



Allergenicity of the urban green areas in the city of Córdoba (Spain)

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ABSTRACT

Gardens provide from the antiquity a place of easing and leisure for the human being. The development of gardens in cities carries the creation of a green space that serves as support to the oxygenation of the air in these and participate in the mitigation of pollution. However, sometimes these parks and gardens can generate health problems in residents due to the presence of species that release high concentrations of allergenic pollen grains into the atmosphere. This work presents a study of potential allergenicity of urban green areas in the city of Córdoba (Spain) to observe if these spaces could be considered as a problem for public health due to its poor air quality. The results obtained suggest that some study spaces present a moderate-high allergenic potential and could represent a risk to the citizens. The main causes of this rate in these areas have been the abundance of individuals of allergenic species, concentrated in a small area.

1. Introduction

Gardens and parks of the cities are perceived by the inhabitants as beneficial for society due to the numerous contributions of them for the health of the human being: direct contact with nature, habitat of numerous plant and animal species, place of meeting and recreation, etc. (Chiesura, 2004; Latinopoulos et al., 2016). Even, urban green areas can be managed to impact the urban water, heat, carbon, and pollution cycles (Livesley et al., 2016).

At the same time, they present some inconveniences to the population due, among other causes, to the increasing incidence of pollen allergy symptoms. Recently, an increment of airborne pollen in urban areas has been observed, becoming one of the main public health problems, with incidence figures in the population above 30 % (Pawankar, 2014). This may have been due to the rapid urbanization in recent years, trying to meet the aesthetic and recreational needs of local residents (United Nations, 2008). Among the causes that have increased the allergenic behavior of the ornamental flora are the low biodiversity, the massive use of a few species (Díaz de la Guardia et al., 2006), the incorporation of new species of unknown allergenicity (García et al., 1997; Trigo et al., 1999) and, above all, the interaction with atmospheric pollutants present in the urban environment (Bosch-Cano et al., 2011; Beck et al., 2013). In addition to the above, it must be added the incorporation of pollen emissions from forest or extensive crops in the

peri-urban environment, i.e. olive pollen in Córdoba (Velasco-Jiménez et al., 2013; Galán et al., 2016).

Respiratory diseases, linked to the presence of pollen in the air, have also been pointed out as some of the problems with greater predictions of increasing in the coming decades as a result of climate change (McMichael et al., 2006) and the deterioration of quality of the urban air (Cariñanos et al., 2001 and Cariñanos et al., 2008).

The challenges that cities must do in the face of the expectations of population growth, and the effects of climate change, further reaffirm their essential role in the context of a sustainable and healthy city (Grimm et al., 2008; Leichenko, 2011; Baker, 2012). However, it is also necessary to review some of the negative effects associated with this ornamental flora, among them the costs derived from the allergic reactions caused by pollen emissions during flowering (Weis et al., 2001).

The ornamental flora has a clear influence on the pollen concentration in the air that affects the population suffering from pollinosis (Staffolani et al., 2011; Velasco-Jiménez et al., 2014; Cariñanos et al., 2017). An analytical study of the presence of potentially allergenic species, their biological characteristics and the factors involved in their activity, as sources of pollen emission, would be very useful when creating and designing new gardens or urban parks, and a solution to redesign those already existing (Cariñanos and Casares, 2011). On the other hand, not all pollen grains have proteins that cause allergy and, among those pollen grains with allergenic proteins, not all have the

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Fig. 1. Location of Córdoba city.

Table 1
General characteristics of the green areas considered in this study.

Name	Year	Typology	Surface (m ²)	N° trees	Geographic location
Parque de la Asomadilla	2007	Large urban park	270,000	1,372	37°54'16.32"N 4°46'38.60"O
Jardines del Alcázar	1328	Historical garden	55,000	619	37°52'30.37"N 4°46'59.22"O
Paseo de la Victoria	1776	Large urban park	52,000	576	37°53'1.54"N 4°47'8.08"O
Parque Cruz-Conde	1950	Large urban park	50,000	1,364	37°52'20.36"N 4°47'24.43"O
Parque Elena Fortú	1990	Small park	40,000	396	37°52'38.18"N 4°47'58.83"O
Jardines de Agricultura	1811	Small park	30,550	351	37°53'16.66"N 4°47'8.54"O
Jardines de la Merced	1905	Small park	19,300	461	37°53'24"N 4°46'42"O
Parque Juan Carlos I	1999	Small park	12,500	316	37°52'59.08"N 4°47'20.43"O

same allergen potency (Behrendt and Becker, 2001), so it is very convenient to know these characteristics of pollen grains.

