

Incidence of *Echium* pollen in the Middle West of Iberian Peninsula: an unusual flowering period and its significance in aerobiological studies

David Rodríguez de la Cruz ·
Estefanía Sánchez-Reyes · José Sánchez-Sánchez

Received: 31 May 2011 / Accepted: 3 November 2011
© Springer Science+Business Media B.V. 2011

Abstract We analysed the occurrence of the *Echium* pollen in the atmosphere of Salamanca, on the basis of 8-year observation (2000–2007) with the aim to evaluate its aerobiological behaviour. Aerobiological samples were collected by the Hirst volumetric method with a 7-day Burkard spore trap. The atmospheric pollen season of *Echium* was observed in late spring (May and June), showing also high levels in midday hours. However, an anomalous flowering period was detected in late autumn and early winter between years 2006 and 2007 and it could be connected with high daily temperature registered in October 2006 in comparison with the 2000–2005 period and its particular increasing tendency similar to those detected in the preceding month of the late spring flowering period. Statistical analysis by means of the Spearman's non-parametrical test and linear regression analysis reflected a positive correlation with temperature and a trend to increase in daily temperature during late October 2006 and April in 2000–2005 with similar indexes ($R^2 = 0.50$, $R^2 = 0.58$, respectively). In conclusion, aerobiological data could contribute to the development of further

studies in order to a better understanding of different plant species phenology.

Keywords Aerobiology · *Echium* · Phenology · Pollen · Salamanca · Spain

1 Introduction

Over the last few years a great number of phenological studies has been carried out using aerobiological data to determine the time of flowering (Peeters 1998; Fuertes-Rodríguez et al. 2007; Ribeiro et al. 2008; García-Mozo et al. 2009) or to model the response of plant phenology to climate (Chuine et al. 1999; Schwartz 2003). Using long aerobiological data series, it is possible to establish the atmospheric pollen season of main pollen types counted in the atmosphere of different cities, and subsequently, it is also possible to evaluate the time of flowering in some species, mainly anemophilous. Some entomophilous species could achieve relevant airborne concentrations, mainly in the case of species with secondary transport by the wind due to the floral disposition of anthers, a great pollen production or even to a small pollen size. The genus *Echium* L. in the Iberian Peninsula comprises 19 species included in one pollen-type, *Echium plantagineum* (Trigo et al. 2008), with entomophilous pollination, reflected by its contribution to floral honeys (Sáenz Laín and Gómez Ferreras 2000). In addition,

D. Rodríguez de la Cruz (✉) · E. Sánchez-Reyes ·
J. Sánchez-Sánchez
Hispano-Luso Agrarian Research Centre (CIALE),
University of Salamanca, Campus de Villamayor,
C/Río Duero N°12, 37185 Villamayor, Salamanca, Spain
e-mail: droc@usal.es

Echium pollen grains present a secondary wind-pollination, as show some aerobiological studies (Salvador de Luna and Sánchez-Sánchez 1990; García-Mozo et al. 2007) carried out in different areas, and it could be responsible for allergic symptoms in sensitised individuals (Katelaris et al. 1982; Matthews et al. 1988).

According to an aerobiological analysis of *Echium* pollen in the Middle West of Spain, the aim of this paper is to contribute to a better knowledge of anomalous flowering periods occurring in years with particular meteorological conditions.

2 Materials and methods

Salamanca stands in the Middle West of the Iberian Peninsula (40° 58' N; 5° 40' W) at 800 metres above the sea level, with around 180,000 inhabitants. The climate is Mediterranean continental (Capel Molina 1981) characterised by cool winters, warm summers and a low annual rainfall level, which determines a drought season during the summer period (Table 1).

In terms of biogeography, the city belongs to the Mediterranean Region (Rivas Martínez et al. 2002), and to the Mediterranean West Iberian Province and, to a lesser extent, Mediterranean Central Iberian Province. The main surrounding forests are represented by pastures with holm oaks (*Quercus ilex* L. subsp. *ballota* (Desf.) Samp.), where a great number of *Echium* individuals appears in spring time, mainly the species *Echium plantagineum* L. and *Echium vulgare* L., if meteorological conditions are favourable.

