

## Pollen allergy related to the area of residence in the city of Córdoba, south-west Spain

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The aim of this study was to analyse the relationship between the distribution of hay-fever patients in the city of Córdoba, south-western Iberian Peninsula, and the specific atmospheric biological content originating from local sources. Four different districts were established in the metropolitan area of the city, according to vegetational and urbanistic characteristics. Air samples were taken in each area using portable Hirst-type samplers (Lanzoni VPPS 1000) and the spectrum of biological content was defined. Patients attending the Allergy Unit at Córdoba Teaching Hospital in 2000 with allergic rhinitis and/or asthma, and displaying a positive reaction to aeroallergen extracts, were distributed within the areas as a function of their district of residence. Aerobiological results revealed differences in pollen content between areas, in terms of both quantity and number of pollen types recorded. These differences were largely due to proximity to rural areas, prevalence of pollen from typically urban species and the possible effect of urban architecture as a barrier to the dispersal/concentration of particles and other pollutants. Patients were not uniformly distributed within the city. The majority lived in districts in which pollen from rural species was mixed with pollen from ornamentals. Patients living in typically urban districts displayed a higher prevalence of allergy to pollen from ornamentals. It is concluded that a high degree of exposure to the same environment may influence the development of sensitisation to the particular pollen load associated with that area.

### Aim of investigation

Environmental conditions have a great impact on the residents' quality of life. Many of the most prevalent diseases are caused or aggravated by pollens and other pollutants that display a marked seasonality, and change with weather conditions. The incidence of allergies, asthma, chronic diseases, *etc.* is increasing and this trend is expected to continue. Public attention has recently focused on seasonal allergies and asthma, because the prevalence and mortality associated with these have increased over the last few decades (see D'Amato *et al.*<sup>1</sup>).

Although pollinosis cannot *per se* be considered a high-risk disease, allergy symptoms may be suffered for a long period throughout the patient's lifetime. Effects include a decline in the quality of life of allergy-sufferers, socioeconomic costs due to absence from school and work, long and expensive treatments and so on. Asthma, which can be aggravated by exposure to pollen, can be life-threatening (Ring *et al.*<sup>2</sup>). In order to reduce these effects, it is essential to promote prevention among potential patients, providing them with effective information and highly-personalised tools that can help them to take last-minute environmental measures. Over 400 European towns and cities already have aerobiological stations from which data on airborne pollen levels can be obtained (Jaeger<sup>3</sup>).

The onset of symptoms in pollen allergy sufferers may be related to the environment to which they are largely exposed. The pollen spectrum recorded by a single sampler in a given city frequently fails to reflect particular events that may occur in that environment. Considerations such as the spatial variability recorded in pollen concentrations due to the fact that pollen

from distant sources is not perfectly mixed in the atmosphere and pollen from nearby vegetation can exert a profound local influence (Frenz,<sup>4</sup> Raynor *et al.*,<sup>5</sup> Emberlin and Norris-Hill<sup>6</sup>), and the existence of interactions with other pollutants that may cause a synergistic effect (Ishizaki *et al.*,<sup>7</sup> Muranaka *et al.*<sup>8</sup>), tend to be overlooked when interpreting results. Local air may be greatly influenced by local sources of emissions, and people exposed to it for several hours a day may develop adverse reactions. Bearing this in mind, this study sought to determine whether the pattern of distribution of hay-fever patients within a city reflected the distribution of airborne biological particles originated by local sources.

### Description of experimental procedures

The study was performed in the city of Córdoba (4°45'W, 37°50'N), in the south west of the Iberian Peninsula. Córdoba is a medium-sized city with about 350,000 inhabitants and a surface area of 50 km<sup>2</sup>; there is little industrial development in the area, although several industrial estates have grown up on the outskirts. Farming, predominantly olive and rainfed cereal crops, is the core of the local economy. The climate is strongly influenced by the Mediterranean Sea, with an annual mean temperature of 18 °C and total annual rainfall of 600–700 mm (according to the records for the last 40 years from the National Institute of Meteorology).

