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# Volumetric analysis of airborne pollen grains in the city of Uşak, Turkey

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**Abstract:** Airborne pollen in Uşak, a province in Turkey, was studied for two years (from 1 February 2014 to 31 January 2016) using the volumetric method and the most recent pollen data of the region were obtained. During the study, 23,915 pollen grains were detected. The pollens detected belonged to 53 taxa. Of the 53 taxa, 28 were woody and 25 were herbaceous. Of the pollen grains detected, 86% (20,565 pollen grains) were from woody plants, 4.74% (1133 pollen grains) belonged to Poaceae, and 8.65% (2071 pollen grains) were from other herbaceous plants, whereas 0.61% (146 pollen grains) were unidentified pollen grains. Of the woody taxa, those whose pollen grains comprised more than 1% each of the total number of pollen grains during the study were *Quercus* (32.60%), Pinaceae (31.96%), Cupressaceae/Taxaceae (10.22%), *Fraxinus* (5.47%), and *Platanus* (1.12%), whereas of the herbaceous taxa, those whose pollen grains comprised more than 1% each of the total number of pollen grains were Poaceae (4.74%), Amaranthaceae (1.82%), *Plantago* (1.59%), and *Rumex* (1.18%). In the two-year period, the highest airborne pollen concentrations were recorded in May (47.30%), followed by April (27.64%) and June (10.47%). The results obtained in the study indicated that the dominant airborne pollen types detected in Uşak generally had allergenic effects at moderate or high levels and that these taxa reached the highest amount in May.

**Key words:** Aeropalynology, pollen calendar, Uşak, Turkey

## 1. Introduction

Allergic diseases affect 20%–30% of Turkish population and constitute an important disease group due to the labor and financial losses they cause (Bıçakçı et al., 2009). In some countries, the rates of diseases causing allergy in humans are as follows: 14% in Finland, 5.9%–18.5% in France, 6.6% in Holland, 13.1%–13.3% in Italy, 12.9%–32.7% in Japan, 10%–20.6% in Norway, 10.6% in Spain, 0.5%–14.2% in Switzerland, 13%–24% in Sweden, 3%–29% in the UK, 10.2%–42% in the US, 9.5%–22.5% in Germany, 12.5% in Denmark, 18.2% in Scotland, and 16.7% in Poland (Bousquet et al., 2008).

Many allergic diseases are caused by airborne pollen due to seasonal pollination. The degree of pollen's allergenic effect on humans differs from one species to another. Turkey, which is home to about 12,000 taxa, has three phytogeographical regions. These regions have different climatic characteristics and different flora, and the amount of different pollen types of wind-pollinated plants vary from one region to another (Bıçakçı et al., 2009). For allergic persons, the first step to protect themselves against pollen allergy is to know the type of the pollen they are allergic to and what period of the year they might be exposed to that type of pollen in the region they live in. Therefore, it is very important to determine the amount of different pollen types in a settlement (Güvensen and Öztürk, 2002). If the treatment process of an individual allergic to pollen is to be managed better, it is also important to determine the amounts of airborne pollen in different regions and to prepare pollen calendars for these regions.

Various studies have been conducted on allergenic pollen in different regions of the world, the effects of the allergenic pollen on vulnerable individuals, and the pollination periods of the taxa producing allergenic pollen by using different methods, and pollen calendars have been created for some of these regions (Gioulekas et al., 2004a; Rodriguez-Rajo et al., 2004; Marínez-Bracero et al., 2015). As in many other countries, similar studies have been conducted in different regions of Turkey, and significant data have been obtained on the detection of the amount of different pollen types, and association between meteorological factors and pollen types and concentrations (İnceoğlu et al., 1994; Bıçakçı et al., 1996; Pınar et al., 1999; Guvensen and Ozturk, 2003; Celenk et al., 2010; Bicakci et al., 2017).

Our aims in the present study were (1) to investigate the airborne pollen in Uşak for the first time with the volumetric method, (2) to prepare the most recent pollen

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map of the region, and (3) to determine the effects of meteorological factors on the distribution of airborne pollen belonging to dominant taxa in the atmosphere.

## 2. Materials and methods

### 2.1. Study area, flora, and climate

Uşak connects West and Central Anatolia and is a gateway between the Aegean and Central Anatolian regions (Figure 1). The population of the city center is 353,048 according to the 2015 census. The majority of the province includes plateaus. However, Murat Mountain (2312 m) in the north–northeast and Bulkaz Mountain (1990 m) in the east form the boundaries of the province. In the floristic studies carried out in these regions, species belonging to three different phytogeographical regions in Turkey have been detected. According to the aforementioned studies, the following species are distributed as Euro–Siberian phytogeographical elements: *Carpinus betulus* L., *Corylus avellana* L., *Fagus orientalis* Lipsky, *Juncus articulatus* L., *Ligustrum vulgare* L., *Pinus sylvestris* L., *Populus tremula* L., *Salix alba* L., *S. cinerea* L., *Tilia rubra* subsp. *caucasica* Rupr., *Urtica dioica* L.; Irano–Turanian phytogeographical elements: *Artemisia spicigera* C.Koch, *Campanula involucrata* Aucher ex A.DC, *Fumana aciphylla* Boiss., *Quercus libani* Olivier; Mediterranean phytogeographical elements: *Cistus laurifolius* L., *Jasminum fruticans* L., *Pinus brutia* Ten., *Plantago holosteum* Scop., *Quercus cerris* L., *Q. coccifera* L., *Q. ithaburensis* subsp. *macrolepis* Kotschy, *Q. vulcanica* Boiss. et Heldr., and *Salix amplexicaulis* Bory et Chaub (Çırpıcı, 1989; Dönmez Şahin and Serin, 2009).

