Polen 10:123-132(1999)

ANALYSIS OF GRASS POLLEN CONCENTRATIONS IN THE ATMOSPHERE OF SEVERAL SPANISH SITES

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(Manuscrito recibido el 11 de Junio de 1999, aceptado el 22 de Octubre de 1999).

SUMMARY: The ambient concentrations of Poaceae pollen were studied at 14 Spanish sites with different geographical features, climates and vegetation. This study was carried out from 1992 through 1998 using Hirst-type volumetric samplers (Burkard or Lanzoni). Grass pollen concentrations are higher in the centre and NW of the peninsula than in the South and West. A Mediterranean-Atlantic gradient was observed at the start of the season, with a difference of 20 or 30 days, although the peaks at all sites were similar (between 8 and 10 weeks).
KEY WORDS: Aeropalinology, Poaceae, Spain.

RESUMEN: Se han estudiado las concentraciones del polen de gramíneas en la atmósfera de 14 localidades españolas, que difieren en su situación geográfica, climática y de vegetación. El trabajo se ha llevado a cabo mediante captadores tipo Hirst (Burkard o Lanzoni), desde 1992 a 1998. Dichas concentraciones son más elevadas en las localidades situadas en el centro y NW peninsular, que en ciudades del sur y este del país. Se observa un gradiente mediterráneo-atlántico en el inicio de los periodos polínicos principales con una diferencia de 20 ó 30 días, aunque el periodo de máxima polinización es semejante y está comprendido entre 8 y 10 semanas.
PALABRAS CLAVE: Aeropalinología, Poaceae, España

INTRODUCTION

The large Poaceae family presents a cosmopolitan distribution and represents almost 20% of world vegetation cover. Most plants from this family are anemophilous, with the exception of cleistogams and a small number that are pollinated by insects. Ambient-controlled factors include dilatation of inflorescence lodicules, the length of anther

filament extension and pollen emission, and pollen grains are not dispersed until the wind shakes or curves the inflorescence. Furthermore, the increase in temperature, the critical photoperiod, and low relative humidity coincide with high grass pollen levels in the atmosphere.

In Spain, the Poaceae grow in different habitats, depending on the taxon. Thus, *Dactylis glomerata, Alopecurus* sp., *Holcus lanatus, Elymus repens, Anthoxantum odoratum, Poa triviales, Phleum pratense*, etc. are usually found in meadows with generally humid and reliable deep soils. They are found in the Eurosiberian Region as well as in the Mediterranean. *Lolium perenne* and *Poa annua* are located in associations in heavily-trodden nitrified meadows with cosmopolitan distribution. *Taeniatherum caput-medusae, Avena* sp. and *Aegilops* sp., grow on nitrophilous summer-winter and optimal Western Mediterranean pastures. *Hordeum murinum, Bromus hordeaceus* and *Bromus sterilis* form subnitrophilous associations of optimal Euro-Siberian that only penetrate the Mediterranean region in rainy areas. Lastly, *Phalaris arundinacea* is located in water-absorbent communities of cosmopolitan distribution, commonly found on water edges, humid mud and other permanent hygrophytes stations.

Given all the above-mentioned characteristics, this botanical family is one of the major cuases of pollen allergies in the world. The literature that describes the flowering and the pollen production of the Poaceae taxon is extensive (DAVIES, 1953; LIEM & GROAT, 1980; PROKUDIN *et al.*, 1982; BANIKONA & GUSIK, 1983; RAJU *et al.*, 1985; CONNOR, 1986). All these publications report its reproductive variability, which is both inter- and intra-specific, according to the latitude, ecology and climatology.

Numerous researchers (DAVIS & SMITH, 1973; BRINGFELT *et al.*, 1982; MOSEHOLM., 1987; LARSSON, 1993; NORRIS-HILL, 1995) have carried out series of studies to statistically reveal the relationships that exist between meteorological parameters and atmospheric pollen concentrations. These authors often propose predictive models of grass pollen levels, which enable both doctors and patients to take appropriate preventive measurements.

