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URTICACEAE POLLEN CONCENTRATION IN THE ATMOSPHERE OF NORTH WESTERN SPAIN

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Abstract: Plants of the Urticaceae family can develop into a pest on soils enriched with nitrogen. Urticaceae pollen is a biohazard because it elicits severe pollinosis. Pollen grains were sampled by using a Lanzoni seven-day-recording trap from February 1995–December 2000 in the atmosphere of the city of Ponferrada (León, North Western Spain). The Spearman test was used to analyse the statistical correlation between Urticaceae pollen and certain meteorological factors in different main pollination periods. Maximum values are reached in June and July, minimum levels are recorded in January and December. The parameters bearing the greatest positive influence on the occurrence of Urticaceae pollen grains are: temperature (maximum, minimum and mean), humidity (absolute, wet-bulb temperature, dew point and mixing ratio) and south western wind direction; negative parameters are: relative humidity, rainfall and period without wind. The highest correlation coefficients were obtained with temperature and wet-bulb. Absolute humidity and wet-bulb temperature yielded better correlation than relative humidity; hence, these two parameters must be included in this type of study. The use of one main pollination period or another in statistical analysis has an influence on the coefficient value. The behaviour of the pollen grains in the atmosphere during the year also influences the results.

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INTRODUCTION

The existence of pollen grains in the atmosphere is a natural phenomenon. It is the result of the sexual cycle of anemophilous plants, such as the Urticaceae family. Hence, pollen dispersal is a dynamic phenomenon and this fact should be reflected in the variables that are used to explain it, such as meteorological parameters. These factors have an influence on the emission, transport, permanence, deposition and capture of pollen grains. The traditional parameters used in airborne pollen studies are maximum, minimum and mean temperature, rainfall, relative humidity, wind speed and wind direction. All these factors may be interrelated and may act at any moment during the life of the plant. Many aerobiological studies have focused on developing pollen season predictive models, particularly to determine pollen season duration, and start and end dates. These models are based on correlations obtained between pollen concentration and the meteorological parameters mentioned previously.

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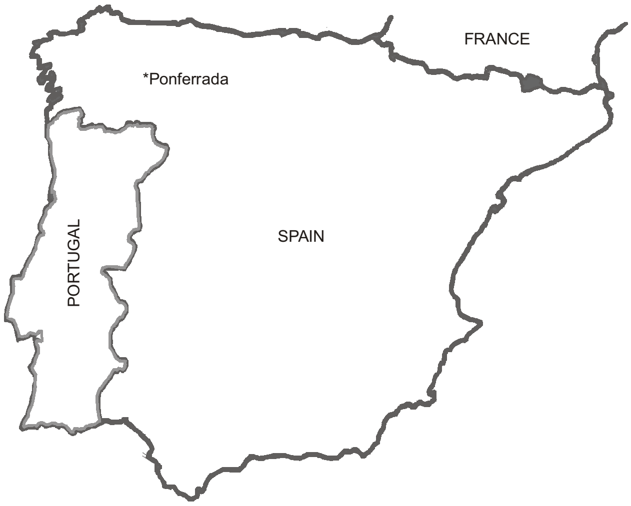

Figure 1. Location of Ponferrada in Spain.

With these models, doctors and pollen-sensitive patients may be warned of the severity of the pollen season. However, all predictive models require a detailed analysis of the role of the controlling variables and an understanding of the relative importance of the meteorological factors in different scenarios [17]. Moreover, relationships found in one area may not always be applicable to another because meteorological parameters are intercorrelated and dependent on a particular site [21].

