

Aerobiological and ecological study of the potentially allergenic ornamental plants in south Spain

M. J. Velasco-Jiménez · P. Alcázar ·
A. Valle · M. M. Trigo · F. Minero ·
E. Domínguez-Vilches · C. Galán

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Abstract A number of ornamental plant species produce pollen grains with allergenic properties, thus posing a potential risk to human health. A comparative study of the ecological and aerobiological characteristics of ornamental urban flora in four Andalusian cities revealed the presence of over 100 potentially allergenic ornamental plant species. Most of these were phanerophytes, and species of Asiatic origin predominated, followed by Mediterranean and American species. However, not all potentially allergenic ornamental plants were of aerobiological significance, since some produce only small amounts of pollen, while others were infrequent or were located at a considerable distance from the sampler. Even so, when designing new urban parks and gardens, every effort should be made to ensure maximum species variability avoiding the excessive use of any single species.

Keywords Aerobiology · Airborne pollen count · Allergenic ornamental plants · Parks and gardens

1 Introduction

Gardens and public parks are a social good, understood and perceived by urban residents as an essential feature of a desirable quality of life (Chiesura 2004). What people require from the urban landscape is, principally, the need for nature and the need for human interaction. This second need underlines the potential role of urban design in enhancing human conditions (Matsouka and Kaplan 2008). In addition, some studies show that urban vegetation can be viewed as compensation to the environmental drawbacks of urbanisation (Jim and Chen 2008; Wania et al. 2012).

However, a number of species commonly used in urban green areas may pose health problems, either because their fruits are toxic (Fernández-Rivas et al. 2008) or because they produce allergenic pollen (Cariñanos et al. 2002b, 2007; Dopazo et al. 2002; Staffolani and Hruska 2008).

Recent research has highlighted a general rise in airborne pollen counts in urban areas, which has prompted an increased incidence of allergic reactions (Lorenzoni-Chiesura et al. 2000; De Linares et al. 2005; D'Amato et al. 2007; Carracedo et al. 2008; Cecchi et al. 2010). Pollen is released not only by plants growing spontaneously in urban areas, but also

M. J. Velasco-Jiménez (✉) · P. Alcázar ·
E. Domínguez-Vilches · C. Galán
University of Cordoba, Cordoba, Spain
e-mail: bv2vejim@uco.es

A. Valle
Universidad de Granada, Granada, España

M. M. Trigo
Universidad de Málaga, Málaga, España

F. Minero
Universidad de Seville, Sevilla, España

from ornamental species planted in parks and gardens. Over recent years, scientific interest in urban green spaces has extended beyond their aesthetic value or their importance to the urban landscape, to focus on their actual and potential impact on public health. A number of studies have specifically addressed the effects of ornamental flora on the health of local residents (Lavaud et al. 2006; Ribeiro et al. 2009; Aira et al. 2011; Staffolani et al. 2011).

In Spain, the rapid urbanisation of the last 20 years appears to have prompted a sharp increase in the incidence of pollen allergies. In seeking to meet the aesthetic and recreational needs of local residents, management schemes for urban green areas have often failed to take into account the risk posed by exotic ornamental plants for allergy sufferers (Elvira et al. 2005; Sabariego et al. 2005; Çeter et al. 2012).

The present study sought to analyse the incidence of potentially allergenic ornamental species in cities of Seville, Cordoba, Granada and Malaga (southern Spain), examining a number of ecological and aerobiological

variables for the species concerned. The information obtained, taken in conjunction with climate data, will undoubtedly be of value when designing new urban green areas and assessing their impact on the local population.

2 Materials and methods

The study was carried out in four cities in Andalusia (southern Spain): Seville, Cordoba, Granada and Malaga (Fig. 1). The main geographical features of each city are shown in Table 1.

Malaga, located on the Costa del Sol, has a Mediterranean subtropical climate with mild winters and temperate summers due to the proximity of the sea. The inland cities of Seville, Cordoba and Granada display a certain degree of continentality, with colder winters and hotter summers (National Meteorology Institute 2001).

