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ORIGINAL PAPER

Comparison of airborne herb pollen types in Córdoba (Southwestern Spain) and Poznan (Western Poland)

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Abstract This study sought to compare airborne pollen counts for a number of common herbaceous species (*Plantago*, Chenopodiaceae–Amaranthaceae, *Rumex*, and Urticaceae) in two cities with differing weather conditions, Córdoba (Southwestern Spain) and Poznan (Western Poland). Pollen seasons for these species were studied from 1995 to 2005. Aerobiological sampling was performed using a Hirst type 7-day spore trap, in accordance with the procedure developed by the European Aerobiology Network. A Spearman correlation test was used to test for correlations between meteorological parameters and daily airborne pollen counts. The Spearman correlation test and the Wilcoxon signed ranks test were also used to compare mean daily pollen counts for the two study sites. In Córdoba, the pollen season generally started around two months earlier than in Poznan, and also lasted longer. These findings were attributed to the presence of a larger number of species in Córdoba, with overlapping pollen seasons, and also to more favorable weather conditions. Trends in pollen season start dates were fairly stable over the study period, with a slight tendency to delayed onset in Córdoba and a modest advance in start date in Poznan. The pollen season end date also remained reasonably stable over the study, with only a slight tendency for the season to end earlier in Córdoba and later in Poznan. A clear trend towards declining annual pollen counts was recorded over the study period for all pollen types in both cities.

Keywords Airborne pollen · Herb pollen types · Meteorology · Poland · Pollen season · Spain

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1 Introduction

The aerobiological study of herbaceous species tends to be more complex than that of trees due to the taxonomical composition of herb pollen types, usually involving a large number of species, genera, or even families. As a result, herbaceous pollen types display more irregular pollen season curves over the year due to individual variations in timing for the various species, genera, or families involved. This diversity may also lead to differences in patterns between geographical regions characterized by different dominant species within the same pollen type, due to the absence of any clearly defined trend (Latalowa et al. 2005). Moreover, species within the same pollen type may have differing climate requirements. Mediterranean climate areas are exceptionally rich in terms of biodiversity.

Generally speaking, airborne pollen counts for herb species tend to be representative only of a local area, while tree pollen counts provide information about a wider area, and even at the regional level (Hicks 1992).

Poaceae pollen has been the object of a considerable amount of research, in view of its potential; the present study, therefore, focused on other herb pollen types, which are, nonetheless, abundant in the air, particularly in Europe: *Plantago*, Chenopodiaceae–Amaranthaceae, *Rumex*, and Urticaceae.

Results are provided for two European sites which include different species within the pollen types studied; the species most commonly encountered in Córdoba (Valdés et al. 1987) and Poznan (Jackowiak 1993) are shown in Table 1.

Of the 35 *Plantago* species found in Europe, 25 grow in the Iberian Peninsula (Moore 1976; Chater and Cartier 1976). *Plantago* pollen has been reported as allergenic in many studies. In Spain, it has been cited as allergenic (Subiza et al. 1995), with percentages of sensitization ranging between 15% in Málaga (Torrecillas et al. 1998) and 78% in Toledo (Moral de Gregorio et al. 1998). Most patients suffering from allergy to *Plantago* are polysensitized, making it difficult to establish the real importance of *Plantago* pollen. In Córdoba, 29% of allergy sufferers are sensitive to *Plantago* pollen (Domínguez-Vilches et al. 1993). A number of authors have reported on the allergenic potential to Chenopodiaceae–Amaranthaceae species (Spieksma et al. 1980; Galán et al. 1989; Guerra et al. 1990). In Córdoba, 22% of allergy sufferers are sensitive to this pollen type (Domínguez-Vilches et al. 1993). *Parietaria* pollen grains have been identified as allergenic in many studies, while *Urtica* pollen grains are considered by most authors to be slightly allergenic. The prevalence of sensitivity to *Parietaria* in Spain varies from 3.5% in Barcelona to 12% in Vigo (March et al. 1993; Belmonte et al. 1998; Botey et al. 1999). In inland Andalusia, *Parietaria* is reportedly responsible for 2.5% of pollen allergies (Domínguez-Vilches et al. 1993), although this figure is higher in coastal areas, mainly along the Mediterranean coast. In Córdoba, two pollen types are considered to be characteristic for this family; one single-species type (*Urtica membranacea*) and the other comprising *Urtica urens* and *Parietaria* (Alcázar et al. 1998; Galán et al. 2000).

