

Airborne pollen sampling in Toledo, Central Spain

Herminia García-Mozo^{1,*}, Rosa Pérez-Badía², Federico Fernández-González² & Carmen Galán¹

*Department of Biología Vegetal, University of Cordoba, Edificio Celestino Mutis, Planta 3, Campus Rabanales, Cordoba, 14071, Spain; Department of Environmental Sciences, University of Castilla la Mancha, Toledo, Spain (*Author for correspondence, E-mail: bv2gamoh@uco.es; Fax: +34-957-218719)*

(Received 31 January 2005; accepted 10 October 2005)

Key words: aeropalinoLOGY, atmospheric pollen, meteorology, pollen calendar, Toledo (Spain)

Abstract

Toledo is one of the main tourist spots of Spain, attracting around two million visitors per year. Its geographical situation in the vast and scarcely monitored Region of Castilla La Mancha and the high number of tourists (especially in the spring) has resulted in the Spanish Aerobiology Network (REA) making this city a major study objective. Air monitoring studies carried out using REA sampling procedures commenced in October 2002. Thirty-two pollen types were identified during the sampling period (October 2002 to October 2004). The annual Pollen Index (PI) was 44124 for the agricultural year October 2002–October 2003, and 29666 in the same period of 2003–2004. The most abundant taxa were, in decreasing order of dominance: Cupressaceae, *Quercus*, Poaceae, *Populus*, *Olea*, Urticaceae, *Platanus*, *Pinus* and *Ulmus*. Other, less well-represented pollen taxa included *Salix*, *Alnus*, *Fraxinus* and *Tamarix*, which were characteristic of riverside areas, and *Morus*, *Artemisia* and Chenopodiaceae. The presence of *Castanea* pollen grains originating from chestnut crops far away from the city was clearly an example of long-distance transport. The highest concentrations of airborne pollen were detected from March to May and also in January, due to the flowering of Cupressaceae species. In general, there was a correlation between pollen and meteorological parameters: a positive correlation with temperature and a negative correlation with rainfall and humidity during the pre-peak period. A negative correlation between temperature and some tree pollen taxa was detected in the principal pollen period correlation analysis due to their long pollination periods.

1. Introduction

Atmospheric pollen is a major cause of allergies, especially in developed countries (D'Amato, 2001; Kovats et al., 2003). In each bio-geographical area, different species make up the characteristic airborne pollen calendar, the composition of which is controlled by meteorological conditions that are changeable among years and microclimates. The release and dispersion of pollen are dependent on specific microclimates, the presence of which explain the differences observed with respect to the onset of flowering within the same

species (Fernández-González et al., 1999; see García-Mozo et al., 1999). Therefore, to obtain reliable information on a whole area, it is important to increase the number of aerobiological monitoring stations up to a point that all of the different climatic and/or phytogeographic areas have been covered.

Aerobiological studies are of a great interest from an ecological and agricultural point of view, but they are of special interest to clinicians and allergy patients as a means of establishing a chronological correlation between the air pollen concentration and hay-fever and asthma symptoms.

This is especially true at the present time due to the climate-change impacts on airborne pollen (Beggs, 2004; Galán et al., 2005). In each geographical area, there is a succession of different flowering species throughout the year. Plant phenology is genetically determined and controlled by meteorological parameters. Consequently, any evaluation of the pollen allergenic risk of a given area will require not only a detailed knowledge of local vegetation but also of the floral phenology and the influence of weather variations.

The Castilla-La Mancha region is located in Central Spain. Its size, 79,300 km², makes it the second largest region of Spain (Figure 1). Its geography is characterized by an extended plain plateau surrounded by mountain chains with a smooth and low relief. This geological feature leads to very homogeneous vegetation through the entire Castilla-La Mancha region. The city of Toledo is the administrative capital of the region. Despite the low number of actual inhabitants of this city, 70,000, it is one of the main tourist spots of Spain, attracting around two million visitors per year (IECM, 2003). Its geographical sit-

uation in the vast and scarcely monitored Region of Castilla La Mancha and the high number of tourists (especially in the spring) has resulted in the Spanish Aerobiology Network (REA) making this city a major study objective.

An investigation on airborne pollen in the region of Castilla-La Mancha was initiated in February 1996 in the city of Ciudad Real, located in the southern part of Castilla-La Mancha (De Pablos, 2001). The results of this investigation revealed that airborne pollen of Poaceae, Cupressaceae, *Quercus*, *Platanus* and *Olea* are the most abundant atmospheric pollen taxa in that particular area. Moral del Gregorio et al. (1998) studied the presence of allergenic pollen and pollinosis in Toledo during 1995–1996. They indicated that the pollen taxa causing the main allergy symptoms were different species of Chenopodiaceae and Poaceae and also *Olea europaea* L.

The objectives of this study were to clarify which types of pollen are present in the atmosphere above Toledo and the time of year when these different types of pollen appear and to determine the effect of weather parameters on



Figure 1. Location of Toledo in Spain.

daily pollen concentration as a means of preventing – or lessening – their effects on sensitive patients and aiding in the planning of medical treatments on an allergic population.

2. Materials and methods

The city of Toledo (39°51' N, 4°01' W) is located in Central Spain, on the banks of the River Tajo, at an altitude of 530 m.a.s.l. Air monitoring studies applying REA sampling procedures began in October 2002 (Dominguez et al., 1992; Galán, 1998). We present here the results obtained for two agricultural years, from October 2002 to October 2004. A Hirst type (Lanzoni®) volumetric spore-trap located on the roof of a building of the Environmental Sciences Faculty, University of Toledo, was used for pollen sampling. This building is situated in a strategic loca-

tion close to the banks of the Tajo River and between the historic district (the most visited) and the “new” district (the most populated).

