The aeropalynology of Es-Sénia airport, Oran, northwest Algeria

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A continuous study of atmospheric pollen in Oran Province, northwest Algeria using the Cour method was undertaken between April 2004 and April 2006. The pollen collecting device was placed in the meteorological station at Es-Sénia airport, near Oran city. It was found that the pollen harvest during the first year was 4230 grains, which is significantly higher than that in the second year which produced 2258 grains. These data gave a mean annual index of 3246 pollen grains, 99.7% of which were positively identified. Pollen from herbaceous plants (69.5%) proved significantly more abundant than arboreal and shrub pollen (27.9% and 2.3% respectively). The pollen types identified, in decreasing order of abundance, were Chenopodiaceae/Amaranthaceae, *Plantago, Olea*, wild Poaceae, *Lygeum,* Cupressaceae, Urticaceae, *Quercus*, *Pinus*, total Asteraceae, *Eucalyptus,* Brassicaceae, *Casuarina, Pistacia*, Arecaceae, Apiaceae, Thymeleaceae and *Rumex*. The abundance range was Chenopodiaceae/Amaranthaceae (41.4%) to *Rumex* (0.6%). The winter pollen spectrum largely comprised Arecaceae and Cupressaceae. Pollination during spring included most taxa, i.e. total Asteraceae, Brassicaceae, Chenopodiaceae/Amaranthaceae, *Lygeum*, *Olea*, *Pinus, Pistacia*, *Plantago,* wild Poaceae, *Quercus*, *Rumex* and Urticaceae. During the summer Apiaceae and *Eucalyptus* both pollinated, and *Casuarina* pollen was largely produced in autumn. A significant correspondence between the airborne pollen spectrum and the vegetation of the region was established.

Keywords: aeropalynology; Cour method; pollen calendar; Oran Province; northwest Algeria

1. Introduction

The analysis of atmospheric pollen provides information on the periodic cycles (phenology) exhibited by anemophilous (wind-pollinated) plants. It also helps to predict crop yields, aids the evaluation of climate change effects on floras at both local and regional scales (Gage et al. 1999; García-Mozo et al. 2006; Galán et al. 2008) and informs the public about levels of allergenic pollen (D'Amato et al. 2007). Anemophilous plants use wind to disperse their pollen, and produce large amounts of pollen in order to maintain biodiversity and sustainability. However wind-borne pollen can cause allergic reactions in humans and animals and, during the last 30 years, pollen allergies have significantly increased (Bousquet et al. 2001).

The aeropalynology of Oran Province, northwest Algeria was studied from 1977 to 1979 by Cambon (1981) using the Cour method (Cour 1974). Similar studies in the Algiers region of northern Algeria were undertaken from 1977 to 1979 by Korteby-Becila (1987) using the Durham method (Durham 1946), and by Gharnaout (2007) between 2001 and 2003 using the Hirst method (Hirst 1952). Other aeropalynological research in North Africa includes Aboulaich et al. (2013) in Morocco using the Hirst method and Oteros et al. (2014) in Tunisia using the Cour method. Similar research has been done in the region immediately northwards of North Africa. These studies include Belmonte & Roure (1991) and Boi & Llorens (2013) in Spain, Calleja et al. (2002) in Lebanon, Rizzi-Longo et al. (2007) and Cristofori & Cristofori (2010) in Italy, and Bilisik et al. (2008) in Turkey.

In Europe and North America, the number of localities studied for aeropalynology since the 1970s has expanded significantly, especially after the adoption of a consistent sampling method (Hirst 1952) and the establishment of international and national networks. Before the standardisation of sampling methodologies in aeropalynological studies, other methodologies can still provide relevant data (Belmonte et al. 1988; 2000; Oteros et al. 2014).

The aim of this study was to determine the annual airborne pollen spectrum at Es-Sénia airport, near Oran city in northwest Algeria (Figure 1). This will allow the amount and diversity of airborne pollen, the pollination periods of the major taxa, the intensity of pollen emissions and the relationship between airborne pollen and the vegetation in the region to be evaluated.