The Urticaceae family consists of around 52 genera and 1,050 species. The two most important genera are *Urtica* and *Parietaria*. The plants of the *Urtica* genus (nettle) are ruderal weeds. They are very common in nitrified areas such as roadsides and between cultivated areas. The plants of the *Parietaria* genus (pellitory of the wall) are found mostly on city walls and other nitrified areas. These plants, are mostly anemophilous. Urticaceae stamens are bent but when temperature and humidity conditions are suitable they rise to the upright position and release their pollen grains. Hence, the release, transportation and dispersal of Urticaceae pollen in the atmosphere are closely linked to atmospheric phenomena. Knowledge of all these relationships is very important because Parietaria pollen grains elicit severe pollinosis in Europe, Africa, Asia, Australia, and the United States of America [3, 5, 7, 8].

Several studies have examined the influence of meteorological parameters on the pollen concentration of the Urticaceae family [4, 6, 10, 15, 16, 18, 20, 27]. In most of these studies, the authors have worked with traditional meteorological parameters and one main pollination period (MPP) (days of the year with a higher percentage of pollen grain release into the atmosphere by one species, genus or family).

The aim of this study was to examine the influence of traditional meteorological parameters and others used for the first time in this type of study (absolute humidity, wet-bulb temperature, dew point and mixing ratio) on Urticaceae pollen concentration in the atmosphere of Ponferrada, city with a high pollinosis level [11]. The authors also studied these relationships in different main

Table 1. Characteristic data for different main pollination periods. CPP: complete pollination period.

Year	Main pollination periods				
	Mullenders *et al.* [22]	Nilsson, Persson [23]	Andersen [1]	Galán *et al.* [17]	CPP
Start date					
1995	9 Jun	23 May	18 May	20 Mar	1 Feb
1996	7 Jun	14 Apr	9 Apr	5 Apr	1 Jan
1997	12 Jun	30 Apr	14 Mar	13 Feb	1 Jan
1998	4 Jun	8 May	27 Apr	16 Mar	1 Jan
1999	7 May	2 Apr	30 Mar	18 Mar	1 Jan
2000	12 Jun	17 Apr	9 Mar	29 Feb	1 Jan
End date					
1995	28 Aug	25 Aug	28 Aug	30 Aug	31 Dec
1996	20 Aug	29 Aug	11 Sep	26 Sep	31 Dec
1997	19 Aug	21 Aug	29 Aug	25 Aug	31 Dec
1998	8 Aug	20 Aug	9 Oct	15 Oct	31 Dec
1999	18 Aug	1 Sep	11 Sep	16 Sep	31 Dec
2000	4 Aug	3 Aug	17 Aug	15 Aug	31 Dec
Duration (days)					
1995	79	93	101	161	331
1996	73	136	154	172	360
1997	55	93	148	173	340
1998	48	85	125	173	364
1999	104	153	166	183	363
2000	54	109	162	173	363
Total *Urticaceae* pollen collected					
1995	364	398	417	428	442
1996	246	302	321	327	337
1997	249	282	296	298	314
1998	148	180	189	194	199
1999	474	591	618	634	653
2000	495	602	635	651	670

pollination periods because each author established a different percentage to determinate this period. As a result, it was determined that MPP was better for devising a predictive model of the seasonal behaviour of Urticaceae pollen grains.

MATERIALS AND METHODS

The city of Ponferrada is located in the north western (NW) part of the Iberian Peninsula (latitude 42º 33´ N, longitude 6º 35´ W, altitude 541 m) (Fig. 1). The city's climate is mediterranean with oceanic influence [25]. During the study period, the mean maximum temperature in the hottest month (July) was 29.4ºC, the mean minimum temperature in the coldest month (January) was 1.8ºC and the mean annual temperature was 13.3ºC. Total annual rainfall ranged between 481 mm in 1998 to 941 mm in 1999.

Pollen monitoring was performed from 1 February 1995–31 December 2000 using a Lanzoni VPPS 2000 seven-day-recording volumetric spore trap sampler [19], located approximately 15 m above ground level in an open space with no nearby buildings that could interrupt the movement of air. The samples were prepared and counted using the method proposed by the Spanish Aerobiology Network [9]. The daily pollen concentration in the air was expressed as number of pollen grains per m^3 within 24 hours [9]. The monthly total concentration was the sum of all daily concentrations per one month, while the total annual concentration was the sum of all monthly concentrations per one year. The mean annual concentration for 6 years of study was obtained by the division of the sum of all annual concentrations by 6.