Complete lists of ornamental flora growing in the urban green areas of each city were compiled from



Fig. 1 Location of the study cities in south Spain

Table 1 Biogeographical data for studied cities

	Geographical coordinates	Altitude (m.s.l.)	Surface (km ²)	No of inhabitants	Density (inhab./km ²)	Average temperature (°C)	Rain (mm)	Biogeographical sector ^a	Mediterranean bioclimatic belts ^a
Seville	5°59'47"N 37°22'59"W	7	140.8	704,414	5,002.94	18.6	534	Hispalense	Termomediterranean
Cordoba	37°53'05"N 4°46'45"W	120	290.23	329,249	1,134.44	17.6	536	Hispalense	Termomediterranean
Granada	37°10'27"N 3°35'55"W	738	88.02	240,099	2,727.78	15.1	357	Malacitano-Almijarens	Mesomediterranean
Malaga	36°43'10"N 4°25'12"W	6	395	576,725	1,406.06	18	526	Malacitano-Almijarens	Termomediterranean

^a Rivas-Martínez 1987

previously published papers (Ayora et al. 1988; Prieto et al. 1992; Díaz de la Guardia and Blanca 1994; Trigo et al. 1996; Candau and Pérez 2000; Staffolani et al. 2011), local council and university databases, and in situ observation. The present paper has been focussed only on allergenic species on these lists. Allergenicity was confirmed by consulting the platform for allergen knowledge (www.allergome.org), the réseau national de surveillance aérobiologique (RNSA) and the atlas aeropalinológico de España (Trigo et al. 2008).

The life form (Raunkiaer 1934), geographical origin and Ellenberg's ecological values (Ellenberg et al. 1992; Pignatti 2005) have been observed for each allergenic species in each city.

Airborne pollen count databases were obtained from sampling stations located in each of the four cities, which belong to the Spanish Aerobiology Network (REA). Sampling was performed from 2006 to 2009, using volumetric suction samplers based on the impact principle, i.e., Hirst-type spore traps (Hirst 1952). The methodology designed by the REA (Galán et al. 2007) was used for sampling and for calculating average daily airborne pollen counts (pollen grains/m³).

3 Results

A total of 339 allergenic ornamental species were found between the four cities. These species belonged to 33 different families, thus providing an idea of the biodiversity involved (Table 2). Families with biggest numbers of species have been Rosaceae, Fabaceae, Arecaceae, Asteraceae, Cupressaceae, Oleaceae, Liliaceae, Moraceae and Pinaceae. Diversity was greatest in Malaga (178 species) and least in Seville (131), while Cordoba and Granada had 154 and 158 allergenic ornamental species, respectively.

Percentages of life forms for allergenic plant in the cities studied are shown in Fig. 2. As expected, most ornamental species (at least 65 % in all four cities) were phanerophytes. Geophyte forms were more frequent in Malaga (12 %) and Seville (8 %) than in Cordoba and Granada (2 %). Nanophanerophytes were slightly more abundant in Granada (8 %) than elsewhere (6 % in Seville and Cordoba, 5 % in Malaga). Hemicryptophyte species accounted for 5 % of the total in Malaga, 4 % in Seville and 3 %

Table 2 Number of species per family for allergenic ornamental flora in each city

Family	Seville	Cordoba	Granada	Malaga
Amaranthaceae	0	0	0	3
Anacardiaceae	1	2	0	1
Araliaceae	1	1	1	1
Arecaceae	9	9	6	28
Asteraceae	4	2	2	17
Betulaceae	0	1	4	0
Brassicaceae	0	0	0	3
Buxaceae	1	1	1	3
Casuarinaceae	2	1	1	2
Cupressaceae	7	11	14	8
Cyperaceae	1	1	0	2
Euphorbiaceae	1	2	1	4
Fabaceae	21	21	18	20
Fagaceae	1	5	4	2
Ginkgoaceae	0	1	1	1
Juglandaceae	1	3	2	2
Liliaceae	8	2	3	13
Moraceae	11	8	4	14
Myrtaceae	4	6	3	10
Oleaceae	13	15	13	9
Pinaceae	7	8	13	4
Platanaceae	1	1	1	1
Poaceae	4	1	1	9
Rosaceae	13	22	31	9
Rutaceae	7	6	4	3
Salicaceae	5	9	8	2
Sapindaceae	2	3	7	1
Simaroubaceae	1	1	1	1
Tamaricaceae	0	1	2	1
Taxaceae	0	1	1	0
Taxodiaceae	0	1	4	1
Tiliaceae	1	3	4	1
Ulmaceae	4	5	3	2
Total	131	154	158	178

in both Cordoba and Granada. Therophytes and chamaephytes were relatively rare, except in Malaga (6 and 4 %, respectively). Malaga thus displayed a greater overall diversity of biological forms.

