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ORIGINAL ARTICLE

Airborne pollen calendar of Salamanca, Spain, 2000–2007

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Abstract
Background: The determination of pollen types and their proportions in the atmosphere of relevant urban areas have increasingly been evaluated in different regions. The final goal has been to elaborate a pollen calendar, providing data about the occurrence of pollen grains in the air, thus permitting medical treatment and prophylaxis.
Methods: An aerobiological study was carried out in the atmosphere of the city of Salamanca, Spain, during eight years (2000–2007) by means of a Hirst type volumetric spore trap. A pollen calendar was elaborated following exponential classes obtained from 10-day average concentrations of the main pollen types.
Results: Mean annual pollen index was 16,916, coming from 72 different types of pollen. During the studied period, an increase of annual pollen levels was registered by means of regression analysis index. The most important types of pollen were *Quercus*, Poaceae, Cupressaceae, *Olea*, and *Plantago*. Arboreal pollen grains (62.7%) were more represented in airborne pollen spectrum than non-arboreal pollen (37.3%). Airborne pollen levels were particularly high between April and July, showing the highest values in May and June.
Conclusions: In aerobiological terms Poaceae pollen seems to be a major risk for potential sensitised individuals due to its known allergenicity and its high atmospheric concentrations between late spring and early summer, followed by Cupressaceae, *Olea* and *Platanus* pollen grains, and taking into account the possible role of *Fraxinus* and *Quercus* in earl spring allergenic courses and in processes of cross-sensitivity, respectively.

Introduction

Pollen is one of the most important sensitising aeroallergens. Individuals sensitised to pollen have increased in the last decades, especially in large cities and industrial areas.[1,2] The presence of these airborne particles mainly depends on the kind of vegetation growing in surrounding places, plant phenology, season of the year and meteorological conditions.[3] One of the most important preventive measures for sensitised patients is to provide information on the occurrence of different pollen types in order to diminish

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exposure to pollen allergens when levels are above clinical thresholds. For this reason, pollen calendars have been prepared in many towns around the world.[4–9]

The aim of this study was to establish the pollen calendar of the city of Salamanca for eight-year pollen records (2000–2007) and to present the annual distribution of the main pollen types in order to describe the atmospheric pollen profile in the Middle West of Spain. In addition, the present study adds information to previous studies on the aerobiology of some taxa in this area.[10,11]

Material and methods

The city of Salamanca is located in the Middle West of the Iberian peninsula (40°58′N; 5°40′W), 800 m above sea level, with a population of 180,000 inhabitants. The climate is Mediterranean continental[12] characterised by cool winters, warm summers and a low annual rainfall level, which determines a drought season during the summer period. The city is surrounded by wide expanses of Mediterranean pastures to the South and West and by arable farming lands to the North-East, being London plane (*Platanus hispanica* Miller ex Münchh.) a tree-shape urban element most used as ornamental.

The aerobiological monitoring was performed using a Hirst type volumetric spore trap (Burkard 7-day spore trap), situated on the roof of a historical city centre building (Urban Board, Salamanca City Council) at a height of 20 metres above ground level. The sampler operated continuously from January 1st 2000 to December 31st 2007 with a flow of 10 litres per minute. Methods were standardised according to the Spanish Aerobiology Network recommendations for sampling, slide preparation and pollen counting[13]. Annual pollen index is an annual sum of mean daily pollen concentrations[14] (expressed as pollen grains per cubic metre) and is used as a synonym of annual pollen counts.[15] Pollens were identified using published keys[16,17] and by comparison with a local pollen collection.

The pollen calendar was constructed following the technique adopted by Spieksma[18]: daily pollen levels of 10 days were summed and averaged over the eight years considered. These average sums were placed in exponential classes and depicted by columns of increasing height in the calendar. In addition, a five-day running mean was calculated during the studied period and plotted to assess the seasonal trend for total pollen content. Statistical analysis was carried out by SPSS (v.12) software package, applying regression analysis to assess the variation of annual pollen indexes. Lastly, in order to evaluate the airborne permanence of main pollen types, we used the classical term of Main Pollen Season (MPS) that delimits the period during which most pollen is recorded and in that case using 95% of the total annual pollen count.[19]

