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ORIGINAL PAPER

Allergenicity of the ornamental urban flora: ecological and aerobiological analyses in Córdoba (Spain) and Ascoli Piceno (Italy)

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Abstract Comparative ecological and aerobiological analyses of ornamental urban flora in the cities of Córdoba (Spain) and Ascoli Piceno (Italy) identified a group of plants with allergenic pollen whose behaviour is influenced by a number of factors. The geographical position and the resulting climate of both cities favoured the presence of Mediterranean species. In Córdoba, strongly allergenic evergreens introduced during the Moorish period predominated (*Cupressus sempervirens,* among others), while in the urban area of Ascoli Piceno, *Pinaceae* were abundant. In both cities, many species of American origin have been introduced for aesthetic reasons, contributing to an increase in the overall allergenicity of urban greenery. The pollen spectrum differed between the two cities: airborne *Oleaceae* and *Cupressaceae* pollen abounded in Córdoba, whilst allergenic pollen from surrounding natural environments (*Corylaceae*) predominated in Ascoli Piceno. These results pointed to a large number of potentially allergenic species in cities, thus highlighting the importance of greater ecological and aerobiological knowledge of allergenic species of urban ornamental flora. Avoidance of more allergenic species when planning new urban green areas could ensure healthier environments for pollen-allergy sufferers.

Keywords Urban flora · Pollinosis · Allergy · Ornamental flora · Urban ecology

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1 Introduction

Given the increasing incidence of pollen-allergy symptoms, it is becoming ever more essential to obtain precise ecological and aerobiological data regarding the plants prompting these allergies. This is particularly true of allergenic plant species growing in urban areas, since sensitive subjects are in direct contact with their pollen throughout the pollen season (Cariñanos et al. 2007). The potential problem posed by plant species growing spontaneously in urban areas is exacerbated by exotic species introduced for ornamental purposes and by the increasing presence of other airborne pollutants and dust, which contribute to allergy symptoms in humans (Popp et al. 1992; Arilla et al. 2004; Gonzalo-Garijo et al. 2006; Staffolani and Hruska 2008).

The expansion of urbanized areas in Mediterranean countries has prompted a sharp increase in the incidence of pollen allergies, particularly in densely

populated cities. In seeking to meet the aesthetic and recreational needs of inhabitants, the management of urban green areas often fails to take into account the allergenicity of the ornamental plants introduced (Alcázar et al. 2004; Cariñanos et al. 2002; Guerra et al. 1995; 1996).

Using data obtained previously on the ornamental flora of Córdoba (Spain) and Ascoli Piceno (Italy), the present study compared the ecological and aerobiological characteristics of the allergenic plant species identified. It was assumed that the information obtained from a comparison of peak pollen-production periods and weather conditions would help to determine the influence of geographical location and human impact, as well as highlighting potential similarities between the two cities.

The final goal was to test for similarities in terms of the ecological strategies adopted by urban allergophytes and in the aerobiological characteristics of allergenic pollen in the Mediterranean basin.

2 Materials and methods

On the basis of several preliminary studies and available data on urban allergenic plants, this study focused on the Italian and Spanish urban ecosystems shown in Table 1. Allergenic plant species in the selected urban areas were identified over the period 2004–2009 by dividing the surface area into 500-m^2 quadrants and identifying the allergophytes in each. For each quadrant, partial lists of allergenic flora were compiled; these lists were later pooled to form a complete list for the cities studied.

Allergenicity was confirmed by consulting the Allergome database (2004–2009, www.allergome.org), selecting allergenic ornamental species planted in urban green spaces, and adding data from the literature (Mincigrucci et al. 1981; Porras et al. 1984; Hernández et al. 2000) together with data on exotic species introduced in the past that have become naturalised.

A comparison was made of ecological data for each selected species, drawn from Tutin et al. (1964–1980), Ellenberg et al. (1992), Tutin et al. (1993) and Pignatti (2005). Data provided by Grant Smith (1990) were used for pollen morphology. Summary graphs of ecological strategies adopted by allergenic ornamental flora were drawn up for Spain and Italy, and morphograms (Fig. 1), chorograms (Fig. 2) and ecograms (Fig. 3) were constructed.