There are numerous criteria for establishing the MPP, and the demarcation varies according to the one chosen. In this paper, we determined the MPP in accordance with the criteria used by the following authors: Mullenders *et al.* [22] (this period includes 85% of the total catch for the year), Nilsson and Persson [23] (corresponding to 90% of the total pollen catch), Andersen [1] (corresponding to 95% of the total pollen catch) and Galán *et al.* [17] (corresponding to 98% of total pollen). We also used the complete pollination period (CPP), which takes into account 100% of total pollen grains.

Non parametric statistical analysis by Spearman's rank order correlation test, was applied to determine whether daily pollen concentration and meteorological parameters were positively or negatively correlated.

The traditional meteorological factors studied were as follows: maximum, minimum and mean temperatures, relative humidity, rainfall, wind speed and direction, and frequency of calms. The new factors used in this study were as follows: wet-bulb temperature, dew point, absolute humidity and mixing ratio. These data were supplied by the Ponferrada station of the Territorial Meteorological Centre of Castilla y León.

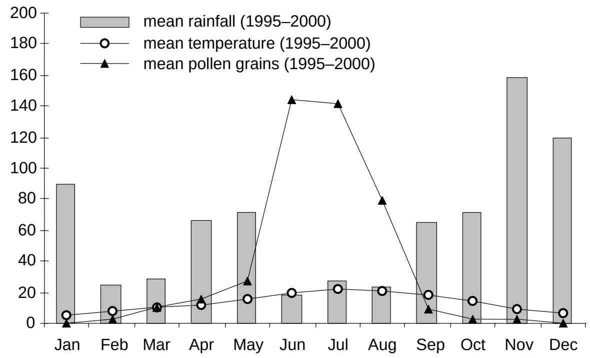

Figure 2. Annual variation of *Urticaceae* pollen (grains/m^3), temperature (ºC) and rainfall (mm). Mean values for the years 1995–2000.

RESULTS

This aerobiological study reports the behaviour of airborne Urticaceae pollen in the atmosphere above Ponferrada throughout the year. The daily concentrations of Urticaceae pollen ranged from 0 to 27 grains/m^3/24 h. The seasonal pattern (Fig. 2) shows that the highest monthly total concentrations were recorded in June and July (on average 144 pollen grains/m^3), while the lowest levels occurred in autumn and winter. The annual total

Table 2. Significant Spearman's correlation coefficients between *Urticaceae* pollen concentrations and temperatures, considering the main pollination periods described by Mullenders *et al.* [22], Nilsson and Persson [23], Andersen [1], Galán *et al.* [17] and the complete pollination period.

	1995	1996	1997	1998	1999	2000	1995–2000
			Maximum temperature				
Mullenders *et al.* (1972)	0.304**	0.324**	0.428**	-	0.486**	0.441**	0.313**
Nilsson and Persson (1981)	0.415**	0.594**	0.523**	-	0.566**	0.751**	0.512**
Andersen (1991)	0.425**	0.545**	0.444**	0.240**	0.508**	0.641**	0.500**
Galán *et al.* (1995)	0.598**	0.556**	0.474**	0.405**	0.538**	0.636**	0.532**
complete pollination period	0.683**	0.653**	0.504**	0.508**	0.741**	0.582**	0.611**
			Minimum temperature				
Mullenders *et al.* (1972)	-	-	0.396**	-0.323*	0.543**	-	0.225**
Nilsson and Persson (1981)	0.239*	0.424**	0.445**	-	0.591**	0.643**	0.443**
Andersen (1991)	0.277**	0.396**	0.531**	-	0.523**	0.581**	0.450**
Galán *et al.* (1995)	0.676**	0.380**	0.562**	0.304**	0.556**	0.565**	0.515**
complete pollination period	0.675**	0.553**	0.442**	0.431**	0.671**	0.511**	0.550**
			Mean temperature				
Mullenders *et al.* (1972)	0.261*	0.277*	0.492**	-	0.578**	0.429**	0.321**
Nilsson and Persson (1981)	0.393**	0.557**	0.551**	-	0.623**	0.773**	0.522**
Andersen (1991)	0.418**	0.520**	0.550**	0.195*	0.558**	0.648**	0.515**
Galán *et al.* (1995)	0.711**	0.526**	0.582**	0.385**	0.587**	0.634**	0.564**
complete pollination period	0.723**	0.642**	0.517**	0.495**	0.739**	0.575**	0.613**