On the other hand, major species planted in the parks, gardens, and the city center are *Acer negundo* L., *A. saccharinum* L., *A. platanoides* L., *A. palmatum* Thunb., *Aesculus hippocastaneum* L., *Betula alba* L., *Catalpa bignonoides* Walter, *Cedrus atlantica* (Endl.), *C. deodara* (Roxb.) G.Don, *C. libani* A.Rich., *Cercis siliquastrum* L., *Cupressus sempervirens* L., *Cupressocyparis leylandii* (A.B. Jacks. & Dallim.) Dallim., *Elaeagnus angustifolia* L., *Fraxinus* spp., *Hibiscus syriacus* L., *Ligustrum japonicum* Thunb., *Malus floribunda* Sieb. ex Van Houtte, *Pinus pinea* L., *Pittosporum tobira* (Thunb.) W.T.Aiton, *Platanus orientalis*, *Prunus cerasifera* Ehrh., *P. serrulata* Lindl., *Rosa* spp., *Quercus* spp., *Robinia pseudoacacia* L., *Salix* spp., *Sophora japonica* L., *Thuja orientalis* L., *Tilia tomentosa* Moench., and *Viburnum* spp.

Due to its location, the region where the Mediterranean climate reigns is also under the influence of continental climate. Due to the increased effect of continental climate, winters are colder in this region than in the Aegean region, and summers are not as warm (Darkot and Tuncel, 1995). Meteorological data (daily average temperature (°C), daily precipitation (mm), daily average relative humidity (%), and daily average wind speed (m/s)) about Uşak were obtained from the data sent to the Turkish Meteorological Data Archiving System (TUMAS) by the Directorate of the Uşak Meteorological Station. According to the meteorological data obtained from the system, in the

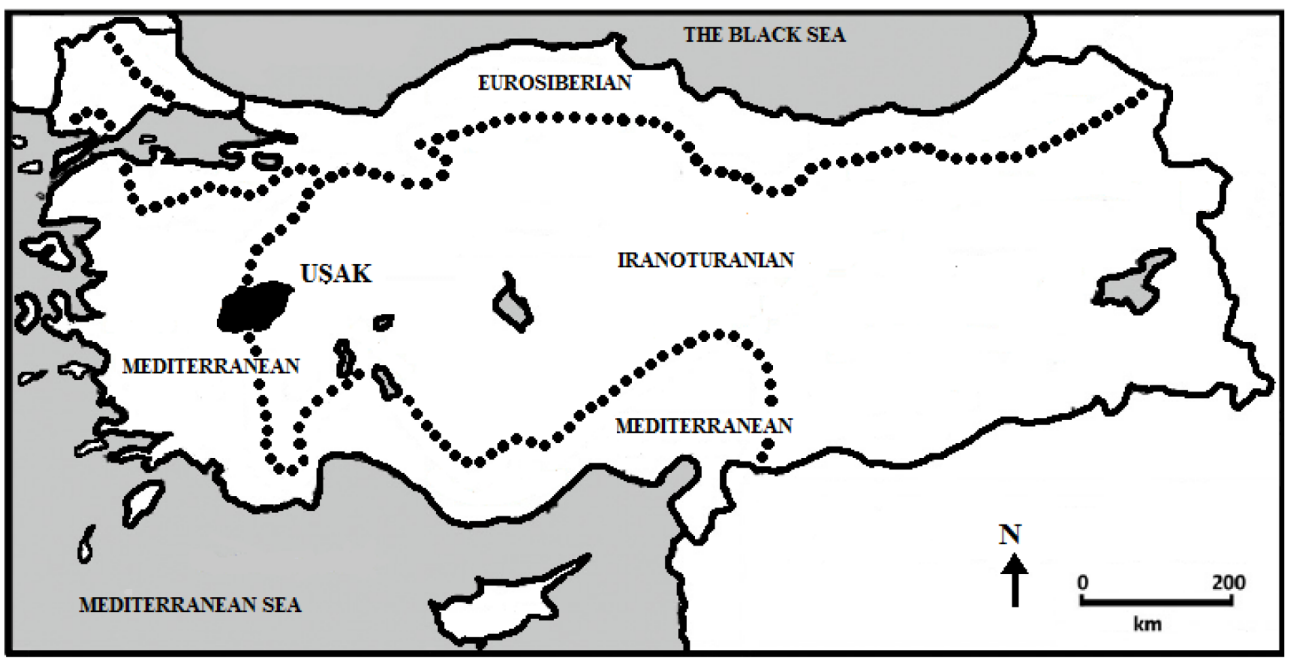


**Figure 1.** Location of the study area (Uşak).

study period, the highest average temperature in Uşak was in July (24.62 °C) and the lowest in January (2.03 °C). The average rainfall was highest in June (8.07 mm) and lowest in July (0.1 mm). The average humidity was lowest in July (42.11%) and highest in January (74.55%). The highest and lowest average wind speeds were recorded in January (1.52 m/s) and in December (0.93 m/s), respectively.