In recent years, several papers (DRIESEN *et al.*, 1989; FRENGUELLI *et al.*, 1989; SPIEKSMA *et al.*, 1989; CADMAN, 1991; EMBERLIN *et al.*, 1994; GALÁN *et al.*, 1995) have highlighted the differences or similarities that exist between pollen counts in the atmospheres of several specific locations in regions with different climates.

In Spain, little is known about the variations between different regions at the start and throughout the Poaceae pollen season (BELMONTE *et al.*, 1991; SUBIZA *et al.*, 1992; GONZÁLEZ MINERO *et al.*, 1998). This paper presents a preliminary study of the seasonal fluctuations of grass pollen stations in fourteen Spanish cities, which, in terms of their vegetation, are the most representative biogeographical and bioclimatical provinces in Spain.

MATERIALS AND METHODS

The study was carried out in 14 locations in the Iberian Peninsula over several years (between 1992 and 1998), although the number of years varied depending on the sampling site. These locations differed in terms of their geographic location, topography, vegetation, etc. (Tab. 1).

Daily pollen content was collected using Hirst-type volumetric samplers (Burkard

Manufacturing Co Ltd. and Lanzoni VPPS 2000). The traps were located in the roofs or flat roofs of buildings (between 15 and 20 m above ground level), thus avoiding architectonic shields that would block air masses from any direction.

For reading and processing samples, the methodology proposed by DOMÍNGUEZ *et al*. (1991) was followed and standarized for the entire Spanish Aerobiological Network (REA). Pollen concentrations were expressed as pollen grains/m^3 of air.

The meteorological dates for each location were provided by the different stations of the National Meteorological Centre. The meteorological variables used in this study were average temperature and rainfall.

In order to define the main pollen period, the study was limited by eliminating days with minimal pollen concentrations at the start and end of the pollen season. These non-estimated periods accounted for 2.5% of total pollen concentration, both at the start and at the end of the season. The pollen season therefore accounted for 95% of data.

RESULTS

Total Poaceae pollen counts in each location varied considerably in different years (Fig. 1). However, in the south of Spain, 1996 was generally the year with the highest pollen production; in the north this was more variable, although higher concentrations were recorded in 1998. Only in Jaén, Barcelona and Tarragona were more homogeneous inter-annual levels recorded (Fig. 1). For the years studied, the annual sum of daily values (expressed as daily averages of pollen grains/m^3) varied between 888 in Barcelona (in 1994)

Sites	Location	Altitude	Mean T	Rain fall	Biogeography/Bioclimatology
Málaga	36º47'N, 4º19'W	5	18	575	Bética, pluviestacional oceánico
Estepona	36º25'N, 5º9' W	48	16,8	556	Bética, pluviestacional oceánico
Granada	37º11'N, 3º35'W	685	15,1	400	Bética, pluviestacional oceánico
Jaén	37º46'N, 3º47W	560	17	592	Bética, pluviestacional oceánico
Córdoba	37º50'N, 4º45'W	123	18	600	Bética, pluviestacional oceánico
Tarragona	41º7'N, 1º15'E	48	15,8	482	Iberolevantina, pluviestacional oceánico
Barcelona	41º24'N, 2º9'E	90	16,5	595	Iberolevantina, pluviestacional oceánico
Lleida	41º37'N, 0º38'E	202	14,8	414	Pirenaica, oceánico
Girona	41º54'N, 2º46'E	125	15	740	Pirenaica, oceánico
Madrid	40º27'N, 3º45'W	600	13,9	438	Iberoatlántica, pluviestacional oceánico
León	42º34'N, 5º35'W	830	11	550	Iberoatlántica, pluviestacional oceánico
Ourense	42º21'N, 7º51'W	130	14	772	Iberoatlántica, pluviestacional oceánico
Vigo	42º14'N, 8º43'W	50	14,9	1412	Cantabro Atlántica, hiperoceánico
Santiago de C.	42º53'N, 8º32'W	270	12,9	1288	Cantabro Atlántica, oceánico occidental

TABLE 1. Sampling site characteristics.

and 7.523 in Vigo (in 1996) (see Tab. 2). Table 2 and Figure 2 present the start and end dates of the main pollen period, based on established criteria, together with the days of maximum pollen concentration and their values. This shows that the start of the pollen season varies from 16 January to 15 March in Madrid and from 17 March to 7 May in Santiago de Compostela. As regards the duration of the pollen period, significant inter-annual differences were observed, from 92, 93 or 94 days in León, Córdoba and Santiago de Compostela, respectively, to 271 and 276 days in Málaga and Barcelona, respectively.

