

Characteristics of grass pollen seasons in areas of southern Spain and the United Kingdom

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Abstract

Spatial and temporal variations in daily grass pollen counts and weather variables are described for two regions with different bio-geographical and climatic regimes, southern Spain and the United Kingdom. Daily average grass pollen counts are considered from six pollen-monitoring sites, three in southern Spain (Ciudad Real, Córdoba and Priego) and three in the United Kingdom (Edinburgh, Worcester and Cambridge). Analysis shows that rainfall and maximum temperatures are important factors controlling the magnitude of the grass pollen season in both southern Spain and the United Kingdom, and that the strength and direction of the influence exerted by these variables varies with geographical location and time.

Introduction

Pollen from the grass family (Poaceae) is considered to be one of the most important aeroallergens in Europe. This is because of its ubiquitous nature and the allergenic capacity of pollen grains from its species. Poaceae is a highly adaptable and extremely large family that is widely distributed but the mix of species varies regionally across Europe. There are approximately 420 species of grass in Spain (García Rollán, 1985) and 250 in the United Kingdom (Stace, 1997), the two countries investigated in this study. The analysis of grass pollen seasons is complicated by the fact that grass pollen is not identified to species level. With few exceptions, all pollen grains from grasses are very similar. From the allergenic standpoint this is not important, as there is a high degree of cross reactivity between them. However, from the forecasting perspective there are a number of ecological and

environmental differences between species that have to be considered.

It is well known that the timing and magnitude of grass pollen seasons differs between regions due to factors that affect pollen abundance and dispersal. These factors include local vegetation type, land use, latitude, altitude and climate (Emberlin et al., 1994; Galan et al., 1995; Emberlin, 1997; Emberlin et al., 1999; Emberlin et al., 2000). However, the relative importance of these factors in different regions is less well understood. In order to construct more accurate regional or local forecast models it is important to understand the relationship between dependent variables (the main characteristics of the grass pollen season or daily average grass pollen counts) and independent variables (meteorological parameters) at different sites.

This paper presents the findings of a study into the relationships between daily grass pollen counts

and weather variables in two regions with different bio-geographical and climatic regimes, southern Spain and United Kingdom. The main objectives of this investigation are to find out the relative importance of different meteorological parameters at the various sites and to determine whether it is feasible to forecast grass pollen counts in the two regions using similar methods. The aim of this study is to develop a better understanding of the factors that influence atmospheric grass pollen concentrations so that more accurate forecast models can be produced in the future.

Material and methods

Records of daily average grass pollen concentrations have been analysed for selected sites in the United Kingdom and southern Spain. The data have been taken from six pollen-monitoring sites (Figure 1), three in southern Spain (Ciudad Real, Córdoba and Priego) and three in the United Kingdom (Edinburgh, Worcester and Cambridge). Pollen data for the years 1995–2000 (1997–2000 at Ciudad Real) were collected at each of the sites by volumetric spore traps of the Hirst design (Hirst, 1952). The traps were located on exposed rooftops and comparable methods were used for counting the slides (Cariñanos et al., 2000).

The climate of the study area in southern Spain is typically Mediterranean, with mild winters and prolonged hot, dry summers. The wettest months are from September to May, with most precipitation falling as torrential downpours. The Mediterranean climate is characterised by enormous variability. Periods of wet and dry weather alternate with dry spells being more frequent than wet. Significant differences can exist within a year, resulting in, for example a very wet winter and very dry spring, or vice versa. Summer months experience only a few heavy showers. The annual total rainfall is affected by periods of recurring drought, when the amount of rainfall is very much lower than the mean, one of the most specific features of the Mediterranean climate (Domínguez Bascón, 1981).

The city of Córdoba (37°55' N 4°45' W; height above sea level 123 m) experiences a Mediterranean type climate with some continental and maritime influences. Temperatures are high (mean temperatures of about 17.4 °C); precipitation is influenced by the passage of depressions that originate in the Atlantic Ocean and result in a mean annual rainfall of 630 mm. Priego (37°26' N 4°11' E; height above

sea level 650 m) to the south of Córdoba is also subject to the maritime influence of the Atlantic but because of its altitude it is wetter with mean annual precipitation of approximately 700 mm. The higher altitude of Priego means that it is also cooler, with mean annual temperatures of about 14.4 °C (Sinambá, 1997). Ciudad Real (38°59' N 3°55' E; height above sea level 623 m) to the north of Córdoba experiences a more continental climate. It is consequently drier with mean annual precipitation of around 450 mm. Mean annual temperatures of about 14.2 °C reflect the altitude of the site.