The city of Córdoba has a dry thermomediterranean climate: for the period 1971–2000, the mean temperature was 17.6°C and annual average rainfall was 536 mm. Climate data for the city of Ascoli Piceno, over the period 1980–2001, showed that the mean temperature was 15.3°C and annual average rainfall was 1,006 mm. In both cities, peak rainfall is recorded in spring.

Comparison of the aerobiological characteristics of urban ornamental species was based on airborne pollen counts provided by the University of Córdoba Botany Department and by ARPAM (The Marches Region Agency for Environmental Protection) in Ascoli Piceno. Pollen counts were expressed as daily mean pollen grains/m^3 of air.

3 Results

Analysis of allergenic ornamental flora was based on a total of 103 plants for Ascoli Piceno and 141 for Córdoba. The morphograms (Fig. 1) indicated the predominance of phanerophytes: these perennial tree and shrub species are more abundant in southern Spain (*Platanus* × *hispanica* (Mill.) Münchh.,

Table 1 Geographical data for Ascoli Piceno (Italy) and Córdoba (Spain)

	Latitude	Altitude m.s.l.	Surface (km^2)	N° inhabitants	Density (inhab./km^2)
Italy					
Ascoli Piceno	42°51′17″N 13°34′31″E	136	160.51	51,630	321.66
Spain					
Cordoba	37°53′05″N 4°46′45″W	120	290.23	329,249	1,134.44

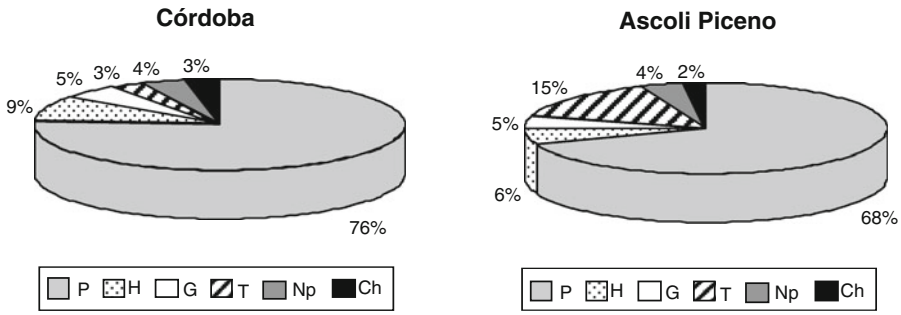

Fig. 1 Morphograms for allergenic ornamental flora in the cities studied (*P* Phanerophytes, *H* Hemicryptophytes, *G* Geophytes, *T* Therophytes, *Np* Nanophanerophytes, *Ch* Chamaephytes)

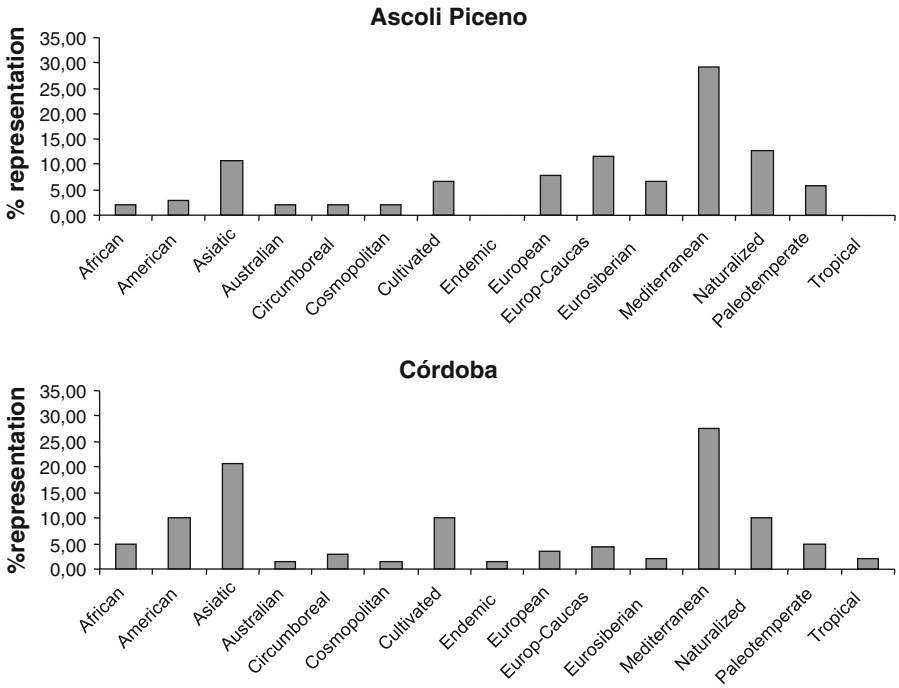

Fig. 2 Chorograms for allergenic ornamental flora in the cities studied (*Europ.-caucas.* European-caucasian)