Aerobiological samples were collected from 2000 to 2007 using a Burkard 7-day volumetric spore trap

located in a historic centre building placed 20 m above ground level, and pollen concentration is expressed as the number of pollen grains in a cubic metre of air per day. Sampling method, slide preparation and data interpretation were performed according to the Spanish Aerobiology Network (Galán et al. 2007).

The term atmospheric pollen season (APS) was used instead of classical term 'main pollen season', due to this term seems more suitable (Jato et al. 2006). The APS was adopted from the period that includes 95% of the annual airborne pollen (Andersen 1991). 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 to assess the seasonal trend.

The intradiurnal airborne pollen concentration was determined for the 2005–2007 period on the basis of the bi-hourly values of atmospheric concentration registered during the APS according to the two methods described by Galán et al. (1991): the days (1) where atmospheric pollen concentrations were superior to the average of the APS concentration and (2) without precipitation occurrence were selected. The values were expressed in percentage rather than in absolute numbers, in order to avoid annual and daily variation and to make both methods comparable.

Since the airborne pollen did not seem to display a normal distribution, the Spearman's non-parametric correlation test was used. This method allows to find out possible correlations between concentrations and the main meteorological variables, such as mean, maximum and minimum temperature (°C), sunshine hours, rainfall (mm), relative humidity (%), mean wind speed (m/s), wind direction (%) and wind calm (%).

Table 1 Annual and monthly mean temperature and total rainfall for Standard Reference Period (1971–2000) and for years 2006 and 2007

Periods/months		J	F	M	A	M	J	J	A	S	O	N	D	Annual T_{mean} and Rainfall
1971–2000	T_{mean}	3.6	5.6	7.7	9.6	13.4	17.9	21	20.5	17.2	12.2	7.3	4.8	11.7
	Rainfall	31	27	22	39	48	34	16	11	32	39	42	42	383
2006	T_{mean}	1.6	2.7	8.3	11.4	16.2	20.2	23.2	20.0	18.0	13.9	9.9	3.4	12.4
	Rainfall	18	41	29	25	12	37	8	35	21	60	44	17	347
2007	T_{mean}	4.1	7.0	7.1	10.4	13.8	17.4	20.5	20.0	17.3	11.4	4.7	3.2	11.4
	Rainfall	9	51	12	70	68	28	1	12	72	57	34	8	422

T_{mean} , mean temperature (°C); Rainfall, total rainfall (mm); Annual T_{mean} and Rainfall, annual mean temperature (°C) and total rainfall (mm)

Correlations took into account the whole studied period, each year studied with its APS and PRE. Meteorological data for 2000–2007 period were supplied by the Spanish State Meteorological Agency, by mean of its meteorological station (Matacán) located 10 km east of the sampling site. The SPSS (v.12) software package was used for the statistical analysis.

3 Results

The annual pollen index of *Echium* was rather variable in the studied period, with the mean value 111, with the highest index of 268 in 2006 and the lowest index of 15 in 2002. Years 2007 and 2001 also displayed rather high and lower annual pollen indexes, with 248 and 19, respectively. The percentage of the *Echium* annual pollen indexes in respect to total pollen counts ranged from 0.2% in 2001, 2002 and 2005 to 1.3% in 2003, with 0.7% as mean value (Table 2).

The presence of *Echium* pollen grains started already from late April, when the daily levels of pollen increased gradually until the second week of June (09 June), when they reached the highest mean daily value (6 p/m³). Subsequently, the mean counts decreased until late July (Fig. 1). In the November–February period, we must point out the important levels of *Echium* pollen, according to 5-days average of the studied years. However, in 5-days average of 2000–2005, there was no pollen presence in autumn and winter months, following the general guidelines in spring and summer months described above.