**2.2. Aerobiological method**

Airborne pollen data in Uşak Province were collected from 1 February 2014 to 31 January 2016, using the 7-day volumetric trap "Lanzoni VPPS 2010" of Hirst's design (Hirst, 1952). The pollen trap was installed on the roof of the rectorate building of Uşak University. The rectorate building was approximately 25-m tall, away from any barrier that might prevent air circulation, and had an uninterrupted energy source. It was located at a place representing the features of the city. Silicone oil was applied to the Melinex tape on the drum of the pollen trap, which completed its full rotation in a week. The tape was replaced weekly. The adhesive tape was brought to the laboratory and divided into 7 equal pieces, each of which was used as a preparation representing one day. To identify and count the pollen grains, an Olympus light microscope with 400× magnification was used. The method described by the Spanish Aerobiological Network was used in the atmospheric sampling and analysis (Galan et al., 2007).

The pollen concentrations of the identified taxa were converted into the number of airborne pollen grains per cubic meter, and pollen tables were formed. Any taxa whose pollen grains comprised more than 1% of the total number of airborne pollen grains in Uşak during the study were defined as dominant taxa. The start date of the main pollen seasons (MPS) of these taxa were calculated when their annual pollen concentrations exceeded 2.5% of the total number of pollen grains and the end occurred when 97.5% of the annual pollen concentration had been reached (Andersen, 1991). At the end of the study, 10-day pollen concentrations were added together for each month, then mean values were calculated, and finally a pollen calendar related to the study period was prepared based on these mean values (Spieksma, 1991).

In the statistical analysis, the average daily pollen concentrations of the 9 taxa (*Quercus*, Pinaceae, Cupressaceae/Taxaceae, *Fraxinus*, Poaceae, Amaranthaceae, *Plantago*, *Rumex*, *Platanus*) with the highest pollen concentrations in the atmosphere of Uşak during the MPS were correlated with the following parameters: average temperature (°C), average relative humidity (%), total precipitation (mm), and average wind speed (m/s). The statistical analysis was performed with the Spearman correlation test using SPSS 20 (IBM, Armonk, NY, USA).

**3. Results**

During the two-year study period, airborne pollen grains of 53 different taxa were detected in Uşak. Of the 53 taxa, 28 belonged to woody plants and 25 belonged to herbaceous plants. Of the 23,915 pollen grains, 14,683 were detected in the first year and 9232 in the second year. Of the pollen grains counted, 86% (20,565 pollen grains) were from woody plants, 13.39% (3204 pollen grains) were from herbaceous plants, and 4.74% (1133 pollen grains) were from Poaceae, whereas 0.61% (146 pollen grains) were not identified (Table 1).

Monthly variation in total pollen concentrations during the two-year period and the variation in woody and herbaceous pollen grains are given in Figures 2 and 3. Of the total annual pollen count, 86.37% was detected in May, April, and June. The months when the highest pollen concentrations were detected in the second year were the same as those in the first year. In both years, the highest pollen concentrations from the woody taxa were detected in May, April, and June, whereas those from the herbaceous taxa were detected in May, June, and July.

Of the woody taxa, those whose pollen grains comprised more than 1% of the total number of pollen grains during the study were *Quercus* (32.60%, 7796 pollen grains), Pinaceae (31.96%, 7643 pollen grains), Cupressaceae/Taxaceae (10.22%, 2445 pollen grains), *Fraxinus* (5.47%, 1307 pollen grains), and *Platanus* (1.12%, 268 pollen grains). The pollen of these five taxa constituted 94.6% of the woody pollen and 81.37% of the total pollen. Of the herbaceous taxa, those whose pollen grains comprised more than 1% of the total number of pollen grains each were Poaceae (4.74%, 1133 pollen grains), Amaranthaceae (1.82%, 436 pollen grains), *Plantago* (1.59%, 380 pollen grains), and *Rumex* (1.18%, 282 pollen grains). The pollen of these four taxa constituted 69.5% of the herbaceous pollen and 9.33% of the total pollen (Table 2).

During the study, the changes in the concentration of the dominant taxa in Uşak atmosphere are given in Figure 4. *Quercus* constituted 32.60% of the total pollen and was the taxon with the highest number of pollen grains. The airborne pollen of this taxon was observed from January to July, and the highest airborne pollen concentration of this taxon was recorded in May (5219 pollen grains, 21.82%) (Table 2). The main pollen season for *Quercus* lasted 54 days between 10 April and 2 June in the first year, and 40 days between 17 April and 26 May in the second year (Table 3).