According to Fig. 3, most species were of Asiatic origin, followed by mediterranean and American species. Spontaneously growing naturalised plants were also well represented in all four cities. Other species had been obtained through hybridisation and

recognised as ‘cultivated’. A greater number of African and Australian species were recorded in Malaga, while in Cordoba and Granada more species were of European and circumboreal origin.

The average of Ellenberg’s ecological values for the allergenic species in each city revealed considerable similarities between cities (Fig. 4). Luminosity and temperature values were higher in Malaga (7.96 and 7.98, respectively) and Seville (7.39 and 7.84, respectively) than elsewhere (6.73 and 6.8 in Granada and 6.83 and 7.25 in Córdoba). Humidity values were highest for Granada (4.21) and Cordoba (4.1) than elsewhere (3.91 in Seville and 3.79 in Málaga). Continentality, soil and nutrients values were very similar among the cities. Malaga showed a slightly higher value for salinity than the other cities (0.1).

Analysis of airborne pollen over the period 2006–2009 focussed on pollen types corresponding to allergenic ornamental species present in the four cities (Table 3) which have aerobiological records: *Acer*, *Arecaceae*, *Casuarina*, *Cupressaceae*, *Fraxinus*, *Ligustrum*, *Moraceae*, *Myrtaceae*, *Olea*, *Pinus*, *Platanus*, *Poaceae*, *Populus*, *Quercus*, *Rosaceae* and *Ulmus*.

Acacia, *Ailanthus*, *Buxaceae*, *Celtis*, *Citrus*, *Fabaceae*, *Hedera*, *Jasminum*, *Juglans*, *Liliaceae*, *Parkinsonia*, *Ricinus* and *Tilia* pollen types have not been taken into account because there are no aerobiological data from these families in the REA database as these pollen types are not usually present in the air.

The Figure 5 shows pollen index achieved for each pollen type in each city and in each year of study. In this figure, differences in the annual pollen content in the cities studied can be seen. The pollen types reaching highest concentrations in the city of Seville are *Arecaceae*, *Fraxinus*, *Ligustrum*, *Morus*, *Myrtaceae* and *Platanus*; in the city of Cordoba, the most important are *Morus*, *Olea*, *Platanus*, *Poaceae*, *Populus*, *Quercus*, *Rosaceae* and *Ulmus*; in the city of Granada, significant annual pollen concentrations of *Acer*, *Cupressaceae*, *Olea*, *Populus* and *Ulmus* pollen have been found ; finally, in the city of Malaga, high concentrations of *Casuarina* and *Myrtaceae* pollen types can be detected.

4 Discussion

The high number of ornamental species found in studied cities shows that urban and suburban parks

Fig. 2 Percentages of life forms for allergenic ornamental flora in the cities studied

(P = phanerophytes, H = hemicryptophytes, G = geophytes, T = therophytes, Np = nanophanerophytes, Ch = chamaephytes)