The highest atmospheric pollen concentrations in Mediterranean areas were generally detected between mid May and early June; 827 grains/m^3 on 4 June 1996 in Córdoba and 484 grains/m^3 on 2 June 1996 in Málaga. In Atlantic areas, between the third week of June and the second fortnight of July, counts were 679 grains/m^3 on 13 July 1993 in Santiago de Compostela and 453 grains/m^3 on 4 July 1998 in Vigo.

Figure 3 shows the average temperatures and rainfalls for each location and year studied.

DISCUSSION

The preliminary analysis revealed the striking differences between the variations in pollen concentrations and seasonal characteristics at different sites in Spain. This is clrealy a consequence of the reciprocal relationship between the specific climate,

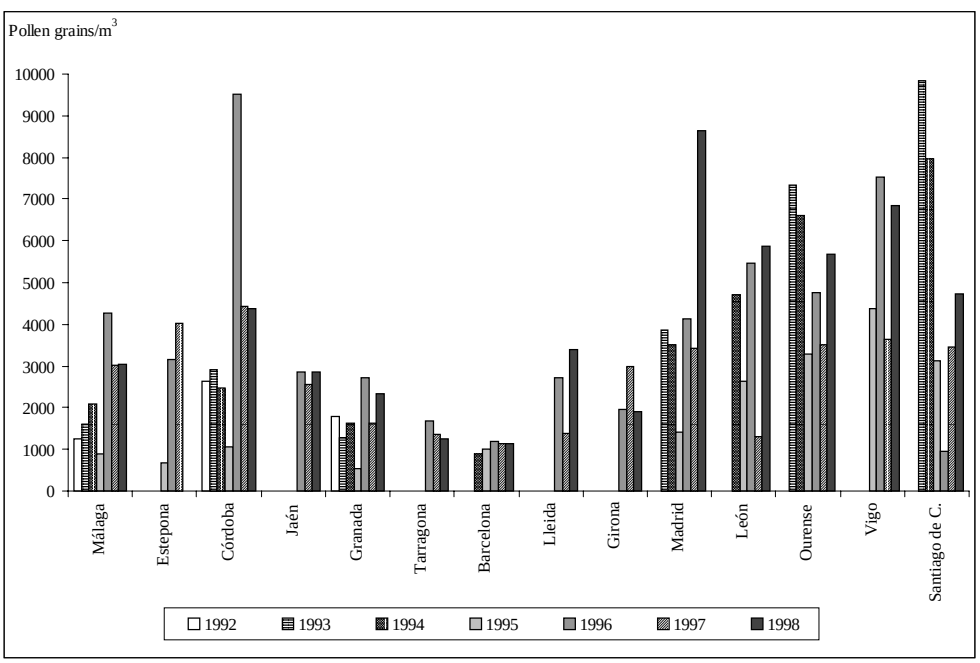

FIGURE 1. Annual concentrations of Poaceae at 14 Spanish sites, 1992-1998.