*$p \leq 0.05$, ** $p \leq 0.01$.

Table 3. Significant Spearman's correlation coefficients between *Urticaceae* pollen concentrations, rainfall and humidities, considering the main pollination periods described by Mullenders *et al.* [22], Nilsson and Persson [23], Andersen [1], Galán *et al.* [17] and the complete pollination period.

	1995	1996	1997	1998	1999	2000	1995–2000
			Rainfall				
Mullenders *et al.* (1972)	-0.323**	-	-	-	-0.212*	-0.269*	-0.186**
Nilsson and Persson (1981)	-0.261*	-0.270**	-0.389**	-0.237*	-0.307**	-0.641**	-0.347**
Andersen (1991)	-0.227*	-0.230**	-	-0.324**	-0.272**	-0.469**	-0.296**
Galán *et al.* (1995)	-0.217**	-0.271**	-	-0.328**	-0.269**	-0.451**	-0.275**
complete pollination period	-0.218**	-0.226**	-0.188**	-0.217**	-0.246**	-0.326**	-0.240**
			Relative humidity				
Mullenders *et al.* (1972)	-0.260*	-0.245*	-0.357**	-	-0.263**	-0.418**	-0.245**
Nilsson and Persson (1981)	-0.253*	-0.415**	-0.274**	-0.219*	-0.356**	-0.726**	-0.378**
Andersen (1991)	-0.231*	-0.351**	-	-0.341**	-0.366**	-0.447**	-0.287**
Galán *et al.* (1995)	-	-0.392**	-	-0.367**	-0.340**	-0.441**	-0.250**
complete pollination period	-0.464**	-0.497**	-0.317**	-0.386**	-0.617**	-0.513**	-0.460**
			Absolute humidity				
Mullenders *et al.* (1972)	-	-	-	-0.289*	0.537**	-	0.203**
Nilsson and Persson (1981)	-	0.415**	0.387**	-	0.585**	0.585**	0.394**
Andersen (1991)	0.214*	0.391**	0.521**	-	0.486**	0.571**	0.414**
Galán *et al.* (1995)	0.619**	0.362**	0.558**	0.303**	0.523**	0.564**	0.487**
complete pollination period	0.566**	0.507**	0.400**	0.417**	0.644**	0.507**	0.512**
			Wet-bulb temperature				
Mullenders *et al.* (1972)	-	0.267*	0.435**	-	0.578**	0.386**	0.297**
Nilsson and Persson (1981)	0.284**	0.526**	0.535**	-	0.592**	0.738**	0.497**
Andersen (1991)	0.327**	0.492**	0.586**	0.189*	0.544**	0.640**	0.499**
Galán *et al.* (1995)	0.696**	0.485**	0.609**	0.371**	0.576**	0.628**	0.558**
complete pollination period	0.695**	0.610**	0.497**	0.477**	0.712**	0.562**	0.591**
			Dew point				
Mullenders *et al.* (1972)	-	-	0.284*	-0.294*	0.546**	-	0.217**
Nilsson and Persson (1981)		0.437**	0.404**	-	0.593**	0.613**	0.410**
Andersen (1991)	0.225*	0.410**	0.528**	-	0.496**	0.583**	0.427**
Galán *et al.* (1995)	0.628**	0.381**	0.563**	0.311**	0.532**	0.575**	0.498**
complete pollination period	0.586**	0.523**	0.409**	0.424**	0.654**	0.514**	0.524**
			Mixing ratio				
Mullenders *et al.* (1972)	-	-	-	-	0.335**	-	-
Nilsson and Persson (1981)	-	-	-	-	0.409**	-	0.116**
Andersen (1991)	-	-	0.350**	-	0.313**	0.331**	0.191**
Galán *et al.* (1995)	0.466**	-	0.374**	0.166*	0.363**	0.342**	0.279**
complete pollination period	0.255**	0.239**	0.177*	0.302**	0.458**	0.326**	0.288**