The British Isles has a maritime temperate climate, which is influenced throughout the year by depressions from the west. The maritime influence is characterized by a relatively small annual range of temperature; high humidity and rainfall; relatively evenly distributed rainfall (with a tendency towards a winter maximum); and rapidly fluctuating weather associated with the passage of fronts and anticyclones (Goudie, 1996; BBC, 2001).

The three sites in the United Kingdom selected for analysis have contrasting local climates that reflect some of the spatial variations witnessed in the British Isles. Worcester (52°11' N 2°13' W; height above sea level 25 m) and Cambridge (52°13' N 0°7' E; height above sea level 30 m) have annual average temperatures of 10 °C. Mean annual precipitation in Worcester, situated to the west, is approximately 800 mm. Cambridge, to the east, is drier with mean annual precipitation of about 550 mm. Because of its northeasterly location and altitude, Edinburgh (55°55' N 3°12' W; height above sea level 134 m) is colder with mean annual temperatures of 8.5 °C and wet, it has a mean annual precipitation around 700 mm (METO, 2001).

Weather parameters selected for analysis were daily rainfall and daily maximum temperature. Previous research has demonstrated that these variables are the most important factors controlling the production of pollen in the spring and that their overriding influence continues into the pollen season for the release and dispersal of pollen grains (Faegri and van der Pijl, 1966; Emberlin et al., 1993; Emberlin et al., 1999).

Instituto Nacional de Meteorología supplied meteorological data for Córdoba and Ciudad Real, and meteorological data for Priego were obtained from Centro de Investigación y Formación Agraria (CIFA) Consejería de Agricultura y Pesca, Junta de Andalucía. The Meteorological Office via the British Atmospheric Data Centre (BADC) supplied the meteorological