The duration of the APS was 89 days on average and it ranged between 43 and 220 days (Table 2). The

earliest APS starting date was on 24 January 2007 and the latest on 18 May 2004, with 28 April as a mean value. The APS ended on average on 25 July, ranging between 26 June 2002 and 2005 and 7 December 2006. During the 2000–2005 period, the mean length of APS was 57, ranging between 43 and 60 days in years 2000 and 2003, respectively. In the same period, the mean start date of APS was 9 May, being the earliest start date on 7 May 2005, whereas the mean end date was 4 July, being the latest end date on 9 July 2004.

The bi-hourly distribution of this pollen in the atmosphere showed that concentrations increased from 11:00 to 17:00, when concentrations reached maximum percentages over the average total counts of the day, and after that, the values decreased softly until midnight, being lower in the first hours of the day (Fig. 2).

The correlations between daily concentrations and the main meteorological parameters were softly positive and significant with temperature and sunshine hours in a large number of cases during the period 2000–2007. The values of correlation between the daily pollen concentration and the relative humidity were usually negative. In respect to the other meteorological parameters analysed, there are no significant correlations with daily *Echium* pollen counts, except in few years and APS or PRE periods (Table 3).

4 Discussion

The number of studies reflecting data about the airborne presence of *Echium* pollen grains was relevant in those that corresponded to different areas

Table 2 Seasonal behaviour of airborne *Echium* pollen

	2000	2001	2002	2003	2004	2005	2006	2007	Mean 2000–2007	Mean 2000–2005
Annual pollen index	124	19	15	113	67	36	268	248	111	64
% total	1.1	0.2	0.2	1.3	0.4	0.2	1.0	0.8	0.7	0.6
Peak value	12	3	3	11	9	4	31	18	6	4
Peak day	25-May	31-May	12-May	11-Jun	09-Jun	29-May	18-Nov	09-Jun	09-Jun	3-Jun
APS length	43	46	46	60	53	51	220	196	89	57
Start APS	16-May	16-May	12-May	09-May	18-May	07-May	02-May	24-Jan	28-Apr	09-May
End APS	27-Jun	30-Jun	26-Jun	07-Jul	09-Jul	26-Jun	07-Dic	06-Ago	25-Jul	04-Jul
PRE length	10	16	1	34	23	23	201	138	43	26

APS, atmospheric pollen season; PRE, pre-peak period

Fig. 1 Seasonal variation (in percentage over annual total average) of airborne *Echium* pollen grains during 2000–2007 and 2000–2005 average (5-day running mean)

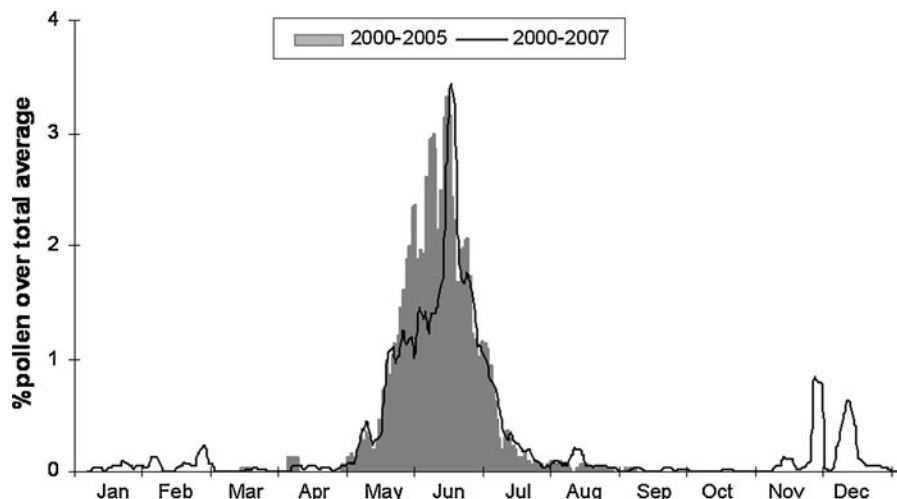
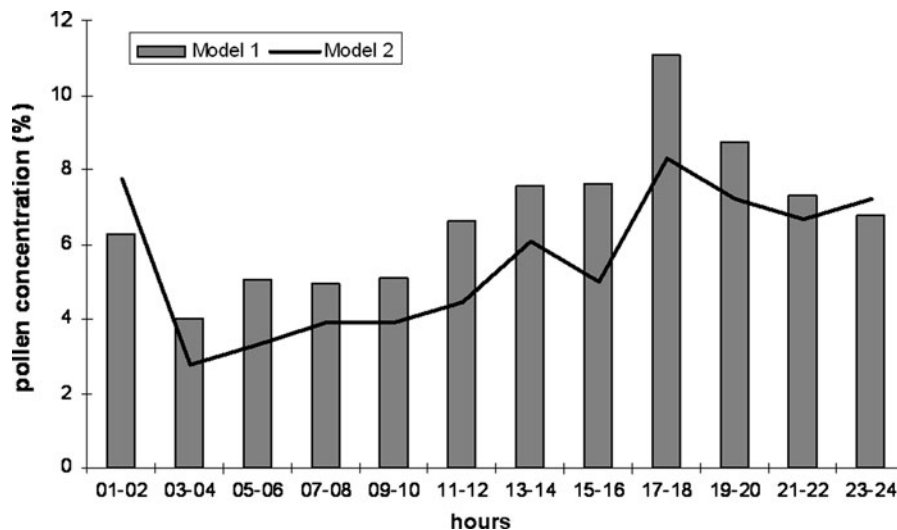