Airborne Pinaceae pollen was observed in all the months during the study. Pinaceae pollen constituted 31.96% of the total pollen and the highest concentration was recorded in May (3324 pollen grains, 13.90%) (Table 2). The main pollen season for Pinaceae was between 29 March and 19 June and lasted for 83 days in the first

**Table 1.** Annual pollen concentrations and percentage of pollen taxa recorded in Uşak atmosphere (1st year: 1 February 2014 to 31 January 2015; 2nd year: 1 February 2015 to 31 January 2016).

| Taxa | 1st year | | 2nd year | | Total | |
|---|---|---|---|---|---|---|
| | Pollen/m$^3$ | % | Pollen/m$^3$ | % | Pollen/m$^3$ | % |
| *Quercus* | 4715 | 32.11 | 3081 | 33.37 | 7796 | 32.60 |
| Pinaceae | 5020 | 34.19 | 2623 | 28.41 | 7643 | 31.96 |
| Cupressaceae/Taxaceae | 1679 | 11.43 | 766 | 8.30 | 2445 | 10.22 |
| *Fraxinus* | 857 | 5.84 | 450 | 4.87 | 1307 | 5.47 |
| *Platanus* | 142 | 0.97 | 126 | 1.36 | 268 | 1.12 |
| *Pistacia* | 104 | 0.71 | 72 | 0.78 | 176 | 0.74 |
| *Alnus* | 119 | 0.81 | 33 | 0.36 | 152 | 0.64 |
| *Salix* | 50 | 0.34 | 48 | 0.52 | 98 | 0.41 |
| *Morus* | 37 | 0.25 | 56 | 0.61 | 93 | 0.39 |
| *Casuarina equisetifolia* | 38 | 0.26 | 40 | 0.43 | 78 | 0.33 |
| *Sarcopoterium spinosum* | 43 | 0.29 | 33 | 0.36 | 76 | 0.32 |
| *Juglans* | 41 | 0.28 | 24 | 0.26 | 65 | 0.27 |
| *Ulmus* | 38 | 0.26 | 21 | 0.23 | 59 | 0.25 |
| *Phillyrea latifolia* | 30 | 0.20 | 13 | 0.14 | 43 | 0.18 |
| *Castanea sativa* | 28 | 0.19 | 7 | 0.08 | 35 | 0.15 |
| *Corylus* | 17 | 0.12 | 17 | 0.18 | 34 | 0.14 |
| Ericaceae | 18 | 0.12 | 14 | 0.15 | 32 | 0.13 |
| Rosaceae | 22 | 0.15 | 10 | 0.11 | 32 | 0.13 |
| Betulaceae | 17 | 0.12 | 12 | 0.13 | 29 | 0.12 |
| *Carpinus* | 4 | 0.03 | 20 | 0.22 | 24 | 0.10 |
| *Fagus* | 12 | 0.08 | 11 | 0.12 | 23 | 0.10 |
| *Populus* | 9 | 0.06 | 6 | 0.06 | 15 | 0.06 |
| *Tilia* | 9 | 0.06 | 5 | 0.05 | 14 | 0.06 |
| *Acer* | 6 | 0.04 | 4 | 0.04 | 10 | 0.04 |
| *Ailanthus* | 6 | 0.04 | 2 | 0.02 | 8 | 0.03 |
| Cistaceae | 5 | 0.03 | 1 | 0.01 | 6 | 0.03 |
| *Eucalyptus camaldulensis* | 3 | 0.02 | 0 | 0.00 | 3 | 0.01 |
| *Aesculus* | 1 | 0.01 | | 0.00 | 1 | 0.00 |
| Woody taxa total | 13,070 | 89.01 | 7495 | 81.18 | 20,565 | 86 |
| Poaceae | 453 | 3.09 | 680 | 7.37 | 1133 | 4.74 |
| Amaranthaceae | 224 | 1.53 | 212 | 2.30 | 436 | 1.82 |
| *Plantago* | 189 | 1.29 | 191 | 2.07 | 380 | 1.59 |
| *Rumex* | 154 | 1.05 | 128 | 1.39 | 282 | 1.18 |
| Urticaceae | 120 | 0.82 | 19 | 0.21 | 139 | 0.58 |
| Apiaceae | 51 | 0.35 | 82 | 0.89 | 133 | 0.56 |
| Asteraceae | 40 | 0.27 | 73 | 0.79 | 113 | 0.47 |
| Brassicaceae | 53 | 0.36 | 42 | 0.45 | 95 | 0.40 |
| *Artemisia* | 29 | 0.20 | 63 | 0.68 | 92 | 0.38 |
| *Xanthium* | 42 | 0.29 | 46 | 0.50 | 88 | 0.37 |
| *Mercurialis* | 37 | 0.25 | 32 | 0.35 | 69 | 0.29 |
| Cyperaceae | 19 | 0.13 | 35 | 0.38 | 54 | 0.23 |

