Aerobiological and phenological study of *Pistacia* in Córdoba city (Spain)

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**HIGHLIGHTS**

- *Pistacia* airborne pollen and flowering phenology have been studied in Córdoba city.
- Pollen index increased and pollen season coincided with phenological observations.
- *Pistacia* pollen counts were sufficient to identify seasonal and diurnal patterns.
- This pollen type should be taken into account in pollen calendars.

**ABSTRACT**

*Pistacia* species grow in temperate regions, and are widespread in the Mediterranean area. Two species can be found in the Iberian Peninsula: *Pistacia lentiscus* L. and *Pistacia terebinthus* L. Airborne pollen from these species, recorded in some Spanish provinces, is regarded by some authors as potentially allergenic, and therefore should be of particular interest, given that these species are actually being introduced as ornamentals in parks and gardens. This paper deals with a study of daily and seasonal *Pistacia* airborne pollen counts in Córdoba city, analysed in parallel with field flowering phenology data. The study was carried out in Córdoba, using a volumetric Hirst-type sampler in accordance with Spanish Aerobiology Network guidelines. Phenological monitoring was performed weekly from January to May at 7 sites in the mountain areas north of Córdoba city. The *Pistacia* pollen season lasted an average of 41 days, from mid-March to end of April. Higher pollen counts were recorded in evening hours. The pollen index increased over the study period, and the pollen season coincided with phenological observations. Some airborne pollen grains were recorded once flowering had finished, due to re-suspension or transport from other locations. *Pistacia* pollen counts in Córdoba were low, but sufficient to identify seasonal and daily patterns. This pollen type should be taken into account in pollen calendars, in order to fully inform potential allergy-sufferers. The number of trees introduced as ornamentals should be carefully controlled, since widespread planting could increase airborne pollen levels.

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**1. Introduction**

*Pistacia* species grow in warm and temperate regions of the northern hemisphere, predominantly in the sclerophyllous scrublands of the Mediterranean Basin (Jordano, 1988). Two species are to be found in the Iberian Peninsula: *Pistacia lentiscus* L., which grows in all kinds of soil, and at altitudes ranging from sea level to over 1000 m, and *Pistacia terebinthus* L., which, though more common on rocky ground, may also grow in all soils from sea level up to 1500 m in more temperate regions (Valdés et al., 1987; Trigo et al., 2008). Both species grow throughout the mountain areas north of Córdoba, where the predominant scrub vegetation is characterised by perennial shrubs; the most abundant associations ([Fig. 1](#)) include Cistaceae, aromatic Lamiaceae, Anacardiaceae, Myrtaceae species as well as *Arbutus unedo* groves (Rivas-Martínez, 1987).

Since both species are dioecious, their breeding success is governed by the proportion of male to female trees in the population (Verdú and García-Fayos, 2002). Male flowers have 8–10 stamens, producing 47–60 × 10³ pollen grains per flower, and are grouped in inflorescences of 8–10 flowers (Jordano, 1989). Pollen grains are tetraporate to polipantoporate, spheroidal, apolar and radiosymmetric, with a slightly reticulate surface (Trigo et al., 2008). Female flowers have unilocular tricarpellate ovaries with a single anatropous ovule (Verdú and García-Fayos, 2002). Flowering takes place between March and May, depending on altitude and climate, and there is some overlap in the flowering of males and females (Jordano, 1988; Correia and Díaz-Barradas, 2000; Martínez-Palle and Aronne, 2000; Verdú and García-Fayos, 2002). After pollination, ovaries remain latent for part of the summer. Subsequent rapid growth ends in the formation of fleshy...
fruits with a single seed. Fruits are initially white; as they ripen, they turn reddish and eventually black (Verdú and García-Fayos, 2002).

This pollen type has been recorded in the air of some areas of Andalusia, Catalonia and Valencia (Trigo et al., 2008), and has been identified as allergenic by some authors, who report cross-reactivity with some Schinus species (Keynan et al., 1997; de Weerd et al., 2002). The potential allergenic impact of Pistacia species is of particular interest, especially since they are being introduced as ornamentals in urban parks and gardens in an attempt to increase public awareness of the value of natural flora (Staffolani et al., 2011; Velasco-Jiménez et al., 2014).

Recent research suggests that the Mediterranean area is becoming warmer due to climate change. This trend should influence the behaviour of Pistacia and other thermophilic species, lengthening their pollen season and modifying their distribution (Palacio et al., 2005; Giorgi and Lionello, 2008; Cecchi et al., 2010; García-Mozo et al., 2010, 2011).

Given the scarce information currently available, this study sought to chart daily and seasonal Pistacia airborne pollen counts in Córdoba city in conjunction with phenological flowering stages. It is hoped that the findings will provide sufficient information to fill the gaps in our knowledge of the aerobiology and phenology of these species.