$^{*}p \leq 0.05$, $^{**}p \leq 0.01$.

concentrations fluctuated between 199 pollen grains/m^3 collected during 1998 and 670 pollen grains/m^3 collected in 2000 (Tab. 1). The annual total counts decreased until 1998 and increased in 1999 and 2000 (Tab. 1). The mean annual concentration registered during 6 years of study was 436 pollen grains/ m^3.

The start of the different MPP varied from 13 February, as reported by Galán *et al.* [17], to 12 June, according to Mullenders *et al.* [22] (Tab. 1). However, the ends of these MPPs were fairly uniform, finishing in August and occasionally in September or October. Moreover, the length of the studied MPP differed from year to year, and as a result the pollen concentrations recorded in each one of these periods varied from one year to the next.

Spearman's correlation coefficients obtained by comparing Urticaceae pollen concentrations and meteorological parameters were calculated for five pollination periods each year and for all the years together. Correlation analysis revealed that temperature was the parameter that generally had a positive significant relationship with Urticaceae pollen levels. Minimum temperature was only related negatively to the MPP defined by Mullenders *et al.* [22]

Table 4. Spearman's correlation coefficients between *Urticaceae* pollen concentrations, wind speed and direction, considering the main pollination periods described by Mullenders *et al.* [22], Nilsson and Persson [23], Andersen [1], Galán *et al.* [17] and the complete pollination period.

	1995	1996	1997	1998	1999	2000	1995–2000
			Wind speed				
Mullenders *et al.* (1972)	-	-0.341**	-0.298*	-	-	-	-
Nilsson and Persson (1981)	-	-	-	-	-	0.246*	-
Andersen (1991)	-	-	-	-	-	0.195*	-
Galán *et al.* (1995)	-	-	-	-	-	0.193*	0.075*
complete pollination period	0.387**	0.134*	0.209**	0.183**	0.286**	0.311**	0.245**
			1st quadrant north–north-east				
Mullenders *et al.* (1972)	-0.371*	-	0.335*	-	-	-	-
Nilsson and Persson (1981)	-	-	-	-	-	-0.229*	-0.111**
Andersen (1991)	-	-	-	-	-	-0.171*	-0.103**
Galán *et al.* (1995)	-	-	-	-	-	-0.158*	-
complete pollination period	0.140*	-0.126*	-	-	-	-	-
			2nd quadrant north-east–south				
Mullenders *et al.* (1972)	-	0.309**	0.392**	0.262*	-	-	0.105*
Nilsson and Persson (1981)	-	0.255**	-	-	-	-	-
Andersen (1991)	-	0.169*	-	-	-	-	-
Galán *et al.* (1995)	-	0.207**	-0.170*	0.149*	-	-	-
complete pollination period	-	-	-0.140*	-	-	-	-0.052*
			3rd quadrant south–south-west				
Mullenders *et al.* (1972)	-	-	-0.387**	-	-	-	-0.109*
Nilsson and Persson (1981)	-	-	-	-	-	0.197*	-
Andersen (1991)	-	-	0.279**	-	-	0.222**	0.109**
Galán *et al.* (1995)	-	-	0.260**	-	-	0.215**	0.098**
complete pollination period	0.280**	0.177**	0.279**	0.166**	0.250**	0.206**	0.229**
			4th quadrant south-west–north				
Mullenders *et al.* (1972)	-	-	-	-	0.225*	-	-
Nilsson and Persson (1981)	-	-	0.267**	-	-	-	-
Andersen (1991)	-	-	0.302**	-	0.161*	-	0.122**
Galán *et al.* (1995)	-	-	0.320**	-	0.173*	0.159*	0.144**
complete pollination period	0.400**	-	0.247**	-	0.250**	0.166**	0.205**
			Calm				
Mullenders *et al.* (1972)	-	-	-	-	0.275**	-	0.139**
Nilsson and Persson (1981)	-	-	-	-	0.176*	-0.304**	-
Andersen (1991)	-	-	-0.195*	-	-	-0.275**	-
Galán *et al.* (1995)	-	-	-0.226**	-	-	-0.268**	-0.067*
complete pollination period	-0.400**	-0.134*	-0.269**	-0.159**	-0.262**	-0.290**	-0.247**