Sites	Year	MPP	Range	Date of peak	Peak	Total Pollen
Málaga	1992	2-2/29-10	271	11-may	60	1248
	1993	4-4/13-9	163	02-jun	99	1595
	1994	20-3/7-9	172	08-may	149	2096
	1995	31-1/16-9	229	25-may	67	906
	1996	5-3/20-8	169	02-jun	484	4273
	1997	17-3/2-9	170	11-may	218	3003
	1998	10-3/4-9	179	15-may	191	3046
Estepona	1995	27-3/16-9	174	19-may	50	686
	1996	4-4/14-9	164	02-jun	432	3149
	1997	3-4/26-8	146	11-may	184	4033
Córdoba	1992	24-3/16-8	136	11-may	200	2638
	1993	19-3/28-7	161	02-jun	237	2908
	1994	21-3/25-6	93	10-jun	300	2463
	1995	2-3/24-7	144	21-may	67	1050
	1996	5-4/9-9	153	04-jun	827	9508
	1997	23-3/10-8	141	13-may	234	4438
	1998	15-3/27-8	163	16-may	271	4362
Jaén	1996	29-3/19-8	144	01-jun	316	2853
	1997	1-3/21-8	174	11-may	134	2555
	1998	21-3/12-9	176	11-jun	147	2848
Granada	1992	11-4/21-9	164	18-may	54	1784
	1993	18-3/12-9	178	05-jun	77	1287
	1994	21-3/9-8	142	08-jun	124	1634
	1995	2-3/25-9	208	25-may	34	535
	1996	7-4/2-8	118	02-jun	309	2709
	1997	27-3/3-8	130	11-may	130	1624
	1998	31-3/11-8	134	11-jun	160	2326
Tarragona	1996	2-4/16-11	221	04-jun	69	1673
	1997	25-2/21-10	239	21-may	46	1355
	1998	4-3/31-10	242	11-jun	46	1257
Barcelona	1994	15-3/27-9	164	04-jun	50	888
	1995	3-2/5-11	276	24-jun	62	1002
	1996	24-3/1-10	188	05-jun	55	1184
	1997	7-3/14-9	192	5,29-jun	33	1153
	1998	26-3/20-10	209	22-may	34	1129
Lleida	1996	3-4/29-9	166	27-may	91	2710
	1997	28-2/12-10	206	25-may	34	1394
	1998	22-3/19-9	181	19-may	93	3391
Girona	1996	11-4/14-9	143	02-jun	117	1952
	1997	5-3/22-9	183	29-may	76	3000
	1998	20-4/18-9	145	22,23-jun	49	1901
Madrid	1993	15-3/2-8	141	04-jun	187	3847
	1994	31-1/9-9	220	07-jun	120	3509
	1995	16-1/10-9	232	06-feb	55	1411
	1996	18-2/1-8	162	08-jun	164	4134
	1997	18-2/16-8	180	25-may	111	3436
	1998	25-2/24-7	150	10-jun	372	8650
León	1994	27-4/27-7	92	06-jun	194	4709
	1995	16-2/15-8	178	07-jun	125	2637
	1996	18-3/29-7	134	11-jun	269	5471
	1997	26-2/25-6	120	18-jun	68	1299
	1998	18-4/9-8	114	17-jun	328	5881
Ourense	1993	14-3/17-8	157	07-jul	344	7331
	1994	24-3/29-7	128	27-jun	327	6608
	1995	21-3/23-8	156	06-jul	177	3278
	1996	9-4/1-9	146	17-jun	239	4762
	1997	7-3/22-9	186	06-jul	166	3510
	1998	18-4/12-8	115	17-jun	301	5673
Vigo	1995	31-3/1-9	155	06-jul	298	4377
	1996	14-4/25-8	134	25-jun	437	7523
	1997	10-3/6-9	181	17-jul	282	3635
	1998	28-3/19-8	145	04-jul	453	6855
Santiago de Compostela	1993	13-4/17-8	127	13-jul	679	9835
	1994	23-4/29-8	129	23-jun	442	7955
	1995	22-3/9-8	141	09-jul	168	3134
	1996	23-3/15-8	146	07-jun	191	950
	1997	17-3/1-9	169	07-jul	322	3464
	1998	7-5/8-8	94	30-jun	279	4730

TABLE 2. Characteristics of the Poaceae pollen season of the 14 Spanish sites.

vegetation and geographical make-up of each biogeographical province where the sampling points are located. It is clear that, generally speaking, the amount of annual pollen in the Northwestern Provinces, both in the Euro-Siberian Region (Santiago and Vigo) and in the Mediterranean Ibero-Atlantic Province (León, Ourense and Madrid), is twice that reecorded in the other locations. This pollen behaviour has already been confirmed by other authors; GONZÁLEZ MINERO *et al*. (1998) and BELMONTE (1987) have attributed certain climatic factors to the occurrence of this phenomenon that provoke an increase in pollen concentrations in Atlantic areas, in contrast to the situation in the Mediterranean locations.

