

# Pollen spectrum in Northern Tunis, Tunisia

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**Abstract** This study has been focused on airborne pollen concentration in Northern Tunis. Pollen has been detected by a volumetric Hirst-type spore trap. This suction sampler was placed for two hydrologic years in the area of Mornag, northeast of Tunisia (36°40N; 10°17E). Fifty-two taxa were identified with heterogeneous daily pollen concentrations and a dominance of anemophilous plants. The main pollen types detected in the atmosphere were *Olea europaea* (38.7 and 20.75%), *Cupressus* (33.57 and 55.4%), *Urticaceae* (9.22 and 12.24%), *Poaceae* (3.55 and 3.32%), *Mercurialis annua* (2.96 and 1.6%) and *Amaranthaceae* (2.49 and 1.55%). The monthly pollen spectrum indicated a seasonal periodicity of airborne pollen with the main pollen season during spring. Two

pollen seasons have been observed during these hydrologic years, due to both *Cupressus* and *Amaranthaceae* airborne pollen is represented during winter or spring, and also during autumn and late summer, respectively. Other pollen types represent a long pollen season, i.e., *Urticaceae*, starting in autumn and following until late spring. Daily pollen concentration showed a different behavior during the flowering season between both years, observing differences related to pollen index. Correlation between daily pollen concentrations of the dominant taxa showed a positive and significant correlation between airborne pollen concentrations of spring-pollinated taxa and mean temperature, but negative with maximum temperature, humidity and rainfall. In the case of minimum temperature, a different response, positive for trees and negative for herbaceous plants, has been observed.

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## 1 Introduction

Airborne pollen studies provide important information on biodiversity and spatiotemporal distribution of flowering on anemophilous plants (Abreu et al. 2003; Galán et al. 2016; Main 2003; Martínez-Bracero et al. 2015; Sabit et al. 2015), reporting the different pollen types present in the atmosphere in a given area. The

qualitative and quantitative features of airborne pollen composition depend not only on the vegetal cover and pollen production by plants, but they are also directly related to pollen emission and weather fluctuations. Different studies have shown relationship between pollen season definition and airborne pollen behavior related to different climatologic and meteorological parameters, i.e., maximum, minimum or mean temperature, relative humidity, rainfall and wind direction and speed (Chafai-Ketfi and Boughdiri 2004; García-Mozo et al. 2007; Ribeiro et al. 2003). On the other hand, airborne pollen is related to air quality and air pollutants can affect pollen and aeroallergen dispersal and composition (Cuinica et al. 2014; D'Amato et al. 2014; Ferreira et al. 2015).

Airborne pollen datasets represent a good bio-indicator of potential anemophilous species richness and also valuable information about the impact of climate change on these plants, as shown in previous papers (Alcázar et al. 2009; Cariñanos et al. 2014; Galán et al. 2016).

The present study sought: (1) to establish the pollen spectrum in the region of Mornag (Northern Tunisia) during two hydrologic years; (2) to classify the main pollen types in the studied region according to their dominance and (3) to evaluate the correlation between airborne pollen and different meteorological parameters.

## 2 Materials and methods

### 2.1 Sampling location

The aerobiological study was carried out in Mornag in the northeast of Tunisia (36°40N; 10°17E) (Fig. 1). It is a semi-arid region (Office of Development of the Northwest 2004) situated in the southern east of the capital Tunis at 40 km and 32 m above sea level. The climate is Mediterranean, characterized by cold and rainy winters and hot and dry summers. The mean annual temperature is about 18.5 °C, and the annual cumulative rainfall is 466 mm, occurring mainly during winter season and with an irregular distribution; prevailing wind are from northwest (NIM 2011). Data for the main meteorological parameters during the two studied hydrologic years 2010–2011 and 2011–2012 were provided by the weather station

nearest to the monitoring unit and the National Institute of Meteorology of Tunis (NIM) (2011–2012).