**Table 1.** (Continued).

| Taxa | 1st year | | 2nd year | | Total | |
|---|---|---|---|---|---|---|
| | Pollen/m$^3$ | % | Pollen/m$^3$ | % | Pollen/m$^3$ | % |
| *Taraxacum* | 19 | 0.13 | 23 | 0.25 | 42 | 0.18 |
| Papaveraceae | 14 | 0.10 | 9 | 0.10 | 23 | 0.10 |
| *Ambrosia* | 15 | 0.10 | 4 | 0.04 | 19 | 0.08 |
| *Centaurea* | 6 | 0.04 | 13 | 0.14 | 19 | 0.08 |
| Lamiaceae | 9 | 0.06 | 9 | 0.10 | 18 | 0.08 |
| *Astragalus* | 9 | 0.06 | 6 | 0.06 | 15 | 0.06 |
| Fabaceae | 10 | 0.07 | 4 | 0.04 | 14 | 0.06 |
| *Typha* | 11 | 0.07 | 1 | 0.01 | 12 | 0.05 |
| Caryophyllaceae | 6 | 0.04 | 2 | 0.02 | 8 | 0.03 |
| Ranunculaceae | 5 | 0.03 | 1 | 0.01 | 6 | 0.03 |
| Rubiaceae | 6 | 0.04 | 1 | 0.01 | 7 | 0.03 |
| *Galium* | 4 | 0.03 | | 0.00 | 4 | 0.02 |
| *Campanula* | 3 | 0.02 | | 0.00 | 3 | 0.01 |
| Herbaceous taxa total | 1528 | 10.41 | 1676 | 18.16 | 3204 | 13,39 |
| Unidentified | 85 | 0.58 | 61 | 0.66 | 146 | 0.61 |
| Total | 14,683 | 100.00 | 9232 | 100.00 | 23,915 | 100.00 |

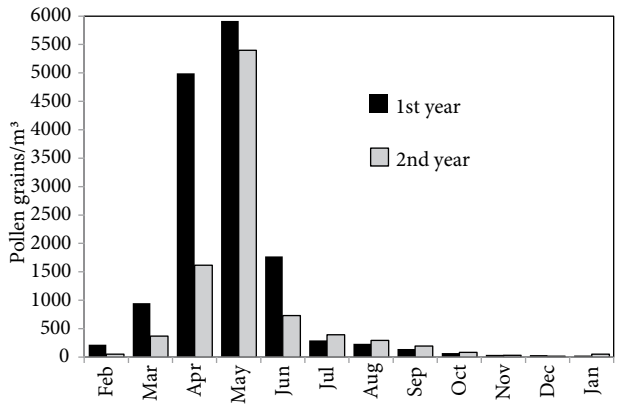


**Figure 2.** Monthly variation in pollen concentration in Uşak.

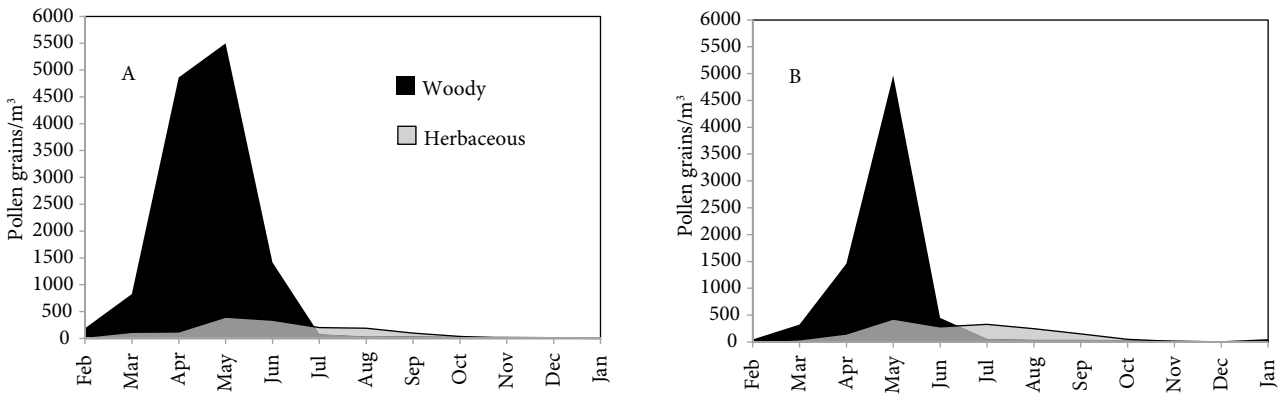


**Figure 3.** Monthly variation in woody and herbaceous pollen grains recorded in Uşak atmosphere; (A) 1 February 2014 to 31 January 2015; (B) 1 February 2015 to 31 January 2016.