The climate is Mediterranean with a touch of continentality. There is a large contrast in annual temperatures. The warmest month is July, with an average temperature of 26 °C, and the coldest is January (average: 6.4 °C). The average annual temperature is 15.4 °C. With respect to rainfall, it is a rather dry climate with an average total annual rainfall record of 382 mm (Ministerio de Medio Ambiente, 2001). The daily meteorological data used for the study were supplied by the MO-MAC Research Group of the University of Castilla-La Mancha, which is responsible for the operation of a meteorological station located in the building of the Environmental Sciences Faculty, University of Toledo, 50 m far from the aerobiological sampler. The main meteorological parameters during the study period (2002–2003

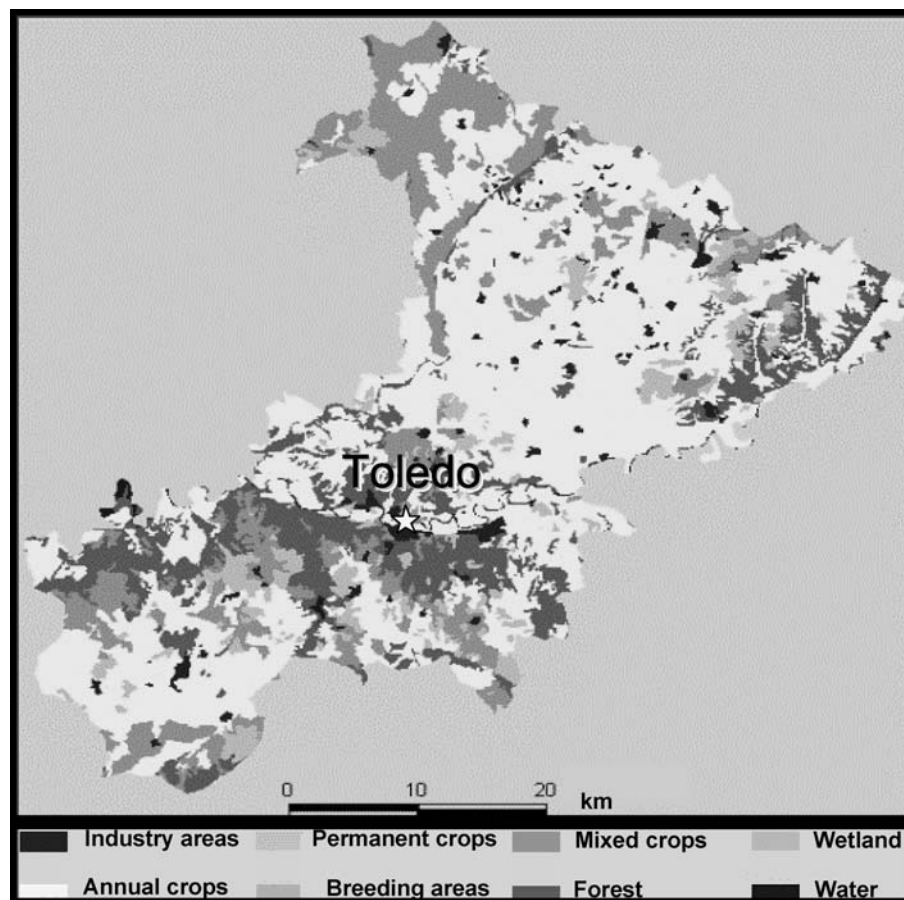


Figure 2. Toledo area: vegetation and crop map.

and 2003–2004) are shown in Figure 3. In terms of meteorology, these 2 years were very similar. In the 2002–2003 study period, 506 mm of rainfall and an average temperature of 16.3 °C were recorded; in the 2003–2004 study period, the measurements for these parameters were the 683 mm and 17.4 °C.

The landscape surrounding Toledo is mainly agricultural and dominated by cereal crops and

olive groves through a smooth relief (Figure 2). Natural vegetation areas are present to the south of the town and consist of Mediterranean open forests and “dehesas” dominated by holm oak [*Quercus ilex* L. subsp. *ballota* (Desf.) Samp.] and Mediterranean shrub lands dominated by *Cistus* spp., *Erica* spp., *Rosmarinus officinalis* L., *Thymus* spp., *Lavandula stoechas* L., among others. The best representations of Mediterranean for-