$^{*}p \leq 0.05$, $^{**}p \leq 0.01$.

in 1998. The highest correlation coefficients were generally observed in CPP and the lowest coefficients with respect to the MPP defined by Mullenders *et al.* [22] (Tab. 2).

Negative significant indices were obtained in terms of daily rainfall for all the years studied. In this case, the highest correlation coefficients were observed with the MPPs reported by Galán *et al.* [17] and Nilsson and Persson [23] (Tab. 3).

Relative humidity presented negative indices, whereas absolute humidity, wet-bulb temperature, dew point and mixing ratio displayed positive correlation coefficients (Tab. 3). With relative humidity, maximum levels were obtained with CPP in most of the years studied. Absolute humidity presented the best correlations with the MPP and CPP reported by Galán *et al.* [17], except for 2000 when better correlations were observed with the MPP defined by Nilsson and Persson [23]. In terms of the other three parameters, it is worth highlighting that the values of the wet-bulb temperature showed a high correlation with the CPP and MPP defined by Galán *et al.* [16].

The lowest correlation was found with respect to wind speed and direction. The test results were not significant, or significant but with low indices (Tab. 4). The highest values were recorded with wind direction from the third (S-SW) and fourth (SW-N) quadrant in the CPP. Generally, there was a negative correlation between calms and daily pollen counts. The coefficients were significant only for CPP throughout all years.

DISCUSSION

Urticaceae pollen concentration in the city of Ponferrada is one of the most significant, although its presence in the atmosphere is not continuous throughout the year. This does not occur in other Spanish towns (see: bulletins of the REA - Spanish Aerobiology Network). The months in which maximum pollen concentrations were recorded were the same in all six years: June and July. Like León [12, 13, 14, 28, 29], Ponferrada is the Spanish city in which maximum values appear later. In Santiago de Compostela, Vigo, Orense, Madrid, Gerona, Manresa and Barcelona, maximum concentrations are collected between May and June, whereas in Jaén, Estepona and Málaga, maximums are recorded in February and March [4]. However, in Central and Northern European towns the highest pollen concentrations occur during July and August [24]. These differences in terms of maximum months are due to temperature. Urticaceae pollination seems to take place when the temperature reaches around 25ºC.

Of all the REA stations, Ponferrada has the lowest total annual concentrations of Urticaceae pollen grains. These values are also much lower than those collected in Northern and Southern European cities [24]. Human action influences the total annual concentration of these pollen grains. During the first four years, total annual Urticaceae pollen concentrations decreased progressively because these plants disappeared as a result of building in areas inhabited by this type of vegetation. However, during the last two years, an important increase was observed because several areas populated by other plants were turned over.