2. Material and methods

2.1. Area studied

The area studied was the meteorological station at Es-Sénia airport, near Oran city, Oran Province, northwest Algeria. This is located c. 430 km west of Algiers at latitude 35° 37' 19.11" N and longitude 0° 36' 59.46" W (Figure 1). The elevation of this site is 90 m amsl. Oran Province is bordered to the north by the Mediterranean Sea, and is surrounded by the provinces of Ain Témouchent, Mascara, Mostaganem and Sidi-Bel-Abbes. The climate of Oran includes a dry summer season between June and September, and a variably rainy season between November and April (Bagnouls & Gaussen 1953). It is within the Mediterranean semi-arid with mild winter bioclimatic region (Stewart 1969).

The vegetation of the Oran area is dominated by the sandarac gum tree (*Tetraclinis articulata*), which is endemic to North Africa, Malta and southern Spain. Other arboreal species present are aleppo pine (*Pinus halepensis*), cork oak (*Quercus suber*), evergreen oak (*Quercus ilex*), jujube (*Ziziphus jujube*) and olive (*Olea europaea*). The flora also includes esparto grass (*Stipa tenacissima*), flax-leaved daphne (*Daphne gnidium*), joint pine (*Ephedra fragilis*), kermes oak (*Quercus coccifera*), marram grass (*Ammophila arenaria*), mastic (*Pistacia lentiscus*), Mediterranean fan palm (*Chamaerops humilis*), Mediterranean heather (*Erica multiflora*), phoenicean juniper (*Juniperus phoenicea*) and retama broom (*Retama bovei*) (see Alcaraz 1977). The cultivated areas largely comprise stands of cereals, fruit trees and vines. In the coastal areas with relatively salty soil, most of the plants are within the families Chenopodiaceae, Compositae, Cruciferae, Plantaginaceae, Polygonaceae and Thymelaeaceae, together with albardine (*Lygeum spartum*) and salt cedar (*Tamarix*).

2.2. Sampling methodology

The pollen collection in this study was all done using a Cour device (Cour 1974), and the laboratory procedures were those described by Belmonte (1988). The collecting device was placed 3 m above ground level at the meteorological station at Es-Sénia airport, Oran, and it functioned continuously between April 2004 and April 2006. The pollen-receiving surface in the Cour trap is a filter comprising five layers of gauze impregnated by an adhesive containing silicone and mounted in a square plastic support with 20 cm sides, thereby providing a capture surface of 400 cm^2. A filter was exposed for one week only, and replaced each Saturday at 09.00 h. Cour devices are normally placed in meteorological stations which have a wind-powered anemometer. These register the length of the column of running air, which is needed for the calculation of the number of pollen grains in the volume of air that passed through the filter in the Cour device (Cour 1974).

The post-exposure filters were submitted to physico-chemical treatment in order to eliminate the gauze fibres and mineral particles, then the pollen grains were subjected to acetolysis and stained using fuchsin. The pure pollen residue was mixed with a known volume of phenolic glycerol-gelatine, then diluted. At the end of the laboratory treatment, each filter provided a sample residue of a specific volume. Following homogenisation, 0.05 ml of the residue was used to make a microscope slide. Pollen grains were counted throughout three longitudinal traverses. The counting was continued depending on the number of new taxa encountered during the third traverse (Gros 1984; Belmonte 1988). The summed mean weekly concentrations of pollen grains per m^3 of air over one year (the Annual Index or AI) are given in Table 1. The AI is an important parameter and allows data gathered using a Cour device to be compared with similar information derived from a Hirst trap. All the relevant parameters involved (i.e. wind run during the filter exposure period, surface of filter treated, volume of sample, proportion of the volume used in slide preparation, number of traverses counted and the optical parameters of the microscope) were taken into account. The mean weekly pollen concentrations of the principal pollen taxa are depicted in the form of a pollen calendar (Table 2). For this procedure, the pollen concentrations were classified into four categories. These are no pollen, low pollen concentration, high pollen concentration and very high pollen concentration. The Chenopodiaceae/Amaranthaceae pollen values proved extremely high compared to other taxa (Table 2).