In Poznan, by contrast, the weakest allergenic potential among the pollen types studied has been reported for *Urtica*. Allergy to *Urtica* pollen is very rare. *Rumex* and *Chenopodium* are consider to be low- or medium-risk allergens, while allergy to *Plantago* pollen is usually associated with hypersensitivity to the pollen of other plant species (Silny and Czarnecka-Operacz 2001; Rapiejko et al. 2001).

This study sought to compare airborne pollen counts for a number of common herb species

Table 1 Species more frequently found in each city for the studied pollen types

Pollen type	Córdoba	Poznan
Plantago	*P. afra, P. major, P. albicans, P. loeflingli, P. bellardi, P. lanceolata, P. lagopus, P. coronopus, P. serraria*	*P. lanceolata, P. major, P. arenaria, P. media, P. pauciflora*
Chenopodiaceae–Amaranthaceae	*Atriplex patula, A. prostrate, A. chenopodioides, A. rosea, Beta vulgaris, Chenopodium botrys, Ch. ambrosioides, Ch. multifidum, Ch. exsuccum, Ch. murale, Ch. vulvaria, Ch. urbicum, Ch. opulifolium, Ch. album, Salicornia ramosissima, Amaranthus albus, A. retroflexus, A. hypochondriacus, A. cruentus, A. graecizans, A. blitoides, A. muricatus, A. deflexus, A. viridis, A. lividus*	*Chenopodium album, Ch. glaucum, Ch. hybridum, Ch. rubrum, Ch. polyspermum*
Rumex	*R. angiocarpus, R. tingitanus, R. scutatus, R. acetosa, R. intermedia, R. crispus, R. conglomeratus, R. pulcher, R. divaricatus, R. palustris, R. bucephalophorus*	*R. acetosa, R. acetosella, R. crispus, R. obtusifolius, R. conglomeratus, R. hydrolapathum, R. maritimus, R. thyrsiflorus, R. confertus, R. sanguineus*
Urticaceae	*Urtica membranacea, U. urens, Parietaria judaica, P. mauritanica*	*Urtica dioica, U. urens*

(*Plantago*, Chenopodiaceae–Amaranthaceae, *Rumex*, and Urticaceae) in two cities located in different bioclimatic areas, Córdoba (Spain) and Poznan (Poland). The pollen seasons of these plants were studied for both cities from 1995 to 2005, comparing the pollen index and the pollen season start date throughout the study period. The influence of meteorological parameters was also examined.

2 Materials and methods

This study was carried out in Córdoba (Southwestern Spain) and Poznan (Western Poland).

Córdoba (37°50′N, 4°45′W) is located at 123 m above sea level; it is a small city, with a population of around 310,000. Córdoba has a Mediterranean climate characterized by cold, rainy winters and hot, dry summers with maximum temperatures above 40°C. The annual average temperature is 17.6°C and the mean annual rainfall over the period 1971–2000 was 536 mm (*Guía resumida del clima en España 1971–2000*; National Institute of Meteorology 2001). The prevailing wind direction is southwesterly. Daily meteorological data for Córdoba were provided by the National Institute of Meteorology from the weather station located at Córdoba airport, 5 km from the aerobiological sampler.

Poznan (52°25′N, 16°53′E) is located 80 m above sea level. It is a medium-sized city with a population of roughly 700,000. Poznan lies at the boundary of the continental climate zone, characterized by frosty winters and warmer summers. The mean annual rainfall is 500 mm, and the annual average temperature is 8.5°C. The prevailing wind directions are westerly and southwesterly. The Institute of Meteorology and Water Management provided meteorological data for Poznan, from a weather station located 1.5 km west of the aerobiological sampler.