**Table 2.** Monthly distribution of pollen grains (PG/m³) and percentage (%) of dominant taxa in Uşak atmosphere.

| Taxa/Month | | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Quercus* | % | 0.00 | 0.21 | 9.15 | 21.82 | 1.39 | 0.01 | | | | | | 0.00 | 32.60 |
| | PG/m³ | 1 | 51 | 2189 | 5219 | 332 | 3 | | | | | | 1 | 7796 |
| Pinaceae | % | 0.12 | 0.69 | 10.72 | 13.90 | 5.38 | 0.33 | 0.20 | 0.14 | 0.16 | 0.13 | 0.08 | 0.11 | 31.96 |
| | PG/m³ | 28 | 166 | 2564 | 3324 | 1287 | 78 | 47 | 33 | 39 | 30 | 20 | 27 | 7643 |
| Cupressaceae/Tax. | % | 0.43 | 2.34 | 4.09 | 2.46 | 0.52 | 0.09 | 0.00 | 0.03 | 0.04 | 0.03 | 0.06 | 0.12 | 10.22 |
| | PG/m³ | 103 | 560 | 979 | 588 | 125 | 21 | 1 | 7 | 10 | 7 | 15 | 29 | 2445 |
| *Fraxinus* | % | 0.08 | 0.20 | 0.36 | 4.58 | 0.23 | 0.00 | | | | | | | 5.47 |
| | PG/m³ | 20 | 49 | 85 | 1096 | 56 | 1 | | | | | | | 1307 |
| *Platanus* | % | 0.01 | 0.22 | 0.74 | 0.13 | 0.02 | | | | | | | | 1.12 |
| | PG/m³ | 2 | 53 | 177 | 32 | 4 | | | | | | | | 268 |
| Total woody | % | 0.64 | 3.68 | 25.06 | 42.90 | 7.54 | 0.43 | 0.20 | 0.17 | 0.20 | 0.15 | 0.15 | 0.24 | 81.37 |
| | PG/m³ | 154 | 879 | 5994 | 10259 | 1804 | 103 | 48 | 40 | 49 | 37 | 35 | 57 | 19459 |
| Poaceae | % | 0.02 | 0.11 | 0.24 | 1.84 | 1.16 | 0.69 | 0.31 | 0.23 | 0.12 | 0.01 | 0.00 | 0.00 | 4.74 |
| | PG/m³ | 4 | 27 | 58 | 440 | 277 | 166 | 73 | 55 | 29 | 2 | 1 | 1 | 1133 |
| Amaranthaceae | % | | 0.01 | 0.01 | 0.07 | 0.14 | 0.36 | 0.73 | 0.33 | 0.13 | 0.02 | 0.00 | | 1.82 |
| | PG/m³ | | 3 | 3 | 17 | 34 | 86 | 175 | 80 | 32 | 5 | 1 | | 436 |
| *Plantago* | % | 0.01 | 0.05 | 0.27 | 0.40 | 0.38 | 0.39 | 0.08 | 0.01 | | | 0.00 | | 1.59 |
| | PG/m³ | 2 | 12 | 64 | 95 | 90 | 94 | 20 | 2 | | | 1 | | 380 |
| *Rumex* | % | 0.02 | 0.08 | 0.22 | 0.42 | 0.31 | 0.13 | 0.01 | | | | | | 1.18 |
| | PG/m³ | 4 | 20 | 52 | 100 | 73 | 31 | 2 | | | | | | 282 |
| Total herbaceous | % | 0.04 | 0.26 | 0.74 | 2.73 | 1.98 | 1.58 | 1.13 | 0.57 | 0.26 | 0.03 | 0.01 | 0.00 | 9.33 |
| | PG/m³ | 10 | 62 | 177 | 652 | 474 | 377 | 270 | 137 | 61 | 7 | 3 | 1 | 2231 |
| Total (over 1%) | % | 0.69 | 3.93 | 25.80 | 45.62 | 9.53 | 2.01 | 1.33 | 0.74 | 0.46 | 0.18 | 0.16 | 0.24 | 90.70 |
| | PG/m³ | 164 | 941 | 6171 | 10911 | 2278 | 480 | 318 | 177 | 110 | 44 | 38 | 58 | 21690 |
| Others | % | 0.41 | 1.51 | 1.74 | 1.56 | 0.86 | 0.77 | 0.82 | 0.64 | 0.17 | 0.11 | 0.03 | 0.08 | 8.69 |
| | PG/m³ | 97 | 362 | 417 | 372 | 206 | 184 | 195 | 152 | 40 | 26 | 8 | 20 | 2079 |
| Unidentified | % | 0.02 | 0.05 | 0.10 | 0.12 | 0.09 | 0.10 | 0.05 | 0.03 | 0.02 | 0.00 | 0.02 | 0.01 | 0.61 |
| | PG/m³ | 5 | 12 | 23 | 29 | 21 | 25 | 12 | 8 | 4 | 1 | 4 | 2 | 146 |
| Total | % | 1.11 | 5.50 | 27.64 | 47.30 | 10.47 | 2.88 | 2.20 | 1.41 | 0.64 | 0.30 | 0.21 | 0.33 | 100.00 |
| | PG/m³ | 266 | 1315 | 6611 | 11312 | 2505 | 689 | 525 | 337 | 154 | 71 | 50 | 80 | 23915 |

year. In the second year, it was between 6 April and 24 September, and lasted 172 days (Table 3).