Air samples were taken using portable Hirst-type Lanzoni VPPS 1000 particle-trap samplers (Hirst<sup>9</sup>) placed at four different city locations. City districts were defined according

to various characteristics, including similarity of urban architecture and presence of natural/ornamental vegetation. The districts studied were as follows:

**Western area:** open rural area with few buildings, over 50,000 inhabitants and one industrial estate. Prevalence of rain-fed crops and weeds, with some influence of natural Mediterranean vegetation (holm oak woods) and ornamental species.

**Central area:** typical urban area with numerous buildings, less than 20,000 inhabitants and intense traffic, particularly during rush hours. Prevalence of ornamental species with a large number of exotic plants.

**Southern area:** semi-rural/semi-urban area comprising both densely built-up zones and open spaces, over 40,000 inhabitants and one industrial estate. Vegetation comprises natural riverbank plants, ornamental plants and crops surrounding the city.

**Northern area:** suburban area, comprising numerous detached and semi-detached houses with small private gardens. This is the most populated area, with 95,000 inhabitants and no industrial estates. Natural vegetation (Mediterranean forest) with numerous exotic plants.

The Eastern area was not included in the study due to the incorrect operation of the sampler. Although this is not the most populated area, it is the most industrialised (three industrial estates). It should be stated, however, that according to air-quality data from Environmental Monitoring and Control Cabins (managed by the Local Division of the Environmental Protection Agency), the measurements for criteria pollutant (particles, SO<sub>2</sub>, CO, O<sub>3</sub> and NO<sub>x</sub>) rarely exceed the limits considered as acceptable for human health (Cariñanos *et al.*<sup>10</sup>)

Samplers were placed on private buildings in each area, following the guidelines recommended in Aerobiology protocols for sampler location (Dominguez *et al.*,<sup>11</sup> Galán<sup>12</sup>) *i.e.* at 15–20 m above ground level, with no surrounding obstacles impeding free air flow. The samplers worked simultaneously 12 h each day, from 8.00 am to 8.00 pm, and three 30 day sampling series were taken over the pollen season 2000–2001, coinciding with the flowering of the most contributory species *i.e.*, Winter, early Spring and mid-Spring. Slides were analysed using the four longitudinal sections counting method (Cariñanos *et al.*<sup>13</sup>).

Clinical records for hay-fever patients were provided by the Allergy Unit at Córdoba's Reina Sofia Teaching Hospital. The study initially screened all patients attending the Allergy Unit in 2000 and presenting respiratory pathologies classified according to Class 8 of the ICD-9-CM diagnosis code as 493: Asthma and 477: Allergic rhinitis. Patients were mostly from the province of Córdoba and other provinces of Andalusia. From this preliminary group, a study population was selected, including all those patients habitually resident in the urban area of the city of Córdoba, according to the postal address appearing in the records. Thus, the preliminary pool of 2208 patients was reduced to 832 charts, corresponding to patients resident in the city of Córdoba; of these, 388 tested 2+ or higher to skin prick-tests with commercial aeroallergen extracts (*Chenopodium album*, *Artemisia vulgaris*, *Lolium perenne*, *Cynodon dactylon*, pollen IV, *Olea europaea*, *Plantago lanceolata*, *Parietaria judaica* and *Salsola kali* from ALK Abelló, Madrid, Spain; *Helianthus annuus* and *Mercurialis annua* from Bial Aristegui, Bilbao, Spain; *Platanus hybrida* from C.B.F. Leti, Barcelona, Spain) standardized in Biological units (BU) and containing 100 BU ml<sup>-1</sup> using 100 mg ml<sup>-1</sup> histamine phosphate as a positive control. The postal address also enabled patients to be grouped according to the proximity to the area of influence of each sampler, following the zonal distribution established by the Spanish National Institute of Statistics (INE). This criterion was met by 236 patients of the 388 residing in the city.