Sampling was carried out at both sites using a Hirst type 7-day spore trap (Hirst 1952), in accordance with the procedure developed by the European Aerobiology Network (http://www.polleninfo.org) and the Spanish Aerobiology Network (Galán et al. 2007).

The start of the pollen season was defined as the first day on which a daily average of at least 1 pollen grain/m^3 was followed by five subsequent days with 1 or more pollen grains/m^3. The end of the pollen season was defined as the last day on which a daily average of at least 1 pollen grain/m^3 was recorded, when counts on the five following days were below this level (García-Mozo et al. 2006).

Spearman's correlation test was used to determine the relationship between meteorological variables (temperature, precipitation, humidity, and hours of sunlight) and the mean daily airborne pollen counts. A non parametric statistic was used since the data were not normally distributed.

Spearman's correlation tests were also performed to test for correlations between pollen counts from the two samplers (i.e., mean daily pollen counts in Córdoba and Poznan). A Wilcoxon signed ranks test was also applied to pollen counts for the two cities. Finally, a paired samples test was applied to the log pollen count recorded by both samplers plus one. The ln form was applied to normalize data for parametric testing.

3 Results

Over the study period, the following temperature data were recorded for Córdoba and Poznan, respectively: average temperature 18.3 and 8.9°C; average maximum temperature 24.9 and 13.3°C; average minimum temperature 11.8 and 4.7°C. The average annual rainfall over the study period was 629 mm in Córdoba and 548 mm in Poznan. Nevertheless, rainfall in Córdoba was torrential, and concentrated into just a few days, prompting low water availability for plants, while in Poznan, rainfall was more evenly distributed over the whole year. The figure for the average number of hours of sunlight was higher in Córdoba (8.6 vs. 5.6 for Poznan). The average humidity was 61.5% in Córdoba and 76.4% in Poznan. Annual data for mean temperature, rainfall, humidity, and sunlight hours are shown in Fig. 1.

The minimum daily temperature over the study period in Córdoba was −8.3°C, compared to −22.3°C in Poznan, while the maximum daily temperature was 46.6°C in Córdoba and 36.8°C in Poznan.

The pollen types studied were recorded in the air of Córdoba during spring and summer, except for Urticaceae pollen, which was present practically throughout the whole year. In Poznan, these pollen types were present in the air from late spring to summer, or even into autumn.