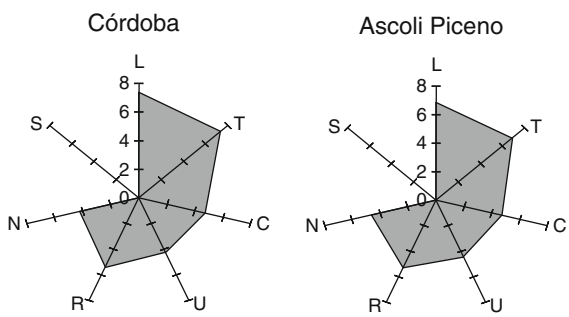

Fig. 3 Ecograms for allergenic ornamental flora in the cities studied (*L* Luminosity, *T* Temperature, *C* Continentality, *U* Humidity, *R* Soil pH, *N* Nutrients, *S* Salinity)

Cupressus arizonica Greene, *Celtis australis* L.) than in Italy (*Corylus avellana* L., *Acer campestre* L., *Pinus* sp., *Castanea sativa* Mill.). Annual allergophytes and other biological forms are less common.

Phanerophytes (P) were introduced into urban areas by inhabitants and local authorities, becoming increasingly abundant over the years. Urban green areas, and particularly avenues and public parks, contain numerous tree species, including *Platanus* x *hispanica* (Mill.) Münchh., *Platanus* x *hybrida* Brot., *Cupressus sempervirens* L., *Aesculus hyppocastanum* L., *Cedrus libani* A. Rich. and *Tilia cordata* Mill., *Melia azederach* L.).

Annual allergophytes (Therophytes) were more common here, indicating a dynamic link with surrounding areas, since most come from cropland (*Brassica nigra* L., *Chrysanthemum segetum* L., *Eruca sativa* Mill., *Helianthus annuus* L., *Solanum nigrum* L., among others).

Comparison of higher taxonomic groups (Table 2) revealed that while for some families—including Cupressaceae, Oleaceae, Rosaceae and Fabaceae—the number of species represented was similar, for others such as Moraceae and Rutaceae in Córdoba and Brassicaceae and Pinaceae in Ascoli Piceno, the number of species varied considerably between cities.

Chorograms (Fig. 2) indicated similarities between Spain and Italy: Mediterranean allergophytes predominated, followed by naturalised European-Caucasian and Asiatic species. There was a notable presence of allergenic plants of American origin, due to trade.

The ecograms (Fig. 3), drawn up indirectly with reference to the ecological valence of individual plants for selected ecological factors (Ellenberg et al. 1992; Pignatti 2005), give a clear idea of the overall situation in the two urban ecosystems.

The pollen morphology of the allergophytes analysed is shown in Table 3. Tricolporate pollen grains predominated, followed by tricolpate grains, indicating differences between the two cities. In Ascoli Piceno, the most abundant pollen types were aperturoidate, tricolporate and tricolpate (*Pinaceae, Brassicaceae, Aceraceae*). In Córdoba, the predominance of tricolporate pollen was attributable above all to the *Oleaceae*; other pollen types were also present in large numbers.

A comparison of the flowering periods of the major families (Fig. 4) was made on the basis of airborne pollen counts. The phenotypical similarity between the two cities was evident in the pollen-curve peaks recorded in spring. Pollen indices were considerably higher in Córdoba.