### 2.2 Vegetation in the sampling location

The studied region is situated next to a national park and a large forest with diverse vegetation (Fig. 2): *Cupressus*, *Quercus*, *Pinus*, *Cedrus*, *Myrtaceae*, *Populus*, *Alnus*, *Fraxinus ornus*, *Fraxinus excelsior* and *Ostrya*. Some trees or shrubs are used for ornamental purposes in the city, i.e., *Chamearops humilis*, *Phillyrea* and *Acacia* (Ghrabi-Gammar and Véla 2008; Radford et al. 2011), while other are present in some private gardens, such as *Citrus*, *Olea europaea*, *Laurus* or *Rosaceae*. Numerous agricultural exploitations were implanted in this region, mainly arboreal cultures such as *Olea europaea*, *Rosaceae* and *Vitis vinifera*, additionally to small surfaces occupied by *Fagus* and *Poaceae*. The native vegetation is mainly composed of herbaceous plants better represented by *Poaceae*, *Asteraceae*, *Euphorbiaceae*, *Plantaginaceae*, *Amaranthaceae*, *Malvaceae*, *Brassicaceae*, *Urticaceae* and *Fabaceae* (Ghrabi-Gammar and Véla 2008).

### 2.3 Airborne pollen sampling

Pollen sampling was performed using a Hirst-type volumetric spore trap (Hirst 1952), model Lanzoni VPPS-2000, placed at 12 m above ground level, with a free and continue air flow during two hydrologic years, from October 2010 to September 2012. Sample analysis was realized following the standard protocol proposed by the Spanish Aerobiology Network (REA) (Galán et al. 2007). Daily data have been expressed as daily average of pollen grain per cubic meter of air. The pollen season was defined using the 98% method, omitting the 1% at the beginning and at the end of the pollen season (Nilsson and Persson 1981). The different pollen types were clustered to different groups according to their contribution in the total pollen index (PI) represented by the percentage of each taxa following the scale classification adopted by Aboulaich (2012).

### 2.4 Statistical analysis

Spearman's correlation test was used to identify potential correlations between daily pollen concentrations of

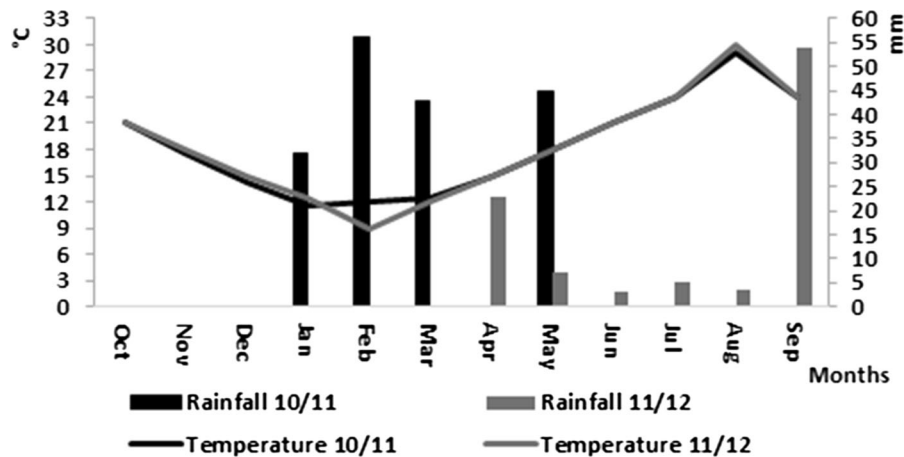


**Fig. 1** Monthly variation of the main meteorological data: mean temperature and rainfall in Northern Tunisia, Mornag, in 2010–2011 and 2011–2012

**Fig. 2** Air sampling location



the most dominant taxa and daily meteorological parameters, during the studied period. Calculations were performed using the SPSS statistical software.

### 3 Results

Monthly mean temperature and rainfall provided by the NIM are presented in Fig. 1. It can be observed mean temperature fluctuation, ranging from 10 to 15 °C, during the coldest months (January and February), and near to 30 °C during the hottest months for both study years (July and August). However, the first studied year (2010–2011) was rainier (271.5 mm) than 2011–2012 (95.5 mm), with important precipitations recorded in winter and spring.

During the two hydrologic years, the pollen index (PI) was 30,049 during 2010–2011 and 39,833 during 2011–2012, corresponding to 52 pollen types, mostly represented by anemophilous species. Higher pollen concentrations were recorded during the second hydrologic year 2011–2012, representing 57% of all the pollen score.