3. Results

3.1. The analytical results

The sum of the mean weekly pollen concentrations (mean AI) for the period studied was 3246 pollen grains, only 0.3% of which could not be identified. The pollen harvest during year one (i.e. between April 2004 and March 2005) was 4230 grains. This is significantly higher than that of year two (i.e. between April 2005 and March 2006) which was 2258 grains. The pollen assemblages are dominated by grains from herbaceous plants (69.5%), with arboreal and shrub pollen being distinctly subordinate (27.9 % and 2.3% respectively) (Figure 2). Moreover, Chenopodiaceae/Amaranthaceae pollen is the major component in the herb pollen fluxes, representing 1345 grains or 41.4% of the mean total pollen flow (Table 1).

3.2. The airborne pollen spectrum and pollen calendar

A pollen spectrum for the Oran area is presented in Table 1, and comprises the main taxa. It includes forms whose mean annual index was >0.6% of the total pollen assemblage. Another 30 pollen taxa were identified which are subordinate (Table 1).

3.2.1. Pollen representing >5% of the total spectrum

The airborne pollen of Chenopodiaceae/Amaranthaceae (goosefoots) is overwhelmingly the most abundant at Es-Sénia airport, representing 41.4% of the palynoflora (Table 1). It was present throughout the year, but was most consistent and numerous between mid March and late October. However, the highest levels were the nine consecutive weeks between the second week of April (week 15) to the first week of June (week 23) (Table 2). Similarly high levels of airborne Chenopodiaceae/Amaranthaceae pollen have also been observed in Vigo, northwest Spain, where they are implicated as the cause of 11% of pollen-related allergies (Belmonte et al. 1998).

3.2.2. Pollen representing >1% of the total spectrum

This important group of pollen types comprises fourteen types which are described below.

Plantago (plantain/fleawort). This was the second most abundant airborne pollen taxon at Oran. Pollination began during the third week of March (week 11) and ended by the second week of September (week 37), with 12 weeks of very high pollen concentration between early April (week 14) and the end of June (week 25) (Table 2). This period corresponds to that of the flowering of five species of plantain, *Plantago coronopus*, *Plantago crassifolia, Plantago lagopus*, *Plantago lanceolata* and *Plantago major* (see Quezel & Santa 1962; 1963). According to Belmonte et al. (1998) this pollen was recognised as a cause of 9% of pollinosis (hay fever) in northwest Spain. The allergenicity index of *Plantago* pollen is very high (Gharnaout 2007).

Cupressaceae. Pollen from the cypress family (Cupressaceae) is the fifth most abundant type in the air at Oran and pollination was divided into two periods. The first occurred in the first quarter of the year (January to March) and this is more intense than the second period, in the final quarter (October to December). Pollen concentrations were very high from the third week of February (week 7) to the last week of March (week 12), and from the end of November (week 48) to the first week of December (week 49) (Table 2). A specific allergy to cypress pollen may result in allergic asthma, conjunctivitis, dry cough and/or rhinitis (Shahali 2011).

Urticaceae. Pollen from the family Urticaceae (nettles) occupied the sixth highest position in the pollen spectrum at Oran, and this type had the longest annual pollination period. Phases of very high Urticaceae pollen concentration were spread over several periods, for example from the second week of March (week 10) to early June (week 23) (Table 2). During the latter interval, *Parietaria mauritanica*, *Parietaria officinalis, Urtica membranacea* and *Urtica urens* are typically in flower (Maire 1961). *Parietaria* is known to have a high allergenicity index and it causes significant levels of pollinosis throughout the Mediterranean region (Charpin et al. 1978; Gharnaout 2007). *Parietaria judaica* and *Parietaria officinalis* are the main allergenic species of this genus (D'Amato et al. 2007). This genus causes 12% of overall pollinosis, and is second only to Poaceae pollen in terms of its allergenicity (Belmonte et al. 1998).

