-0.2392**	-0.2154**	-0.1215	-0.2881**	-0.3747**
Accumulative rainfall	-0.0813	-0.5355**	-0.5436**	-0.4515**	0.0426
Humidity	-0.0160	0.0915	-0.0171	0.0257	-0.1949**
Wind speed	-0.2479**	-0.4155**	-0.1850*	0.0388	0.0892
Calm	0.0890	0.1772*	-0.1275	0.3071**	0.1806*
1st Quadrant	-0.0072	0.0020	0.2083**	0.0053	-0.0103
2nd Quadrant	-0.1224	-0.0776	0.2235**	-0.0193	-0.0668
3rd Quadrant	-0.1829*	-0.1166	0.2006*	-0.2532**	-0.1207
4th Quadrant	0.2462**	0.1966*	0.0217	0.2933**	-0.2007**

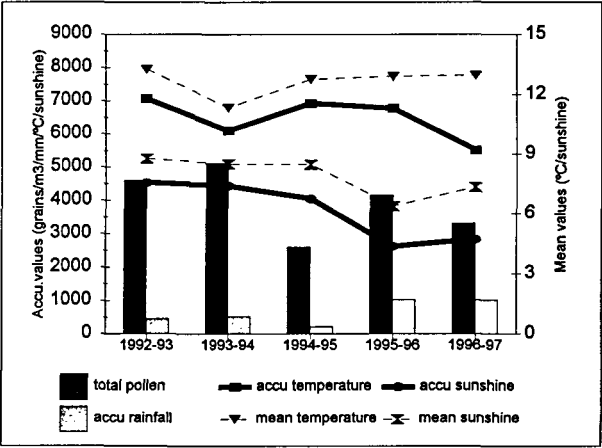


Fig. 4. Relationship between total pollen count for the MPS and main meteorological parameters (mean seasonal and accumulated values).

dispersion of airborne pollen, thus decreasing the levels recorded through aerobiological counts (Subba Reddi & Reddi 1985). Inversely, an increase in periods of calm during the post-peak period causes these pollen types to fall from the upper layer of the atmosphere. For wind direction (Fig. 5), the correlation obtained differs between the pre- and post-peak periods; during the former, prevailing winds from the third quadrant lead to high pollen counts, since these south-westerly winds bear the pollen of the area's major *Parietaria* populations, whereas during the post-peak period, although the prevailing winds continue to be south-westerly, they have no positive influence on the pollen counts recorded, while the north-westerly winds do have a positive influence, because of the less frequent but flowering *Urticaceae* populations to the NW of the city.

A theoretical predictive pattern has been devised (Fig. 6 A) from the data obtained during the five periods sampled, showing the curve that provides the best fit with our data and the predictive equation, using maximum temperature as

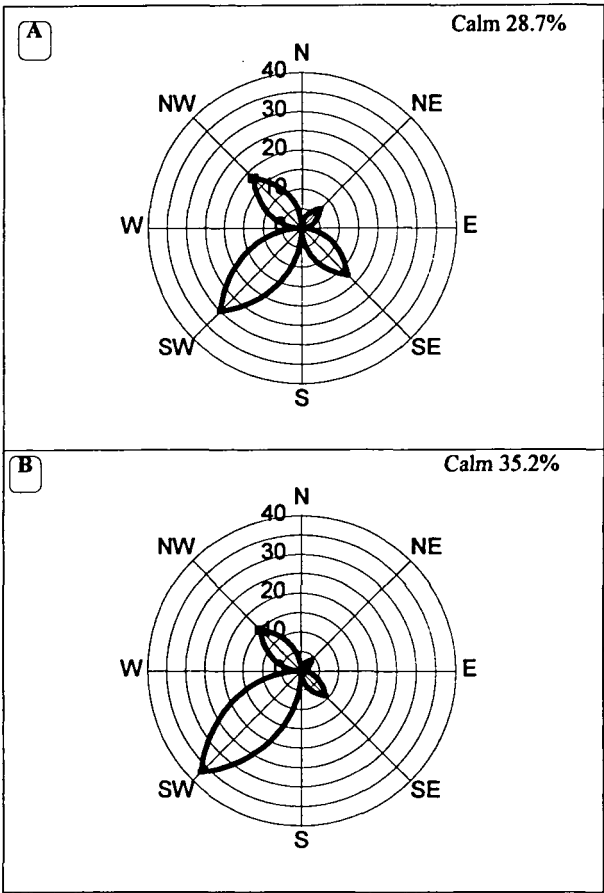


Fig. 5. Mean relative frequency of wind direction during: (A) pre-peak period; (B) post-peak period.

the only independent variable. The maximum daily temperature allows us to determine only 16% of the diurnal variation of *Urticaceae* in future pollen seasons. The remainder of the MPS (84%) cannot be forecast, because this pollen type is

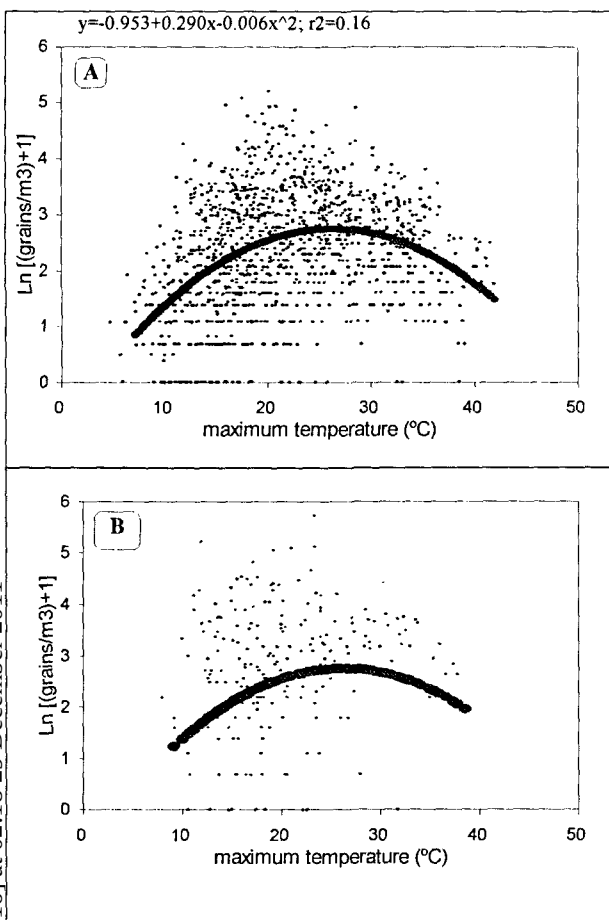


Fig. 6. (A) Total *Urticaceae* pollen during the MPS and theoretical predictive patterns related to maximum temperature; (B) Predictive pattern tested against data from the 1997-98 pollen season.

shared by a number of species with diverse, overlapping phenological characteristics, with some of them (e.g. *P. judaica*) presenting an extremely long MPS. The prediction model has been tested against the data corresponding to the 1997-98 pollen season (Fig. 6B), showing a widely scattered distribution of points.

Nevertheless, this theoretical pattern indicates that the release of airborne pollen is optimal when the maximum daily temperature ranges between 20°C and 30°C; when the maximum daily temperature is <20°C or >30°C, the airborne pollen levels in Granada decrease considerably.

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