Monthly airborne pollen concentration from different pollen types was illustrated in the pollen spectrum (Fig. 3). These results have shown that 55% of pollen was emitted by herbaceous plants. Most taxa follow a seasonal spring pattern. Pollen of *Urticaceae* and *Mercurialis annua* remained into the atmosphere over a long period of time and with high airborne pollen levels starting in winter until late spring. On the

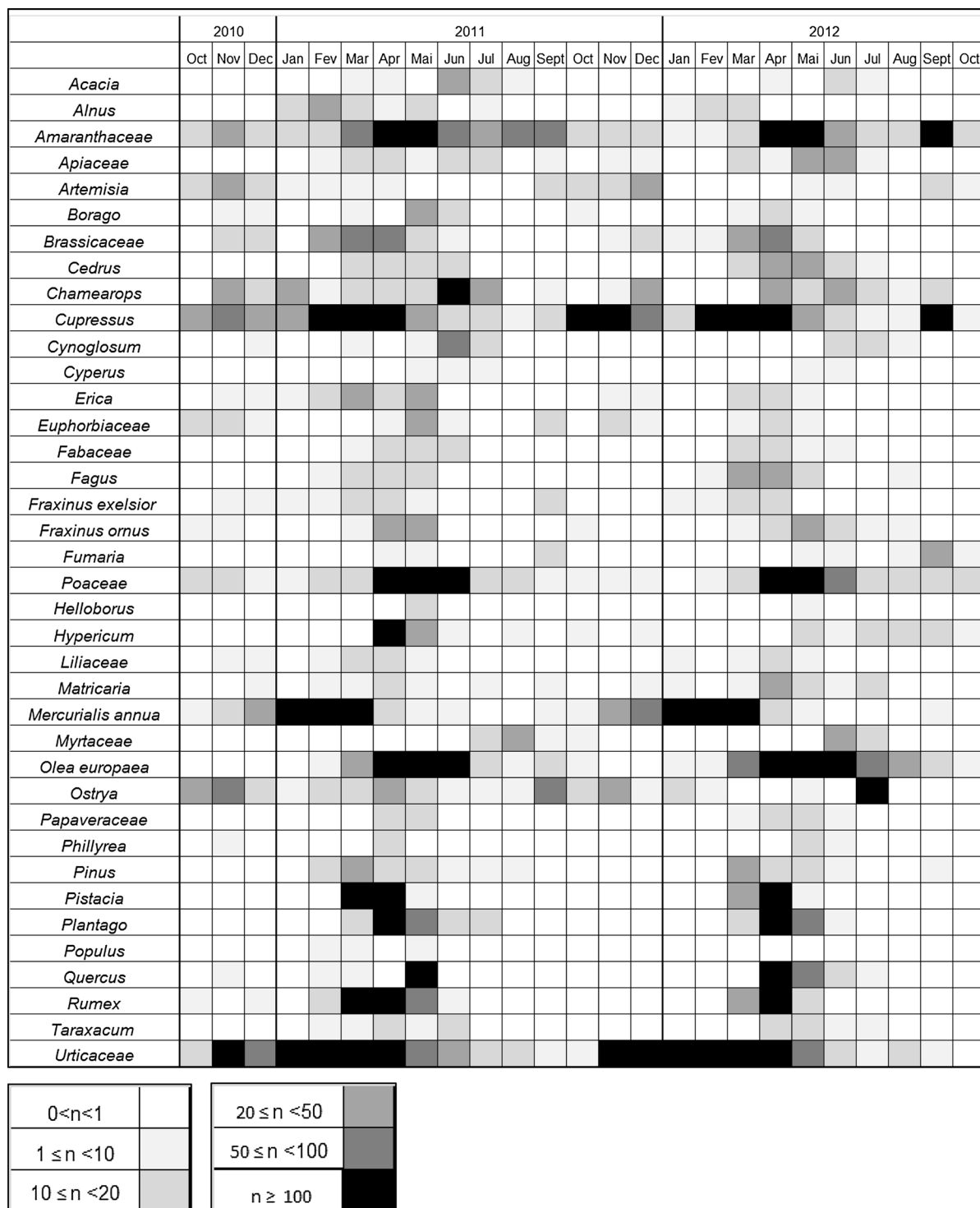


**Fig. 3** Monthly pollen index of the main identified taxa in Mornag (Northern Tunisia) during 2010–2011/2011–2012

contrary, other pollen types are represented with low pollen concentrations and irregular oscillations (i.e., *Fagus*, *Euphorbiaceae*). Moreover, pollen from *Cupressus* showed two different flowering periods, the first during autumn and the second during end of winter–spring. *Amaranthaceae* also showed two different pollen seasons, but in this case during spring and late summer.