Brassicaceae. The family Brassicaceae (cabbage/mustard) is eleventh position in the Oran airborne pollen spectrum. Pollination occurred from the second week of February (week 6) to the fourth week of July (week 30). There were two very high pollen concentrations, the second and last weeks of April (weeks 15 and 18 respectively) (Table 2). Allergies caused by Brassicaceae pollen are suffered by young children, often under 3 years old (Rancé 2003).

Pinus (pine). This important genus lies eighth in the Oran pollen spectrum, Pollination took place in a single period, from early March (week 9) to late June (week 25), with a maximum in mid-March (weeks 10 to 12) and the final week of April (week 18) (Table 2). The allergenicity index of *Pinus* is very low (Gharnaout 2007).

Lygeum. This genus of the family Poaceae (grasses) grows in semi-arid conditions and is represented at Oran by a single species, *Lygeum spartum* (esparto grass or albardine). This form appeared in the airborne pollen spectra in the second week of March (week 10) and continued until the third week of May (week 21) with one week of especially high concentrations (the fourth week of March, week 12) (Table 2). This flowering period is consistent with the findings of Maire (1953).

Pistacia (pistachio). This distinctive member of the cashew or sumac family Anacardiaceae is in thirteenth position in the Oran pollen spectrum. On average, its flowering lasted for five weeks from the last week of March (week 13) to the fourth week of April (week 17). The main phase of pollen production was the three successive weeks from week 13 to week 15 (Table 2).

Wild Poaceae. These grasses occupy fourth position in the pollen spectra at Oran. This pollen is present in the air at this locality for virtually the entire year, with a very high concentration for the 12 successive weeks, from the first week of April (week 14) to the third week of June (week 25) (Table 2). The end of flowering is in October. No cereal pollen from the family Poaceae was found. Poaceae pollen is one of the main causes of pollen allergy in industrialised countries (Abreu et al. 2008; De Linares et al. 2010).

Asteraceae. Pollen from the family Asteraceae (daisys) is in ninth position in this pollen spectrum. The majority of the Asteraceae pollen is the more echinulate types (Liguliflorae), as opposed to the fenestrated Asteraceae (Tubuliflorae) and *Artemisia. Centaurea* pollen types (knapweed) dominated the total Asteraceae pollen. The pollination lasted from the second week of February (week 6) to the last week of December (week 53); the highest concentrations were in April (weeks 17 and 18) (Table 2). Within the family Asteraceae, the genus *Artemisia* (mugwort) is the most allergenic (Gharnaout 2007).

Quercus (oak). *Quercus* occupies seventh position in the airborne pollen spectra and is mainly represented by pollen from evergreen species. Their flowering lasted from the first week of April (week 14) to mid July (week 29). The highest pollination was from the second week of April (week 15) to the end of June (week 25) with maximum values in April (weeks 16 to 18) (Table 2). The allergenic potential of *Quercus* is low (Korteby-Becila 1987).

Oleaceae. The olive family or Oleaceae is in third position and was chiefly represented by olive (*Olea*) pollen. Pollination commenced during the third week of April (week 16) and ended in the last week of June (week 26). Especially high concentrations were recorded for eight weeks between the fourth week of April (week 17) to the second week of June (week 24) (Table 2). It has recently been shown that pollen from the European olive (*Olea europaea*) is highly allergenic due to the allergen Ole e 1 (De Linares et al. 2007).

Eucalyptus. This important genus of the family Myrtaceae is tenth in the overall ranking. Eucalyptus is an introduced genus in Algeria, and it readily adapted to the environment, in particular the soil. The flowering period was from the second week of June (week 24) to the first week of October (week 41), with four weeks of especially high pollen concentrations in July (weeks 29 to 31) and September (week 37). Pollen concentration was especially low in late March (week 13) (Table 2).