This study focused on the most important parks and gardens in the city of Córdoba (Spain) to study the allergenic potential of these areas, to know which trees species have the most influence on this allergenic potential. On the other hand, it is intended to update the pollen calendar of the city of Córdoba to know the periods of maximum concentration of pollen from these allergenic species and contribute to better management and minimize the impact on the resident population.

2. Material and methods

2.1. Study area

Córdoba (37° 50' N, 4° 45' W) is located in Andalusia, south Spain, at 111 m above sea level (Fig. 1); it is a medium-sized city with a population of around 325,708 inhabitants (according to the last census of 2018) and a surface of 1254.91 km². It is characterized by a Mediterranean climate with some continental features, cold, rainy winters and hot, dry summers. The annual average temperature is 18.2 °C, mean annual rainfall is 605 mm (data from 1981 to 2010, AEMET – State weather agency).

Inside the city, the 8 most important public parks and gardens, with a suitable surface to apply the Allergenicity Index detailed below have been studied. The antiquity, architecture and surface characteristics, as well as the typology, according to the classification of Rall et al. (2015), are detailed in Table 1. The green areas studied in the city of Córdoba can be classified into three types, according to the mentioned bibliography:

- Large urban park: green area with an area greater than or equal to 50,000 m²
- Historical garden: similar to large urban parks, but with distinct management due to heritage status.
- Small park: green area with an area less than 50,000 m²

2.2. Ornamental flora data

Complete lists of trees and palms growing in the urban green area were compiled by the Parks and Gardens Services of the Town Councils (<https://infraestructuras.cordoba.es/sec-parqujard/especieszv/listadoszv/>) and checked by the authors with *in situ* observation.

Shrubs or herbaceous species have not been taken into account due to the frequent pruning carried out by maintenance personnel. This work causes that the flowering of these species is minimal since much flowers are eliminated in these actions

2.3. Estimating the Index of Allergenicity of urban green areas

The potential allergenicity of urban parks was calculated using the index of allergenicity of urban green zones (IUGZA) developed by Cariñanos et al. (2014), which takes into account a number of biological and biometric parameters for tree and palm species growing in green spaces. Analysis of biological parameters enables a potential allergenic value (VPA) to be assigned to each species, while the biometric parameters enable estimation of their actual behaviour as a source of allergen emissions. VPA itself results from combining three natural variables: type of pollination, duration of the pollen season and intrinsic allergenicity of pollen grains, (Database of parameters for the calculation of the IUGZA, registered in Safe Creative platform, N° IPR-684). A list of biological parameters for the 100 most common tree species in Mediterranean cities is provided in Cariñanos et al. (2016). This value can range between 27 (highly allergenic species) and 1 (non-allergenic species)

Biometric parameters were based on crown diameter and height;

Table 2
Percentage of highly-allergenic species, density of trees, Species richness, and species of the 8 urban spaces considered in this study.