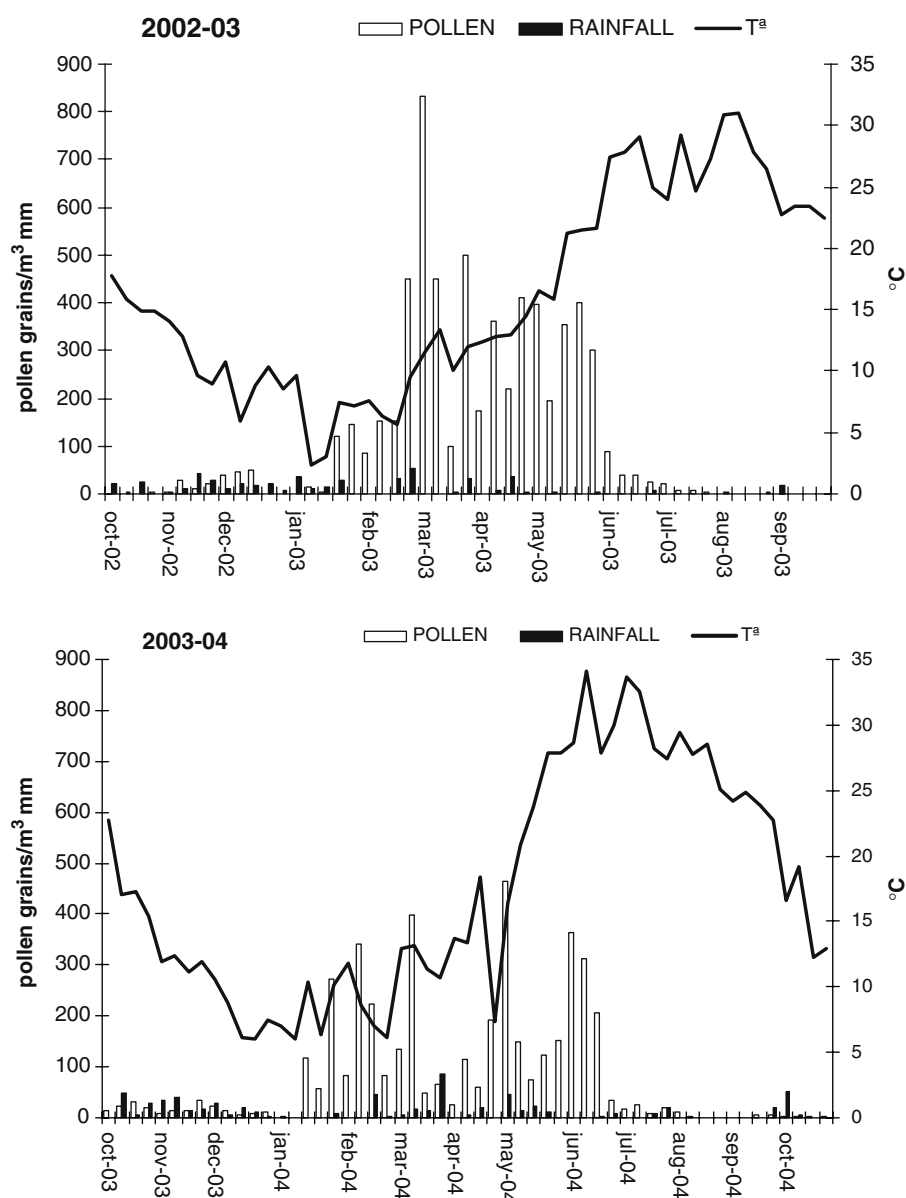


Figure 3. Weekly average variations in total pollen counts and the main meteorological parameters during the agricultural years studied (October 2002–October 2004).

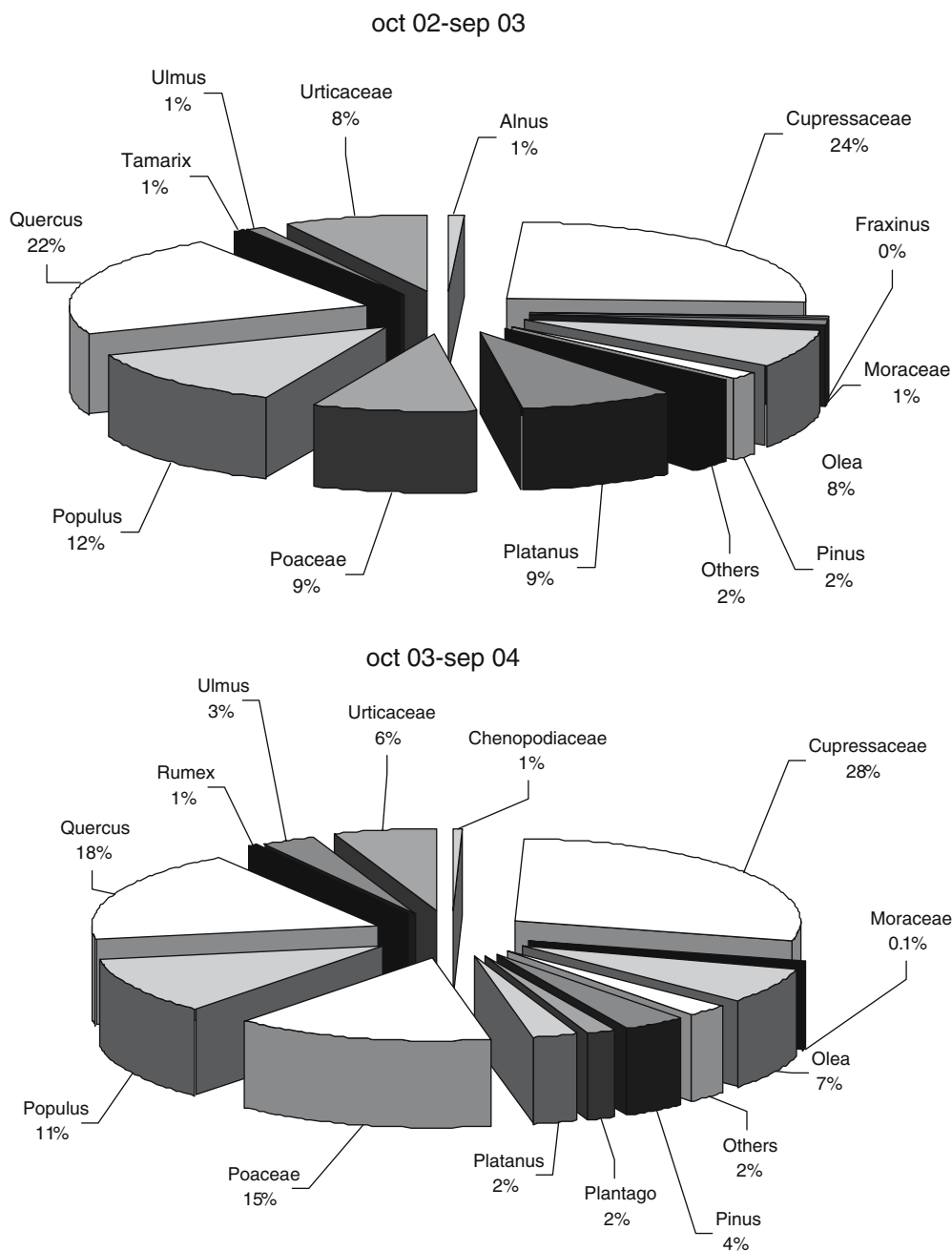


Figure 4. Pollen concentrations (in percentages) per taxon.

ests in the area are located in the Montes de Toledo range and include holm oak [*Q. ilex* L. subsp. *ballota* (Desf.) Samp.], cork oak (*Q. suber* L.) and deciduous oak (*Q. pyrenaica* Willd., *Q. faginea* Lam.) pure and mixed forests. The Tajo River crosses the city and still shelters some good representations of riparian forests dominated by

Populus alba L., *P. nigra* L., *Salix* spp., *Tamarix* spp., *Ulmus minor* L. and *Fraxinus angustifolia* Vahl. (Fernández-González et al., 2005).