Casuarina. This genus belongs to the family Casuarinaceae (the she-oaks). *Casuarina* pollen lies twelfth in the spectrum at Oran. Pollination occurred during autumn, with a phase of high pollination in 4 successive weeks, from the last week of September (week 40) to the third week of October (week 43) (Table 2). Pollen of *Casuarina esquitifolia* (the Filao tree) is known to be responsible for seasonal pollinosis between April and May, and in September–November (Omarjee et al. 2013).

Arecaceae (the palm tree family). Ranked last in the spectrum, this pollen type exhibited the shortest pollination period of all the taxa studied, lasting only for the third week of December (week 51) (Table 2). In this period, concentration was very high in the first year studied (2004-2005). Arecaceae pollen is only slightly allergenic, but it can cause seasonal allergies (Raffard 2003; Gharnaout 2007).

3.2.3. Pollen representing 0.5–1.0% of the total spectrum

The Polygonaceae (knotweeds) were represented by *Rumex*, which pollinated from the last week of March (week 13) to the first week of May (week 19); the highest concentration was collected during the fourth and fifth weeks of April (weeks 17 and 18) (Table 2). The Apiaceae (parsley family) lies in fifteenth position in the Oran airborne pollen spectrum. It has a single pollination period from the first week of June (week 23) to the third week of July (week 29). Particularly high concentrations were observed during five successive weeks from the second week of June (week 24) to the second week of July (week 28) (Table 2). Thymelaeaceae pollen is not depicted in the calendar (Table 2) due to its discontinuous distribution throughout the year. This is a dominantly arboreal family within the order Malvales.

3.2.4. Pollen representing <0.5 of the total spectrum

In the present study, this category of pollen expression represents between one and nine grains only. The highest percentage was of *Acacia* (0.3%). Also present were *Ailanthus, Alnus, Betula,* Boraginaceae, Cannabaceae, *Castanea, Cedrus,* Cistaceae, *Citrus, Coriaria,* Cyperaceae, *Ephedra,* Ericaceae, *Euphorbia,* herbaceous Fabaceae, *Geranium, Lotus, Mercurialis,* herbaceous monocotyledons, *Morus, Myoporum,* Papaveraceae, Ranunculaceae, Rubiaceae, *Sambucus, Schinus,* Solanaceae, *Tamarix* and *Vitis* (Table 1).

3.3. Pollen distribution throughout the year

Pollen production in winter was largely from the Arecaceae, which pollinated for only one week, and the Cupressaceae. Most pollen grains were collected in the spring; these forms include Asteraceae, Brassicaceae, Chenopodiaceae/Amaranthaceae, *Lygeum, Olea, Pinus, Pistacia, Plantago,* wild Poaceae, *Quercus, Rumex* and Urticaceae. Markedly high pollen concentrations were produced by *Plantago* and wild Poaceae during 12 consecutive weeks, Chenopodiaceae/Amaranthaceae during nine weeks and *Olea* eight weeks. In summer, the Apiaceae and *Eucalyptus* produced pollen. In autumn, only *Casuarina* pollinated, and this genus had a pollination period of four weeks. In the Oran pollen calendar, these taxa are clearly represented in a natural and coherent annual/seasonal phenological order (Table 2).

4. Discussion

There is normally variation in the annual pollen indexes in successive years (Belmonte et al. 1998). In this study, the large pollen yield during the first year (2004–2005) was chiefly due to the very high concentration of herb pollen, mainly Chenopodiaceae/Amaranthaceae, followed by *Plantago, Olea* and wild Poaceae (Tables 1, 2). Airborne pollen is usually a reflection of the vegetation immediately surrounding the sampling site, although long range transport may also contribute (Belmonte et al. 2008, Sofiev et al. 2013). This study has enabled the establishment of the airborne pollen calendar for Oran, and hence allowing a comparison with the autochthonous vegetation of the region.