4 Discussion

From the taxonomical point of view, the ornamental floras examined are fairly different, especially in qualitative terms. Numerous families were noted, their presence related most of all to the climatic conditions, followed by the historical-artistic choices

Table 2 Number of species per family for allergenic ornamental flora in Córdoba and Ascoli Piceno

Family	N° of species		Aerobiological characteristic	
	Córdoba	Ascoli Piceno	Allergenecity	Pollen in air
Acanthaceae	1	1	High	No
Aceraceae	2	5	High	Yes
Agavaceae	3	0	High	No
Alliaceae	0	2	High	No
Amaranthaceae	1	2	High	Yes
Amaryllidaceae	1	1	High	No
Anacardiaceae	2	0	High	Yes
Apiaceae	0	1	High	Yes
Apocynaceae	2	1	High	No
Aquifoliaceae	1	0	Low	No
Araliaceae	1	1	High	No
Arecaceae	4	3	High	Yes
Asteraceae	5	4	High	Yes
Betulaceae	2	3	High	Yes
Brassicaceae	0	5	High	Yes
Buxaceae	1	1	Low	No
Caprifoliaceae	3	3	Low	No
Caryophyllaceae	1	0	High	No
Casuarinaceae	1	0	High	Yes
Celastraceae	2	0	High	No
Corylaceae	0	2	High	Yes
Cupressaceae	10	6	High	Yes
Cyperaceae	1	0	High	Yes
Eleagnaceae	1	0	Low	No
Euphorbiaceae	1	0	High	No
Fabaceae	6	5	High	No
Fagaceae	4	4	High	Yes
Geraniaceae	3	0	High	No
Ginkgoaceae	1	1	High	No
Hyppocastanaceae	1	1	Low	No
Iridaceae	0	1	High	No
Juglandaceae	1	1	High	No
Lamiaceae	5	1	High	No
Lauraceae	1	1	High	No
Liliaceae	2	0	High	No
Lythraceae	1	1	High	No
Magnoliaceae	2	1	High	No
Malvaceae	2	0	High	No
Moraceae	7	2	High	Yes
Myrtaceae	1	1	High	Yes

Table 2 continued

Family	N° of species		Aerobiological characteristic	
	Córdoba	Ascoli Piceno	Allergenecity	Pollen in air
Nephrolepidaceae	1	0	High	No
Nyctaginaceae	2	0	High	No
Oleaceae	11	6	High	Yes
Pinaceae	6	11	High	Yes
Platanaceae	1	2	High	Yes
Poaceae	4	3	High	Yes
Primulaceae	1	0	Low	No
Rhamnaceae	1	0	High	No
Rosaceae	12	8	High	No
Rutaceae	7	0	High	No
Salicaceae	3	4	High	Yes
Saxifragaceae	1	0	Low	No
Simaroubaceae	1	1	Low	No
Solanaceae	0	2	High	No
Tamaricaceae	1	0	High	Yes
Taxaceae	1	0	High	Yes
Taxodiaceae	1	0	Medium	No
Tiliaceae	1	2	High	Yes
Ulmaceae	2	2	High	Yes
Vitaceae	1	1	High	No

Table 3 Number of species per pollen type for allergenic ornamental flora in Córdoba and Ascoli Piceno

Type of pollen	Examples of some family	N° of species	
		Córdoba	Ascoli Piceno
Analeptomate	Pinaceae	6	11
Biporate	Moraceae	2	1
Spores	Nephrolepidaceae	1	0
Inaperturate	Cupressaceae, Taxaceae	15	9
Monocolpate	Arecaceae, Agavaceae	12	9
Monoporate	Poaceae	6	4
Policolpate	Lamiaceae	6	1
Poliporate	Ulmaceae, Amaranthaceae	9	6
Tetraporate	Betulaceae	2	3
Tricolpate	Oleaceae, Platanaceae	13	27
Tricolporate	Asteraceae, Salicaceae, Rosaceae, Fagaceae	61	31
Triporate	Moraceae	7	1

of the inhabitants (Porras et al. 1984; Hernández et al. 2000). *Cupressaceae,* a non-local family, were introduced into Córdoba and southern Spain in general during the Roman occupation of the Iberian peninsula, while the presence of *Citrus* sp., *Prunus* sp. and *Phoenix* sp. is due to Muslim domination of the peninsula throughout much of the Middle Ages.