We studied the characteristics of the pollination period of the most abundant pollen taxa, recording the dates of the beginning and end of the season, maximum pollen count and date and

the number of days during the pollination season. The start of the pollen seasons were defined according to García-Mozo et al. (1999) as the day on which a concentration of 1 pollen grain/m³ was reached and at least 5 subsequent days containing 1 or more pollen grains/m³. The end of season was the last day on which 1 pollen grain/m³ was recorded and then subsequent days presented concentrations below this level.

The correlation between main meteorological variables – mean temperature, maximum temperature, minimum temperature, rainfall, relative humidity, atmospheric pressure, wind velocity and wind direction, and pollen concentration – was analysed by means of a Spearman correlation test. In most cases, the principal pollen period (PPP) and the pre-peak (PP) time were separately analysed. The PP period can be defined as the period from the start date until the peak day, the latter referring to the day when the maximum pollen concentration is recorded.

3. Results

During the 2-year study, a total of 73,790 pollen grains were detected. The total annual Pollen Index (PI) was 44,124 for the agricultural year 2002–2003 and 29,666 in 2003–2004. Figure 3 shows the main meteorological parameters and weekly total pollen registered in the study period as a means of obtaining a better understanding of the results. It should be noted that unusually

rainy winters and an extremely hot and dry summers were registered in the study period.

Figure 4 shows the percentages of pollen concentrations in the two study years. The best-represented pollen type through the entire period was Cupressaceae with 18,191 pollen grains; this value represents, on average, 26% of the total pollen concentration. It is followed by pollen from *Quercus*, 14,927 (20%); *Populus*, 87,17 (11.5%); Poaceae, 8260 (12%) and *Olea*, 5591 (7.5%). Other, less common pollen types that were detected include *Platanus* (5.5%), *Ulmus* (2%) and *Morus* (0.5%). All these taken together with Cupressaceae represent the pollen from the cultivated urban floral population of the city. On the other hand, pollen from riparian vegetation is also abundant in the atmosphere above Toledo: *Populus*, *Alnus* (0.5%), *Tamarix* (0.5%), *Fraxinus* (0.2%) and *Salix* (0.1%). The presence of *Castanea sativa* pollen grains from chestnut crops located far away from the city is an example of long-distance transport. Pollen originating from herbaceous species are less frequent in the atmosphere, with the most abundant being Poaceae and Urticaceae (7%), followed by *Plantago*, Brassicaceae, Chenopodiaceae, *Rumex*, *Mercurialis* and *Urtica membranacea*.

With respect to the time of year that different concentrations of airborne pollen can be detected, the highest percentages in relation to the annual total were obtained during the period from March to May (Figure 5). The spring peak was found to occur in March. This month accounts for an average of 24% of the total annual pollen content. High concentrations were likewise

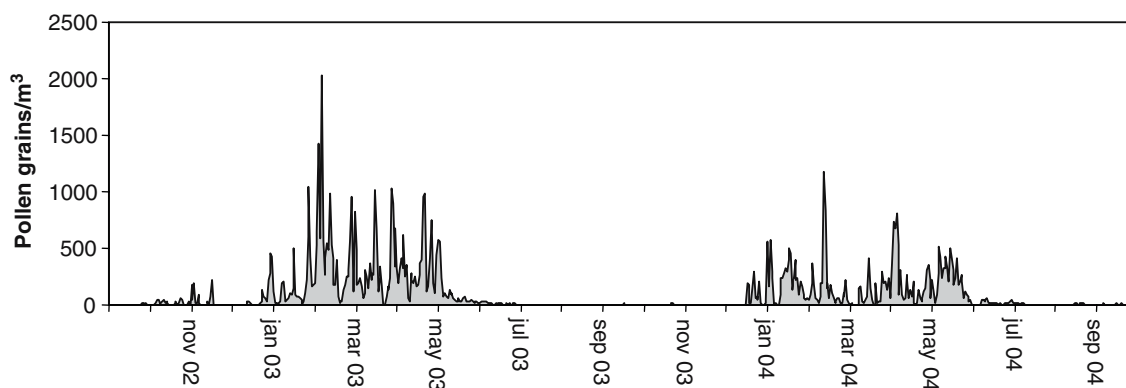


Figure 5. Daily variations in total pollen during the study period (October 2002–October 2004).

Table 1. Coefficients of correlation between pollen concentration and the main meteorological parameters based on the Spearman correlation test

	Cupressaceae			Populus			Platanus			Urticaceae			Quercus			Olea			Poaceae			Artemisia Chenopodiaceae		
	PP ^a	PPP ^a	PP	PP	PPP	PP	PP	PPP	PP	PP	PPP	PP	PP	PPP	PP	PP	PPP	PP	PP	PPP	PP	PPP	PP	PPP
2002–2003 period																								
Mean temperature	0.64**	0.17	0.58**	0.33*	0.95	0.35	0.72**	0.38**	0.35*	0.13	–0.20*	0.48	–0.54**	0.84**	0.12	–0.12	0.28							
Maximum temperature	0.61**	0.22*	0.41*	0.16	0.43	0.67	0.72**	0.43**	0.13	–0.22*	0.24	–0.53**	0.72**	0.10	–0.07	0.26								
Minimum temperature	0.47**	0.15	0.47*	0.32*	0.68	0.50	0.34**	0.17*	0.41*	–0.22*	0.59*	–0.58**	0.68**	0.11	–0.10	0.22								
Rainfall	–0.11	–0.14	–0.22	–0.21	0.59	0.56	–0.31**	–0.27**	–0.05	0.04		–0.03	–0.48**	–0.27**	–0.01	–0.10								
Humidity	–0.19	–0.03	–0.21	0.23	1.38	0.18	–0.25*	–0.15	–0.01	0.28**	–0.30	0.18	–0.58**	–0.06	–0.02	–0.34								
Atmospheric pressure																								
Wind speed	0.10	–0.05	0.24	–0.11	0.12	0.91	–0.15	–0.17	0.06	0.19	–0.43	–0.05	0.10	0.01	0.02	0.10								
2003–2004 period																								
Mean temperature	0.29*	0.06	–0.19	–0.10	0.40	0.35	0.54**	0.46**	0.63**	0.39**	0.71*	0.63**	0.75**	0.69**	0.06	0.29+								
Maximum temperature	0.60**	0.34**	0.19	0.17	0.29	0.22	0.59**	0.49**	0.60**	0.39**	0.71*	0.57**	0.66**	0.64**	0.11	0.33*								
Minimum temperature	0.50**	0.35**	–0.46**	–0.39**	0.74*	0.41	0.30**	0.35**	0.31*	0.26**	0.32	0.51**	0.51**	0.58**	0.08	0.18								
Rainfall	–0.19	–0.14	–0.34**	–0.24	0.03	0.04	–0.33**	–0.28**	–0.52**	–0.33**	–0.50	0.02	–0.24	–0.32**	–0.05	–0.32*								
Humidity	0.01	0.00	–0.60**	–0.52**	–0.57	0.16	–0.32**	–0.30**	–0.69**	–0.41**	–0.74**	–0.18	–0.25	–0.41**	–0.35	–0.32*								
Atmospheric pressure	0.21	0.12	0.04	–0.06	–0.63	–0.17	0.17	0.07	–0.06	–0.27*														
Wind speed	0.38**	0.40**	–0.21	–0.11	0.33	–0.33	0.02	0.04	0.11	0.07	0.50	0.01	0.03	–0.07	–0.35	–0.15								