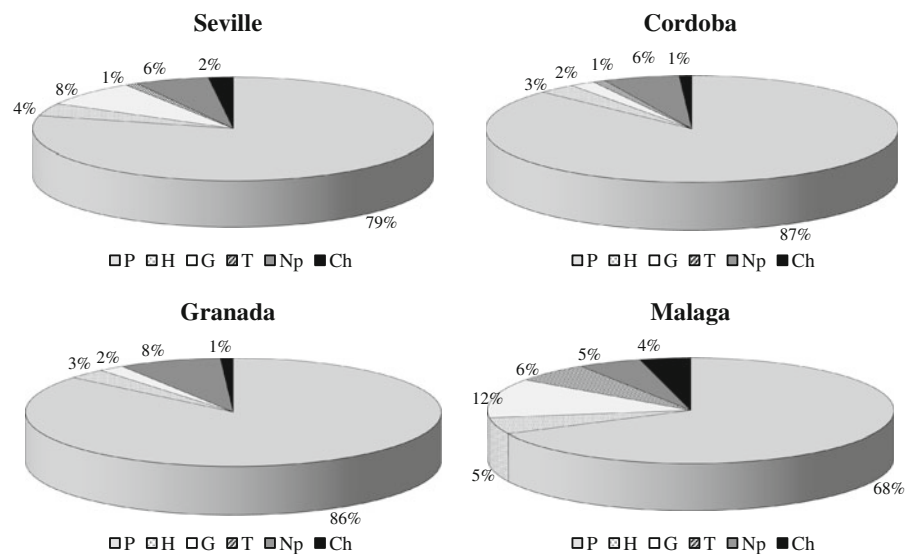
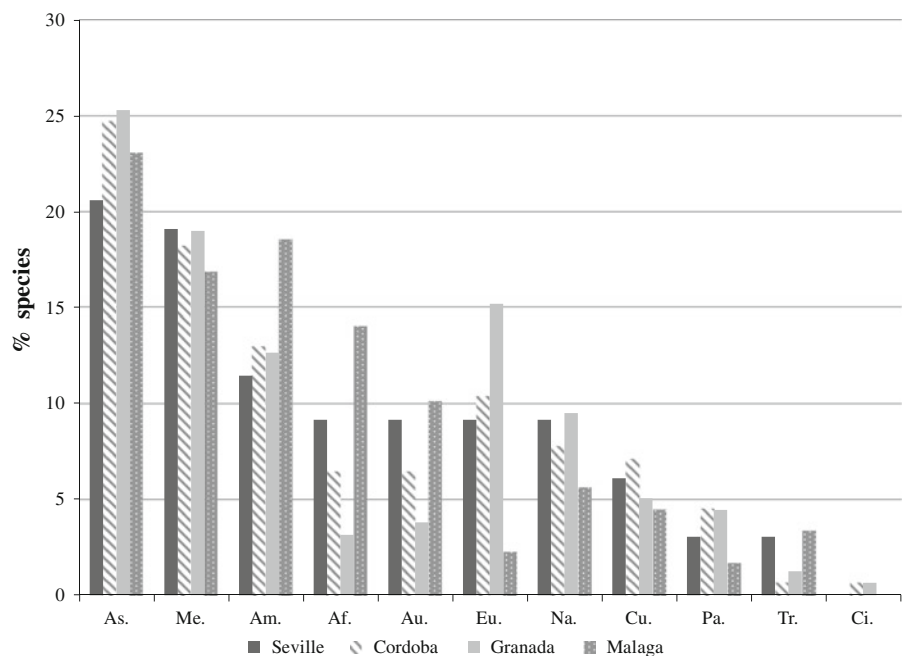


Fig. 3 Origin of allergenic ornamental flora in the cities studied

(As. = Asiatic, M. = Mediterranean, Am = American, E. = European, Af. = African, N. = Naturalised, Au. = Australian, Cu. = cultivated, P. = paleotemperate, T. = tropical, Ci. = circumboreal)