These characteristics may be due to the seasonal nature of annual rainfall, which is similar or has more of an impact on the composition and distribution of plant communities than on their size. In this connection, rain patterns in Atlantic areas are more or less intense, but rainfall is never absent, thus favouring the development and growth of these herbaceous plants.

The aerobiological graphics of Poaceae are characterised by long periods of low pollen concentration and one relatively short period of maximum pollen production (between 8 and 10 weeks). However, in general, the main pollen season becomes progressively shorter as one moves from the Mediterranean to the North East of the peninsula. This behaviour has been already reported by SPIEKSMA *et al*. (1989), WEEKE (1989) and GALÁN *et al*. (1995) for locations in Mediterranean and Atlantic Europe, and confirms that there is a minimal difference of 20 days with regard to the start of Poaceae pollination between the south and the north (GONZÁLEZ MINERO *et al*., 1998).

Although the rhythm of seasonal photoperiods, marked by the difference in latitude, represents a threshold in the development of many plant communities, previous studies that have compared the pollen concentrations in locations with different climates show that temperature is the main control factor at the start of the grass pollen season and also at the moment when peak values are reached. This is due to the fact that dry and warm periods favour anther dehiscence (SPIEKSMA *et al*., 1989; CADMAN, 1991; GALÁN *et al*., 1995). In this study, in all eastern and southern locations under the Mediterranean influence, the temperatures at the start of the pollen season ranged from 10ºC and 12ºC to maximum concentrations of 18ºC and 21ºC. In the Atlantic areas (Ourense, Vigo, Santiago de Compostela), the start of the pollen season coincided with similar temperatures of around 12ºC, although the highest values occurred when this was between 15ºC and 18ºC. One exception to this pollen behaviour was observed in León and Madrid; in these locations, the pollen season starts when the temperature is between 5ºC and 10ºC. The semi-continental climate of Madrid and the altitude a.s.l. of León (the highest of all the stations) may account for the particular phenology of Poaceae in these locations.

This study did not inclue a detailed analysis of the Poaceae communities characteristic of the biogeographic regions described above, since most of the taxa that release pollen into the atmosphere are cosmopolitan. Nevertheless, it is important to mention that this is only a preliminary comparative study and does not include any statistical analysis. It is therefore clear that a comparison must be made of the same years used for pollen sampling in all the locations in order to obtain a more accurate inter-