Name	Allergenic species (%)	Density (Trees/ha)	Species richness	Species (N° individuals)
Parque de la Asomadilla	43.75	51	32	<i>Olea europaea</i> (505)
				<i>Punica granatum</i> (157)
				<i>Celtis australis</i> (119)
				<i>Pinus pinea</i> (90)
				<i>Crataegus monogyna</i> (79)
				<i>Ulmus minor</i> (78)
				<i>Quercus ilex</i> (71)
				<i>Quercus faginea</i> (54)
				<i>Cupressus sempervirens</i> (107)
				<i>Platanus hispanica</i> (97)
Jardines de la Merced	39.29	239	28	<i>Phoenix dactylifera</i> (88)
				<i>Citrus aurantium</i> (62)
				<i>Washingtonia</i> sp. (17)
				<i>Yucca elephantipes</i> (17)
				<i>Lagerstroemia indica</i> (13)
				<i>Citrus aurantium</i> (53)
				<i>Ulmus minor</i> (39)
				<i>Populus alba</i> (29)
				<i>Catalpa bignonioides</i> (23)
				<i>Sophora japonica</i> (22)
Parque Juan Carlos I	39.29	253	28	<i>Jacaranda mimosifolia</i> (21)
				<i>Washingtonia robusta</i> (20)
				<i>Citrus aurantium</i> (291)
				<i>Cupressus sempervirens</i> (206)
				<i>Citrus limon</i> (19)
				<i>Broussonetia papyrifera</i> (15)
				<i>Cupressus arizonica</i> (11)
				<i>Ligustrum lucidum</i> (11)
				<i>Pinus granatum</i> (11)
				<i>Casuarina equisetifolia</i> (4)
Jardines del Alcázar	38.46	113	39	<i>Ulmus americana</i> (4)
				<i>Ailanthus altissima</i> (4)
				<i>Sophora japonica</i> (62)
				<i>Citrus aurantium</i> (37)
				<i>Robinia pseudoacacia</i> (33)
				<i>Ulmus minor</i> (32)
				<i>Platanus x hispánica</i> (28)
				<i>Brachycton populneus</i> (25)
				<i>Citrus aurantium</i> (112)
				<i>Phoenix canariensis</i> (60)
Parque Elena Fortú	37.50	99	24	<i>Platanus hispanica</i> (54)
				<i>Washingtonia robusta</i> (20)
				<i>Trachycarpus fortunei</i> (18)
				<i>Washingtonia filifera</i> (11)
				<i>Cercis siliquastrum</i> (9)
				<i>Casuarina equisetifolia</i> (7)
				<i>Cupressus sempervirens</i> (6)
				<i>Ligustrum japonicum</i> (6)
				<i>Pinus pinea</i> (146)
				<i>Platanus hispanica</i> (136)
Parque Cruz-Conde	31.71	273	41	<i>Melia azedarach</i> (105)
				<i>Cedrus deodara</i> (90)
				<i>Ulmus pumila</i> (87)
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				<i>Ulmus pumila</i> (87)

Table 2 (continued)

Name	Allergenic species (%)	Density (Trees/ha)	Species richness	Species (N° individuals)
Paseo de la Victoria	28.13	110	32	<p><i>Ligustrum</i> sp. (86) <i>Pinus halepensis</i> (86) <i>Vitex agnus-castus</i> (79) <i>Punica granatum</i> (48) <i>Callistemon citrinus</i> (47) <i>Pitiosporum tobira</i> (47) <i>Citrus aurantium</i> (235) <i>Celtis australis</i> (80) <i>Phoenix canariensis</i> (45) <i>Platanus hispanica</i> (44) <i>Phoenix dactylifera</i> (44) <i>Washingtonia filifera</i> (25) <i>Casuarina equisetifolia</i> (18) <i>Cercis siliquastrum</i> (18)</p>
				<p><i>Acer negundo</i> (24) <i>Thuja plicata</i> (23) <i>Robinia pseudoacacia</i> (22) <i>Phoenix canariensis</i> (19) <i>Morus alba</i> (18) <i>Brachycton populneus</i> (14) <i>Cupressus sempervirens</i> (8) <i>Brachycton populneus</i> (8) <i>Yucca</i> sp. (6) <i>Populus nigra</i> (5) <i>Chamaerops humilis</i> (4) <i>Cedrus atlántica</i> (4) <i>Pitiosporum tobira</i> (4) <i>Jacaranda mimosifolia</i> (4)</p>
				<p><i>Casuarina equisetifolia</i> (9) <i>Celtis australis</i> (9) <i>Abies</i> sp. (8) <i>Parkinsonia aculeate</i> (6) <i>Feijoa sellowiana</i> (6) <i>Ginkgo biloba</i> (3) <i>Quercus ilex</i> (3) <i>Magnolia grandiflora</i> (3) <i>Robinia pseudoacacia</i> (3) <i>Araucaria excelsa</i> (2) <i>Pinus pinea</i> (2) <i>Sophora japonica</i> (2) <i>Punica granatum</i> (2)</p>
				<p><i>Yucca</i> sp. (2) <i>Araucaria</i> sp. (1) <i>Sophora japonica</i> (1) <i>Prunus salicina</i> (1) <i>Olea europea</i> (1) <i>Aesculus hippocastanum</i> (1) <i>Ligustrum lucidum</i> (1) <i>Cedrus deodara</i> (1) <i>Lauro nobilis</i> (1) <i>Ceratonia siliqua</i> (1) <i>Arbutus unedo</i> (1) <i>Prunus cerasifera</i> (1)</p>

this facilitates calculation of allergen emission volumes by assimilating treetops to a geometric figure of similar shape (Cariñanos et al., 2014).