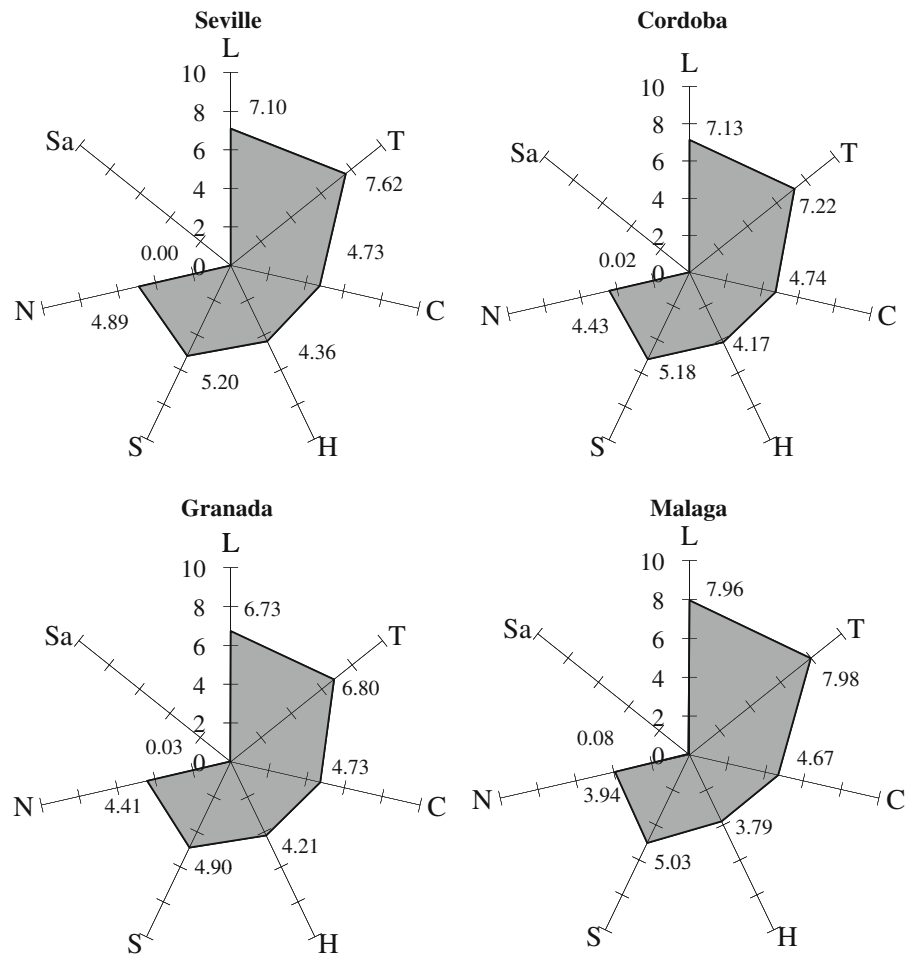
may be considered important ‘hotspots’ of biodiversity in cities (Fernández-Juricic and Jokimäki 2001). However, the lists of ornamental flora compiled for the four cities highlight the extensive use of potentially allergenic species, a finding also reported by Staffolani et al. (2011) in the city of Cordoba or Cariñanos and Casares-Porcel (2011) in the city of Granada.

More than 100 different species were recorded for each city, of which 49 were common to all four. Among these common species, it would highlight

Olea europea L., *Cupressus* sp. or *Platanus* × *hispanica* Miller ex Münchh by their allergenic pollen grains (Guerra et al. 1996; Torrecillas et al. 1998; Sánchez-Mesa et al. 2005, among others).

From the life form point of view, it is logical to see how most species in the four studied cities are trees and shrubs, as these species persist longer and does not need to reset each year. However, the city of Malaga mind with a greater proportion of geophytes and therophytes, and it is probably due to its climate, with

Fig. 4 Average of Ellenberg's ecological values for the allergenic species in each city (L = luminosity, T = Temperature; C = continentality; H = humidity; S = soil pH; N = nutrients; Sa = salinity)



milder winters and warmer summers due to its proximity to the sea.

With regard to the geographical origin of ornamental flora, common features have been appreciated that match the influence that these cities have had over its history: Roman, Arab, European, Asian, American tropical, etc., how result of cultural exchanges (Hernández-Bermejo et al. 2000). Despite these commonalities, some differences were observed in response to the percentage of each type of species, caused indirectly by the influence of climate in each city (Staffolani et al. 2011). Thus, Malaga has a greater abundance of species from tropical climates (Africa, Australia and Central America), due to a more temperate climate. By contrast, the more continental climate of Cordoba and Granada, with frequent nights of frost during the winter, can explain the greater representation of species with European origin and a lower percentage of tropical species. The fact that

Seville does not count with often nights of frost, due to the thermoregulatory influence exerted by the Guadalquivir River, has allowed the acclimatisation of some species from Australia and tropical Africa, although with a slightly lower percentage to Malaga.