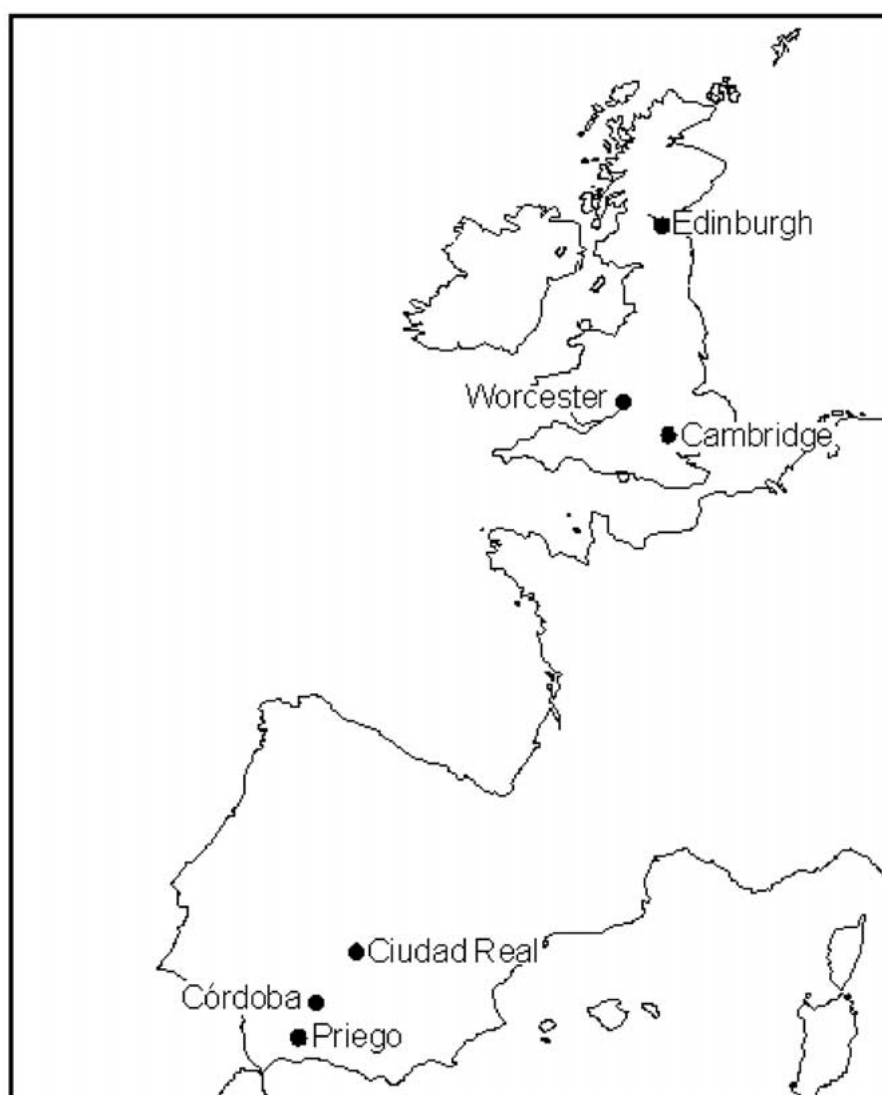


Figure 1. Location of the sampling sites.

logical data for the United Kingdom. Table 1 shows the distance between the pollen traps and meteorological stations used in this work.

In this study the grass pollen season has been delimited using the Threshold 30 method whereby, the start and end of the grass pollen season are defined as the first and last days when the pollen counts are ≥ 30 grains/m³. This technique eliminates the long tails of low values at the start and the end of the seasons that may introduce bias to the results during statistical analysis. Grass pollen concentrations and weather variables were subjected to correlation analysis.

Table 1. The distance between the pollen traps and meteorological stations used in this study

Site of pollen trap	Distance to meteorological station (km)
Edinburgh	5
Worcester	8
Cambridge	1
Ciudad Real	1
Córdoba	5
Priego	8

Results

As would be expected from the differences in climate there is a relationship between the start date of the grass pollen season and the latitude of the sites (Table 2). The season starts earlier in southern Spain than in the United Kingdom, and Edinburgh has the latest start to the season.

There is a great deal of fluctuation in the severity of the grass pollen season in southern Spain (Table 2). A fact previously observed by Fernández-González et al., (1999). For example, in Córdoba sums of grass pollen recorded in the 1995 and 1996 grass pollen seasons were 701 and 8885 grains respectively.

Mean monthly (1995–2000) cumulative rainfall and mean maximum temperatures from January 1st to August 31st are given on Figure 2. Comparison between monthly cumulative rainfall from January 1st in 1995 and 1996 in Córdoba (Figure 3) and the mean shows that the winter and early spring were very dry in 1995 and exceedingly wet in the winter and spring prior to the 1996 grass pollen season.

Out of the sites examined during this investigation, Edinburgh and Priego exhibited the shortest grass pollen seasons in the United Kingdom and Spain respectively. This fact may be related to latitude (Edinburgh) and altitude (Priego), circumstances that influence the development of grasses.

Relationships between daily grass pollen counts and meteorological parameters were investigated at each site for all grass pollen seasons combined (Table 3) and for individual seasons (Table 4) using correlation analysis. Results of both analyses show that daily grass pollen counts are generally more highly related to maximum temperatures than to rainfall and, on the whole, correlations are stronger in the United Kingdom than in southern Spain. When data from each of the six sites were analysed, for all grass pollen seasons combined, it was found that the strongest correlations were at Edinburgh the most northerly site. The same analysis showed that the weakest correlation between daily grass pollen counts and rainfall was at Ciudad Real; there was also a significant inverse relationship ($R = -0.17$) between grass pollen counts and maximum temperatures at this site.

Analysis of individual grass pollen seasons at each site also shows that the strength of the relationship remains fairly constant from season to season in the United Kingdom but differs annually in southern Spain. In order to investigate this further, correlation

Table 2. The main characteristics of the grass pollen seasons at the six sites analysed. Start and finish dates of the grass pollen season are shown as number of days from January 1st, maximum concentration in grains/m³