Finally, in order to determine the relative value of allergen emissions in a given area or space, the values obtained were compared with those of a space with the same features and surface area, in which all trees planted had maximum values for all parameters, according to the following formula (Cariñanos et al., 2014):

$$IUGZA = \frac{1}{\max VPAxST} \sum_{i=1}^k VPAxSi x Hi$$

Where:VPA = Potential Allergenicity Value for each species.ST = Surface area of the urban park.k = number of species in the park.Si = Area occupied by each species in the park.Hi = maximum height reachable by mature tree.

Application of the index yields a value between 0 (null allergenicity) and 1 (maximum allergenicity). An urban green space will have a low IUGZA value when it is below 0.2, moderate between 0.2-0.3 and high above 0.3 (Cariñanos et al., 2019).

2.4. Airborne pollen

Airborne pollen databases were obtained from sampling station located in the University Campus of Rabanales (Córdoba), which belongs to the Spanish Aerobiology Network (REA). Sampling was performed during the last 10 years (2009–2018), 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), in compliance with the minimum requirements set out by the European Aerobiology Society (EAS) (Galán et al., 2014), was used for sampling and for calculating average daily airborne pollen concentration (pollen grains/m³).

For the representation of the pollen calendar, the 10-day average daily pollen concentration (Julian calendar) was taken as a single value corresponding to the arithmetic mean for a period of ten consecutive days; for 31-day months, the last group contained 11 days, while February was taken as a 29-day month, the last group comprising 9 days, as recommended by Spieksma (1991), Martínez-Bracero et al. (2015) and Gutiérrez et al. (2006). The airborne pollen classification recommended by Stix and Ferretti (1974) and Martínez-Bracero et al. (2015) has been the following: 1–2 pollen grains/ m³ of air; then 3–5, 6–11, 12–24, 25–49, 50–99, 100–199, 200–399, 400–799, 800–1600, and finally over 1600 pollen grains/m³ of air. The names of the pollen types have been considered as they appear in the Atlas aeropalínológico de España (Trigo et al., 2008).

3. Results

The major findings are shown in Table 2. The proportion of highly allergenic species, expressed as a percentage of the total number of trees, ranged from 28.13 % for “Paseo de la Victoria” to 43.75 % for the “Parque de la Asomadilla”. The number of trees per ha have also varied considerably, from less than 100 trees/ha (“Parque de la Asomadilla” and “Parque de Elena Fortú”), to over 200 trees/ha (“Parque de Cruz-Conde”, “Parque Juan Carlos I” and “Jardines de la Merced”). The green areas with the most species richness have been “Parque Cruz-Conde”, “Jardines del Alcázar” and “Jardines de Agricultura”.

The origin of the species found in each urban green area, expressed in percentage, has been represented in Fig. 2. In 5 parks, most of the species have been of Asian origin (“Parque Elena Fortú”, “Jardines del Alcázar”, “Parque Cruz-Conde”, “Jardines de Agricultura” and “Jardines de la Merced”); in 2 parks, most of the species have been of Mediterranean origin (“Parque de la Asomadilla” and “Paseo de la Victoria”); in “Juan Carlos I” Park, most species have been of American origin. Species of European and Australian origin have also been found but to a lesser extent.