The ecological requirements of the flora in the studied cities are very similar, showing that these species located in these green spaces are adapted to the climatic conditions present in the cities. The average value of 7 for the luminosity and temperature is indicator for taxa that endure medium light, i.e., plants will tolerate shade but also direct light, and heat. The average value of 5 for continentality and soil reactivity indicates that these plants support an intermediate continental climate and moderate tolerance to acidity. The average value of 4 indicate that moisture and nutrients are an intermediate tolerance to these variables. Finally, the value of 0 for salinity expresses no tolerance by the studied species (Ellenberg et al. 1992). There have been slight differences

Table 3 Common allergenic ornamental species in all studied cities

Species	Pollination type ^a	Pollen type ^a
<i>Acacia</i> sp.	Entomophilous	Acacia
<i>Acer</i> sp.	Mixed	Acer
<i>Ailanthus altissima</i> (Mill.) Swingle	Mixed	Ailanthus
<i>Aloe</i> sp.	Entomophilous	Liliaceae
<i>Broussonetia papyrifera</i> (L.) Vent	Anemophilous	Moraceae
<i>Buxus sempervirens</i> Dallim	Mixed	Buxaceae
<i>Casuarina</i> sp.	Anemophilous	Casuarina
<i>Cedrus</i> sp.	Anemophilous	Pinus
<i>Celtis australis</i> L.	Anemophilous	Celtis
<i>Ceratonia siliqua</i> L.	Mixed	Fabaceae
<i>Cercis siliquastrum</i> L.	Entomophilous	Fabaceae
<i>Chaenomeles</i> sp.	Entomophilous	Rosaceae
<i>Chamaecyparis</i> sp.	Anemophilous	Cupressaceae
<i>Chamaerops humilis</i> L.	Mixed	Arecaceae
<i>Citrus</i> sp.	Entomophilous	Citrus
<i>Cortaderia selloana</i> Asch	Anemophilous	Poaceae
<i>Cupressus</i> sp.	Anemophilous	Cupressaceae
<i>Eriobotria japonica</i> (Thunb.) Lindl	Entomophilous	Rosaceae
<i>Eucaliptus</i> sp.	Mixed	Myrtaceae
<i>Ficus</i> sp.	Entomophilous	Moraceae
<i>Fraxinus</i> sp.	Anemophilous	Fraxinus
<i>Gleditsia triacanthos</i> L.	Entomophilous	Fabaceae
<i>Hedera helix</i> L.	Mixed	Hedera
<i>Jasminum</i> sp.	Entomophilous	Jasminum
<i>Juglans regia</i> L.	Anemophilous	Juglans
<i>Ligustrum</i> sp.	Entomophilous	Ligustrum
<i>Morus</i> sp.	Anemophilous	Moraceae
<i>Myrtus comunis</i> L.	Anemophilous	Myrtaceae
<i>Olea europaea</i> L.	Mixed	Olea
<i>Parkinsonia aculeata</i> L.	Entomophilous	Parkinsonia
<i>Phoenix</i> sp.	Anemophilous	Arecaceae
<i>Pinus</i> sp.	Anemophilous	Pinus
<i>Platanus</i> × <i>hispanica</i> Miller ex Münchh	Anemophilous	Platanus
<i>Populus</i> sp.	Anemophilous	Populus
<i>Prunus</i> sp.	Entomophilous	Rosaceae
<i>Quercus</i> sp.	Anemophilous	Quercus
<i>Ricinus communis</i> L.	Mixed	Ricinus
<i>Robinia</i> sp.	Entomophilous	Fabaceae
<i>Spiraea cantonensis</i> Lour	Entomophilous	Rosaceae
<i>Thuja</i> sp.	Anemophilous	Cupressaceae
<i>Tilia</i> sp.	Mixed	Tilia
<i>Ulmus</i> sp.	Anemophilous	Ulmus
<i>Washingtonia</i> sp.	Mixed	Arecaceae
<i>Wisteria sinensis</i> (Sims.) Sweet	Entomophilous	Fabaceae