	Start date	Finish time	Length	Peak day	Max. conc.	Total pollen
1995						
Edinburgh	171	210	39	200	182	1383
Worcester	164	206	42	186	192	2725
Cambridge	156	215	59	170	474	3802
Córdoba	125	146	21	139	71	701
Priego	135	146	11	136	74	498
1996						
Edinburgh	158	208	50	198	105	1911
Worcester	158	209	51	170	272	3643
Cambridge	151	208	57	169	299	4139
Córdoba	108	184	76	153	827	8885
Priego	134	166	32	147	328	3108
1997						
Edinburgh	167	200	33	187	103	781
Worcester	155	208	53	186	176	2199
Cambridge	151	208	57	187	145	2239
Ciudad Real	121	178	57	130	303	3731
Córdoba	114	177	63	130	227	3571
Priego	120	172	52	131	151	1872
1998						
Edinburgh	168	212	44	184	134	1281
Worcester	151	222	71	172	338	4016
Cambridge	149	216	67	160	280	3794
Ciudad Real	129	195	66	160	420	3865
Córdoba	126	176	50	136	271	3543
Priego	135	156	21	152	160	1134
1999						
Edinburgh	168	208	40	175	156	1250
Worcester	147	212	65	164	354	5204
Cambridge	147	205	58	165	312	4198
Ciudad Real	131	156	25	148	97	783
Córdoba	133	156	23	141	88	800
Priego	133	155	22	136	79	598
2000						
Edinburgh	168	212	44	202	162	1687
Worcester	159	218	59	170	380	3504
Cambridge	137	203	66	164	554	4799
Ciudad Real	132	192	60	146	630	7555
Córdoba	134	163	29	151	404	3002
Priego	133	169	36	149	361	3583
Average						
Edinburgh	167	208	42	191	140	1382
Worcester	156	213	57	175	285	3548
Cambridge	149	209	61	169	344	3828
Ciudad Real	128	180	52	146	362	3983
Córdoba	123	167	44	142	315	3417
Priego	132	161	29	142	192	1799