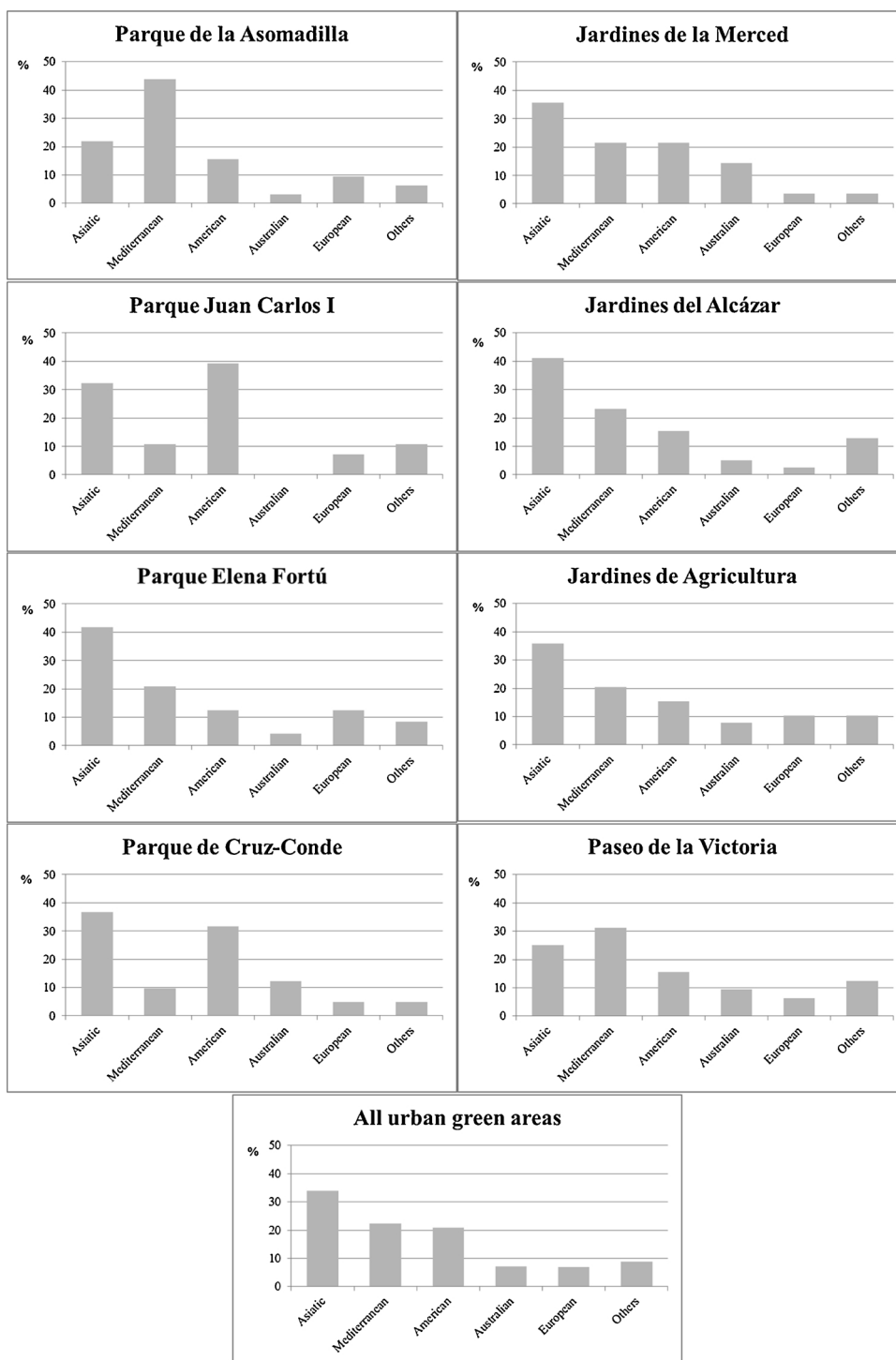


Fig. 2. Origin for ornamental flora in the studied gardens, expressed in percentage of species.

In order to estimate the allergenicity index, the VPA of all tree species was calculated. The highest values were found for those taxa with the following natural features: wind pollination, pollen season lasting longer than six weeks, and allergenic pollen grains. The genera and species recording maximum VPA (27) have been: paper mulberry (*Broussonetia papyrifera*), australian pine (*Casuarina equisetifolia*), cypress (*Cupressus* sp.), juniper (*Juniperus* sp.), mulberry (*Morus* sp.), bald cypress (*Taxodium* sp.) and thuja (*Thuja* sp.). Other species with a high VPA value (18) have been: olive (*Olea europaea*), plane tree (*Platanus hispanica*), poplar (*Populus alba*) and elm (*Ulmus minor*). In the case of juniper, bald cypress and thuja species, they have not been found in all

the parks and, in those that appear, the number of trees is very low (between 1 and 3).