Time spent in the district was also estimated: 41.6% of



**Fig. 1** Area of the four urban districts established for this study and location of the portable air samples.

patients spent most of the day in the same district for school and work reasons; 21.3% moved to other parts of the city during working hours; the remainder had no routine procedures. Prevalent pollen types (positive skin prick-tests as a percentage of allergic patients per area) were also considered in order to determine the possible relationship with the pollen spectrum in each area.

## Results

Fig. 1 shows the division of areas within the city. Districts were determined as a function of floral and urbanistic similarity. Boundaries between areas were marked, considering the radius around the sampler as uninterrupted by architectural barriers. Table 1 shows the main characteristics of the districts, with an indication of the prevalent plant species acting as pollen sources.

The prevalence of allergy by pollen type used in skin prick-tests in the urban areas studied here is shown in Fig. 2. *Olea* and *Poaceae* are the main pollen types in terms of the percentage of patients affected in the four areas. Allergy to pollen types specific to given areas was also marked (*i.e.* *Helianthus* and *Plantago* in Southern and Western areas, and *Artemisia* in the Western district). *Mercurialis*, *Platanus* and *Parietaria* were among the least important causes of allergy in the resident population.

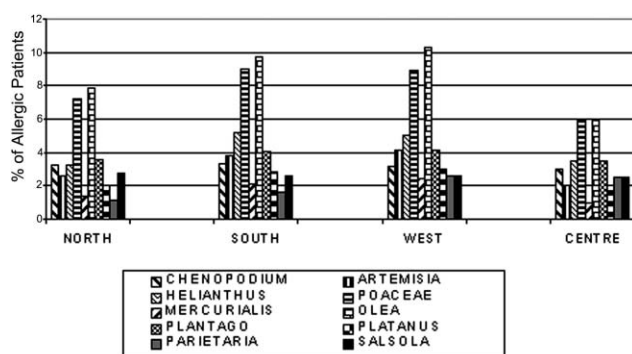
Table 2 shows the distribution of patients by district of residence, gender and age. The percentage of male patients was virtually identical to that of female patients (49.5% vs. 50.5%). Most patients (66.5% of the total) were in the 11–30 age-group. The Northern area contained the largest number of allergy-sufferers, and the Central area contained the fewest.

Aerobiological analysis of the samples taken in the four urban districts (Table 3) shows that the number of pollen types detected ranged from 31 in the Western area to 37 in the Southern area. More marked differences can be observed in the pollen index for each area; indices were very similar in the Central and Northern areas, slightly higher in the Western

**Table 1** General characteristics of the four urban districts considered in this study<sup>a</sup>

Zone	Districts	Surface/ km <sup>2</sup>	Residents	% of allergic over the population of the zone/ × 10 <sup>-2</sup>	Main vegetation
West	10	8.96	53584	12.50	Crops: Cereal, sunflower, olive. Natural vegetation: Mediterranean forest, riparian ( <i>Populus</i> , <i>Ulmus</i> ). Ornamental: <i>Platanus</i> , <i>Cupressus</i> , <i>Palmae</i> , <i>Populus</i> , <i>Ulmus</i> , <i>etc.</i>
Centre	3,4,7,8	1.32	19836	7.56	Ornamental: <i>Platanus</i> , <i>Casuarina</i> , <i>Cupressus</i> , <i>Ulmus</i> , <i>Populus</i> , <i>etc.</i> Herbs: <i>Parietaria</i>
South	9	4.62	42144	12.57	Crops: Cereal, sunflower, olive. Natural vegetation: riparian ( <i>Populus</i> , <i>Ulmus</i> , <i>Poaceae</i> , <i>Cyperaceae</i> , <i>Urticaceae</i> , <i>Chenopodiaceae</i> , <i>Rumex</i> ). Ornamental: <i>Platanus</i> , <i>Ulmus</i> , <i>Acer</i> , <i>Palmae</i> , <i>Ligustrum</i>
North	1,6	16.28	95303	10.59	Crops: olive (abandoned). Natural vegetation: Mediterranean forest. Ornamental: <i>Ligustrum</i> , <i>Ulmus</i> , <i>Acer</i> , <i>Populus</i> , <i>Pinus</i> , <i>Cupressus</i> , <i>Morus</i> , <i>Olea</i> , <i>Ailanthus</i> , <i>Broussonetia</i> , <i>etc.</i> Alot of exotic species in private gardens.