Significance levels: *95%, **99%.

^aPP, Pre-peak period; PPP, principal pollen period.

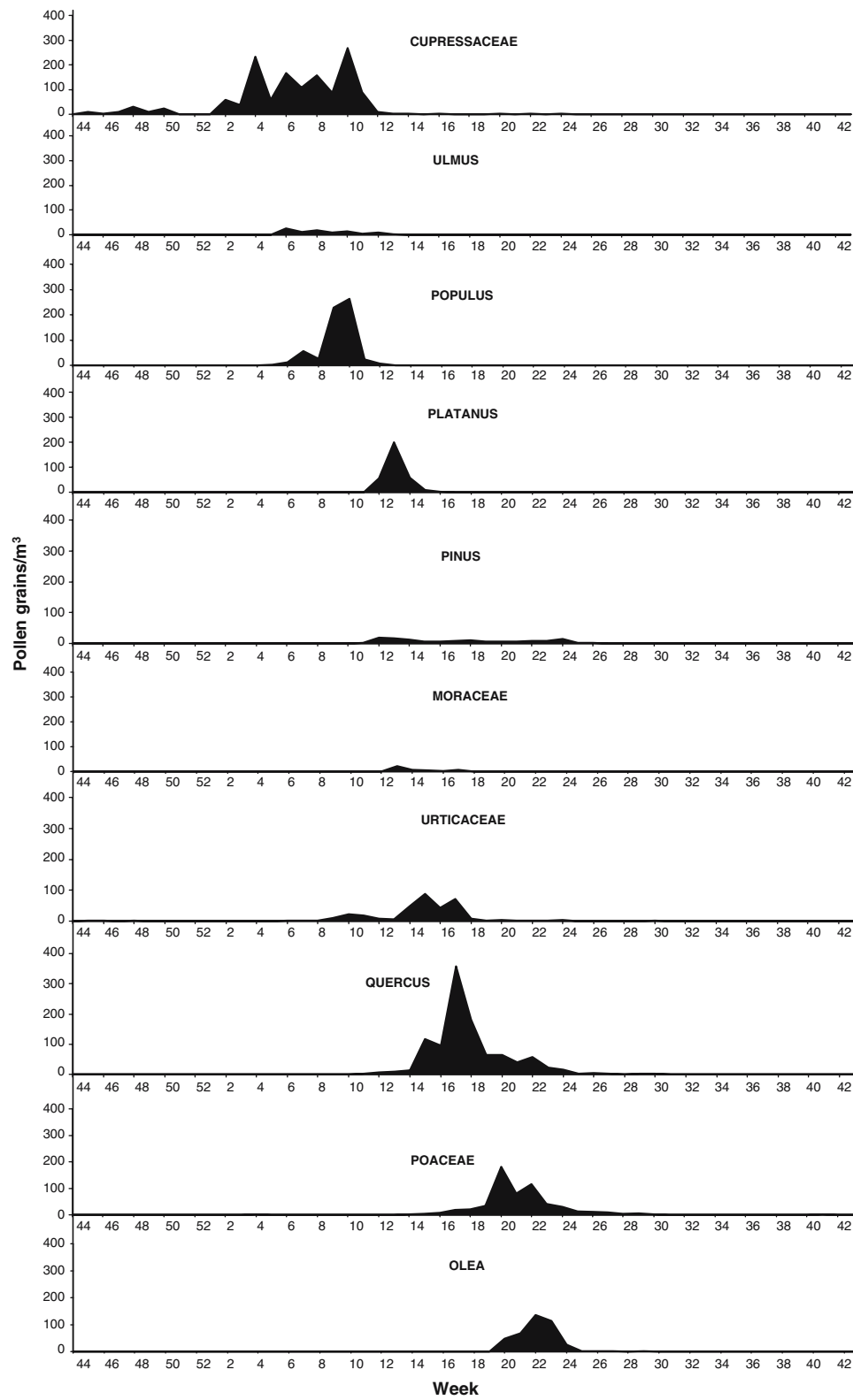


Figure 6. 2-year average preliminary calendar of Toledo.