Cupressaceae/Taxaceae was the taxon with the third highest pollen concentration and its pollen constituted 10.22% of the total pollen. Airborne pollen of Cupressaceae/Taxaceae was observed in all months during the study, but the highest pollen concentration of this taxon was recorded in April (4.09%, 979 pollen grains) (Table 2). The main pollen season for this taxon lasted 126 days between 11 February and 16 June in the first year, and 76 days between 5 March and 19 May in the second year (Table 3).

*Fraxinus* pollen accounted for 5.47% of the total airborne pollen. Airborne pollen of *Fraxinus* was observed from February to July, and the highest pollen concentration of this taxon was recorded in May (4.58%, 1096 pollen grains) (Table 2). The main pollen season for this taxon lasted 75 days between 20 March and 2 June in the first year and 54 days between 10 April and 2 June in the second year (Table 3).

Poaceae pollen was detected in the air during the entire study period. Poaceae was the herbaceous taxon with the highest number of pollen grains and constituted 4.74% of the total pollen. While the highest pollen concentration of

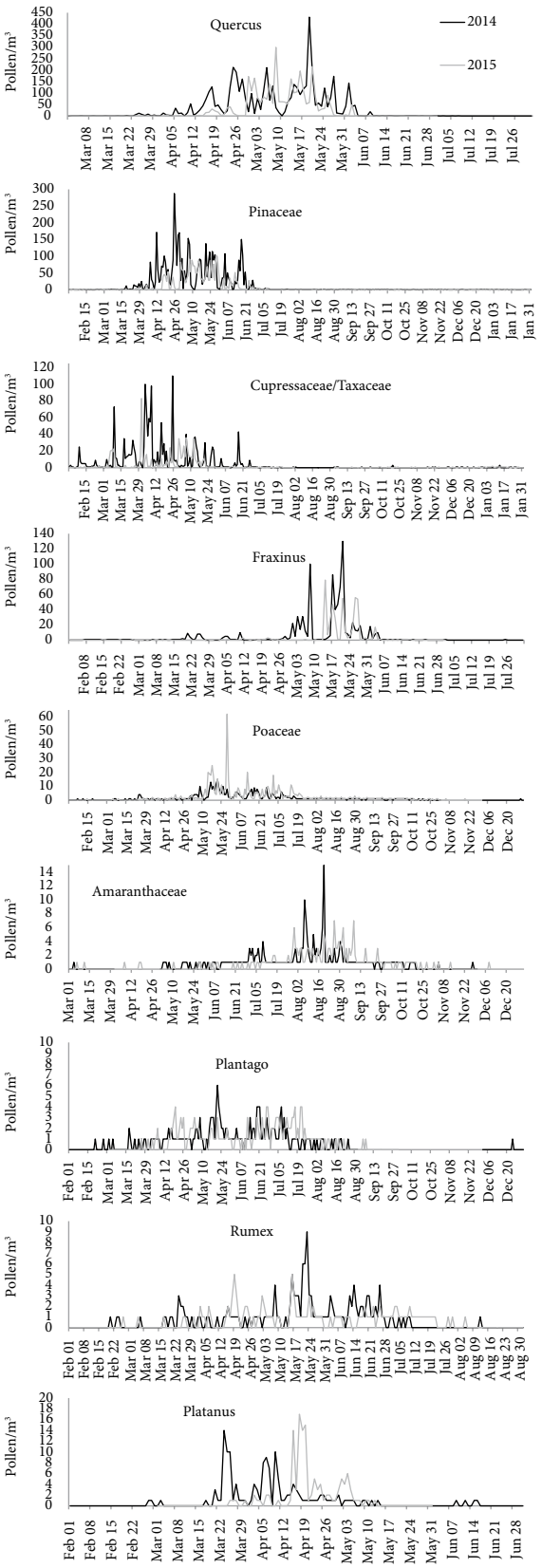


**Figure 4.** Seasonal variation in dominated pollen types in Uşak atmosphere (2014–2015).

Poaceae was recorded in May (1.84%, 440 pollen grains), 1 pollen grain was detected in December and January (Table 2). The main pollen season of Poaceae was between 24 March and 3 October (194 days) in the first year and between 12 April and 3 October (175 days) in the second year (Table 3).

The airborne pollen of Amaranthaceae was observed in all the months except January and February. The highest concentrations were detected between May and October. This taxon, which constituted 1.82% of the total pollen grains, peaked in August (0.73%, 175 pollen grains) (Table 2). The main pollen season for this taxon lasted 147 days between 17 May and 10 October in the first year, and 147 days between 27 May and 20 October in the second year (Table 3).

*Plantago* pollen constituted 1.59% of the total pollen. *Plantago* pollen was detected in the atmosphere between February and September. The highest amounts of *Plantago* pollen were detected in May (95 pollen grains), July (94 pollen grains), and June (90 pollen grains) (Table 2). The main pollen season for this taxon lasted 151 days between 17 March and 14 August in the first year, and 136 days between 4 April and 17 August in the second year (Table 3).

*Rumex* pollen constituted 1.18% of the total pollen grains in Uşak during the study. *Rumex* pollen was detected in the atmosphere between February and August and peaked in May (0.42%, 100 pollen grains) (Table 2). The main pollen season for *Rumex* lasted 108 days between 19 March and 4 July in the first year, and 134 days between 16 March and 27 July in the second year (Table 3).