<sup>a</sup>Inhabitants: 311708 (Population considered in this study: 210867). Total surface: 50 km<sup>2</sup> (area considered in this study: 31.18 km<sup>2</sup>).



**Fig. 2** Prevalence of pollen allergy to the different pollen types in the four urban areas of Córdoba.

area, and significantly higher in the Southern district. The pollen index includes the sum of daily averages of pollen grains with proven allergenic capacity.

The list of the five main contributory taxa in each area shows that *Olea*, *Platanus* and *Urticaceae* were present in the four areas, with widely varying percentages. Attention is drawn to

**Table 2** General characteristics of the 236 patients considered in this study

	West	Centre	South	North	Total
Male	39	9	26	43	117
Female	28	6	27	58	119
Age: 1–10	10	0	3	7	20
11–20	20	3	20	36	79
21–30	21	8	16	33	78
31–40	11	2	7	10	30
41–50	1	1	7	12	21
<50	4	1	0	3	8

**Table 3** Aerobiological characterization of the urban districts of Córdoba considered in this study

Zone	No. of pollen types	Pollen index <sup>a</sup>	Five main taxa (% over the pollen index of the zone)	Other types of interest
West	31	31.446	<i>Platanus</i> : 36.6%, <i>Olea</i> : 26.2%, <i>Cupressaceae</i> : 9.96%, <i>Urticaceae</i> : 6.13%, <i>Moraceae</i> : 5.2%	<i>Helianthus</i> : 2%, <i>Chenopodiaceae</i> – <i>Amaranthaceae</i> : 0.8%
Centre	33	27.570	<i>Olea</i> 33.6%, <i>Platanus</i> : 23.6%, <i>Quercus</i> : 10.7%, <i>Cupressaceae</i> : 8.21%, <i>Urticaceae</i> : 7.5%	<i>Casuarina</i> : 0.4%, <i>Ligustrum</i> : 0.34%, <i>Palmae</i> : 0.62%
South	37	65.074	<i>Platanus</i> : 67.3%, <i>Olea</i> : 14.15%, <i>Urticaceae</i> : 4.9%, <i>Poaceae</i> : 2.66%, <i>Plantago</i> : 2.61%	<i>Artemisia</i> : 0.10%, <i>Fraxinus</i> : 0.15%, <i>Chenopodiaceae</i> – <i>Amaranthaceae</i> : 0.2%, <i>Palmae</i> : 0.14%, <i>Populus</i> : 0.4%
North	36	27.924	<i>Cupressaceae</i> : 25.6%, <i>Olea</i> : 25.38%, <i>Urticaceae</i> : 14.6%, <i>Poaceae</i> : 8.03%, <i>Platanus</i> : 6.5%	<i>Mercurialis</i> : 1%, <i>Pinus</i> : 0.61%

<sup>a</sup>Pollen index: Sum of daily pollen concentrations.

the striking contribution of *Platanus* pollen in the Southern area, although significant amounts were also recorded in the Central and Western areas. *Olea* pollen reached very high concentrations all over the city, maximum values being recorded in the Central and Southern areas, where it accounted for 33.6% and 14.5%, respectively, of total pollen. In terms of absolute values, these figures exceed 9,000 pollen grains. The highest *Urticaceae* pollen levels were found in the Northern area of the city, although certain features of the two pollen types included in this category will be discussed later. *Cupressaceae* pollens also figured among the five major taxa in three of the four areas, with the exception of the Southern area. *Quercus*, *Morus* and *Poaceae*, together with other pollen types, were recorded in varying percentages in the four different areas, and may be used as indicators of the specific surrounding flora. Other pollen types of allergenic interest are also listed in Table 3.