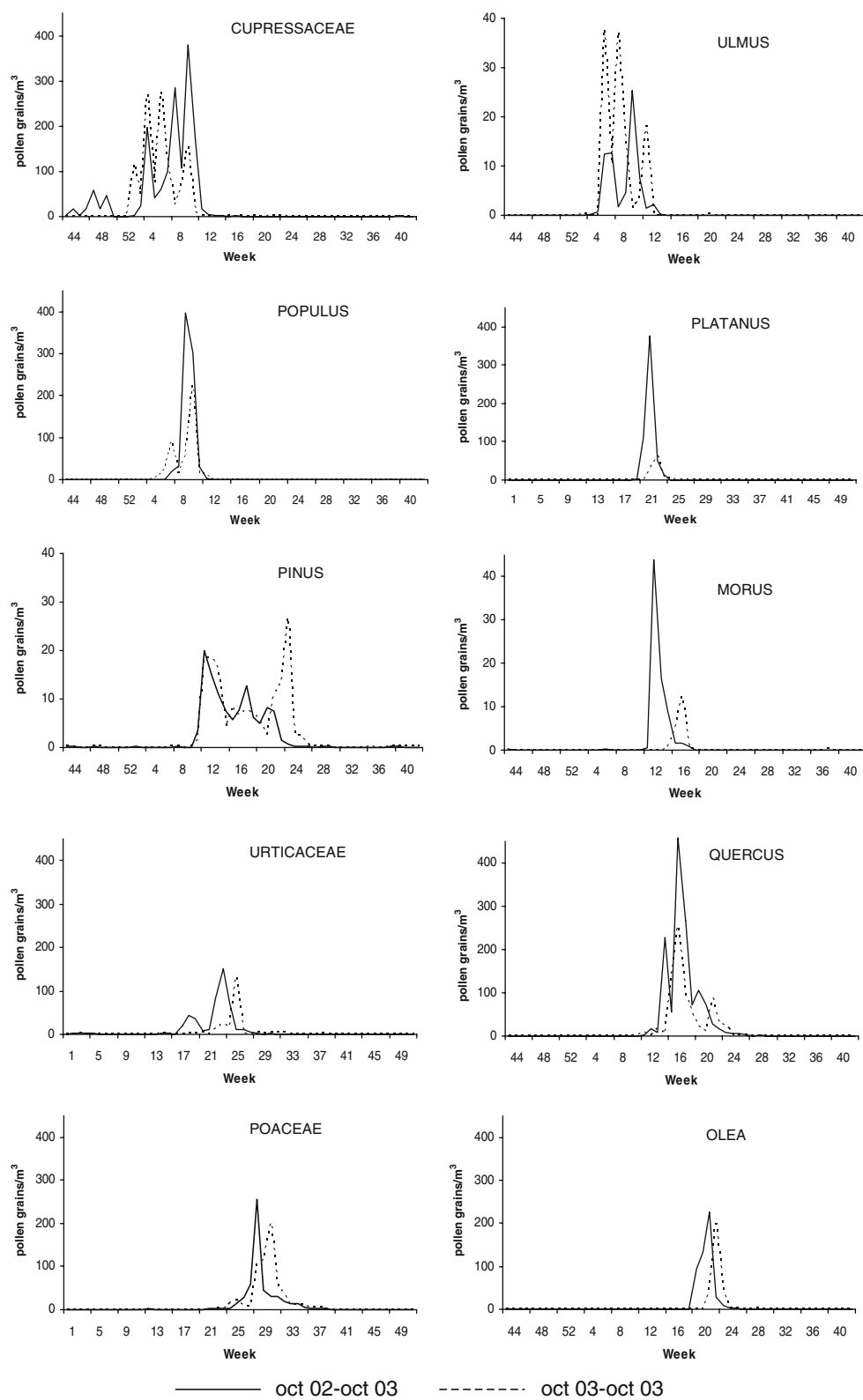


Figure 7. Weekly pollen dynamics of the most abundant pollen types in the atmosphere above Toledo.

obtained in the winter (January and February) due to the *Cupressus* flowering season. Autumn is the season with the lowest pollen values, frequently including days with an absence of atmospheric pollen due to the very low number of species flowering in the autumn, and to the cleaning of the atmosphere by rainfall. Figure 6 shows the preliminary pollen calendar of the city of Toledo. Only taxa that produced more than 2% of the total pollen content are represented in the graphs. We detected a temporal order to the appearance of various pollen types in the air above Toledo. The first pollen grains in the air were detected in January and belong to *Alnus*, *Fraxinus* and Cupressaceae. *Ulmus* and *Populus* usually flower during February and March and, as a result of rising temperatures in these months, the pollen season for other tree taxa also commences: *Salix*, *Platanus*, *Pinus*, *Morus* and *Quercus*. Pollen of *Olea* and *Tamarix* was detected in April. *Olea* pollen usually remains in the air until July. With respect to the herbaceous pollen types, the earliest is Urticaceae, although maximum pollen concentrations of this genus are found in March and April. Around this time Poaceae' airborne pollen begins to show an increase, as do other herbaceous pollen types, such as *Plantago*, Brassicaceae, *Chenopodiaceae* and *Rumex*, although these are mostly detected in the summer months (July and August). *Artemisia* pollen is present during early autumn. Other less abundant types, such as *Mercurialis* and *U. membranaceae*, are present in the atmosphere above Toledo practically year-round, although higher concentrations do appear in the spring.

In Figure 7 it is possible to observe the weekly pollen dynamics of the ten most abundant pollen types in Toledo's atmosphere. Differences in pollen concentrations and aerobiological behavior and dates are apparent among the two study years. Although winter-flowering species present very similar pollen season starts and peak dates on this graph, spring species such as *Quercus*, *Morus*, Poaceae and *Olea* show an average delay of 15 days in the spring of 2004 relative to the dates in 2003. Five of the taxa analysed, *Populus*, *Platanus*, Moraceae, Poaceae and *Olea*, show only one well-defined pollen peak during the season, while Cupressaceae, *Ulmus*, *Pinus*, *Quercus* and Urticaceae have curves with two or more peaks throughout their flowering time.