Fig. 2 *Echium* intradiurnal patterns (bi-hourly variation) during 2005–2007



of the Iberian Peninsula (Subiza et al. 1995; González Minero et al. 1998; Ruiz García et al. 1998; Paulino et al. 2002) in comparison with few papers reporting to airborne presence of *Echium* pollen worldwide (Latorre and Pérez 1997; Celenk and Bicakci 2005). This fact could reflect many *Echium* species occurring in the Iberian Peninsula area and their possible role as a causative agent of local respiratory allergic disorders (Jong et al. 1998). The pollen shedding course of *Echium* in Salamanca area corresponds to that already described during the APS in other Spanish areas (Tavira Muñoz et al. 1998; Gutiérrez Bustillo et al. 2002) in May and June, except in some southern places of the Iberian Peninsula where APS was centred in April and May (Silva et al. 1998; Trigo et al. 1998),

probably due to climatic differences among these areas. The intradiurnal pattern of *Echium* airborne pollen displayed a greatest representation in midday hours being also similar than other Spanish aerobiological stations (Muñoz et al. 2005).

As previously stated, there was an anomalous APS in the late autumn and the early winter between 2006 and 2007. The daily mean temperature registered during the late of October 2006 was higher than daily mean temperature average recorded in the same month of 2000–2005 period. In addition, there was an increase in daily mean temperature registered in the late of October 2006 (Fig. 3). This increase had an equal tendency in the mean average temperature registered in the late April during the 2000–2005

Table 3 Spearman's correlation coefficients established for *Echium* pollen concentrations and meteorological parameters along the atmospheric pollen season (APS) and pre-peak (PRE) periods