Regarding the sharp heterogeneity of airborne pollen concentrations during the monitoring period, the different taxa were clustered according their individual contribution in the PI and following the classification scale adopted by Aboulaich (2012). Five different groups were defined and are presented in Table 1. *Olea europaea*, *Cupressus*, *Urticaceae*, *Poaceae* *Mercurialis annua* and *Amaranthaceae* pollen represented the dominant taxa group by a contribution of near 90% in the PI, expressed individually by different annual proportions (Table 2). Indeed, *Olea europaea*, *Mercurialis annua* and *Amaranthaceae* were better represented during the first year, while *Cupressus*, *Poaceae* and *Urticaceae* pollen during the second year.

The airborne pollen season of the dominant taxa (Fig. 4) showed an important variability during their flowering season. The highest pollen peaks were recorded for *Olea europaea* and *Cupressus*, exceeding a daily peak of 1,500 pollen/m<sup>3</sup> of air; however, lower peaks from dominant taxa were detected in the case of grasses and other herbaceous plants, between 50 and 400 pollen/m<sup>3</sup> of air (*Urticaceae*, *Poaceae*, *Amaranthaceae* and *Mercurialis annua*). It has been also observed annual fluctuation with different pollen peaks, regarding pollen concentration and date. *Olea europaea*, *Poaceae*, *Amaranthaceae* and *Mercurialis annua* pollen have shown higher peaks during the first year and during the same period in both years. On the contrary, in the case of *Urticaceae*, pollen peak was detected in January 2011 but three months later during

2012, with a lower value. It should be also noted that the annual pollen concentration varied, showing only one pollen peak during the flowering season (*Urticaceae*, *Olea europaea* in 2012 and *Cupressus* in 2011) or different pollen peaks with similar or different intensities during different season (*Amaranthaceae*, *Poaceae* and *Mercurialis annua*).

During the studied period, correlation between daily pollen concentration of the dominant taxa and different meteorological parameters has been observed (Table 3). Results have shown significant negative correlation with maximum temperature, relative humidity and rainfall, and also with minimum temperature in the case of herbaceous plants; however, significant positive correlation has been observed with mean temperature and also with minimum temperature, for winter or early spring flowering trees (*Cupressus*, *Olea europaea*). It has been not observed significant correlations in taxa with longer pollen season (*Mercurialis annua*, *Urticaceae* and *Amaranthaceae*).

#### 4 Discussion

This study dealt with airborne pollen concentration in the area of Mornag, Northern Tunisia, during two continuous hydrologic years. Annual PI represents the flowering intensity of anemophilous plants depending on climate and weather (Galán et al. 2016; Pérez-Badia et al. 2010; Ziello et al. 2012). Our results have shown differences in the dominant species during the studied years. The higher percentage of pollen types was attributed to trees (*Olea europaea* and *Cupressus*), but an important percentage of pollen types was also attributed to herbaceous plants, from higher to lower values *Urticaceae*, *Poaceae*, *Mercurialis annua*, and *Amaranthaceae*, with clear anemophilous pollination and well presented in the urbanized environments under

**Table 1** Pollen-type classification according to their contribution on the PI during the studied period

| Classes of taxa | Individual contribution (%) | Number of taxa | Classes contribution (%) |
|-----------------|-----------------------------|----------------|--------------------------|
| Dominant        | ≥1                          | 6              | 91.66                    |
| Secondary       | [0.2–1]                     | 12             | 5.87                     |
| Intermediate    | [0.02–0.2]                  | 11             | 2.2                      |
| Minority        | [0.01–0.02]                 | 21             | 0.2                      |
| Rare            | <0.01                       | 2              | –                        |
| Total           |                             | 52             | 100                      |