Meteorological parameters and pollen data for Cupressaceae, *Populus*, *Platanus*, Urticaceae, *Quercus*, *Olea*, Poaceae, *Artemisia* and *Chenopodiaceae* were analysed. The correlation between pollen concentration during the main pollination period and the main meteorological parameters was significant in a large number of cases (Table 1). The results indicate that the parameters that exerted the greatest influence on the concentration of pollen in the atmosphere above Toledo were the mean, maximum and minimum temperatures, rainfall and humidity. Both rainfall and humidity had a negative influence on pollen concentration, while temperatures usually had a positive influence. Nevertheless, differences among the PP and PPP analyses were found for all of the tree pollen taxa. With respect to *Quercus* and *Olea*, we found a negative influence of temperature during the PPP and a positive influence of temperature during the PP.

4. Discussion

During the study period we attained an average of 37,000 pollen grains per year, which is similar to the value recorded in the southern part of the Castilla La-Mancha region (city of Ciudad Real) (Sánchez et al., 2000; De Pablos, 2001; Prieto et al., 2002). Nevertheless, this concentration is lower than those recorded in neighbouring Spanish regions, such as Andalucía, where olive crops release very high pollen concentrations (Díaz de la Guardia et al., 1999; Ruiz et al., 2002), Extremadura, with very high values of Poaceae and *Quercus* (Paulino et al., 2002; Silva et al., 2002) or even the city of Madrid (71 km from Toledo), where the higher number of plants of ornamental species of Cupressaceae and *Platanus* release high quantities of pollen (Gutierrez Bustillo et al., 2002).

The conclusions drawn from the investigations in Ciudad Real were that Poaceae, Cupressaceae, *Quercus*, *Platanus* and *Olea* (in decreasing order of abundance) are the most abundant pollen types in the atmosphere. Some of these results fit with those found in the present study, with the exception of *Platanus*, which it is not very abundant in the city of Toledo. We found that Cupressaceae produced the most airborne pollen in Toledo, followed in decreasing order by

Quercus, Poaceae, *Populus* and *Olea*. Our results reflect the diversity of the vegetation, which consists of: (1) cultivated trees in the streets and parks of the urban area – *Cupressaceae* (26%), *Platanus* (5.5%), *Ulmus* (2%), *Morus* (0.5%); (2) spontaneous tree species associated to the riverside which surrounds the city – *Populus* (11.5%), *Tamarix* (0.5%), *Fraxinus* (0.5%) and *Salix* (0.1%); (3) spontaneous herbs species – Poaceae (12%), Urticaceae (7%); (4) the vegetation in the outskirts of the city, which is also well represented in the pollen spectrum by the high concentrations of *Quercus* pollen (20%) from the natural areas of Mediterranean forest and “dehesas”. Although Toledo is not one of the most important olive oil-producing areas of Spain, olive crops situated in the surroundings of the town were found to release high quantities of *Olea* pollen (7.5%). The low percentage of pollen produced by herbaceous taxa is worth note: an average of 22% of the total pollen detected in the study period. The characteristics of the zone, an urbanised area surrounded by olives and oaks and cereal crops could explain this fact. Although cereal crops belong to the Poaceae family, the cultivated species have a high degree of autogamy, and in most cases fecundation and subsequent anther dehiscence occurs before flower aperture.

In general, most taxa show a well-defined annual curve of pollen concentration. One-half of the analysed pollen types have one-peak curves that reflect a homogeneous phenology pattern, probably due to the flatted geographical relief of the area. Nevertheless, some taxa, such as *Cupressaceae*, *Quercus*, *Ulmus*, *Pinus*, and Urticaceae, show a multi-peak curve, probably due to the number of species involved. Field phenological studies carried out in other areas of Spain have revealed that each species of both *Cupressaceae* and *Quercus* families show characteristic floral phenology patterns in a given area (Gómez-Casero, 2003; Hidalgo et al., 2003).

Although some approaches to determining and measuring the atmospheric pollen spectrum of the city of Toledo have been made in the past (Moral del Gregorio et al., 1998), prior to this study no information was available on the relation of this spectrum with meteorological parameters. The study period was characterised by very rainy winters and extremely hot and dry

summers. It is a common characteristic of a Mediterranean climate that rainy winters can result in higher quantities of pollen grains being produced in the spring, whereas extreme aridity conditions during the summer can lead to a scarcity of pollen grains during the summer and early autumn. Daily temperature variables showed positive coefficients in most of the PP equations, whereas some of the results for the whole season displayed significant negative coefficients. This phenomenon was observed overall in some of the tree taxa analyses, such as those for *Quercus* and *Olea*, which have long pollination periods. The increase in temperature in the late spring/early summer coincides with the end of the season: this is a time of decreasing pollen concentrations, a post-peak period due to the individual phenology of the plant, which has already emitted the major percentage of pollen grains and is starting a gradual lower emission. Similar results have been observed for both *Olea* and *Quercus* in the city of Cordoba, southern Spain (Vázquez et al., 2003; García-Mozo, 2004).

Based on their results, Moral del Gregorio et al. (1998) concluded that *Olea*, Poaceae and Chenopodiaceae pollen are responsible for most of the pollinosis cases in Toledo. In the case of Chenopodiaceae, our results differ from this conclusion. Pollen from this family appears in the atmosphere above Toledo only at a very low percentage (0.35%). Moral del Gregorio et al. also reported a 50.5% of prevalence in allergy prick tests for Betulaceae pollen. However, the very low concentration of Betulaceae pollen (<0.5%) detected during our survey suggests to us that this pollen taxa cannot be a significant cause of pollinosis in the city. Skin-prick tests using commercial pollen extracts may reveal a high percentage of prevalence experimental studies; nevertheless, they do not always mean that these pollen taxa will be the main causes of pollinosis in a given area (Frenz, 2001).

With respect to pollen concentrations, Moral del Gregorio et al. (1998) reported higher values of airborne pollen from herbaceous taxa (Chenopodiaceae, *Plantago* and *Rumex*) during the period 1995–1996 than those detected in the present work. On the other hand, these authors showed significant lower values of some tree taxa, such as *Populus* and *Ulmus*. These differences could be attributed to different causes,

including trap location, analysis method and the different meteorological characteristics of the years analysed. Taking into account the spectra and concentrations of the airborne pollen described herein, a detailed study on the causes and effects of pollen allergy should be carried out in the Toledo area.