## Discussion

Detailed analysis of the distribution of patients within the city and the aerobiological characterization of each area suggests that the two may be related. A strong correlation was observed, particularly in the Southern area, which recorded the highest total pollen count and also the largest percentage of allergy sufferers, although it is not the most heavily-populated area of the city. As mentioned earlier, the high pollen count was due mainly to the amount of *Platanus* pollen, which accounted for 67.3% of the total 43,799 in absolute values. The presence of a clump of plane trees relatively close to the sampling unit might favour over-representativity of plane pollen at the expense of other pollen types, since pollen from sources within the city—not perfectly mixed in the atmosphere—exerts a profound influence (Emberlin<sup>6</sup>). However, several points must be considered: firstly, this area had the highest number of pollen types collected—37 in total; secondly, it is a busy,

densely-populated area, close to the tourist district and with a local school. Although the daily variation pattern of *Platanus* shows a maximum at midday (Galán *et al.*<sup>14</sup>), coinciding with the lunch break, during the height of the season amounts may exceed the threshold limit that triggers symptoms almost 24 h a day. The moderate allergenicity of its pollen grains reported by some authors (Subiza *et al.*<sup>15</sup>) is currently being reviewed (Varela *et al.*<sup>16</sup>).

The semi-rural character of this area is evident in the high presence of pollen from Poaceae, *Plantago*, *Artemisia* and Chenopodiaceae, typical of rural areas, but also in the values recorded for *Olea* and *Helianthus* from surrounding crops. Olive pollen was detected earlier in this area than in the rest of the city due to the gradual flowering of crops, starting with those located in the warmest areas (Díaz de la Guardia *et al.*,<sup>17</sup> Fornaciari *et al.*<sup>18</sup>). Moreover, the prevalence of SW winds in the period of olive flowering brings pollen to this area from crops located in the far Southern mountain regions. The presence of an industrial estate in the neighbourhood could be an aggravating factor, given the worsening of symptoms that may be caused by non-biological pollutants in already sensitised people (Ishizaki *et al.*,<sup>7</sup> Muranaka *et al.*<sup>8</sup>).

The Western area presented the highest prevalence of allergy for 7 of the 10 pollen types included in the set used in skin prick-tests (Fig. 2). However, it was also the area in which almost no pollen type, with the exception of *Morus* and Chenopodiaceae, reached peak concentrations. This may be due to the existence of open rural spaces together with newly-designed urban areas with a high incidence of ornamental plants, thus exposing people to a huge variety of allergens. Rural indicators include the marked presence of weeds, including species from Poaceae and Chenopodiaceae families, *Plantago*, *Rumex* and *Helianthus*. In some cases, such as Chenopodiaceae (including *Salsola*) and *Helianthus*, the percentage of patients showing positivity was the highest in the city. Similarly, pollen records for both taxa were the highest recorded. Chenopodiaceae species grow wild in the large ruderal areas in the area and sunflower is one of the main crops alternating with cotton. The allergenic potential of both has been reported elsewhere (Galan *et al.*,<sup>19</sup> Jiménez *et al.*,<sup>20</sup> Cariñanos *et al.*<sup>21</sup>).

It is also worth mentioning that this area records the highest number of young allergy sufferers. From the 67 patients residing in the Western area, 29.8% were under 20 and 14.9% under 10 (Table 2). Analysis of case histories showed that almost all patients attended the Allergy Unit for the first time in 2000, by appointment. This area has been the subject of major town-planning changes over the last 10 years; 8-storey blocks have been built, roads paved and traffic reorganised. The consequences of these changes were frequently reflected in the pollutant levels measured in the closest Environmental Monitoring and Control Cabins, which were the highest in the city. *Platanus* and *Cupressus* have been grown as the main ornamentals. The list of the 5 pollen types contributing most to hay fever in the Western area (Table 3) also includes mulberry pollen (Moraceae). The amounts of this pollen type detected in the area were three–five times higher than those recorded in the other three areas. Although this was not included in the set of pollen types used in skin prick-tests, it has been reported as an allergen by Al-Doory *et al.*,<sup>22</sup> Stanley and Linskens,<sup>23</sup> and Sing and Babu.<sup>24</sup>