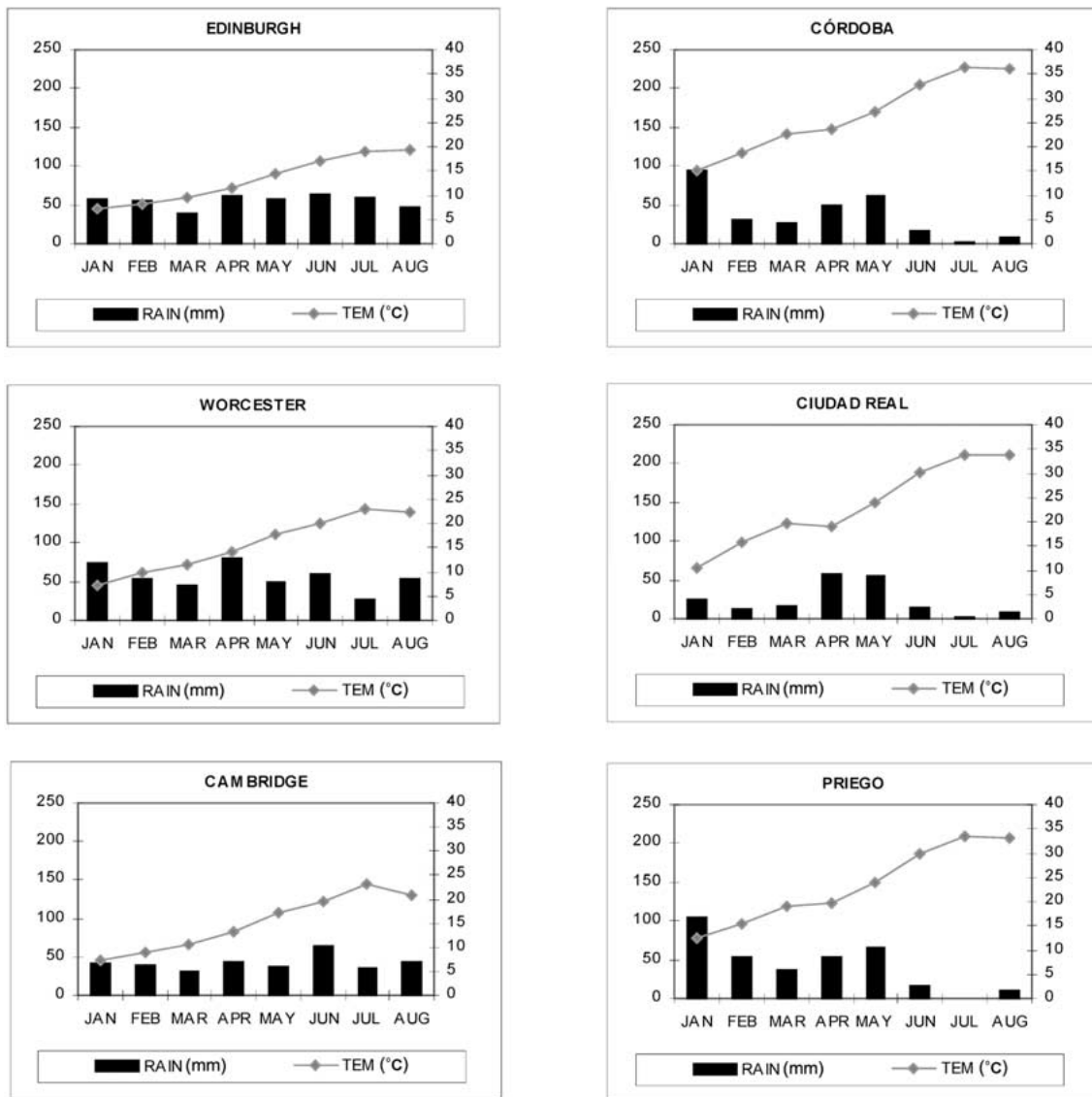


Figure 2. Mean monthly (1995–2000) cumulative rainfall and mean maximum temperatures from January 1st to August 31st, all sites.

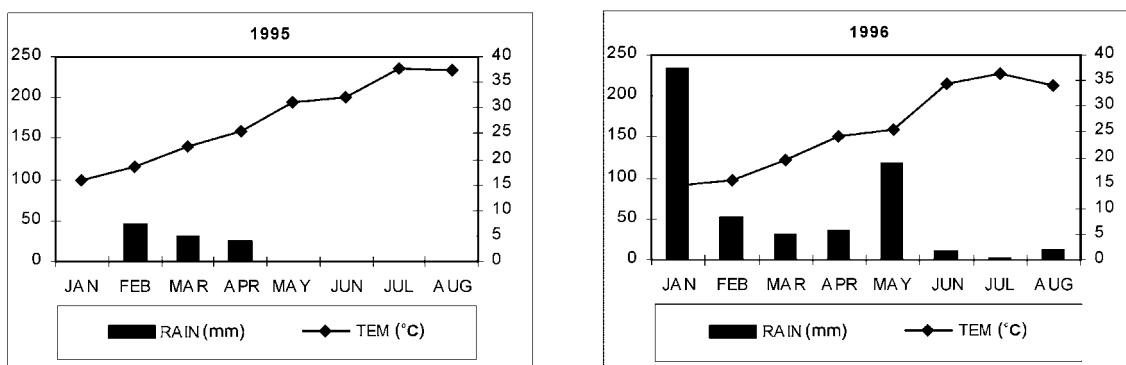


Figure 3. Cumulative rainfall and mean maximum temperatures from January 1st to August 31st, Córdoba.

Table 3. Results of correlation analysis between daily average grass pollen concentrations and meteorological parameters (all seasons together)

	EDINBURGH		WORCESTER		CAMBRIDGE		CIUDAD REAL		CÓRDOBA		PRIEGO	
	RAIN	M.T.	RAIN	M.T.	RAIN	M.T.	RAIN	M.T.	RAIN	M.T.	RAIN	M.T.
95–00	–0.32*	0.51*	–0.22*	0.38*	–0.23*	0.31*	–0.12*	–0.17*	–0.23*	0.18*	–0.23*	0.30*

*Marked correlations are significant at $p < 0.05$.

M.T. = Maximum Temperature.

Table 4. Results of correlation analysis between daily average grass pollen concentrations and meteorological parameters (whole season)

	EDINBURGH		WORCESTER		CAMBRIDGE		CIUDAD REAL		CÓRDOBA		PRIEGO	
	RAIN	M.T.	RAIN	M.T.	RAIN	M.T.	RAIN	M.T.	RAIN	M.T.	RAIN	M.T.
1995	–0.35*	0.45*	–0.07	0.28	–0.12	0.02	—	—	–0.11	0.48*	0.00	0.38
1996	–0.19	0.44*	–0.42*	0.20	–0.13	0.24	—	—	–0.27*	0.26*	–0.31	0.42*
1997	–0.34*	0.50*	–0.35*	0.32*	–0.31*	0.57*	–0.30*	0.05	–0.37*	0.13	–0.38*	0.02
1998	–0.34*	0.60*	–0.24*	0.40*	–0.08	0.38*	–0.01	–0.37*	–0.21	0.11	–0.17	0.77*
1999	–0.32*	0.61*	–0.07	0.39*	–0.24	0.19	–0.35	0.06	–0.32	0.28	–0.49*	0.00
2000	–0.28	0.46*	–0.13	0.53*	–0.34*	0.65*	0.21	–0.40*	–0.14	0.04	–0.33*	0.15

*Marked correlations are significant at $P < 0.05$.