The results obtained by applying potential allergenicity index to the study areas are shown in Fig. 3. Values ranged from a minimum of 0.04 for the “Parque de la Asomadilla” to a maximum of 0.6 for “Jardines de la Merced”. Since an index value of 0.2 was taken as the threshold considered sufficient to trigger allergy symptoms in the sensitive population, three of the spaces analyzed here, with moderate (Jardines de Agricultura) and high values (Jardines de la Merced and Parque de Cruz-Conde), may be regarded as unhealthy for pollen-allergy sufferers. The others green areas can be classed as low or very low allergenic.

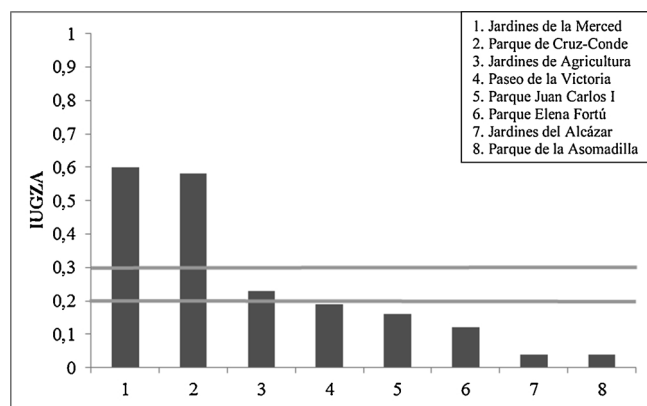


Fig. 3. IUGZA of the urban parks considered in this study, according to the Index proposed by Cariñanos et al. (2014).

Pollen calendar of the principal ornamental pollen types observed in the city of Córdoba during the period 2009–2018 have been represented in Fig. 4. During winter, the most important pollen types are Cupressaceae and *Populus* and, to a lesser extent, *Fraxinus*, *Ulmus* and *Alnus*; in early spring are *Platanus*, *Morus*, *Pinus* and *Quercus*; in late spring are *Olea* and, to a lesser extent, *Arecaceae* and *Myrtaceae*; finally, *Casuarina* pollen type appears in autumn but with low concentrations.

4. Discussion

In the present study, 8 green areas have been analyzed, with a total area of 529,350 m². Taking into account that the total green area is 5,132,956.72 m², estimated by the Council of Córdoba, is 5,132,956.72 m², about 10 % of this area has been sampled. The studied green areas studied correspond to the parks and gardens of greater area of the city, although there are numerous smaller landscaped areas, and without trees, in most of the streets. On the other hand, the most abundant species found in the studied parks (*Citrus aurantium*, *Celtis australis*, *Platanus hispanica*, *Melia azederach*, *Ulmus minor* and *Robinia pseudoacacia*) are also cited in the list of the Council of Córdoba among the most abundant in the city. The species present in the studied gardens are the typical species used by the Council and, therefore, are the species that are usually used in the city. These species can be considered as representative ornamental species throughout the city. In the gardens that have not been studied, the same species are used in general.

The study of the ornamental flora carried out in Córdoba city has shown the diversity of species used, both taxonomic groups and diverse origins, which contributes to enrich the urban landscape of the city.

The majority of the species present in the studied parks and gardens are from Asian origin. These species are common in the city of Córdoba from the Muslim period (Ubera, 1996). The second group of most abundant species is the one of Mediterranean origin. These species have recently been incorporated, trying to present the residents of the city with the great richness of our natural flora. However, some Mediterranean species have a high allergenic pollen, such as *Cupressus sempervirens* and *Olea europaea* (Rodríguez et al., 2001; Charpin et al., 2005; Cariñanos et al., 2017). On the other hand, Córdoba is characterized by a climate with a certain degree of continentality, with frequent nights of frost in winter, which could explain the presence of some European species, and a lower percentage of tropical species than coastal cities, such as Málaga (Velasco et al. 2014). The results confirmed that both native and allochthonous taxa contributed to the allergenicity index. Thus, there is no justification for replacing non-native species by native flora (Jianan et al., 2007; Cariñanos et al., 2017).