Qualitative taxonomical differences between cities in terms of ornamental flora were quite striking: the presence of many families was determined largely by climate conditions and by the historical aesthetic preferences of local inhabitants (Porras et al. 1984; Hernández et al. 2000). In general terms, these allergenic species are of considerable ornamental value and adapt well to urban ecological conditions (*Platanus* sp., *Ficus carica* L., *Eucalyptus camaldulensis* Dehnh, *Acacia dealbata* L.). The *Corylaceae* family was represented in Italy by *Ostria carpinifolia* Scop. and the highly allergenic *Corylus avellana* L., deriving from natural environments. The *Pinaceae* (*Cedrus deodara* G..Don., *Cedrus libani* A. Rich., *Picea excelsa* (Lam.)Link, *Pinus cembra* L., *P. sylvestris* L., *P. nigra* Arnold) form part of the historic greenery of Italian cities. More recently, they have been replaced by *Oleaceae* in park landscaping. In Spain, the *Cupressaceae* are extremely abundant (Guerra et al. 1996) and highly allergenic (Michel et al. 1978; D'Amato and Licciardi 1994); like the *Platanaceae,* they are widely used as ornamentals in Spanish cities, primarily because of their resistance to urban pollution (Bytnerowicz et al. 2007). The *Salicaceae,* now common in Córdoba, grow well because of the ecological conditions linked to the course of the River Guadalquivir (*Populus alba* L., *P. nigra* L., *Salix alba* L., *S. babylonica* Hort., *S. eleagnos* Scop.). These were introduced during the upgrading of Spanish green areas and mixed with local spontaneous vegetation.

In both cities, the strong influence of geographical location accounts in large measure for the abundance of Mediterranean species, while cultural trends have fostered the introduction of exotic species, many of which have become spontaneous (*Robinia pseudoacacia* L., *Ailanthus altissima* (Miller) Swingle, *Magnolia grandiflora* L.). There is a notable presence of allergenic plants of American origin, due to commercial exchanges.

The morphogram for Italian allergenic ornamental flora was fairly similar to that of its Spanish counterpart, reflecting the presence of many exotic