The Central area was also the least populated (Table 1), with the lowest pollen index (Table 3). Since this is a typical urban area, it is unusual for *Olea* and *Quercus* to appear at the top of the list of main taxa recorded in the area. The explanation for this may lie in the scarce renewal of air in densely built urban environments, where the masses of air are trapped in narrow streets, preventing the free flow of air and allowing for the accumulation of pollutants (Qin and Kot,<sup>25</sup> Oke<sup>26</sup>). Emberlin and Norris-Hill,<sup>6</sup> also reported that pollen from distant sources

mixes in the atmosphere during transport, so that the concentrations measured at several locations within the city are similar. The other pollen types listed as those contributing most to hay fever corresponded mainly to ornamental species: *Platanus*, the prevalent roadside and shade-line species; Cupressaceae genus, with a high representation of the *Cupressus sempervirens* species in cemeteries and *C. arizonica* and *C. macrocarpa* in parks and gardens; Urticaceae pollen came mainly from pellitory-of-the-wall, due to the affinity of this species, as its name indicates, for old wet walls in the Old Town.

It is also interesting to note the presence of other pollen types. The three listed in Table 3—*Casuarina*, *Ligustrum* and Palmae—are exotic species used in gardening. Australian pine (*Casuarina*) has been studied as a cause of allergy in areas where this plant has become naturalized (Bucholtz *et al.*,<sup>27</sup> Garcia *et al.*<sup>28</sup>). Most of the 100 individuals of this species growing in the city are located within the boundaries of the Central Area. Privet pollen (*Ligustrum* spp.) has also been reported recently as a potential cause of local allergy problems in certain urban areas of the city where these are widely used as ornamental plants. Differences of over 90% between pollen concentrations collected with a permanent sampler located 5 km away from the source of emission and those collected by a sampler placed in the vicinity of the source were detected (Cariñanos *et al.*<sup>29</sup>). The observation of positive reactions to date-palm pollen in atopic patients suggest that *Phoenix dactylifera* pollen should be included in the battery of allergens, particularly in those parts of the world where date palms are grown commercially (Harfi *et al.*<sup>30</sup>).

In contrast to the Central area, the Northern area is the most heavily-populated, with the second highest pollen index after the Southern area. This is a district characterised by the marked prevalence of detached and semi-detached houses with small private gardens. It is also located on the slopes of Sierra Morena, close to natural Mediterranean forest vegetation, as shown by the presence of pine pollen, but also close to areas reforested with *Cupressus* spp. by the Nature Conservation Institute (ICONA) in the 1940s. This would account for the high concentrations of *Cupressus* pollen in the area (Table 3). The allergenic importance of *Cupressus* pollen in Córdoba has been reported by Guerra *et al.*,<sup>31</sup> who reported that sensitivity to *Cupressus* accounted for 13% of all outpatients attending the Allergy Unit, 18% of patients with respiratory disorders and 35% of patients with hay fever.

Fig. 2 shows that, after *Olea* and Poaceae, ruderal species (Chenopodiaceae, *Plantago*) are the most prevalent. Plane tree pollen presents the lowest levels in the city and this is reflected in the prevalence of pollen allergies, which are also the lowest. In contrast, no clear correlation has been reported between *Mercurialis* pollen counts (Table 3) and its prevalence.

Most of the Allergy Unit patients resident in this area were in the 11–30 age-group (which accounted for 68.1% of the total). Upper middle-class couples with young teenage children move to this area from other parts of the city in search of open spaces and lower levels of non-biological air pollution.

## Conclusions

The results suggest a possible relationship between the distribution of hay-fever patients in a city and the local atmospheric biological content originating from local sources. Lasting exposure to the same environment may have a strong influence on the development of allergic reactions to a particular pollen type associated with the characteristic flora of the area. Spaces in which pollen from ornamental species coexist together with pollen from rural species seem to affect most profoundly the quality of life of residents. The presence of other air pollutants may also cause a co-adjuvant effect, aggravating respiratory symptoms.

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