Among the most represented species most used in the studied parks and gardens are several listed as highly allergenic (Cariñanos et al.,

2017), with a VPA value of 27, as is the case of: cypress in the “Jardines de la Merced” and the “Jardines del Alcázar” or paper mulberry in the “Jardines del Alcázar”. Allergenic species are also frequent, with a VPA value of 18, such as: plane tree in the “Paseo de la Victoria”, “Jardines de la Merced”, “Parque de Cruz-Conde” and “Jardines de Agricultura”; olive in the “Parque de la Asomadilla” or elm and poplar in the “Parque Juan Carlos I”.

On the other hand, numerous individuals of species with a low VPA index have also been found, i.e orange tree (*Citrus aurantium*), indian bean tree (*Catalpa bignonioides*) and pomegranate (*Punica granatum*), among others. However, although these species have a low index, they could cause problems for the local population in those streets or avenues where the number of individuals is high (Cariñanos et al., 2002; Alcázar et al., 2016).

It is interesting to note how in the “Parque de la Asomadilla”, of very recent construction, with more than 500 olive trees, despite the proven negative effect of its pollen on the population (Cariñanos et al., 2002; Sánchez-Mesa et al., 2005; D’Amato et al., 2007; Cebrino et al., 2017). In addition, the cultivation of olive trees is widespread in the province of Córdoba, reaching to occupy about 25,600 ha (data from the Government of Andalusia, 2017). The fact of including specimen of this tree in the city only worsens the effects that already exert extensive crops (Velasco-Jiménez et al., 2014). For future management, entomophilic autochthonous species, with a very low VPA value, could be used, as carob tree (*Ceratonia siliqua*). Nonetheless, this park has the lowest IUGZA index of all the studied ones, due to the large area it occupies, which gives rise to the lower density of tree population.

On the three urban green spaces with an IUGZA index greater than 0.2, and therefore susceptible to trigger allergy symptoms to the local population, comment that they have a high density of trees and also highly allergenic species predominate, as above. In the study carried out by Cariñanos et al. (2017) the relation existing between a high value of the IUGZA index and the density of trees was already exposed. However, in this study we have found parks, such as Juan Carlos I, with a high density of trees but low IUGZA index. We have checked that the predominant species in this park is *Citrus aurantium*, with a VPA value of only 3. Therefore, although the density of trees is important for the IUGZA index, as much or more is the choice of the species used and the number of individuals of these. It is also true that the following species, in order of abundance in this park, *Ulmus minor* and *Populus alba*, are considered allergenic and have a VPA of 18, similar to olive or plane tree. But the pollen concentrations in the air of these species reach are much lower than *Olea* and *Platanus*.

For some years it has been observed that the massive use of individuals of the same species is causing a significant increase in pollen concentrations in the air (Velasco-Jiménez et al., 2014). This fact has already been discussed for some cases of trees especially allergenic, and also of allochthonous origin, such as the plane tree (Alcázar et al., 2004 and Alcázar et al., 2011), cypress (Cariñanos et al., 2016) or the casuarina (García et al., 1997; Trigo et al., 1999). And yet, the most recent urban green areas (Parque de la Asomadilla, Parque de Cruz-Conde and Parque Juan Carlos I) are the ones that have presented the highest percentage of allergenic species. This makes us see that there is still a lot to be done in this issue to raise awareness among city managers of the need to have expert advice on this subject.

Another aspect to keep in mind is that the parks and gardens do not present a continuous allergenicity over time, so that its effect will be greater only during the flowering season of the allergenic species. According to the latest pollen calendar published for the cities in Andalusia (Martínez-Bracero et al., 2015), in Córdoba, most study species bloom in spring, which makes it the most adverse time for allergic people who often cross these gardens or spend time in them. Nevertheless, some species bloom during other times, like winter (cypress) or autumn (Australian pine). So the population sensitive to these pollen types should take special care also on these dates.