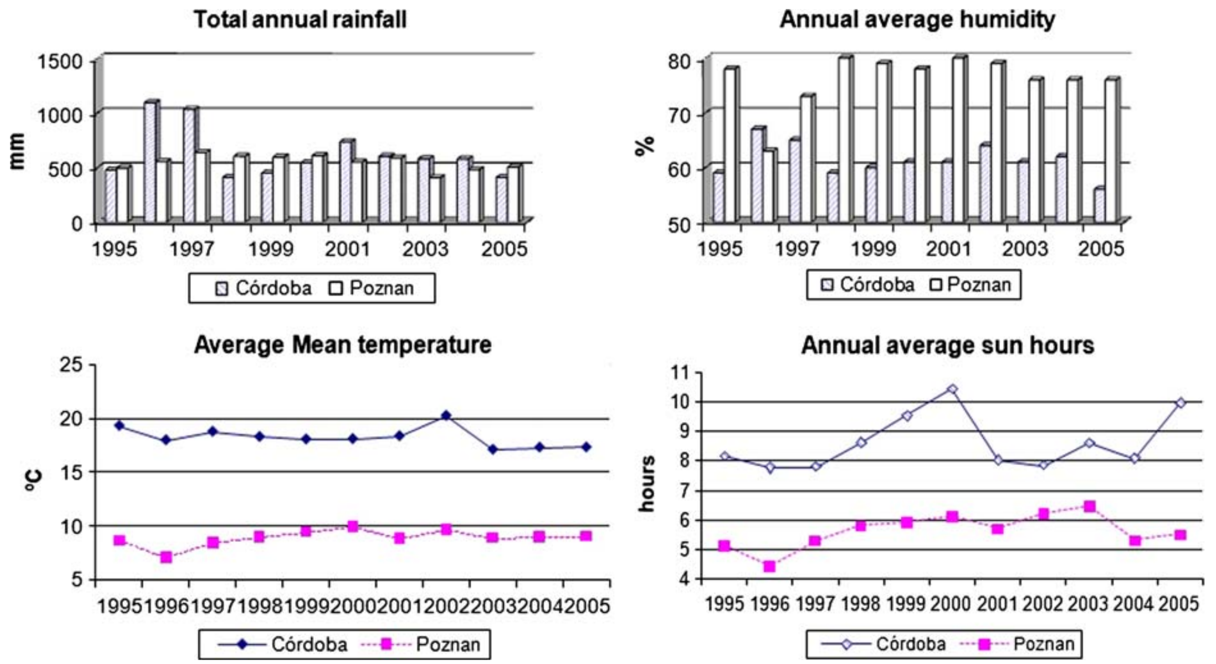

Fig. 1 Annual data for rainfall, mean temperature, humidity and sunlight hours

In Córdoba, the Chenopodiaceae–Amaranthaceae pollen season generally started during the second fortnight in April or the first fortnight in May and lasted until late October or early November. In Poznan, it started in late June or July and lasted until late August or September. The pollen season started around two months earlier in Córdoba than in Poznan, and lasted an average of 196 days in Córdoba and 68 days in Poznan, and was, thus, three times longer in Córdoba.

In Córdoba, the *Plantago* pollen season generally started during the second fortnight in March and lasted until June/July. In Poznan, it usually lasted from late May until June, thus, beginning two months later and lasting considerably shorter than in Córdoba. The *Plantago* pollen season lasted an average of 112 days in Córdoba and 67 days in Poznan.

By contrast, the *Rumex* pollen season was longer in Poznan (114 days) than in Córdoba (97 days). It generally started in March in Córdoba and in May in Poznan, and finished in June or early July in Córdoba and in August or September in Poznan. *Rumex* appears to behave differently to other herb pollen types in Poznan, displaying fewer restrictive temperature requirements; it flowered earlier in March, in low temperatures, and lasted longer with high temperatures during the summer.

The Urticaceae pollen season lasted from May–June to September in Poznan, while in Córdoba, pollen from this family was recorded almost throughout the year, except in August, when high temperatures prompted a drop in pollen levels.

As Fig. 2 shows, a longer post-winter interval is required in Poznan to trigger the pollen season onset. For Urticaceae, the pollen season start date in Córdoba was calculated only for *Urtica membranacea*, since the other type (*Urtica urens–Parietaria*) appeared continuously in the air, and it was, thus, impossible to identify the start date. The pollen season start date proved to be fairly constant over the 11-year study period, with no strong trend towards advanced or delayed onset. A slight trend towards delayed onset was noted in Córdoba, as was an equally modest trend towards earlier onset in Poznan. The end date was relatively stable throughout the period, with a slight trend towards an earlier finish in Córdoba and a later finish in Poznan. The trend was, thus, towards a longer pollen season in Poznan and a shorter one in Córdoba.

Annual pollen counts varied considerably between the two study sites (Fig. 3), with differences being more marked in earlier study years. For Chenopodiaceae–Amaranthaceae and *Plantago*, pollen counts in Córdoba were much higher than in Poznan, although