^a Trigo et al. 2008

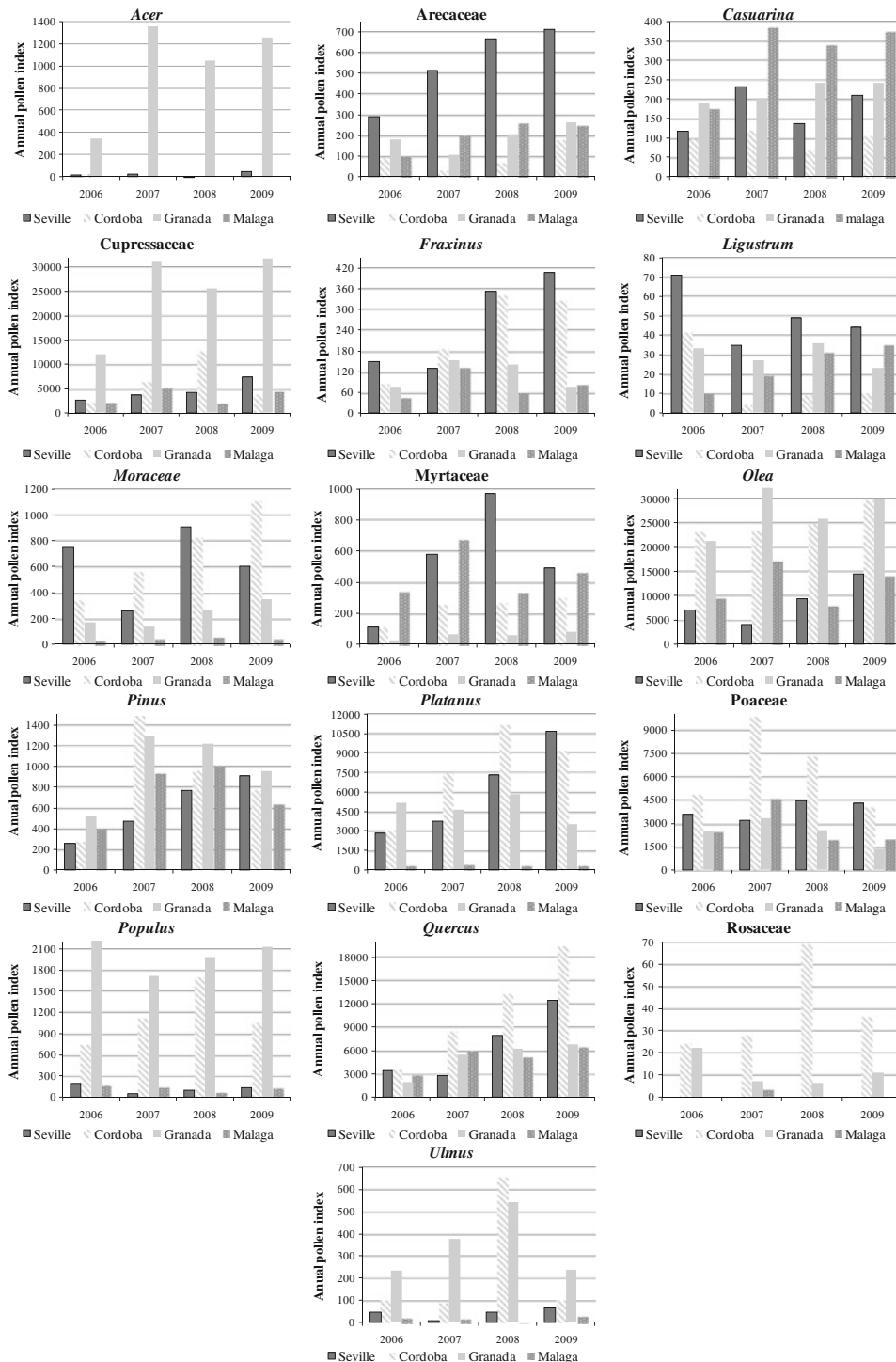


Fig. 5 Annual pollen index in the cities studied during 2006–2009

in these values, especially in the city of Malaga, where the values for light, temperature and salinity were slightly higher than in the rest. This result corroborates earlier

findings, in which it has been seen as this city has a higher proportion of tropical ornamental flora with a slight tendency to salinity, being a coastal city.