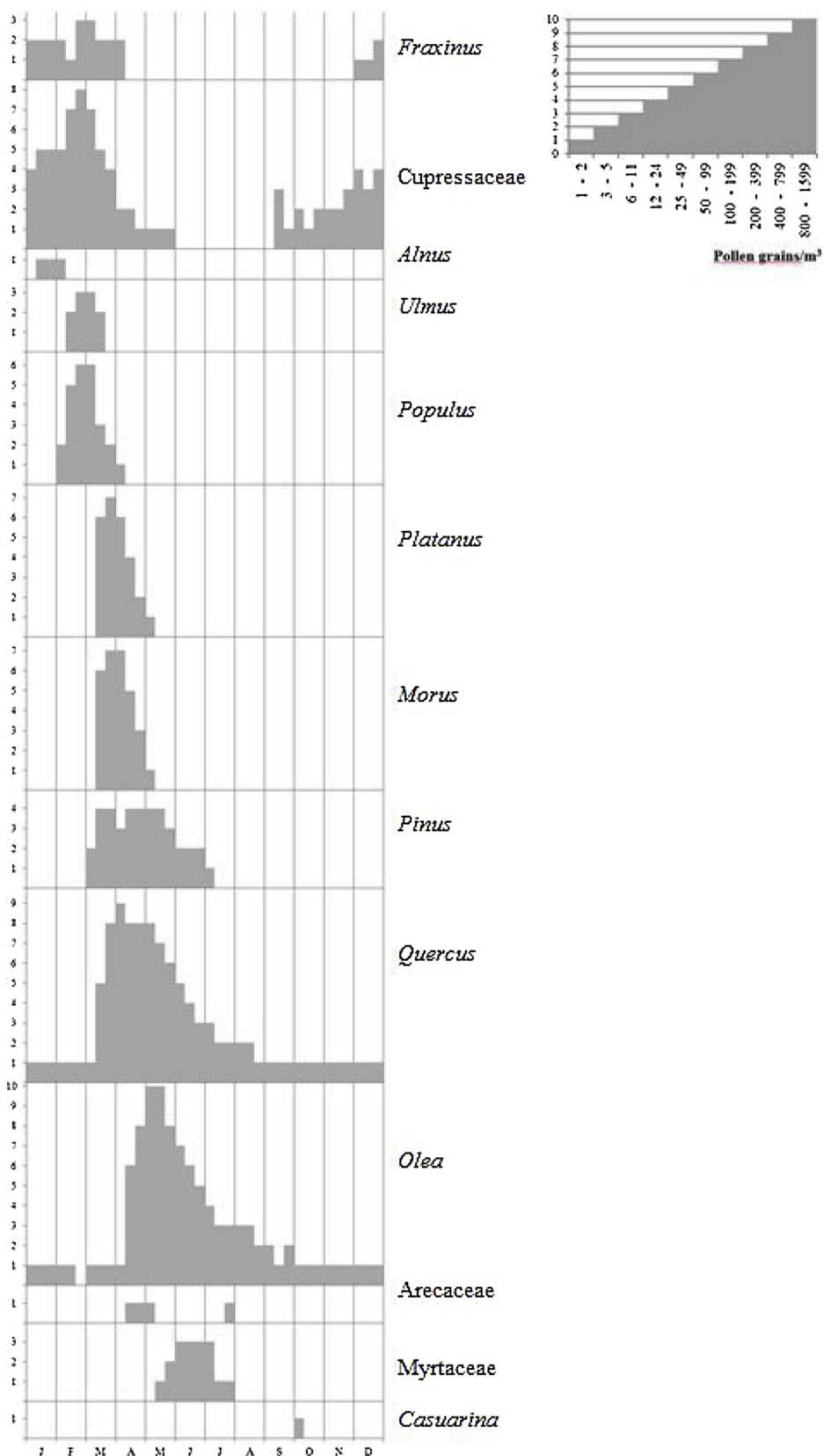


Fig. 4. Pollen Calendar of Córdoba during 2009–2018, related to ornamental flora.

5. Conclusion

The urban green areas studied in the city of Córdoba have a moderate-low allergenicity index. Three of the parks analyzed have

exceeded the value of 0.2, considered as susceptible to trigger allergy symptoms to the local population.

The most allergenic species that have been found in these parks and gardens have been paper mulberry, australian pine, cypress, olive,

plane tree, poplar and elm.

The factors that have contributed most to the allergenicity index of each urban green area have been the abundance of individuals of allergenic species and the surface of the park. Although it is also important to take into account the final amount of pollen that is released into the atmosphere by each species.

Since some of these spaces are of recent construction, this makes us see that there is still a lot to be done in this issue to raise awareness among city managers of the need to have expert advice on this subject.

It would be convenient to complete this initial study with other garden areas of the city and even extend it to other locations in the province.

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