Results

During the period 2000–2007 a total of 72 different types of pollen were identified, with the most abundant types being included in Table 1. The mean annual pollen index obtained in Salamanca during the studied period was 16,916. An increase in airborne pollen levels was observed by the index of regression analysis ($R^2 = 0.81$) (Table 2). The highest seasonal values were recorded in late spring between May and June (35% and 27% average percentage of mean total pollen during the eight years analysed, respectively) and the lowest in autumn months (1.5% during October, November and December). The seasonal course of airborne total pollen grains is presented in Figure 2, by means of the average of the five-days running mean, showing an increase from early February until mid March, where levels decreased softly. In the first weeks of April, pollen counts rose until early May, when airborne pollen concentrations increased abruptly until early June. From mid June to late September, pollen levels decreased gradually, showing low concentrations during autumn weeks. Total arboreal pollen count was higher than non-arboreal (62.7% vs. 37.3%).

Arboreal pollen peak days were also higher than non-arboreal (Table 1), with 904 pollen/m^3 on 27 May, 2005 for *Quercus*; 550 p/m^3 on 4 March, 2007 for Cupressaceae; and 429 p/m^3 on 17 May, 2006 for *Olea*. Non-arboreal taxa did

Table 1 Aerobiological data for main recorded types of pollen in Salamanca during years 2000–2007

Main pollen types	Annual Pollen Index[1]	% over total pollen grains	Date of Peak day (value[2])	MPS Length in days
Quercus	4459	26.4	27/5/05 (904)	61
Poaceae	3626	21.4	30/6/07 (355)	151
Cupressaceae	1823	10.8	4/3/07 (550)	154
Olea	792	4.7	17/5/06 (429)	50
Plantago	661	3.9	13/7/07 (159)	103
Pinus	648	3.8	14/4/05 (132)	94
Populus	606	3.6	26/3/06 (271)	39
Platanus	602	3.6	16/4/07 (297)	34
Rumex	588	3.5	15/5/06 (75)	90
Urticaceae	529	3.1	31/3/06 (59)	217
Castanea	282	1.7	24/6/05 (78)	40
Chenopodiaceae	197	1.2	9/8/06 (22)	123

MPS: Main Pollen Season.
[1]8-years average.
[2]Value of peak day in pollen/m^3.

not exceed 100 p/m^3 in the studied period, except for Poaceae, with the highest value (355 p/m^3) on 30 June, 2007; and *Plantago* (159 p/m^3) on 13 July, 2007.

A total of 32 pollen types were individually represented in the pollen calendar (Figure 3), reporting only pollen types reaching a 10-day mean pollen sum equal to or higher than 1 p/m^3. Three principal pollen seasons could be identified in the city of Salamanca on the basis of the predominance of different pollen types: winter season (*Alnus*, Cupressaceae, *Fraxinus*, *Ulmus* and *Populus*); spring season (Urticaceae, *Pinus*, *Platanus*, *Quercus*, *Plantago*, *Betula*, *Rumex*, *Acer*, Ericaceae, *Olea*, *Ailanthus*, *Echium* and Poaceae); and summer season (*Castanea*, Chenopodiaceae and *Artemisia*). There were no specific pollen types in the last months of the year, having no autumn season in the pollen calendar.

By means of the length of MPS, we evaluated the permanence of different pollen types in the atmosphere as shown in Table 1, having Urticaceae the longest MPS, followed by Cupressaceae, Poaceae, Chenopodiaceae and *Plantago*. The remaining pollen types presented a duration of 50 days or less, except *Pinus*, *Rumex* and *Quercus*.

Table 2 Statistical analysis by means of regression analysis for the total pollen counts, and arboreal and non-arboreal totals during the studied years

Statistical analysis	Regression analysis [y=b1x+c]					
	R^2	F	d.f.	Sig.	Const	Coef.b1
Total pollen	0.81	24.94	7	0.002	1.5675	0.0013
Arboreal pollen	0.81	25.686	7	0.002	−185.86	2079.7
Non-arboreal pollen	0.625	9.999	7	0.02	931.32	1037.2

R^2: Determination index; F: Mean Squares statistic; d.f.: Degrees of freedom; Sig.: Significance; Const: Constant; Coef.b1: Coefficient b1.