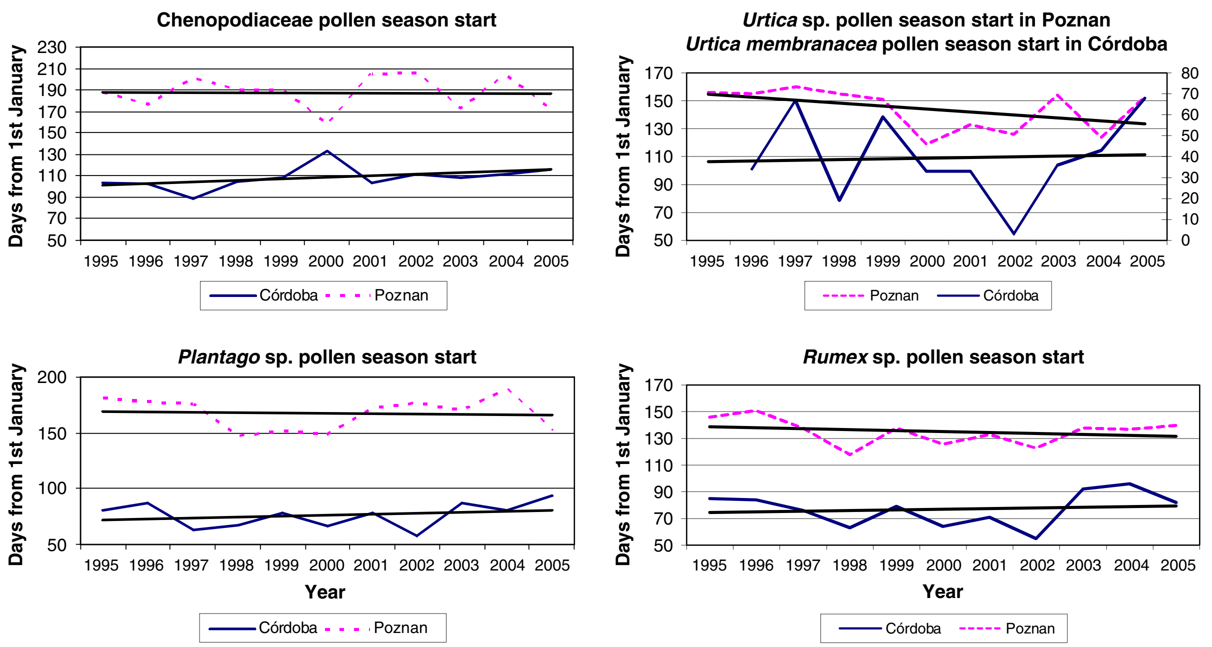

Fig. 2 Start of the pollen season for the studied period and taxa in each city (in Urticaceae, additional scale on the Y-axis for Córdoba data)