By far the most abundant pollen type is Chenopodiaceae/Amaranthaceae (41.4% of the total airborne pollen). The main source of this pollen type is the halophilic vegetation surrounding salt lake Sebkha which is c. 15 km south of Oran (Morgan 1982; Morgan & Boy 1982; Ministère de l’Agriculture 2001). The length of the period of pollination is also relevant; Chenopodiaceae/Amaranthaceae pollen is produced for a sustained interval (Cambon 1981; Korteby-Becila 1987; Belmonte & Roure 1991; Gharnaout 2007; Murray et al. 2010). Other plants surrounding the salt lake Sebkha area, and present in the airborne pollen spectra, (i.e. autochthonous vegetation) but in far smaller proportions are Apiaceae, Asteraceae, Brassicaceae, *Casuarina*, Cupressaceae, *Eucalyptus*, *Lygeum, Olea, Pistacia*, *Plantago*, wild Poaceae, *Rumex* and Urticaceae (Ministère de l'Agriculture 2001).

The relatively high proportion of Cupressaceae pollen (6.3%) is explained by its abundance in the autochthonous vegetation. Representatives of this family include *Cupressus* spp., *Juniperus oxycedrus*, *Juniperus phoenicea* and *Tetraclinis articulata* (see Santa & Daumas 1958). This pollen type is widespread in the Mediterranean area from the beginning of the year until autumn (Maire 1952). Cupressaceae pollination dynamics, with high concentrations in the winter, exhibit a consistent pattern around the Mediterranean (Cambon 1981; Korteby-Becila 1987, Belmonte & Roure 1991; Belmonte et al. 1998; 2008; Gharnaout 2007). However at mountain sites, such as Seu d'Urgell in northeast Spain, *Juniperus* predominates and the pollen curves peak during spring rather than in winter (Belmonte et al. 1999).

Urticaceae pollen is also relatively common (5.0%). In Oran, Urticaceae pollen was recorded throughout the year with the maximum between March and June. Other studies from Algeria have noted only spring pollination of this family (Cambon 1981; Korteby-Becila (1987; Gharnaout 2007). Appreciable proportions (2.2%) of Brassicaceae pollen were also recorded (Table 1). Other investigations in the region recorded significantly lower levels (Cambon 1981; Korteby-Becila 1987; Gharnaout 2007). *Plantago* represents 9.3% in the pollen spectrum; it exhibits very high pollination levels in spring over 12 consecutive weeks (Tables 1, 2). Cambon (1981), Korteby-Becila (1987) and Gharnaout (2007) reported similar pollination phases in the region. However, in northern Spain, this pollen production phase extends until autumn (Belmonte et al. 1998).

Wild Poaceae pollen represent 5.3% of the pollen spectrum (Table 1). This appears unlikely in terms of the landscape of the region, much of which appears to be steppe. The maximum pollination period, over 12 consecutive weeks, is longer than that recorded by Cambon (1981), Korteby-Becila (1987), Belmonte et al. (2000) and Gharnout (2007). However, it is shorter than that of Rizzi-Longo et al. (2007). In Spain, these pollen are more numerous in central and northwest Spain than in the south and west of this country (Fernández-González et al. 1999). Among the wild Poaceae, *Lygeum spartum* (1.1%) grows in northern Algeria in semiarid conditions (Maire 1953). This species pollinates in spring, with one week of very high pollination levels in March (Cambon 1981). *Pistacia* (1.2%) usually grows in association with *Olea* and *Ziziphus* (jujube). The maximum pollination is in spring, between late March and late May. This phenomenon was also observed by Cambon

(1981), Korteby-Becila (1987) and Belmonte & Roure (1991). Total Asteraceae, mostly Liguliflorae, attained 3.0% (Table 1). In this study, the maximum pollination was only in spring. Other authors have recorded this event between spring and early winter (Cambon 1981; Korteby-Becila 1987; Gharnaout 2007).