The differences in diversity in airborne pollen types in each city respond to the different green spaces, designs and the species used in each city. Some pollen types reach high concentrations in the four studied cities, i.e., Cupressaceae, *Olea*, *Platanus*, *Quercus* and Poaceae. However, analysis of airborne pollen counts confirmed that not all potentially allergenic ornamental species were actually likely to pose a health risk for allergy sufferers. Pollen counts for other species tended to be negligible, either because these were entomophilous species (i.e., Rosaceae pollen type) or because they were represented by few individuals (i.e., *Acer* pollen type in some cities). A further factor for low pollen counts could be the distance of the plants from the sampler (Velasco-Jiménez et al. 2013).

Thus, the use of potentially allergenic species is a traditional feature of southern Spanish cities, i.e., *Cupressus* sp., *Citrus* sp., *Morus alba* L. and *Phoenix* sp. (Mas-Candela and Salmerón de Diego 1991; Martín-Consuegra and Uberta 1996; Ramón-Laca 2003; Ruggles 2008). Other species are typically Mediterranean and they have recently been incorporated into urban parks and gardens, i.e., *Pinus* sp. and *Quercus* sp., trying to transmit to the citizens the value of our natural flora. These species, in principle, do not pose a great risk for people suffering from allergy because their pollen grains have a low allergenic capacity (Harris and German 1985; Kornutá and Ostrolucká 1992). Noteworthy is the special case of *Olea europea* L.; Olive represents a Mediterranean species that accounts for 30 % of arable land in Andalucía, according to the Andalusia government. This species is the main cause of pollinosis in the Mediterranean (Trigo et al. 2008). However, in recent years, this species is being introduced in the cities for decorating parks, gardens and roundabouts.

For cultural and historical reasons, the presence of these species cannot be readily reduced. However, it is essential to avoid increasing their numbers in new urban green areas, in order not to aggravate their impact on allergy sufferers. Any increase in urban biodiversity would involve a reduction in the presence of traditional species with allergenic potential (Cariñanos and Casares-Porcel 2011). Airborne pollen counts in urban areas are strongly influenced by the design of green spaces. In the *Cármenes*, Moorish residences with extensive gardens and orchards in Granada, *Cupressus* sp. is the dominant species (Mas-Candela and Salmerón de Diego 1991), while *Citrus*

sp. and *Phoenix* sp. are typical of the Moorish gardens preserved in Seville and Cordoba (Ruggles 2008; Ramón-Laca 2003; Martín-Consuegra and Uberta 1996). The current widespread use of single species such as *Platanus hispanica* Miller ex Münchh. in the gardens of newly urbanised areas has prompted a marked increase in airborne pollen counts (Alcázar et al. 2011). At the same time, greater effort should be made to limit the presence of exotic species, such as *Casuarina* sp., *Thuja* sp. and *Ligustrum* sp., in urban areas, since they are known to trigger symptoms in sensitised residents (Charpin et al. 2002a, 2005; García et al. 1997).

5 Conclusions

Comparative aerobiological and ecological analysis of allergenic ornamental flora in the studied cities highlighted the considerable diversity of species, influenced by a variety of factors as geographical location, history, culture and dynamic exchanges with the areas and ecosystems surrounding the urban environment.

The selection of ornamental species for urban green spaces has reflected a constant aesthetic and management-related preference for woody species. The abundance of allergenic species in the studied cities, especially in historical gardens and urban areas, has contributed to an increase in the overall allergenicity of the urban environment. Pollen grains emitted in urban surrounding areas constitute a further source of allergy, i.e., cropland or woods and shrub woods. The urban aerobiological spectrum is therefore enriched by windborne pollen from beyond the city.

There is an urgent need to screen ornamental plants for allergenicity before introducing them into urban green spaces, in order to improve the quality of the urban environment and protect pollen-allergy sufferers. Aerobiological criteria should be taken into account when planning urban green spaces for leisure use. Valid strategies include using insect-pollinated species, which tend to produce less pollen, and less aerodynamic pollen, than wind-pollinated species and ensuring the predominance of female plants in the case of dioicous species. It is also important to promote greater species diversity when designing new gardens, in order to avoid the excessive use of monospecific stands, which can prompt a sharp increase in airborne pollen counts.

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