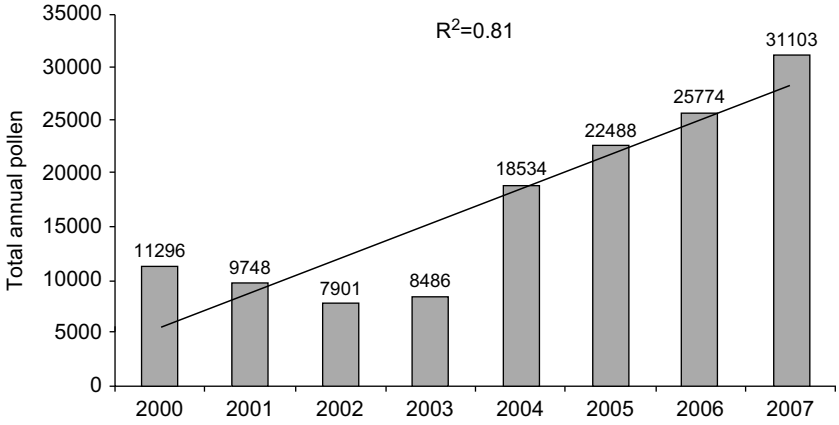

Figure 1 Total annual sums (annual pollen index) of daily pollen concentrations in Salamanca (2000–2007 period).

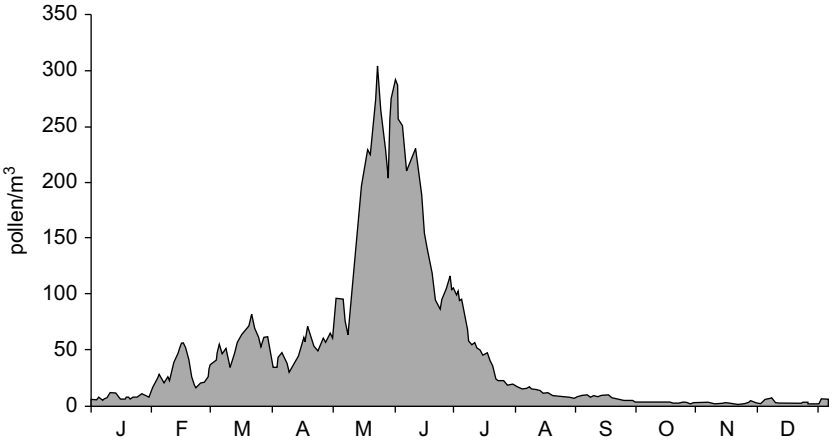

Figure 2 Mean annual variation in five-days running mean of total daily counts in Salamanca over the studied years.