Cultivated and/or wild *Olea* is well represented on the pollen calendar herein (7.5%). This is probably due to the importance of olive cultivation in the region. The high pollination in Oran is during spring (between late April and mid June), and this period is similar to those recorded by Cambon (1981), Korteby-Becila (1987), Belmonte et al. (2000) and Gharnaout (2007). However in Bahía Blanca, Argentina, a single short period of pollination of *Olea* was observed in autumn (Murray et al. 2010). Generally, peak *Olea* pollen concentrations in Spain were recorded during May and June; the peaks depending upon meteorological and topographical conditions (Ribeiro et al. 2006).

Rumex pollen attained 0.6%) and the maximum pollen production was during spring (late April) (Tables 1, 2). This pollination phase is significantly shorter than those reported by Cambon (1981), Korteby-Becila (1987), Gharnaout (2007) and Rizzi-Longo et al (2007). For the Apiaceae (0.6%), summer was the main period of high pollination (Table 2). This is similar to other reports of this family (Cambon 1981; Rizzi-Longo et al. 2007). The presence of Thymelaeaceae (0.6%) reflects the local vegetation. However, this family is not listed in the pollen calendar because the distribution is discontinuous throughout the year (Table 2).

Eucalyptus (2.7%) is widely used in reforestation because of its rapid growth and its high levels of water retention. The high pollen concentration in July observed herein is similar to pollination intervals recorded by Cambon (1981), Korteby-Becila (1987) and Gharnaout (2007). In northern Spain, this event is in spring (Belmonte et al. 1998) and, in Bahía Blanca in Argentina, it is during autumn and winter (Murray et al. 2010). *Casuarina* (1.3%) is frequently cultivated as an ornamental tree and, on the coast, stands are widely used as windbreaks. The maximum pollen production in this study was between late September to late October. This pollination period corresponds to those of *Casuarina equisetifolia*, *Casuarina glauca*, *Casuarina tenuissima* and *Casuarina torulosa* (Maire 1961). The autumn pollination of this genus is also consistent with the observations of Cambon (1981), Korteby-Becila (1987) and Trigo et al (1999).

By contrast, the pollen from allochthonous vegetation is from the Arecaceae, Betula, *Pinus* and *Quercus.* Arecaceae pollen was recorded for only one week in December 2004 at Oran in significant proportions, 1.1% of the total pollen (Tables 1, 2). Palms are present both as ornamental trees (e.g. *Phoenix*) and in the natural vegetation of uncultivated areas (e.g. *Chamaerops humilis*). By contrast, in Algiers this pollination event occurs in spring, summer and winter (Korteby-Becila, 1987; Gharnaout, 2007). Cambon (1981) found that, in Oran, palm pollen normally represents only 0.08% of the total pollen and it is considered to be of Mediterranean provenance.

Quercus (4.2% of the total pollen spectrum) may include pollen from neighbouring regions which are rich in this genus (Santa & Daumas 1958). At Oran, the maximum period of high pollination in spring, shows the same pattern as observed by Cambon (1981), Korteby-Becila (1987), Belmonte et al. (1998), Gharnaout (2007) and Rizzi-Longo et al. (2007). In the Mediterranean region, the maximum and minimum temperatures are the main parameters influencing the daily pollen emission of *Quercus* (García-Mozo et al. 2006).

Pinus attained 3.8% of the total pollen, and at least some this is probably regional as opposed to local. In this study, the maximum of *Pinus* pollen was in April, like in Oran (Cambon 1981) and northern Spain (Belmonte et al. 1998). However studies in Algiers have recorded high concentrations in winter (Korteby-Becila 1987; Gharnaout 2007) and between late August to late October (Murray et al. 2010). *Betula* (birch) pollen, at 1%, is the only taxon which was far-travelled; this arboreal genus is absent throughout North Africa.

5. Conclusions

A Cour device was used to collect airbourne pollen near Oran city, northwest Algeria between 2004 and 2006, and the resultant data were recorded using the maximum weekly average method. This allowed the airborne pollen spectrum and calendar to be determined for this two-year interval (Tables 1, 2). A good correspondence was found between the endemic vegetation in Oran and the airborne pollen.