Acknowledgements

We sincerely thank Prof. Dr. Manuel de Castro, of the MOMAC Research Group of the University of Castilla-La Mancha, who provided the meteorological data. We are also grateful to Ana Rapp Benito, technician of the Department of Environmental Sciences of the University of Castilla-La Mancha for her collaboration in the collection of samples.

References

- Beggs P.J.: 2004, Impacts of climate change on aeroallergens: past and future, *Clin. Exp. Allergy* **34**, 1507–1513.
- D'Amato G.: 2001, Allergenic Pollen, in G. D'Amato, S. Bonini, J. Bousquet, S. Durham and T.A.E. Platts-Mills (eds), *Pollinosis 2000. Global Approach*. JGC Editions: Naples, pp. 69–76.
- De Pablos Alcázar L.: 2001, Aerobiología en Ciudad Real: Modelos de Pronóstico, PhD thesis, University of Cordoba, Cordoba, Spain.
- Díaz de la Guardia C., Galán C., Domínguez E., Alba F., Ruiz L., Sabariego S., Recio M., Fernández-González D., Méndez J., Vendrell M. and Gutierrez-Bustillo M.: 1999, Variation in the *Olea europaea* L. main pollen season at selected sites in the Iberian Peninsula, *Polen* **10**, 103–113.
- Domínguez-Vilches E., Galán C., Villamandos F. and Infante F.: 1992, Handling and evaluation of the data from the aerobiological sampling, *Monografías REA/EAN* **1**, 1–13.
- Fernández-González D., Valencia R., Vega A., Díazde la Guardia C., Trigo M.M., Cariñanos P., Guardia A., Pretiñes C. and Rodríguez F.J.: 1999, Analysis of grass pollen concentrations in the atmosphere of several Spanish sites, *Polen* **10**, 127–136.
- Fernández-González F., Loidi J., Moreno J.C. Del Arco M., Fernández-Cancio A., Galán C., García-Mozo H., Muñoz J., Pérez-Badía R., Sardinero S., Tellería M.: 2005, Impact on plant biodiversity, in Moreno J.M. (ed.), *Impacts on Climatic Change in Spain*, ECCE, Ministerio de Medio Ambiente: Madrid, pp. 183–248.
- Frenz D.A.: 2001, Interpreting atmospheric pollen counts for use in clinical allergy: allergic symptomatology, *Ann. Allergy Asthma Immunol.* **86**, 150–157.
- Galán C.: 1998, Introducción a la REA, *REA* **3**, 5–6.
- Galán C., García-Mozo H., Vázquez L., Ruiz-Valenzuela L., DíazDeLa Guardia C. and Trigo-Perez M.: 2005, Heat requirement for the onset of the *Olea europaea* L. pollen season in several places of andalusia region and the effect of the expected future climate change, *Int. J. Biometeorol.* **49**, 184–188.
- Gómez-Casero, M.T.: 2003, Fenología floral y Aerobiología en distintas especies perennifolias de Quercus en la provincia de Córdoba, PhD thesis, University of Córdoba, Córdoba, Spain.
- García-Mozo H.: 2004, *Optimización de los modelos predictivos a corto y largo plazo de polen de tipo Quercus* en distintas zonas climáticas españolas, University of Córdoba: Córdoba, Spain.
- García-Mozo H., Galán C., Cariñanos P., Alcázar P., Méndez J., Vendrell M., Alba F., Sáenz C., Fernández D., Cabezo B. and Domínguez E.: 1999, Variations in the *Quercus* sp. pollen season at selected sites in Spain, *Polen* **10**, 59–69.
- Gutiérrez Bustillo M., Cervigón Morales P. and Pertíñez Izquierdo C.: 2002, Aerobiología en Madrid: estación de Ciudad Universitaria (2000–2001), *REA* **7**, 225–230.
- Hidalgo P.J., Galán C. and Domínguez E.: 2003, Male phenology of the genus *Cupressus*: correlation with airborne pollen, *Trees* **17**, 336–344.
- Institute of Statistics of Castilla la Mancha (IECM): 2003, *Anuario Estadístico de Castilla la Mancha*, Junta de Comunidades de Castilla la Mancha: Toledo, Spain.
- Kovats S., Ebi K.L., Menne B.: 2003, *Health and Global Environmental Change*. World Health Organization, Geneva, pp. 59–62.
- Ministerio de Medio Ambiente: 2001, *Guía Resumida del clima en España (1971–2000)*. Centro de Publicaciones Secretaría General Técnica Ministerio de Medio Ambiente: Madrid.
- Moral del Gregorio A., Senent Sánchez C., Cabañes Higuero N., García Villamuza Y. and Gómez-Serranillos Reus M.: 1998, Allergenic pollen and pollinosis of Toledo in 1995–1996, *Rev. Esp. Alergol. Immunol. Clin.* **13**, 126–134.
- Paulino R., Tormo R., Silva I. and Tormo R.: 2002, Aerobiología en Extremadura: estación de Cáceres (2000–2001), *REA* **7**, 177–182.
- Prieto J.C., de Pablos L., Domínguez E. and Galán C.: 2002, Aerobiología en Castilla la Mancha: estación de Ciudad Real (2000–2001), *REA* **7**, 113–118.
- Ruiz L., Díaz de la Guardia C., Cano A. and Cano E.: 2002, Aerobiología en Andalucía: estación de Jaén (2000–2001), *REA* **7**, 77–82.
- Sánchez J.A., Hidalgo P.J., de Pablos L., Galán C. and Domínguez E.: 2000, Aerobiología en Andalucía: estación de Ciudad Real (1999), *REA* **6**, 63–66.
- Silva I., Moreno A., Muñoz A.F. and Tormo R.: 2002, Aerobiología en Extremadura: estación de Badajoz (2000), *REA* **7**, 173–176.
- Vázquez L.M., Galán C. and Domínguez E.: 2003, Influence of meteorological parameters in *Olea* pollen, *Int. J. Biometeorol.* **48**, 83–90.