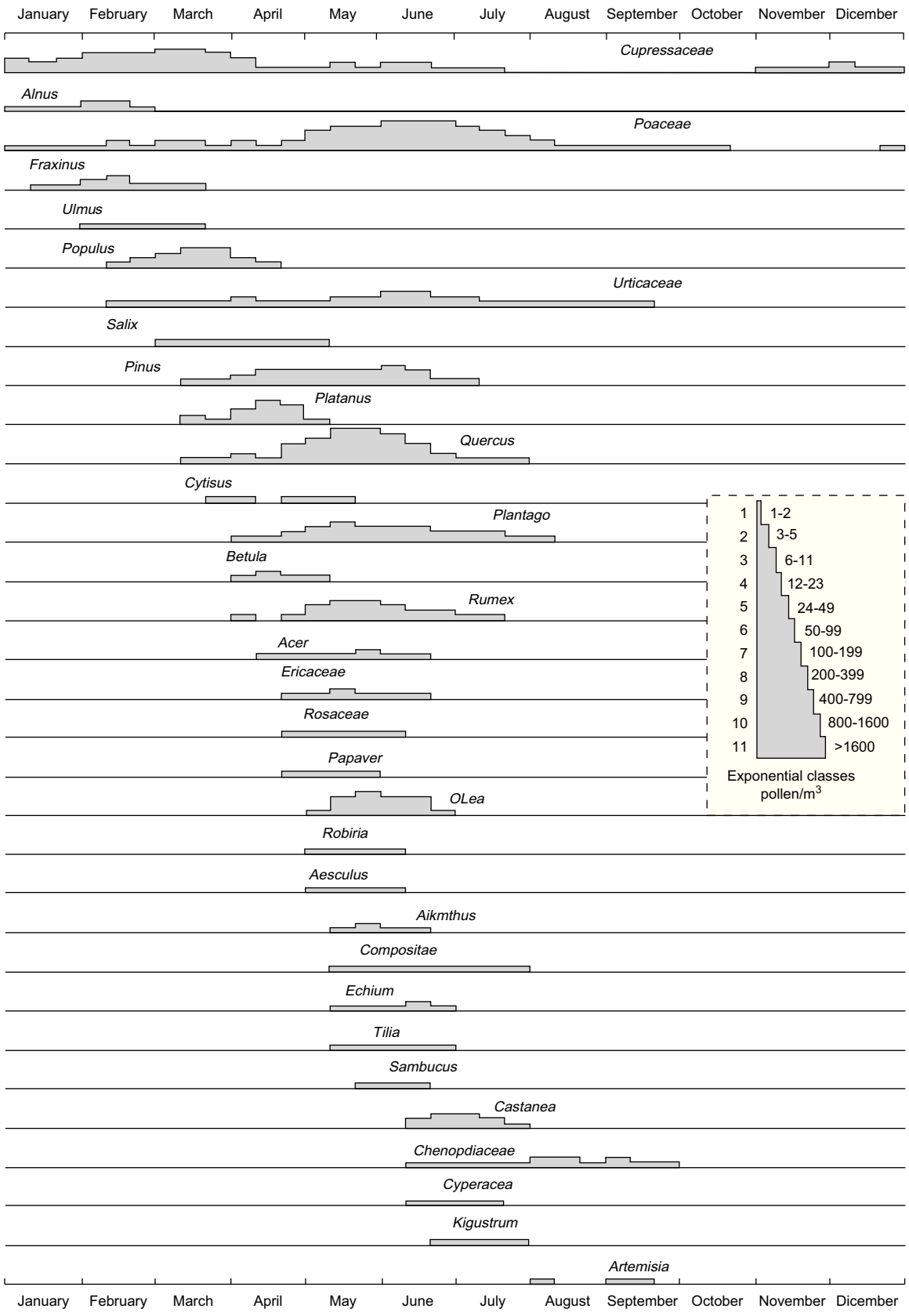

Figure 3 Pollen calendar of Salamanca (2000–2007).

Discussion

The mean annual pollen index (16,916) recorded in Salamanca between 2000 and 2007 was lower than the mean annual total found in other European sites, such as Zagreb[20] and other Spanish cities.[21,22] The pattern was similar to that of other Spanish cities located around 200 kilometres South or South-East from Salamanca, such as Madrid[23] and Cáceres[24]; but different to cities situated at the same distance to the North, such as León[25] or even further afield, like Santiago de Compostela[26] whose mean annual total was lower than that registered in Salamanca. In addition, the airborne pollen spectrum of Salamanca and percentages of each pollen type over total registered were different to those of other Iberian cities, probably due to the kind of vegetation present in different regions of the Iberian Peninsula, in addition to the composition and management of ornamental trees in urban environments.[27]

The increase of airborne pollen counts in the atmosphere of Salamanca during the 2000–2007 period, showed by the index of regression analysis (Figure 1; Table 2), was more accentuated in the case of arboreal pollen grains than in the case of non-arboreal pollen. In other European cities[28,29] an increase in pollen levels coming from main arboreal species, such as *Betula* or *Platanus*, has also been observed. A similar fact has been described in the Iberian Peninsula[30,31] for the case of *Quercus* and *Olea*. The increment in pollen concentrations could be related to the known effect of climate change on higher pollen levels and subsequently a great number of allergic processes.[32,33]

Regarding the main allergenic pollen types in the Mediterranean area and in the Iberian Peninsula[34,35] there was a potential risk for allergic patients in the case of Poaceae, because of its high levels between May and July and its long permanence in the atmosphere; *Platanus*, whose pollen grains were located during few weeks but with important daily concentrations in April, and *Olea* with also high pollen counts in May. The presence of Fra e 1, homologous of Ole e 1 from *Fraxinus*[36], could explain some of the early allergic courses that appear during February. Other possible symptom eliciting allergens could come from Cupressaceae pollens, whose levels are also high in late winter. Despite its quantitative first position among identified pollen types in Salamanca, *Quercus* could only be responsible for allergic symptoms when airborne pollen grains are abundant[37], taking into account processes of cross-sensitivity with other pollen types[38]. This fact coupled with recent studies reporting monosensitisation to *Quercus* pollen[39], pointed out its possible role in sensitised individuals living in the Salamanca area.