<i>Echium</i>	T_{mean}	T_{max}	T_{min}	Sunshine	Rainfall	RH	W_{speed}	CF	Wind NW	Wind NE	Wind SE	Wind SW
2000												
Annual	0.369**	0.344**	0.380**	0.269**	-0.112*	-0.297**	0.049	-0.126*	0.067	0.047	-0.040	0.063
95% APS	0.123	-0.012	0.350*	-0.454**	0.240	0.119	0.026	-0.134	-0.217	0.171	0.401**	-0.028
PRE	-0.100	-0.156	0.256	-0.621	0.245	0.066	0.598	-0.649*	-0.263	-0.644*	0.661*	0.368
2001												
Annual	0.242**	0.238**	0.231**	0.255**	-0.086	-0.256**	0.021	-0.030	-0.060	-0.058	0.081	0.186**
95% APS	0.286	0.197	0.398**	0.190	-0.021	-0.245	0.165	-0.095	-0.140	-0.119	0.229	0.127
PRE	0.073	-0.039	0.363	-0.205	-0.123	0.238	0.326	-0.397	-0.181	-0.265	0.141	0.047
2002												
Annual	0.195**	0.187**	0.184**	0.142**	-0.006	-0.188**	0.016	-0.035	-0.052	-0.012	0.051	0.046
95% APS	0.063	0.032	0.114	-0.181	0.224	0.046	0.028	-0.067	0.087	0.183	-0.023	-0.068
PRE	-	-	-	-	-	-	-	-	-	-	-	-
2003												
Annual	0.391**	0.372**	0.370**	0.310**	-0.095	-0.413**	0.013	-0.060	-0.094	-0.020	0.136**	0.124*
95% APS	0.395**	0.305**	0.466**	-0.330*	0.155	-0.143	-0.114	0.115	-0.189	0.397**	0.274*	0.003
PRE	0.418*	0.269	0.540**	-0.464**	0.272	0.030	-0.053	0.164	-0.244	0.413*	0.462**	-0.004
2004												
Annual	0.373**	0.362**	0.361**	0.334**	-0.102	-0.289**	0.121*	-0.017	-0.085	-0.010	-0.003	0.237**
95% APS	0.354**	0.319*	0.281*	0.084	-0.132	-0.104	0.051	-0.012	-0.134	-0.006	0.019	0.201
PRE	0.468**	0.343	0.532**	0.021	-0.149	0.063	0.285	-0.185	-0.377	-0.157	0.283	0.315
2005												
Annual	0.322**	0.295**	0.288**	0.263**	-0.054	-0.324**	0.022	-0.046	-0.050	0.025	0.097	0.120*
95% APS	0.251	0.223	0.150	0.348*	-0.169	-0.411**	-0.011	0.102	0.041	0.027	0.011	-0.162
PRE	0.508*	0.498*	0.321	0.219	-0.111	-0.467*	0.010	-0.033	0.029	0.043	0.078	-0.303
2006												
Annual	0.208**	0.192**	0.194**	-	-0.027	-0.193**	-0.002	-0.135*	-0.127*	-0.023	0.137*	0.091
95% APS	-0.117	-0.135*	-0.128	-	-0.010	-0.095	-0.033	-0.094	-0.078	-0.015	0.117	0.035
PRE	-0.020	-0.043	-0.039	-	-0.021	-0.224**	0.001	-0.089	-0.042	-0.004	0.093	0.053
2007												
Annual	0.329**	0.282**	0.360**	0.199**	0.008	-0.188**	0.165**	-0.125*	-0.29**	-0.096	0.351**	0.088
95% APS	0.434**	0.384**	0.487**	0.222**	-0.117	-0.209**	0.035	0.087	-0.24**	-0.121	0.291**	-0.112
PRE	0.340**	0.272**	0.382**	0.110	-0.045	-0.095	-0.015	0.053	-0.122	-0.033	0.163	-0.150
Total	Annual	0.288**	0.272**	0.217**	-0.053**	-0.211**	-0.06**	-0.058**	-0.07**	0.001	0.090**	0.124**

T_{mean} , mean daily average temperature (°C); T_{max} , maximum daily average temperature (°C); T_{min} , minimum daily average temperature (°C); Sunshine, daily average sunshine (hours); Rainfall, total daily rainfall (mm); RelHum, daily average relative humidity (%); W_{speed} , daily average wind speed (km/h); Wind NE, daily average frequency of north-eastern winds (%); Wind SE, south-eastern winds (%); Wind SW, south-western winds (%); Wind NW, north-western winds (%); CF, daily average frequency of calms (%)

Significance levels: *95%; **99%

Fig. 3 Daily variation of mean temperature in Salamanca during October and April of the 2000–2005 period and during October 2006. Values of regression indexes show tendencies (R^2)