**Table 2** Annual pollen index and percentage of the dominant taxa in Mornag (Northern Tunisia) during 2010–2011 and 2011–2012

| Taxa                     | 2010–2011 |       |     |     | 2011–2012 |       |     |     |
|--------------------------|-----------|-------|-----|-----|-----------|-------|-----|-----|
|                          | PI        | %     | PSS | PSE | PI        | %     | PSS | PSE |
| <i>Olea europaea</i>     | 12,306    | 60.8  | 101 | 131 | 798       | 39.2  | 114 | 135 |
| <i>Cupressus</i>         | 10,932    | 35.05 | 7   | 52  | 20,257    | 64.94 | 69  | 113 |
| <i>Poaceae</i>           | 1106      | 46.58 | 83  | 95  | 1267      | 53.4  | 140 | 149 |
| <i>Urticaceae</i>        | 2893      | 45.7  | 1   | 106 | 3428      | 54.3  | 353 | 92  |
| <i>Mercurialis annua</i> | 937       | 60.4  | 352 | 125 | 631       | 39.57 | 352 | 125 |
| <i>Amaranthaceae</i>     | 749       | 54.31 | 80  | 227 | 630       | 45.68 | 92  | 262 |

Pollen season start (PSS) and end (PSE) in Julian days

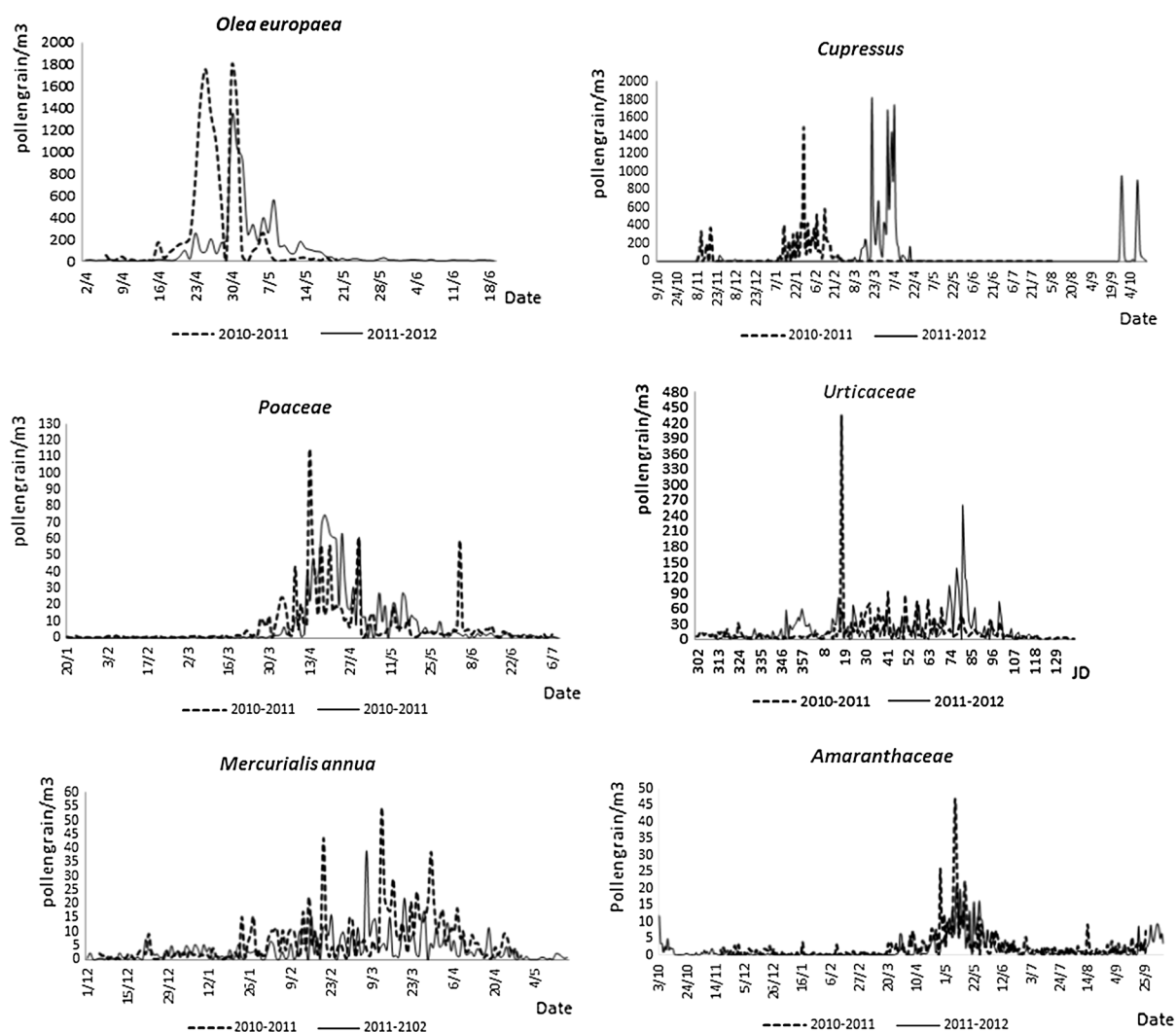
**Fig. 4** Daily variations of the airborne pollen concentration for dominant taxa in Mornag (Northern Tunisia) during 2010–2011 and 2011–2012