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References

1. Obtulowicz K, Kotlinowska T, Stobiecki M, Dechnik A, Obtulowicz A, Manecki M, et al. Environmental air pollution and pollen allergy. Ann Agric Environ Med. 1996;3:131–8.
2. D'Amato G, Cecchi C, Bonini S, Nunes C, Annesi-Maesano I, Behrendt H, et al. Allergenic pollen and pollen allergy in Europe. Allergy. 2007;62:976–90.
3. D'Amato G, Liccardi G. Pollen related allergy in the European Mediterranean area. Clin Exp Allergy. 1994;24:210–9.
4. Berna Dursun A, Çelik GE, Alan S, Münevver Pınar N, Mungan D, Mısırlıgil Z. Regional pollen load: Effect on sensitisation and clinical presentation of seasonal allergic rhinitis in patients living in Ankara, Turkey. Allergol et Immunopathol. 2008;36:371–8.
5. González Romano ML, Candau P, González Minero FJ. Pollen calendar of Seville and its relation to allergies. J Investig Allergol Clin Immunol. 1992;2:323–8.
6. González O, Fuentes Y, Rodríguez R, Martínez I, Rodríguez P, Pérez V. Calendario polínico en una región de Ciudad de La Habana. VacciMonitor. 2009;18:1–4.
7. Gioulekas D, Balafoutis C, Damialis A, Papakosta D, Gioulekas G, Patakas D. Fifteen-year records on airborne allergenic pollen and meteorological parameters in Thessaloniki. Int J Biometeorol. 2004;48:128–36.
8. Newnham RM, Fountain DW, Cornford CC, Forde BM. A national survey of airborne pollen and grass flowering in New Zealand, with implications for respiratory disorder. Aerobiologia. 1995;11: 239–52.
9. Rizzi-Longo L, Pizzulin-Sauli M, Stravisi F, Ganis P. Airborne pollen calendar for Trieste (Italy), 1990–2004. Grana. 2007;46:98–109.
10. Hernández Prieto M, Lorente Toledano F, Romo Cortina A, Dávila González I, Laffond Yges E, Calvo Bullón A. Pollen calendar of the city of Salamanca (Spain). Aeropalynological analysis for 1981–1982 and 1991–1992. Allergol et Immunopathol. 1998;26: 209–22.
11. Rodríguez de la Cruz D, Sánchez Reyes E, Sánchez Sánchez J. Aerobiological study of Fagaceae pollen in the Middle West of Spain. Aerobiologia. 2008;24:67–76.
12. Capel Molina JJ. In: Los climas de España. S.A. Barcelona: Ed. Oikos-Tau; 1981.
13. Domínguez E, Galán C, Villamandos F, Infante F. Manejo y evaluación de los datos obtenidos en los muestreos aerobiológicos. REA. 1991;1:1–18.
14. Damialis A, Halley JM, Gioulekas D, Vokou D. Long-term trends in atmospheric pollen levels in the city of Thessaloniki. Greece Atmos Environ. 2007;41:7011–21.
15. Galán C, Cariñanos P, García-Mozo H, Alcázar P, Domínguez-Vilches E. Model for forecasting *Olea europaea* L. airborne pollen in South-West Andalusia, Spain. Int J Biometeorol. 2001;45: 59–63.
16. Valdés B., Díez M.J., Fernández I. editores. Atlas polínico de Andalucía Occidental Sevilla: Instituto de Desarrollo regional n°43, Universidad de Sevilla. Excma. Diputación de Cádiz, 1987. p. 450.
17. Faegri K, Iversen J, editors. Textbook of pollen análisis. Chichester: J. Wiley & Sons; 1989.
18. Spieksma FThM. Regional European pollen calendars. In: D'Amato G, Spieksma FThM, Bonini S eds.: Allergenic pollen and pollinosis in Europe. Oxford: Blackwell Sci Publ; 1991. p. 49–65.
19. Andersen T. A model to predict the beginning of the pollen season. Grana. 1991;30:269–74.
20. Peternel R., Čulig J., Mitić B., Vukušic I., Šostar Z. Analysis of airborne pollen concentrations in Zagreb, Croatia, 2002. Ann Agric Environ Med. 2003; 10: 107–112.
21. Munuera Giner M, Carrión García JS, Navarro Camacho C. Seasonal fluctuations of the airborne pollen spectrum in Murcia (SE Spain). Aerobiologia. 2002;18:141–51.