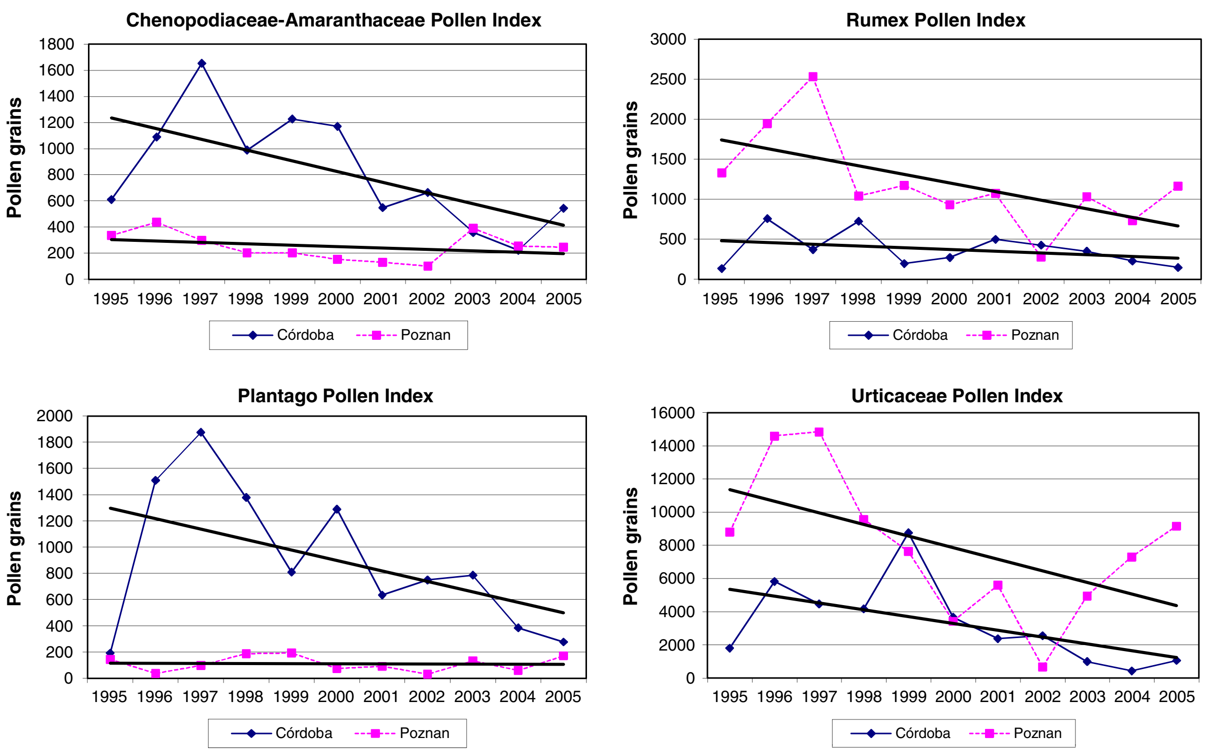

Fig. 3 Annual sum of pollen grains recorded in each city for the studied period and taxa

the difference was less marked in later years. For *Rumex*, the reverse was true: annual pollen counts in Poznan were higher than in Córdoba, again with less marked differences in later years. For Urticaceae, counts were higher in Poznan in the early years of the study, similar in the central period, and again higher in Poznan in the final years of the study.

A clear decline in pollen counts was recorded over the study period for both sites and all pollen types (Fig. 3).

Daily pollen counts for 2005 are shown in Fig. 4. The pollen season in Poznan generally began when the season in Córdoba was finishing. Thus, the increase in pollen counts in Poznan tended to coincide with decreasing counts in Córdoba. This was not true of Chenopodiaceae–Amaranthaceae, whose pollen season started earlier in Córdoba but also lasted longer, thus, coinciding over a certain interval with that of Poznan.

Correlation analysis between pollen counts and meteorological parameters (Table 2) revealed a positive correlation between temperature and daily pollen counts for Chenopodiaceae–Amaranthaceae, *Plantago*, and *Rumex* in both cities and for Urticaceae in Poznan. The correlation between temperature and Urticaceae pollen counts in Córdoba was negative. At both sites, rainfall displayed a negative correlation with daily pollen counts for all pollen types studied, with the exception of Urticaceae in Córdoba, which showed a positive correlation with both rainfall and humidity.

The results of statistical analyses applied to the mean daily pollen counts at the two study sites are shown in Table 3. A significant correlation ($P < 0.01$) was found for all four pollen types studied; the correlation was positive for Chenopodiaceae–Amaranthaceae and negative for the rest (*Plantago*, *Rumex*, and Urticaceae). The Wilcoxon signed ranks test also yielded significant results ($P < 0.05$) for all pollen types. This test studied the distribution of both series, establishing the number of days recording the highest counts at each sampler, in order to chart differences in pollen season distribution in each city. The results showed significant differences ($P < 0.05$) in the pollen counts obtained in the two cities for all pollen types. For Chenopodiaceae–Amaranthaceae, *Plantago*, and Urticaceae, higher counts were recorded on more days in Córdoba, while *Rumex* counts tended to be higher in Poznan.

A *t*-test revealed significant differences for the mean in both cities: the means were significantly higher in Córdoba for all pollen types except *Rumex*, which displayed higher mean values in Poznan.