M.T. = Maximum Temperature.

Table 5. Results of correlation analysis between daily average grass pollen concentrations and meteorological parameters (from the start of the season to the day of maximum pollen count)

	EDINBURGH		WORCESTER		CAMBRIDGE		CIUDAD REAL		CÓRDOBA		PRIEGO	
	RAIN	M.T.	RAIN	M.T.	RAIN	M.T.	RAIN	M.T.	RAIN	M.T.	RAIN	M.T.
1995	–0.45*	0.55*	–0.10	0.58*	–0.30	0.67*	—	—	–0.13	0.81*	0.00	0.44
1996	–0.19	0.46*	–0.62*	0.24	–0.02	0.38	—	—	–0.34*	0.72*	–0.34	0.82*
1997	–0.36	0.58*	–0.41*	0.45*	–0.34*	0.69*	–0.40	0.34	–0.42	–0.14	–0.29	–0.10
1998	–0.20	0.62*	–0.28	0.81*	–0.02	0.70*	–0.35*	0.47*	–0.59	0.68*	–0.13	0.74*
1999	–0.43	0.79*	0.08	0.46	–0.33	0.49*	–0.39	0.21	–0.52	0.80*	–0.75*	0.38
2000	–0.36*	0.63*	0.13	0.64*	–0.35	0.76*	0.07	0.14	–0.26	0.45	–0.39	0.01

*Marked correlations are significant at $p < 0.05$.

M.T. = Maximum Temperature.

analysis was applied to grass pollen concentrations and meteorological parameters from the start of the season to the day with the maximum grass pollen count (Table 5). The results of this investigation show that, at all sites, correlation coefficients often increase when this part of the season is considered on its own.

Discussion

As would be expected, this study has shown that grass pollen seasons start later in the United Kingdom than they do in southern Spain. These findings concur with those of previous studies into the regional variations

of grass pollen counts (Galan et al., 1995; Emberlin et al., 2000).

Increases in temperatures in the spring influence the heading times of flowers and the start of anthesis prior to the start of the main grass pollen season (Emberlin et al., 1993; Emberlin et al., 1999). The highest concentrations of grass pollen in Spain occur in May and coincide with increasing temperatures above 25 °C and decreasing precipitation. The summer in the south of Spain is characterised by very little rainfall and high temperatures. This fact brings the annual life cycle of grasses and consequently the grass pollen season to an end (Gonzalez Minero et al., 1998). However, in the United Kingdom, the temper-

ate climate allows grasses to flower for the duration of the British summer. Most species flower throughout May, June and July, with the greatest number blooming in June (Hubbard, 1992).

In general, daily grass pollen counts and temperature are positively correlated. However, in extremely hot conditions a negative relationship can exist between the two variables, especially in southern Spain (Galan et al., 1995). This study has also revealed that correlations between daily grass pollen counts and meteorological parameters were higher when data from the start of the grass pollen season to the day of maximum pollen count were entered into the analysis rather than data from complete grass pollen seasons.

The results illustrate the fact that the temperate maritime climate of Britain helps maintain strong relationships between grass pollen concentrations and meteorological parameters. These relationships persist throughout the grass pollen season but tend to weaken following the day of maximum grass pollen count. Conversely, in southern Spain there is a notable contrast between pre-peak and post peak periods. Correlations are strongest in the spring before the onset of the Mediterranean summer, which is very hot and dry and causes grasses to wither and die. This creates weak or inverse relationships between grass pollen counts and meteorological parameters in the post-peak period. It can therefore be supposed that grass pollen counts at the beginning of the season are predominantly controlled by weather, whereas other factors such as the resuspension of pollen grains become more important later.

Conclusion

The magnitude of the grass pollen season in both southern Spain and the United Kingdom is primarily controlled by two factors, rainfall and temperature. Rainfall in winter and spring and spring temperatures both control growth rates and therefore they both influence the start dates and severity of grass pollen seasons. The grass pollen season will commence as soon as conditions are favourable for the release and dispersal of pollen grains after the plants have reached maturity.