The pollen harvest in year one (2004-2005) was much higher than that of the second year (2005-2006). Pollen from herbs dominate the assemblages, followed by tree pollen then shrubs. The dominance of herbs is due to high concentrations of Chenopodiaceae/Amaranthaceae, followed by *Plantago*, wild Poaceae and Asteraceae. The relative importance of allochthonous pollen at Oran is low; most pollen is from autochthonous vegetation. Specifically, in spring, the abundance of Chenopodiaceae/Amaranthaceae from Sebkha reflect dense and large populations of goosefoots in the region. This is followed by

Plantago and wild Poaceae which have the most sustained high concentrations, i.e. 12 consecutive weeks from early April to late June. In summer, Apiaceae, Asteraceae, Brassicaceae, *Eucalyptus*, *Lygeum*, *Olea*, *Pistacia*, *Rumex* and Urticaceae pollinate. By contrast, only the genus *Casuarina* pollinates in autumn.

Pollen from allochthonous vegetation includes Arecaceae (winter), *Pinus* and *Quercus* (spring). A single specimen of far-travelled birch (*Betula)* pollen was blown to northwest Algeria by the mistral, a strong northwesterly wind. Most of the highly allergenic pollen are from the autochthonous plants, specifically Asteraceae, Brassicaceae, *Casuarina*, Chenopodiaceae/Amaranthaceae, Cupressaceae, *Olea*, *Plantago*, wild Poaceae and Urticaceae,

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Display material captions:

Figure 1. A sketch map illustrating the location of the pollen collection site at Es-Sénia airport, near Oran city, Oran Province, northwest Algeria.

Figure 2. The absolute numbers counted (on the vertical axis) and percentages of pollen grains (herbs, trees, shrubs and indeterminate) recorded in this study. These data were given for each of the two years studied (in the left hand and centre columns), and as means (the right hand column).

Table 1. The pollen spectrum between 2004 and 2006 at Es-Sénia airport, Oran city, Algeria. The Annual Index and the percentage with respect to the total pollen grains counted is given for each pollen type for 2004–2005, 2005–2006 and 2004–2006. *****AI = Annual Index. This is the sum of the mean weekly concentrations of pollen per m^3 of air during the respective year(s). **Others. These are pollen types other than those listed specifically (above in the table). They are, in alphabetical order: *Acacia*; *Ailanthus*; *Alnus*; *Betula*; Boraginaceae; Cannabaceae; *Castanea*; *Cedrus*; Cistaceae; *Citrus*; *Coriaria*; Cyperaceae; Ericaceae; *Ephedra*; *Euphorbia*; herbaceous Fabaceae; *Geranium*; herbaceous monocotyledons; *Lotus*; *Mercurialis*; *Morus*; *Myoporum*; Papaveraceae; Ranunculaceae; Rubiaceae; *Sambucus*; *Schinus*; Solanaceae; *Tamarix*; and *Vitis.*

Table 2. A pollen calendar for between 2004 and 2006 at Es-Sénia airport, Oran city, Algeria giving the concentrations of pollen grains per m^3 of air. * = the numbers of the weeks within each month; ** = the numbers of weeks within the year. For each week, the respective pollen type is designated as being low in concentration (a small circle), high in concentration (grey ornament) or very high in concentration (black ornament). There are three different concentration parametisations. For the Chenopodiaceae/Amaranthaceae, low is 0.1–16.0 pollen grains per m^3 of air, high is 16.1–50.0 pollen grains per m^3 of air and very high is >50.1 pollen grains per m^3 of air. For the shrubs and other herbs, low is 0.1–2.0 pollen grains per m^3 of air, high is 2.1–6.0 pollen grains per m^3 of air and very high is >6.1 pollen grains per m^3 of air. For the trees, low is 0.1–3.0 pollen grains per m^3 of air, high is 3.1–10.0 pollen grains per m^3 of air and very high is >10.1 pollen grains per m^3 of air.