The results obtained in this work show that maximum, minimum and mean temperatures, wet-bulb temperature and absolute humidity are the best meteorological parameters for explaining the behaviour of Urticaceae pollen grains in any pollination period. Other authors [6, 10, 15, 16, 18, 27] have even reported that temperature is the factor that exerts the greatest influence on these pollen grains. Temperature increases faster pollen liberation from the anther, although excessive increases may be harmful because they may cause plants to wither.

Rainfall yielded negative correlations since water droplets take away pollen particles found in the air, producing an atmospheric washing. In Ponferrada, correlation coefficients between Urticaceae pollen concentration and rainfall were low. Therefore, its influence on Urticaceae pollination is poor. In that sense, we agree with some authors [6, 15] who reported that only strong rainfall may influence Urticaceae pollen levels. However, other authors consider that this meteorological factor and temperature are the parameters that bear a stronger influence on these pollen grains [2, 10, 18].

It is also important to highlight that correlation coefficients were positive with absolute humidity, presenting higher values than coefficients obtained with relative humidity. Hence, a certain level of humidity is required for Urticaceae pollen grain release. This meteorological parameter must therefore be included in this type of study.

The correlations coefficients do not show clear trends with meteorological parameters related to wind, as other authors have reported [26, 27], and they also present low values. Hence, wind has no significant influence on the release of these pollen grains because these plants do not have a passive pollen release mechanism. In Ponferrada, the best positive indices generally appear with high wind speeds and a wind direction from the south-west and north-west, because these are areas with human activity. However, this city borders the Galaico-Astúricos mountains and the León mountains to the north–north-east and south–south-east, respectively, where Urticaceae plants are not predominant.

The variations in the lengths and dates of the beginning and end of the different MPP studied are also explained by meteorological parameters [20]. Rainfall distribution may account for the significant difference observed between the start date of the MPPs defined by Mullenders *et al.* [22] and Galán *et al.* [17], particularly in 1997 and 2000, when rainfall was heaviest in winter.

The authors studied the MPP in order to eliminate long tails of low values at the start and the end of the pollen season, which may introduce bias in the results during statistical analysis [17]. However, in this study the authors observed a better correlation with CPP concentrations. Urticaceae pollen grains appeared in low or null concentrations in Ponferrada; therefore it is not advisable to work with MPP because necessary information for performing good predictions of this pollen type is lost.

The behaviour of these pollen grains differed throughout the six years of the study. As a result, the correlations also differed. When pollen grains were in the atmosphere in higher concentrations for few days, the best coefficients were obtained with Nilsson and Persson’s [23] MPP. However, when concentrations were low and pollen grains remained in the atmosphere for several days, the best coefficients were obtained with CPP. Due account must therefore be taken of behaviour, number of pollen grains and the MPP to be used in order to achieve good pollen forecasts.

In general, numerous meteorological factors influence airborne pollen concentrations. As a result, positive and negative factors occasionally overlap and correlations are therefore not always clear. The challenge would be to determine the influence of each meteorological factor separately, which is difficult to accomplish in a natural environment.

CONCLUSIONS

Spearman's correlation analysis revealed that maximum, minimum and mean temperature, absolute humidity, wet-bulb temperature, dew point, mixing ratio, wind speed and wind direction from south-west and north-west presented positive significant coefficients. Conversely, rainfall, relative humidity and calm yielded negative significant coefficients. Absolute humidity and wet-bulb temperature, the meteorological parameters which were used for first time in this type of study showed a great influence on Urticaceae pollen grains. The use of these new meteorological parameters could be a major step forward in the methodology of forecasting of the pollen concentration in the air.

We observed that the use of specific MPP influenced the correlations between meteorological factors and Urticaceae pollen concentrations. In this study, the highest coefficients were generally obtained with CPP and the lowest indices with the MPP defined by Mullenders *et al.* [22]. It is therefore necessary to take into account the number and behaviour of pollen grains before choosing a specific MPP.

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