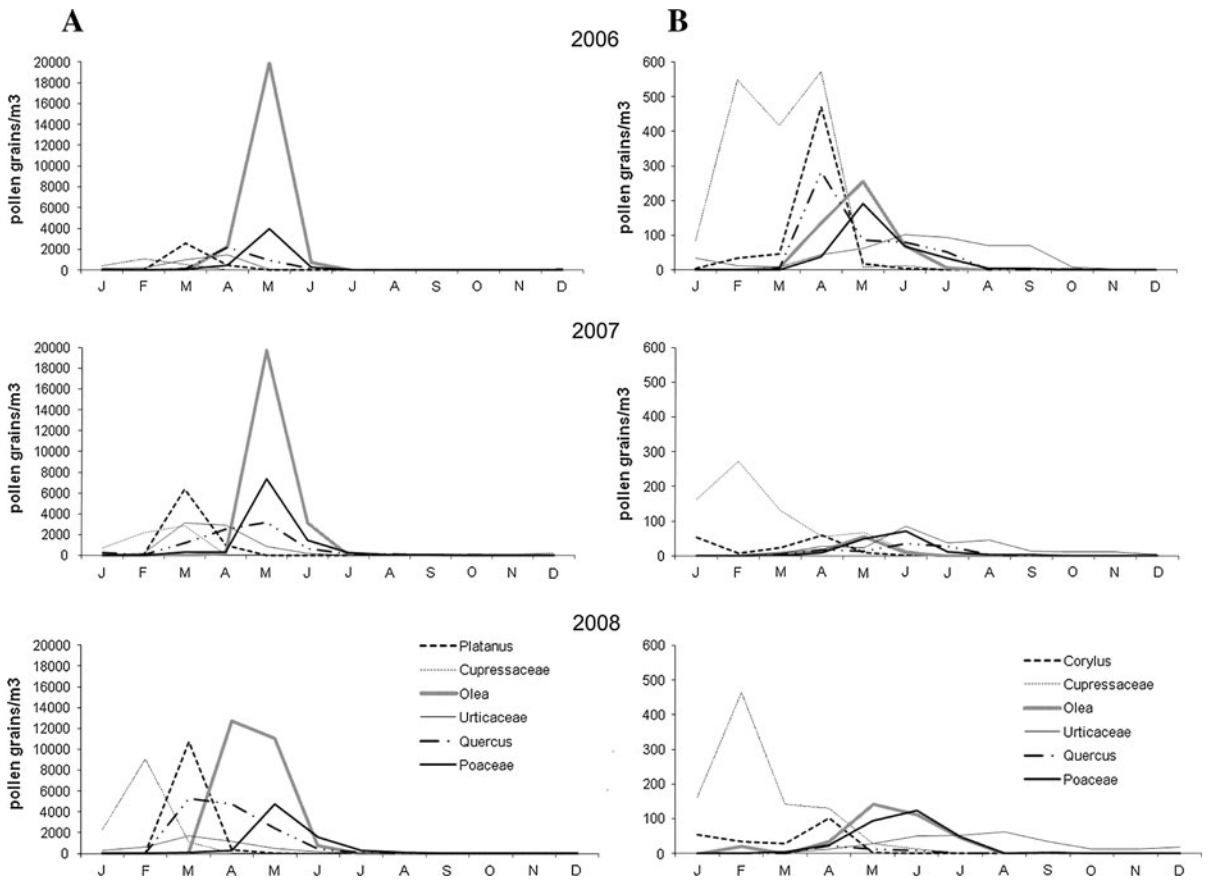

Fig. 4 Airborne pollen counts in Córdoba **a** and Ascoli Piceno **b** in 2006, 2007 and 2008

species introduced into gardens in the past for ornamental purposes, which over the years grew wild and became spontaneous (Viegi 2004).

The high values for the indices of luminosity (L) and temperature (T) are due to the layout and the geographical location of the individual cities. The presence of adequate soil nutrients also reflects the general condition of Mediterranean urban ecosystems.

In Ascoli Piceno, *Cupressaceae* pollen was the most abundant in the winter months, followed by *Oleaceae* and *Corylaceae*. *Urticaceae* pollen, associated mainly with an urban environment (Kasprzyk 2006), was more abundant in Italy, where members of this family find suitable habitats, such as city walls. Though not ornamental flora, their allergenic importance is considerable, since local inhabitants are in direct contact with them. The abundance of *Platanaceae* pollen reflects the widespread use of this family for urban ornamental purposes, while the geographical position of the individual cities accounts for the presence of other pollen types, including *Corylaceae* (Staffolani and Hruska 2008).

In Córdoba, *Oleaceae* pollen was the most abundant, with peaks in April and May, followed by *Fagaceae*, *Poaceae*, *Cupressaceae* and *Platanaceae* (Cariñanos et al. 2007). *Urticaceae* pollen was less abundant than in Ascoli Piceno, because there is less woodland surrounding Córdoba and because the climate is more continental (Domínguez-Bascón 2002). *Corylaceae* pollen grains were not recorded here (Hernández et al. 2000).

The phenotypical similarity of the two urban territories studied is seen in the peaks in the pollen curve during spring.

5 Conclusions

Comparative aerobiological and ecological analysis of allergenic ornamental flora in the Spanish and

Italian cities studied highlighted the considerable diversity of species, influenced by a variety of factors, chief among which were climate as a function of geographical location, the historical cultural preferences of local inhabitants and dynamic exchanges with the areas and ecosystems surrounding the urban environment.

The climate of the study areas indirectly influenced the characteristics of urban ornamental flora, prompting a widespread use of Mediterranean species, particularly in Spain.

Human impact has taken two forms. First, the layout of cities has largely mirrored standard architectural practice in the Mediterranean basin, where land use is strongly related to urban topography; this has given rise to a scarcity of free areas, which has done little to foster the development of a true urban vegetation. Secondly, and more important, the selection of ornamental species for introduction into cities, both in Spain and in Italy, has reflected a constant aesthetic and management-related preference for woody species. The abundance of allergenic species, especially in historic gardens and urban areas, has contributed to an increase in the overall allergenicity of the urban environment. Current knowledge regarding the allergenicity of various ornamental species should be taken into account when designing new urban green areas, in order to avoid introducing dangerous species.

Pollen grains released by species in areas surrounding the cities constitute a further source of allergy. In Spain, this pollen arises mostly from cropland (*Olea europea* L., Domínguez et al. 1993), while in Italian cities, the presence of species from natural environments (woods and shrubwoods) is more abundant (*Corylus avellana* L, among others). The urban aerobiological spectrum is therefore enriched by windborne pollen from beyond the city, as evident in a comparison of airborne pollen curves.

Given the multiple factors influencing the presence of allergophytes in the urban environment of the cities studied, and their adverse effects on local inhabitants, there is an urgent need to screen ornamental plants for allergenicity before introducing them into urban green areas, in order to improve the quality of the urban environment and protect pollen-allergy sufferers.

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