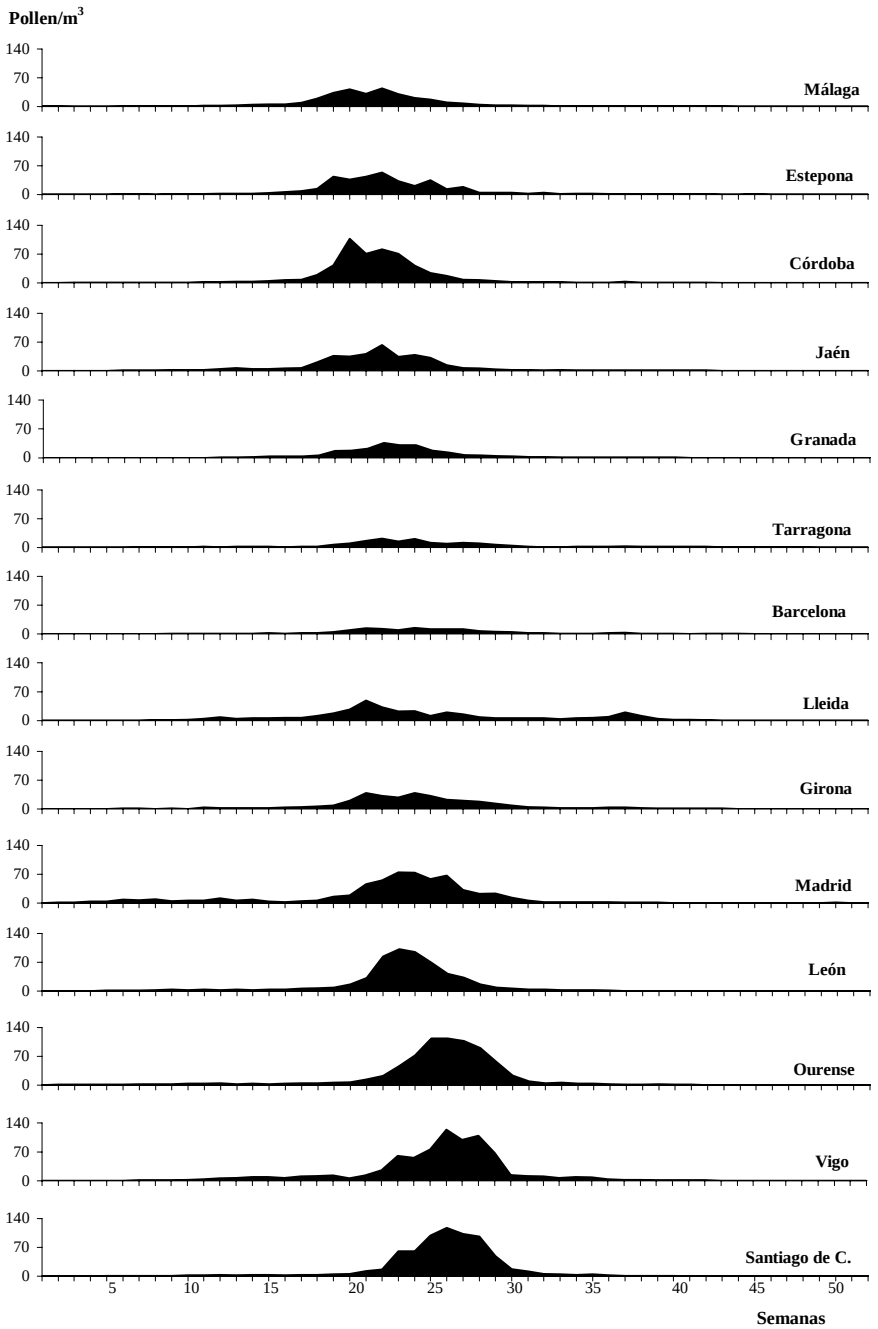

FIGURE 2. Pollen calendar for Poaceae at 14 Spanish sites using average data for 1992-1998.