22. Docampo S, Recio M, Trigo MM, Melgar M, Baltasar B. Risk of pollen allergy in Nerja (southern Spain): a pollen calendar. Aerobiologia. 2007;23:189–99.
23. Gutiérrez M, Sabariego S, Cervigón P. Calendario polínico de Madrid (Ciudad Universitaria). Período 1994–2004. Lazaroa. 2006;27:21–7.
24. Tavira Muñoz J, Tormo Molina R, Muñoz Rodríguez AF, Silva Palacios I, Gonzalo Garijo A. Calendario polínico de la ciudad de Cáceres. Rev Esp Alergol Inmunol Clin. 1998;13:288–93.
25. Vega Maray AM, Fernández-González D, Valencia-Barrera RM, Fernández Salegui AB, Santos F, Latasa M. Aerobiología en Castilla y León: Estación de León (2000–2001). Rea. 2002;7: 119–24.
26. Dopazo A, Aira MJ, Armisén M, Vidal C. Relationship of clinical and aerobiological pollen data in the norht-west of Spain. Allergol et Immunopathol. 2002;30:74–8.
27. Sánchez-Reyes E, Rodríguez de la Cruz D, Sanchís-Merino ME, Sánchez-Sánchez J. First results of *Platanus* pollen airborne content in the middle-west of the Iberian Peninsula. Aerobiologia. 2009;25:209–15.
28. Spieksma FThM, Corden JM, Detandt M, Millington WM, Nikkels H, Nolard N, et al. Quantitative trends in annual totals of five common airborne pollen types (*Betula*, *Quercus*, Poaceae, *Urtica*, and *Artemisia*), at five pollen-monitoring stations in western Europe. Aerobiologia. 2003;19:171–84.
29. Tedeschini E, Rodríguez-Rajo FJ, Caramiello R, Jato V, Frenguelli G. The influence of climate changes in *Platanus* spp. pollination in Spain and Italy. Grana. 2006;45:222–9.
30. García-Mozo H, Galán C, Jato V, Belmonte J, Díaz de la Guardia C, Fernández D, et al. *Quercus* pollen season dynamics in the Iberian Peninsula: Reponse to meteorological parameters and possible consequences of Climate Change. Ann Agic Environ Med. 2006;13: 209–24.
31. Trigo M.M., Recio M., Docampo S., García-Sánchez J., Melgar M., Aguilera F. et al. Incidencia del polen de olivo en la atmósfera de Andalucía. In: Boi M, Llorens L, Gil L, editors. Proceedings of XVI International APLE Symposium of Palynology; 2008; Palma de Mallorca, España; 2008. p. 18.
32. Shea KM, Truckner RT, Weber RW, Peden DP. Climate change and allergic disease. J Allergy Clin Immunol. 2008;122:443–53.
33. Osborne CP, Chuine I, Viner D, Woodward FI. Olive phenology as a sensitive indicator of future climatic warming in the Mediterranean. Plant, Cell & Environ. 2000;23:701–10.
34. Subiza J, Jérez M, Jiménez JA, Narganes MJ, Cabrera M, Varela S, et al. Allergenic pollen and pollinosis in Madrid. J Allergy Clin Immunol. 1995;96:15–23.
35. D'Amato G, Cecchi L, Bonini S, Nunes C, Annesi-Maesano I, Behrendt H, et al. Allergenic pollen and pollen allergy in Europe. Allergy. 2007;62:976–90.
36. Hemmer W, Focke M, Wantke F, Götz M, Jarisch R, Jäger S, et al. Ash (*Fraxinus excelsior*) pollen allergy in central Europe: specific role of pollen panallergens and the major allergen of ash pollen, Fra e 1. Allergy. 2000;55:923–30.
37. Holmquist L, Ekebom A, Alm Kübler K, Vesterberg O. Airborne birch and oak pollen grains and pollen allergens at common sampling station in Stockholm. Grana. 2005;44:104–7.
38. Weber RW. Guidelines for using pollen cross-reactivity in formulating allergen immunotherapy. J Allergy Clin Immunol. 2008;122:219–21.
39. Bartra J, San Miguel-Moncin M, Lombardero M, Alonso R, Fernández Parra B, Tella R, et al. Rhinoconjunctivitis and bronchial asthma due to monosensitization to *Quercus* pollen. J Allergy Clin Immunol. 2004;113:64–5.