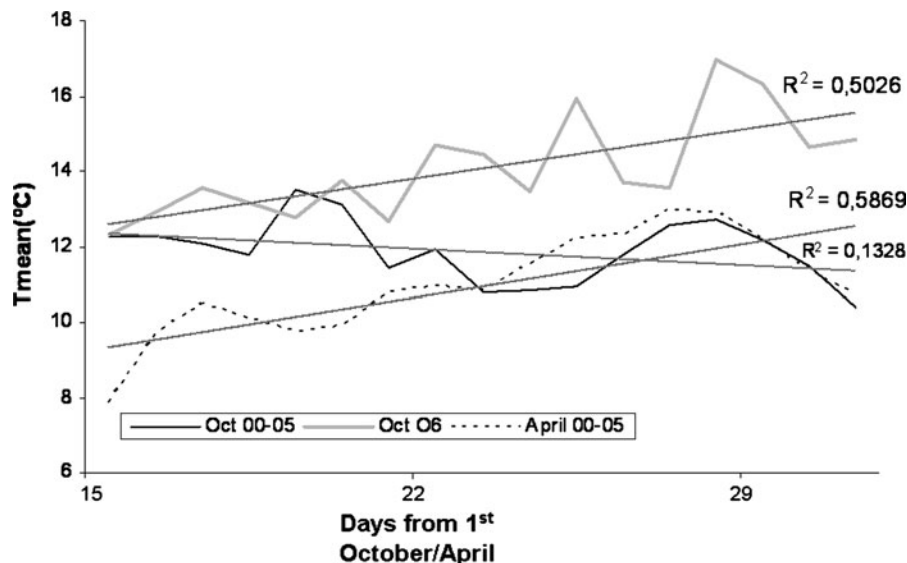
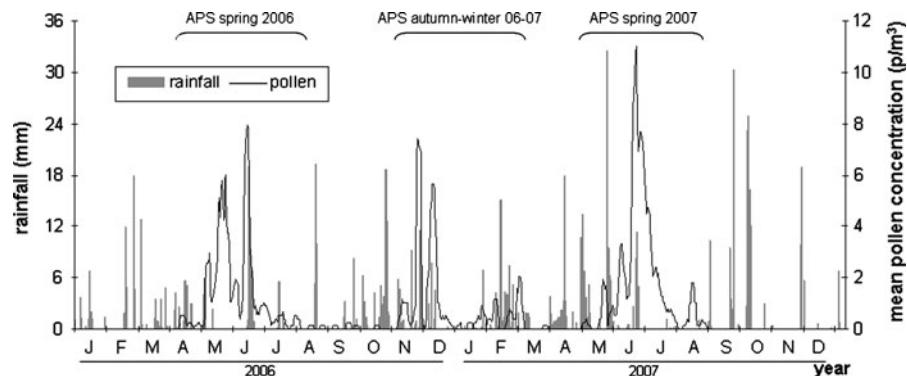


Fig. 4 Seasonal variation of airborne *Echium* pollen grains and total daily rainfall during years 2006 and 2007 (5-days running mean)



period, reflected by the index of linear regression analysis. According to these facts, the particular increase of anomalous higher daily mean temperature in October joined with previous rainfall events occurred in the same month could be related with the late autumn 2006 flowering period for *Echium* (Fig. 4). The combination of temperature dynamics and rain in spring would seem to indicate their influence in subsequent flowering period (Fitter et al. 1995). In years 2006 and 2007, it would be more accurate to define three APS, one more in late autumn and early winter besides of the two APS occurring usually in the late spring (Fig. 4). The possible role of resuspension effects in *Echium* airborne concentrations could be considered in early winter, as it also occurred in pollen of other taxa as *Urticaceae* (Vega-Maray et al. 2003) or *Olea* (Alba et al. 2000). Main environmental factors, such as

temperature, may drive autumn phenology (Menzel 2002), and further studies should be undertaken in order to evaluate the possible correlation between unusual weather parameters and airborne pollen counts which could be the basis for plant phenology forecasting. Aerobiological studies can provide accurate information to complete data from other field or mathematical studies in order to a better knowledge of plant phenology, especially in cases of anomalous flowering periods.