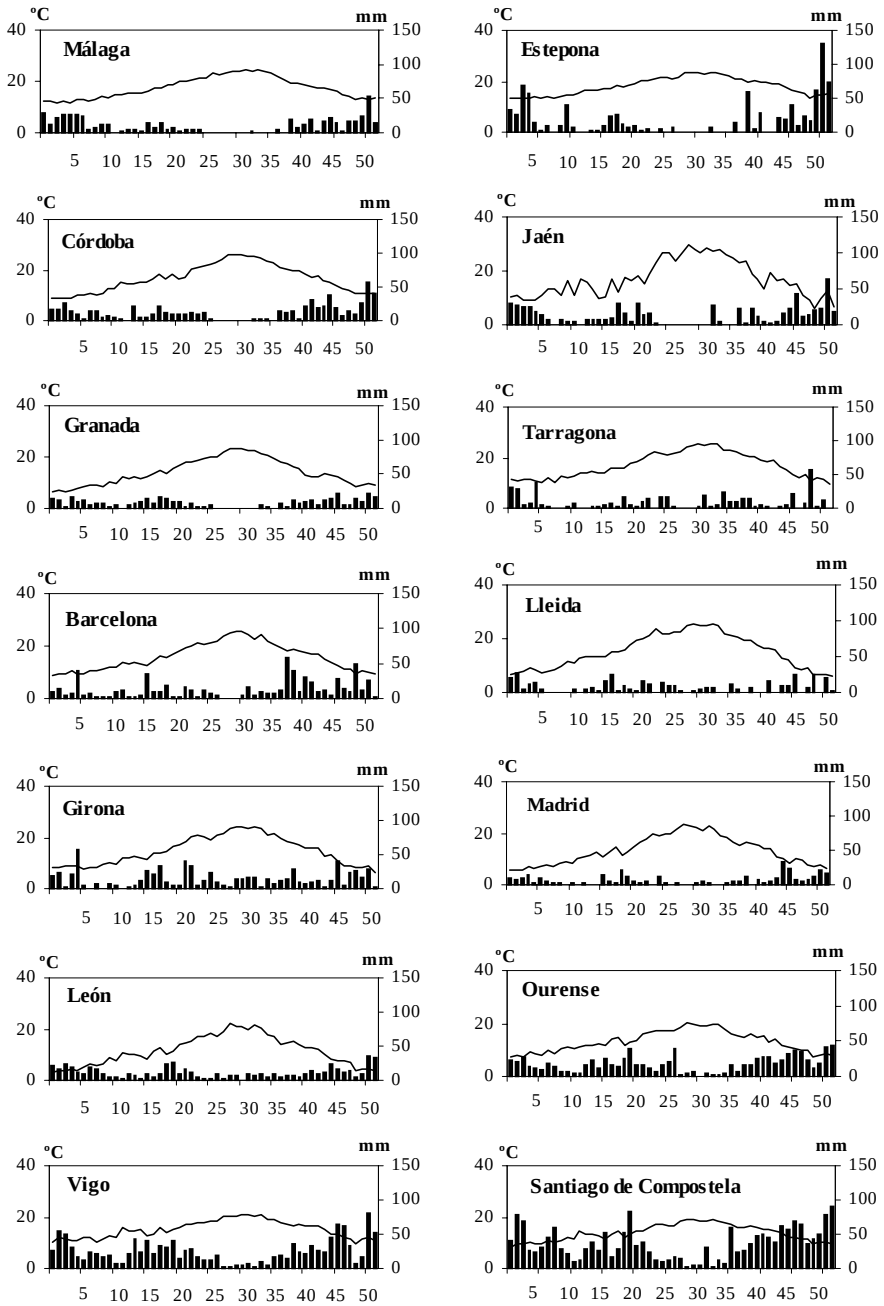

FIGURE 3. Mean temperatures and rainfall variations during the sampling period at 14 Spanish sites, 1992-1998.

pretation of the variations. The results of this study highlight the need for a more detailed individual analysis of each area, based on more complex bioclimatical indexes, and taking into account the fact that predictive pollen models are only acceptable if the climate patterns of each region are known.

CONCLUSIONS

Although each sampling site presented significant inter-annual differences in terms of pollen concentrations and the start of pollen emissions, certain territorial characteristics based on climatology, vegetation and geography clearly define each location.

The study of the airborne pollen behaviour of Poaceae reveals the aerobiological differences that exist between different bioclimatic areas in Spain. This could be taken into consideration in future statistical studies.

Grass pollen concentrations are much higher in the air above the Hyper-Oceanic Cantabrian Atlantic (Vigo), Western Oceanic Cantabrian Atlantic (Santiago de Compostela) and Mediterranean Ibero-Atlantic Oceanic rainstational (Ourense, León, Madrid) bioclimates, than in the cities located in the Betic Oceanic rainstational (Málaga, Estepona, Córdoba, Granada and Jaén), Mediterranean Ibero-Levantine Oceanic rainstational (Barcelona, Tarragona) and Pyrenaic oceanic (Girona, Lleida) biolclimates.

As regards as the start of the pollen season, a Mediterranean-Atlantic gradient was observed, with a difference of between 20 and 30 days. Nevertheless, the pollen curves at all the sites followed a general model, with a period of maximum concentrations that lasted between 8 and 10 weeks. The critical temperatures that affect the start of these periods range between 10ºC and 12ºC in all the areas, except in Madrid and León (between 5ºC and 10ºC).

ACKNOWLEDGMENTS

The authors wish to thank Dr. Santiago Gutierrez Martín for the translation into English of the paper. This work is supported by the DGICYT through Project AMB97-0457-CO7-01.

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