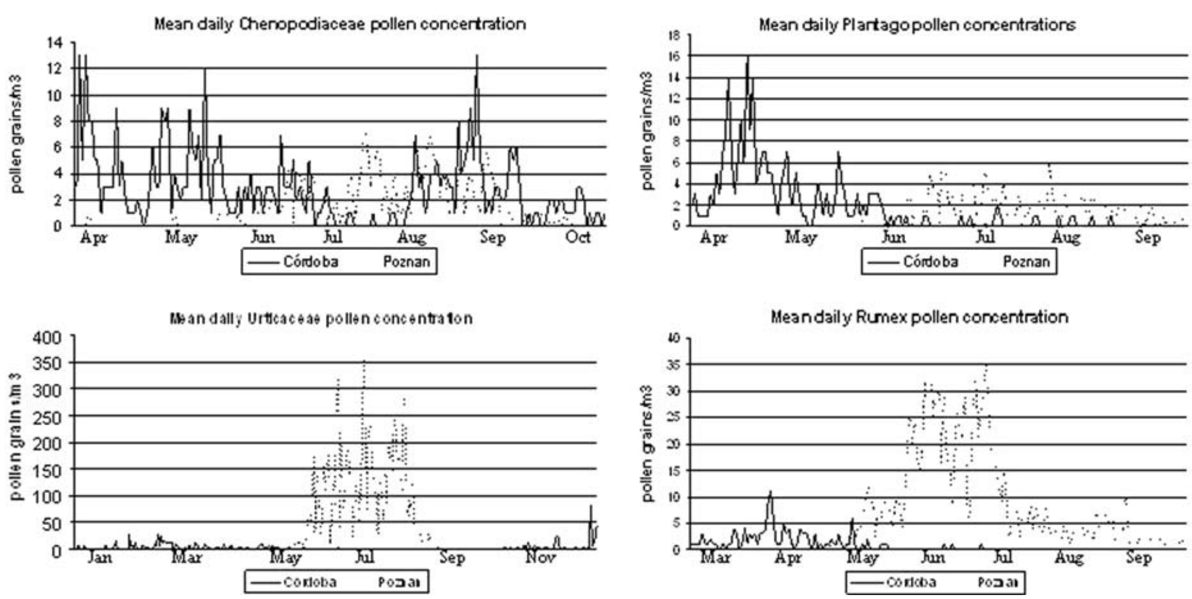

Fig. 4 Daily pollen counts for 2005

Table 2 Spearman correlation applied to daily pollen concentrations and meteorological parameters during the studied years

	T_{mean}	T_{max}	T_{min}	Rain	Humidity	Sun hours
Chen-C	0.754**	0.732**	0.713**	−0.248**	−0.570**	0.463**
	0.000	0.000	0.000	0.000	0.000	0.000
Chen-P	0.551**	0.543**	0.522**	−0.084**	−0.346**	0.330**
	0.000	0.000	0.000	0.000	0.000	0.000
Plan-C	0.211**	0.241**	0.113**	−0.096**	−0.268**	0.273**
	0.000	0.000	0.000	0.000	0.000	0.000
Plan-P	0.456**	0.447**	0.431**	−0.043**	−0.269**	0.296**
	0.000	0.000	0.000	0.007	0.000	0.000
Rume-C	0.068**	0.106**	−0.022	−0.083**	−0.151**	0.203**
	0.000	0.000	0.181	0.000	0.000	0.000
Rume-P	0.687**	0.674**	0.648**	−0.051**	−0.423**	0.428**
	0.000	0.000	0.000	0.001	0.000	0.000
Urti-C	−0.386**	−0.355**	−0.423**	0.126**	0.312**	−0.167**
	0.000	0.000	0.000	0.000	0.000	0.000
Urti-P	0.712**	0.694**	0.686**	−0.035*	−0.405**	0.394**
	0.000	0.000	0.000	0.026	0.000	0.000

Spearman's rho: correlation coefficient

Sig. (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

Table 3 Statistical tests applied to the mean daily pollen concentrations recorded in both cities during the studied years

	Correlation coefficient	Sig. (2-tailed)	*n*			
Spearman's correlations						
Chenopodiaceae	0.118**	0.000	2,097			
Plantago	−0.357**	0.000	1,764			
Rumex	−0.313**	0.000	1,932			
Urticaceae	−0.423**	0.000	3,927			
Wilcoxon signed ranks test						
	Córdoba > Poznan	Poznan > Córdoba	=	*Z*	Asymp. sig. (2-tailed)	
Chenopodiaceae	1,595	261	241	−27.348	0.000	
Plantago	1,026	370	368	−20.568	0.000	
Rumex	630	1,038	264	−16.310	0.000	
Urticaceae	2,315	1,089	523	−7.628	0.000	
Paired samples test						
	Mean	SD	SE	*T*	*df*	Sig. (2-tailed)
Chenopodiaceae	0.8735	1.0003	2.177E02	40.13	2111	0.000
Plantago	0.7990	1.3871	3.300E02	20.21	1,766	0.000
Rumex	−0.6005	1.6697	3.799E02	−15.81	1,931	0.000
Urticaceae	0.3020	2.4281	3.831E02	7.88	4,017	0.000

**Correlation is significant at the 0.01 level (2-tailed)

4 Discussion

The Mediterranean climate is temperate, with rare frosts and long, hot periods of summer droughts. The continental climate is characterized by cold, snowy winters.