Acknowledgments This study was partially supported by the Public Health Council of Junta de Castilla y León, agreement code H42. We are grateful to the Immunoallergic Services of Salamanca University Hospital for kindly providing us with different slide preparations. We also thank anonymous reviewers for their useful comments which have improved the manuscript. The first author would like to thank the University of Salamanca for his research grant.

References

- Alba, F., Díaz de la Guardia, C., & Comtois, P. (2000). The effect of meteorological parameters on diurnal patterns of airborne olive pollen concentration. *Grana*, 39, 200–208.
- Andersen, T. B. (1991). A model to predict the beginning of the pollen season. *Grana*, 30, 269–275.
- Capel Molina, J. J. (1981). *Los climas de España*. Barcelona: Oikos-Tau.
- Celenk, S., & Bicakci, A. (2005). Aerobiological investigation in Bitlis, Turkey. *Annals of Agricultural and Environmental Medicine*, 12, 87–93.
- Chuine, I., Cour, P., & Rousseau, D. (1999). Selecting models to predict the timing of flowering of temperate trees: implications for tree phenology modelling. *Plant, Cell and Environment*, 22, 1–13.
- Fitter, A. H., Fitter, R. S. R., Harris, I. T. B., & Williamson, M. H. (1995). Relationships between first flowering date and temperature in the flora of a locality in central England. *Functional Ecology*, 9, 55–60.
- Fuentes-Rodríguez, C. R., González-Parrado, Z., Vega-Maray, A. M., Valencia-Barrera, R. M., & Fernández-González, D. (2007). Effect of air temperature on forecasting the start of Cupressaceae pollen type in Ponferrada (León, Spain). *Annals of Agricultural and Environmental Medicine*, 14, 237–242.
- Galán, C., Cariñanos, P., Alcázar, P., & Domínguez, E. (2007). *Spanish Aerobiology Network (REA): Management and quality manual*. Córdoba: Servicio de Publicaciones de la Universidad de Córdoba.
- Galán, C., Tormo, R., Cuevas, J., Infante, F., & Domínguez, E. (1991). Theoretical daily variation patterns of airborne pollen in the South-West of Spain. *Grana*, 30, 201–209.
- García-Mozo, H., Domínguez-Vilches, E., & Galán, C. (2007). Airborne allergenic pollen in natural areas: Hornachuelos Natural Park, Córdoba, Southern Spain. *Annals of Agricultural and Environmental Medicine*, 14, 63–69.
- García-Mozo, H., Galán, C., Belmonte, J., Bermejo, D., Candau, P., Díaz de la Guardia, C., et al. (2009). Predicting the start and peak dates of the Poaceae pollen season in Spain using process-based models. *Agricultural and Forest Meteorology*, 149, 256–262.
- González Minero, F. J., Candau, P., Morales, J., & Tomás, C. (1998). A study of non-arboreal pollen collected during ten consecutive years in the air of the SW Spain. Effect drought period on pollen spectrum. *Grana*, 37, 367–373.
- Gutiérrez Bustillo, M., Cervigón Morales, P., & Pertinhez Izquierdo, C. (2002). Aerobiología en Madrid: Estación de Ciudad Universitaria (2000–2001). *Rea*, 7, 225–230.
- Jato, V., Rodríguez-Rajo, F. J., Alcázar, P., De Nuntis, P., Galán, C., & Mandrioli, P. (2006). May the definition of pollen season influence aerobiological results? *Aerobiologia*, 22, 13–25.
- Jong, N. W., Vermeulen, A. M., Gerth van Wijk, R., & de Groot, H. (1998). Occupational allergy caused by flowers. *Allergy*, 53, 204–209.