**Table 3** Spearman correlation between daily pollen data of the dominant taxa and main meteorological parameters during 2010–2011/2011–2012

|                          | $T_{\max}$ | $T_{\min}$ | $T_{\text{mean}}$ | $HR_{\text{mean}}$ | Rainfall |
|--------------------------|------------|------------|-------------------|--------------------|----------|
| 2010–2011                |            |            |                   |                    |          |
| <i>Olea europaea</i>     | −0.06      | 0.4**      | 0.17**            | −0.41**            | 0.26**   |
| <i>Cupressus</i>         | −0.33*     | 0.39**     | 0.52**            | −0.29**            | −0.5*    |
| <i>Poaceae</i>           | −0.31*     | −0.39      | 0.44              | −0.25              | −0.57**  |
| <i>Urticaceae</i>        | −0.23*     | −0.23*     | 0.28**            | −0.23*             | −0.1     |
| <i>Mercurialis annua</i> | 0.09       | 0.04       | 0.12              | −0.11              | −0.007   |
| <i>Amaranthaceae</i>     | 0.04       | −0.1       | 0.04              | 0.28               | 0.15     |
| 2011–2012                |            |            |                   |                    |          |
| <i>Olea europaea</i>     | −0.31**    | 0.36**     | 0.34**            | −0.21*             | 0.4**    |
| <i>Cupressus</i>         | −0.46**    | 0.03       | 0.6**             | −0.29**            | −0.5*    |
| <i>Poaceae</i>           | −0.22*     | −0.29**    | 0.25**            | −0.25**            | −0.27**  |
| <i>Urticaceae</i>        | −0.08      | −0.08      | 0.01              | −0.09              | −0.14    |
| <i>Mercurialis annua</i> | −0.06      | −0.12      | 0.09              | −0.067             | −0.12    |
| <i>Amaranthaceae</i>     | −0.24      | −0.2       | 0.18              | −0.36*             | −0.04    |

\* Significant correlation at  $p < 0.05$

\*\* Significant correlation at  $p < 0.01$

anthropogenic pressure, as has been supported by Belmonte et al. (1999) and Cariñanos et al. (2014). Galán et al. (2016) presented higher grass pollen concentrations in comparison with other herbaceous plants in south Spain; however, *Urticaceae* pollen type was the most represented pollen type in herbaceous plants in north Tunisia.

The quantitative and qualitative composition of the monthly airborne pollen spectrum showed a dominance of wind-pollinated species, mainly flowering in spring. Other pollen types are presented in lower concentrations, probably because the plant is not well represented in the studied area, or the population is located far from the sampler (Velasco-Jiménez et al. 2013), or because their entomophilous pollination. Despite their limited presence, their contribution to the flora richness of the studied area is not negligible.