The influence of these two variables continues into the grass pollen season. Correlation analysis has shown that the release and dispersal of pollen from the plant is highly reliant on weather that can change from season to season in both regions. Corre-

lations are generally improved by analysing grass pollen concentrations and meteorological parameters from the start of the season to the day with the maximum grass pollen count. Associations between grass pollen counts and meteorological parameters are dynamic and change as the season progresses. The summers in southern Spain are very dry and maximum temperatures can regularly exceed 35 °C, which weakens correlations between grass pollen counts and meteorological parameters and can even cause inverse relationships to exist. The strength of correlations in the United Kingdom will also decline as the season advances.

The study of two regions with different biogeographical and climatic regimes has shown that there are a number of spatial variations between sites and also temporal variations that occur from year to year or within grass pollen seasons. The two regions have inherently different climates. Studying the affect of differences in precipitation and temperature on grass pollen counts helps to increase knowledge and thereby improve the construction of forecast models. Furthermore, the results have emphasised the need for adopting different approaches when forecasting daily grass pollen concentrations in the two regions.

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References

- BBC BBC Weather Centre: 2001, *British Weather, part one. web page*. <http://www.bbc.co.uk/weather/features/britain1.shtml>.
- Cariñanos P., Emberlin J., Galan C. and Dominguez Vilches E.: 2000, Comparison of two pollen counting methods of slides from a Hirst type volumetric trap. *Aerobiologia* **16**(3/4), 339–346.
- Domínguez Bascón P.: 1981, Pluvimetría de Córdoba (de 1902 a 1979). *Paralelo 37. Revista de Estudios Geográficos*, 173–182.
- Emberlin, J.: 1997, Grass tree and weed pollens. In A.B. Kay (ed), *Allergy and Allergic Diseases*. Vol. 2, Blackwell Science.
- Emberlin J., Savage M. and Jones S.: 1993, Annual variations in grass pollen seasons in London 1961–1990: Trends and forecast models. *Clinical and Experimental* **23**, 911–918.
- Emberlin J., Mullins J., Cordon J., Jones S., Millington W., Brooke M. and Savage M.: 1999, Regional variations in grass pollen seasons in the UK, long term trends and forecast models. *Clinical and Experimental Allergy* **29**, 347–356.
- Emberlin J., Jaeger S., Dominguez Vilches E., Galan Soldevilla C., Hodal L., Mandrioli P., Rantio Lehtimäki A., Savage M., Spiekma F.T. and Bartlett C.: 2000, Temporal and geographical variations in grass pollen seasons in areas of western Europe:

- And analysis of season dates at sites of the European pollen information system. *Aerobiologia* **16**, 373–379.
- Emberlin J., Jones S., Bailey J., Caulton E., Cordon J., Dubbels S., Evans J., McDonagh N.M.J.W.M., Mullins J., Russel R. and Spencer T.: 1994, Variation in the start of the grass pollen season at selected sites in the United Kingdom, 1987–1992. *Grana* **33**, 94–99.
- Faegri K. and van der Pijl L.: 1966, *The Principles of Pollination Ecology*. Pergamon Press.
- Fernández-González D., Valencia R.M., Vega A., Díaz de la Guardia C., Trigo M.M., Cariñanos P., Guardia A., Pertiñez C. and Rodríguez F.J.: 1999, Analysis of grass pollen concentrations in the atmosphere of several Spanish sites. *Polen* **10**, 127–136.
- Galan C., Emberlin J., Dominguez E., Bryant R. and Villamandos F.: 1995, A comparative analysis of daily variations in the Gramineae pollen counts at Cordoba, Spain and London, UK. *Grana* **34**, 189–198.
- García Rollán M.: 1985, *Claves de la Flora de España*. Ediciones Mundiprensa.
- Gonzalez Minero F.J., Candau P. and Morales J.: 1998, Airborne grass (Poaceae) pollen in southern Spain. Results of a 10-year study. *Allergy* **53**, 266–274.
- Goudie A.: 1996, *The Nature of the Environment*. Blackwell.
- Hirst J.M.: 1952, An automatic volumetric spore trap. *The Annals of Applied Biology* **39**(2), 257–265.
- Hubbard C.E.: 1992, *Grasses: A guide to their Structure, Identification, Uses and Distribution in the British Isles*. Penguin Books.
- METO Met Office: 2001, *1961–90 Mapped Averages*. Internet. <http://www.meto.gv.uk/climate/uk/averages/mapped.html>.
- Sinamba Sistema de informacion ambiental de Andalucia: 1997, *La información ambiental de Andalucía. CD-ROM*. Consejería de medio Ambiente, Junta de Andalucía.
- Stace C.: 1997, *New Flora of the British Isles*. Cambridge University Press.