- Katellaris, C., Baldo, B. A., Howden, M. E., Matthews, P. A., & Walls, R. A. (1982). Investigation of the involvement of *Echium plantagineum* (Paterson's Curse) in seasonal allergy. IgE antibodies to Echium and other weed pollens. *Allergy*, 37, 21–29.
- Latorre, F., & Pérez, C. F. (1997). One year of airborne pollen sampling in Mar del Plata (Argentina). *Grana*, 36, 49–53.
- Matthews, P. A., Baldo, B. A., & Howden, M. E. (1988). Cytochrome c allergens isolated from the pollens of the dicotyledons English plantain (*Plantago lanceolata*) and Paterson's Curse (*Echium plantagineum*). *Molecular Immunology*, 25, 63–71.
- Menzel, A. (2002). Phenology: Its importance to global change community. *Climate Change*, 54, 379–385.
- Muñoz, R. A. F., Molina, R. T., Palacios, I. S., Corchero, A. M., & Muñoz, J. T. (2005). Airborne behaviour of *Echium* pollen. *Aerobiologia*, 21, 125–130.
- Paulino, R., Tormo, R., Silva, I., & Muñoz, A. F. (2002). Aerobiología en Extremadura: Estación de Cáceres (2000–2001). *Rea*, 7, 177–182.
- Peeters, A. G. (1998). Cumulative temperature for prediction of the beginning of ash (*Fraxinus excelsior* L.) pollen season. *Aerobiologia*, 14, 375–381.
- Ribeiro, H., Cunha, M., & Abreu, I. (2008). Quantitative forecasting of olive yield in Northern Portugal using a bioclimatic model. *Aerobiologia*, 24, 141–150.
- Rivas Martínez, S., Díaz, T. E., Fernández-González, F., Izco, J., Loidi, J., Lousã, M., et al. (2002). Vascular plant communities of Spain and Portugal. Addenda to the syntaxonomical checklist of 2001. *Part I. Itinera Geobotanica*, 15, 5–432.
- Ruiz García, L., Díaz de la Guardia, C., & Mota, J. F. (1998). Analysis of airborne pollen in the town of Almería (South-East Spain), 1995–1996. *Aerobiologia*, 14, 281–284.
- Sáenz Laín, C., & Gómez Ferreras, C. (2000). *Mieles españolas. Características e identificación mediante el análisis de polen*. Madrid: Mundi-Prensa.
- Salvador de Luna, J. V., & Sánchez Sánchez, J. (1990). Polen de plantas entomófilas en la atmósfera de Valladolid. In G. Blanca, C. Díaz, M. C. Fernández, M. Garrido, M. I. Rodríguez, & A. T. Romero (Eds.), *Polen, esporas y sus aplicaciones. VII Simposio de Palinología* (pp. 363–368). Granada: Universidad de Granada.
- Schwartz, H. J. (2003). *Phenology: An integrative environmental science*. Dordrecht: Kluwer.
- Silva, I., Muñoz, A. F., & Tormo, R. (1998). Aerobiología en Extremadura: Estación de Badajoz (1997). *Rea*, 4, 95–98.
- Subiza, J., Jerez, M., Jiménez, J. A., Narganes, M. J., Cabrera, M., Varela, S., et al. (1995). Allergenic pollen and pollinosis in Madrid. *Journal of Allergy and Clinical Immunology*, 96, 15–23.
- Tavira Muñoz, J., Tormo Molina, R., Muñoz Rodríguez, A. F., Silva Palacios, I., & Gonzalo Garijo, M. A. (1998). Calendario polínico de la ciudad de Cáceres. *Revista Española de Alergología e Inmunología Clínica*, 13, 288–293.
- Trigo, M. M., Jato, M. V., Fernández, D., & Galán, C. (2008). *Atlas aeropalinológico de España*. León: Universidad de León.
- Trigo, M. M., Recio, M., Toro, F. J., & Cabezero, B. (1998). Aerobiología en Andalucía: Estación de Málaga (1995–1996). *Rea*, 3, 33–36.
- Vega-Maray, A. M., Valencia-Barrera, R. M., Fernández-González, D., & Fraile, R. (2003). Urticaceae pollen concentration in the atmosphere of North Western Spain. *Annals of Agricultural and Environmental Medicine*, 10, 249–255.