Airborne pollen concentrations showed a heterogeneity sharp when different species contribute to the curve. Airborne pollen depends on pollen production by individual species and the spatial distribution of the vegetation around the sampling site (Skjoth et al. 2013). Nevertheless, atmospheric pollen concentration is in relation not only with intrinsic factors but also with environmental conditions which are considered as a fundamental agent affecting flowering intensity and pollen aerodynamic features. For example, during the first year, the rainy pre-season period during successively 3 months (January to March) with a total rainfall 271.5 mm supported water availability

and then highest airborne pollen in herbaceous plants flowering during spring, i.e., *Urticaceae* (Laaidi et al. 1997; Recio et al. 2010).

Clear seasonal behavior was observed for several taxa flowering during spring (i.e., *Olea europaea*, *Rumex*, *Plantago*, *Quercus*, *Poaceae*); however, other pollen types were well represented during a longer period of time, from winter until late spring, i.e., from January to May (i.e., *Urticaceae*) with variable pollen concentrations depending on the number of species per pollen type with possible different behavior. Similar findings were showed by Sabit et al. (2015), while *Mercurialis annua* pollen type was presented all over the year with high pollen concentrations representing a continuous blooming period (Lisci et al. 1994). In the case of *Cupressus* and *Amaranthaceae*, two separate pollen seasons were observed, the first flowering season occurs during end of winter or spring with higher pollen concentrations comparatively to the second pollen season during, respectively, autumn and late summer. Flowering during different period of the year may be attributed to the presence of species with different flowering season. Comparable observations were cited by several authors (Dahl et al. 2013; Gómez-Casero 2007; Jato et al. 2004).

*Olea europaea* is represented by clear pollen season during spring, because this pollen only represents to one species. This pollen is the most abundant into the atmosphere because olive trees constitute a fundamental compound of the Mediterranean environment

(Loumou and Giourga 2003) and a typical characteristic of the Tunisian landscapes, covering 70% of the arboreal areas with an important olive cultivars settlement, distributed from north to the south of Tunisia (Office National de l'Huile 2015; Trigui and Msallem 2002). This species is also used as an ornamental tree in the urban spaces. Olive pollen season has followed a clear pattern during the two studied years, but with changes depending on the weather availability.

Correlation between pollen data of the most represented taxa and meteorological parameters indicated a positive and significant correlation between airborne pollen and mean temperature in spring flowering plants. Low level of hygrometric degrees is also an important factor for anther dehiscence and pollen release (Laaidi et al. 1997). Numerous authors highlighted the deep effect of weather conditions on atmospheric pollen dispersal, mainly daily temperature and low relative humidity, reporting that an increasing trend of atmospheric pollen dispersion is associated with warm (temperature and isolation) as well as thermal currents (Alba et al. 2003; Pérez-Badía et al. 2010). However, pollen release is decreased by rainfall which can usually promote a longer pollination season when happening during the flowering period, as reported by Galán et al. (2008) and Oteros et al. (2012). In addition, a high air hydration more than 70% can also inhibit airborne pollen dispersion since pollen grains are highly hygrophilous cells and hydrate in the presence of high humidity in the air, thus gaining weight and falling to the ground by gravity (Kizilponar et al. 2010; Laaidi et al. 1997). In Tunis, a significant negative correlation between airborne pollen concentrations and maximum temperature has been observed. In the case of minimum temperature, we have observed a different response, positive for trees and negative for herbaceous plants that better respond to water availability. No significant concentrations have been observed among these parameters and *Urticaceae*, *Mercurialis annua* and *Amaranthaceae* pollen concentration, and this may be related to their limited requirements in the studied area. Considering the high sensitivity of flowering of plants to the environmental conditions, the airborne pollen may be a good bio-indicator of climate conditions fluctuations and the environmental status. Thus, further advanced studies and longer datasets were needed for monitoring and predicting the environmental situation.

## 5 Conclusions

During this aerobiological study:

1. We identified 52 pollen types in the atmosphere of Mornag, predominated by anemophilous plants.
2. The main identified taxa were *Olea europaea*, *Cupressus*, *Amaranthaceae*, *Poaceae*, *Urticaceae* and *Mercurialis annua*.
3. Monthly pollen spectrum showed dominance of spring flowering plants with a second flowering season of *Cupressus* and *Amaranthaceae*. Longer flowering period was observed for *Urticaceae* and *Mercurialis annua*.
4. Correlation between daily airborne pollen data of the dominant taxa and daily meteorological parameters showed different response of trees and herbaceous plants to minimum temperature.

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