2. Material and methods

The study was carried out in Córdoba (341642 X, 4192085 Y), a medium-sized city with a population of 329,618 (latest census, 2013); the city covers a surface area of 290.23 km² and is situated at 123 m above sea level. It has a Mediterranean climate with some continental features, characterised by cold, rainy winters and hot, dry summers. The mean annual temperature is 17.6 °C and means annual rainfall is 536 mm (1971–2000); prevailing winds (66%) are south-westerly (Instituto Nacional de Meteorología, 2001).

Aerobiological data were collected over the period 2009–2011 using a Hirst-type volumetric spore trap based on the impact principle (Hirst, 1952). The trap is located 22 m above ground level, on the roof of the Celestino Mutis Building at the Córdoba University Campus, roughly 8 km from the phenological sampling sites.

Samples were prepared and read following the guidelines laid down in the Quality and Management Manual published by the Spanish Aerobiology Network; hourly and daily mean pollen counts were expressed as pollen grains/m³ of air (Galán et al., 2007).

The start date of the pollen season was defined as the first day on which ≥ 1 pollen grain/m³ was recorded, with 5 subsequent days recording one or more pollen grains/m³; the end date was the last day on which at least one pollen grain/m³ was recorded and when no counts were recorded on 5 subsequent days. This definition of the pollen season was chosen since airborne Pistacia pollen count patterns are clearly-defined over time (Velasco-Jiménez et al., 2013).

Hourly data were recorded on rain-free days when pollen counts exceeded the daily mean for the main pollen period (Domínguez-Vilches et al., 1995).

Phenological monitoring of male flowers was carried out at 7 sampling sites containing both species, in the mountain areas, from now, Sierra de Córdoba, located at a representative range of altitudes and with a varying degree of exposure to sunlight (Fig. 1). Geographical features for each site are listed in Table 1.

Table 1

<table>
<thead>
<tr>
<th>Sampling points</th>
<th>UTM X</th>
<th>UTM Y</th>
<th>Altitude (m)</th>
<th>Incline (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Torreárboles</td>
<td>344494</td>
<td>4206480</td>
<td>547</td>
<td>35</td>
</tr>
<tr>
<td>2. Los Villares</td>
<td>341168</td>
<td>4202339</td>
<td>531</td>
<td>55</td>
</tr>
<tr>
<td>3. Las Ermitas</td>
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<td>4198884</td>
<td>523</td>
<td>20</td>
</tr>
<tr>
<td>4. Arroyo del Moral</td>
<td>341168</td>
<td>4205590</td>
<td>505</td>
<td>14</td>
</tr>
<tr>
<td>5. Las Jaras</td>
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<td>4203634</td>
<td>447</td>
<td>0</td>
</tr>
<tr>
<td>6. Río Guadalmó</td>
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<td>4205768</td>
<td>310</td>
<td>44</td>
</tr>
<tr>
<td>7. Río Guadiato</td>
<td>336189</td>
<td>4204600</td>
<td>332</td>
<td>35</td>
</tr>
</tbody>
</table>
identifying number. Field work consisted in weekly visits from January to May, in order to study the morphological changes taking place from budding to flower fall. For data collection purposes, the Extended BBCH Scale (Hack et al., 1992) was used. The scale was reduced to five stages (1 to 5) to facilitate the representation of results: Stage 1 (BBCH 51) — flower buds starting to swell, and separated by a small stalk; Stage 2 (BBCH 54) — inflorescence expanded, individual buds clearly visible, but still closed; Stage 3 (BBCH 61) — start of flowering (roughly 10% of flowers open); Stage 4 (BBCH 65) — full flowering (over 50% of flowers open); Stage 5 (BBCH 68) — flowers wilting (Fig. 2). Phenological development was recorded using a linear interpolation of weekly data, following Oteros et al. (2013). An individual was regarded as being at a given reproductive stage when at least 10% of the crown displayed the reproductive structures characteristic of that stage. The length of each stage in each study year and for each population was plotted on a bar chart.

3. Results

Table 2 shows meteorological and aerobiological data during the pollen season in the study years. Average temperature was lower during 2010 and higher in 2011, while rain was higher in 2010. Wind direction was from north-west in 2009 and 2011 and from south-west during 2010. In this year, wind speed was higher. About aerobiological data, the Pistacia species pollen season started in mid-March and ended in late April, lasting on average 41 days. The longest pollen season was recorded in 2009, when it started earlier and ended later than other years. The peak pollen count to the 2009 start-date, but ended considerably sooner. The pollen season in the study area took place in March and April, as also reported by Jordano (1988) for Doñana, Moreno-Durán et al. (1997) for Cádiz, Montserrat-Martí and Pérez-Rontomé (2002) for north-eastern Spain and Verdú and García-Fayos (2002) for various sites in Portugal, Spain, Italy and Israel.

Annual differences in the content of Pistacia pollen in the air can be due to the meteorological characteristics of each year. Thus, low temperature and high rainfall occurred during the pollen season in 2010 may have caused the delay in the pollen season and the decrease in pollen concentration reached.