Córdoba is warmer than Poznan, so the temperature required to trigger flowering is reached earlier. The pollen season for Chenopodiaceae–Amaranthaceae, *Plantago*, and *Rumex* generally began 2 months earlier in Córdoba than in Poznan. As pollen counts started to decline in Córdoba, they began to rise in Poznan.

The biological richness of Mediterranean climate areas and its considerable species-specific diversity are well established. Generally speaking, herb pollen seasons are longer than tree pollen seasons, because a larger number of taxa are involved. The pollen types studied included more species in Córdoba than in Poznan. This, together with more favorable temperatures, might account for the longer pollen season recorded in Córdoba. Moreover, a given pollen type may comprise different, and differently behaving, species in each city.

With regard to pollen season timing, the trend remained very similar throughout the study period, tending towards a slight advance in Poznan and an equally slight delay in Córdoba. Other studies of herbs (grasses) in Córdoba report similar findings; however, the reverse is true of tree pollen seasons, for which a trend towards earlier pollen season start dates has been noted (Galán et al. 2005; García-Mozo et al. 2006). In Poznan, the advance in the pollen season confirms findings for other herb species, such as *Artemisia* (Stach et al. 2007). In Poznan, herbs generally enjoy abundant water availability, so that temperature becomes the determining parameter; a potential increase in temperatures cause by global warming might favor an advance in the pollen season. By contrast, in Córdoba, rainfall is concentrated over very few days, and tends to be torrential, leading to lower water availability. In Mediterranean climates, water stress is a greater limitation than temperature for herbs. The lack of water would account for the fact that herbs in Córdoba fail to display earlier pollen season onset, despite rising temperatures (García-Mozo et al. 2008).

A striking decline was observed in the overall pollen counts for both cities over the study period. This may be attributed to the urbanization of the areas close to the samplers as a consequence of city development (Stach et al. 2007).

Statistical analysis revealed significant correlations between daily meteorological variables (temperature, rainfall, humidity, and hours of sunlight) and mean daily pollen counts. The correlation was positive for temperature (mean, maximum, and minimum) and sunlight hours, but negative for rainfall and humidity, except in the case of Urticaceae in Córdoba, where pollen counts displayed a positive correlation with humidity and rainfall and a negative correlation with temperature. Similar findings have been reported by other authors, who note that humidity positively affects the release of pollen grains from the anther in these herbs (Alcázar et al. 1998; Galán et al. 2000). It is also worth noting that *Parietaria* usually grows on walls, with little soil, and, therefore, displays an immediate positive response to rain. In Córdoba, *Parietaria* flowers in autumn and winter at low temperatures. In Poznan, *Parietaria* does not grow and *Urtica* flowers only in spring. This may account for the differing behavior of this pollen type in response to temperature.

Finally, the statistical analysis revealed a negative correlation between mean daily pollen counts in Córdoba and Poznan for *Plantago*, *Rumex*, and Urticaceae. Pollen counts started to rise in Poznan when flowering was almost finished in Córdoba and pollen counts were, thus, falling. The exception was Chenopodiaceae–Amaranthaceae, whose pollen season in the two cities partially overlapped. Mean counts for Chenopodiaceae–Amaranthaceae, *Plantago*, and Urticaceae were also significantly higher in Córdoba, while *Rumex* counts were significantly lower than in Poznan.

5 Conclusion

Differences observed in the pollen records for these pollen types between the two cities studied may be due to differing weather conditions, but may also be attributable to the different species or even genera included in the same pollen type in each city.

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