Both Jordano (1989) and Verdú and García-Fayos (2002) regard these Pistacia species as wind-pollinated, taking into account their flower structure and high pollen production. However, the present data showed that airborne pollen counts were considerably lower than

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**Fig. 2.** Phenofases of the male flowers in Pistacia lentiscus L.
those recorded for other wind-pollinated species growing in the same areas of the Sierra, such as *Quercus* and *Pinus*, for which concentrations in the season of 10,000 and 800 pollen grains/m³, respectively, have been reported (Galán et al., 1991; García-Mozo et al., 2006). These low airborne pollen counts suggest a limited capacity for pollen-grain dispersal (Trigo et al., 2008). Furthermore, wind may also influence in the pollen count reached by the sampler. In 2010, the predominance wind direction was southwest and populations of *Pistacia* are located in the north-west of Córdoba city. This could also provoke the low concentrations of pollen grains detected this year. Anyway, if it is found to be allergenic, this pollen type should be taken into account when producing pollen calendars for potential allergy-sufferers. Similarly, number of trees introduced in future as ornamentals should be carefully controlled, since widespread planting could increase airborne pollen levels.

Analysis of diurnal variations showed that the highest *Pistacia* pollen counts were recorded in the evening. By contrast, other studies (Alcázar et al., 1999; Galán et al., 2000; Recio et al., 2002) report an increase in counts for other pollen types at midday, noting that the increase in air temperature accelerates pollen release and favours transport. *Pistacia* pollen, released in mountain areas close by, may be transported to the city on the mountain-valley winds flows, a finding also reported for *Quercus* by Galán et al. (1991).

Analysis of phenological data showed that flowering in both species took place earlier at the sunnier and open sites, as is the case of Los Villares and Las Ermitas. Flowering lasted longest in the most northerly sites (6 and 7), whose proximity to watercourses ensures a supply of water over a longer period. No significant differences in the timing of flowering were observed as a function of altitude, although research in other species suggests that flowering tends to take place later in populations at higher altitudes (Fornaciari et al., 2000; García-Mozo et al., 2006, 2009; Gómez-Casero et al., 2007; Oteros et al., 2013). The preflowering phase (swelling and separation of buds) lasted longer in *P. terebinthus* L., while subsequent phenophases were recorded earlier than in *P. lentiscus* L., with the result that flowering occur earlier. Ceballos et al. (1971); Castro-Diez and Monserrat-Martí (1998) report that *P. terebinthus* L. is more resistant to cold, and thus needs to accumulate more heat in order to break dormancy, leading to a longer preflowering stage. This was observed in 2011, which had higher temperatures, and *P. terebinthus* L. flowering was earlier regarding *P. lentiscus* L. Thereafter, however, flower development was faster than in the case of *P. lentiscus* L., where flowering phenophases took place earlier. The fact that in some study years and in some sampling points may have not observed phenophase 3 suggests to us that futures studies should increase the frequency of field visits at least 2 times per week in full flowering in order to collect this information.

Comparing the phenological phases with aerobiological data shows that the different peaks in the curve are related with the flowering in different sampling points. It seems that *P. lentiscus* L. contributes better to the pollen curve because peaks of this curve often coincide with the flowering period of this species. This was particularly observed in 2010 when the gap between the flowerings of both species was greater.

Given the clear relation between pollen release and flowering phenology, the joint use of aerobiological and phenological methods provides an efficient research tool (Jato et al., 2002; León-Ruiz et al., 2011). A number of studies report a positive correlation between the development of reproductive structures and airborne pollen counts for various tree species, including *Quercus* (Gómez-Casero et al., 2007), *Ulmus* and *Fraxinus* (Late and Bianchi, 1998), *Betula* (Jato et al., 2002, 2007), *Alnus*, Betula and *Corylus* (Kasprzyk, 2003) and *Cupressus* (Hidalgo et al., 2003). Phenological observations have also been used to confirm the real contribution of olive pollen (Orlandi et al., 2005;
García-Mozo et al., 2006) and grass pollens (León-Ruiz et al., 2011) to the overall pollen curve. Here, the timing of flowering phenophases matched the timing of the main pollen season. Although, future studies should increase the sampling points and the number of individuals in order to represent more communities of Pistacia and explain better the origin of the pollen.

Fig. 5. Daily pollen concentrations vs. phenological phases in both species in each sampling point during the three years of study.
5. Conclusions

It has been observed a clear relation between field flowering phenology of *Pistacia* and airborne pollen in the study area. *P. lentiscus* L. contributes better to the pollen curve, coinciding the peaks of this curve with the flowering period of this species. This pollen type should be taken into account when producing pollen calendars for potential allergy-sufferers. Similarly, number of trees introduced in future as ornamentals should be carefully controlled, since widespread planting could increase airborne pollen levels.

Acknowledgements

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