*Platanus* pollen constituted 1.12% of the total pollen grains. *Platanus* pollen was detected in the air between February and June and peaked in April (0.74%, 177 pollen grains) (Table 2). While *Platanus* pollen was not among the dominant pollen types in the first year (in other words, its pollen concentration was not over 1%), its main pollen season lasted for 42 days from 27 March to 7 May in the second year (Table 3). In addition to these taxa, airborne pollen grains belonging to 22 woody taxa and 22 herbaceous taxa were detected in Uşak. Each of these pollen grains comprised less than 1% of total pollen (Table 1). Pollination seasons of these taxa are given in Figure 5.

Seasonal variation in average temperature (°C), average relative humidity (%), total precipitation (mm), and average wind speed (m/s) are given in Figure 6. Although the monthly average temperature and average humidity values measured in the two years differed from one year to the other (%), the differences were not significant in general. However, the average outdoor temperature in Uşak in February, March, and April in the first year was higher than that in the second year. On the other hand, the amount of precipitation varied remarkably in certain

**Table 3.** Characteristics of the main pollen season (MPS) for the most important taxa in Uşak atmosphere.

| | | 1st year | 2nd year |
|---|---|---|---|
| *Quercus* | Main pollen season | 10/04–02/06 | 17/04–26/05 |
| | Season length (days) | 54 | 40 |
| | Max. daily pollen/m$^3$ - date | 431 - 19/05 | 299 - 08/05 |
| Pinaceae | Main pollen season | 29/03–19/06 | 06/04–24/09 |
| | Season length (days) | 83 | 172 |
| | Max. daily pollen/m$^3$ - date | 288 - 24/04 | 104 - 27/05 |
| Cupressaceae/ Taxaceae | Main pollen season | 11/02–16/06 | 05/03–19/05 |
| | Season length (days) | 126 | 76 |
| | Max. daily pollen/m$^3$ - date | 110 - 24/04 | 83 - 30/03 |
| *Fraxinus* | Main pollen season | 20/03–02/06 | 10/04–02/06 |
| | Season length (days) | 75 | 54 |
| | Max. daily pollen/m$^3$ - date | 130 - 20/05 | 79 - 13/05 |
| *Platanus* | Main pollen season | | 27/03–07/05 |
| | Season length (days) | | 42 |
| | Max. daily pollen/m$^3$ - date | 14 - 23/03 | 17 - 17/04 |
| Poaceae | Main pollen season | 24/03–03/10 | 12/04–03/10 |
| | Season length (days) | 194 | 175 |
| | Max. daily pollen/m$^3$ - date | 15 - 20/05 | 62 - 27/05 |
| Amaranthaceae | Main pollen season | 17/05–10/10 | 27/05–20/10 |
| | Season length (days) | 147 | 147 |
| | Max. daily pollen/m$^3$ - date | 15 - 19/08 | 7 - 26/08 and 08/09 |
| *Plantago* | Main pollen season | 17/03–14/08 | 04/04–17/08 |
| | Season length (days) | 151 | 136 |
| | Max. daily pollen/m$^3$ - date | 6 - 20/05 | 4 - 19/04, 25/06, 26/06, 16/07, 20/07, 21/07 |
| *Rumex* | Main pollen season | 19/03–04/07 | 16/03–27/07 |
| | Season length (days) | 108 | 134 |
| | Max. daily pollen/m$^3$ - date | 9 - 22/05 | 5 - 18/04, 15/05 |

periods of the two years. The amount of the rainfall in spring period in the second year was particularly high and effective. Average wind speed values measured in the second year were higher than were those in the first year.

According to statistical results in the first year, significant positive correlations were determined between average temperatures and pollen concentrations of *Quercus*, *Fraxinus*, Amaranthaceae, and *Rumex* ($P < 0.01$ and $P < 0.05$). However, the negative effects of the total rainfall and average humidity on Cupressaceae/Taxaceae, *Quercus*, and Amaranthaceae pollen were statistically significant ($P < 0.01$). In the second year, the positive effect of the average temperature on *Quercus*, Cupressaceae/ Taxaceae, Amaranthaceae, *Rumex*, and *Platanus* pollen was statistically significant. However, the same parameter had a negative impact on pollen concentrations of Pinaceae and Poaceae ($P < 0.01$ and $P < 0.05$). On the other hand, statistical data from the second year showed that the total rainfall had a positive effect on Pinaceae pollen and a negative effect on *Plantago* pollen. Furthermore, the average humidity had a positive effect on Poaceae and Pinaceae pollen and a negative effect on Cupressaceae/ Taxaceae and Amaranthaceae ($P < 0.01$ and $P < 0.05$) (Table 4).

## 4. Discussion

The first four taxa (*Quercus*, Pinaceae, Cupressaceae/ Taxaceae, and *Fraxinus*) with the highest airborne pollen concentrations were woody plants and their pollen comprised 80.25% of the total airborne pollen. This is due the fact that these plants, which are pollinated by the wind and release a large number of pollen in the atmosphere,

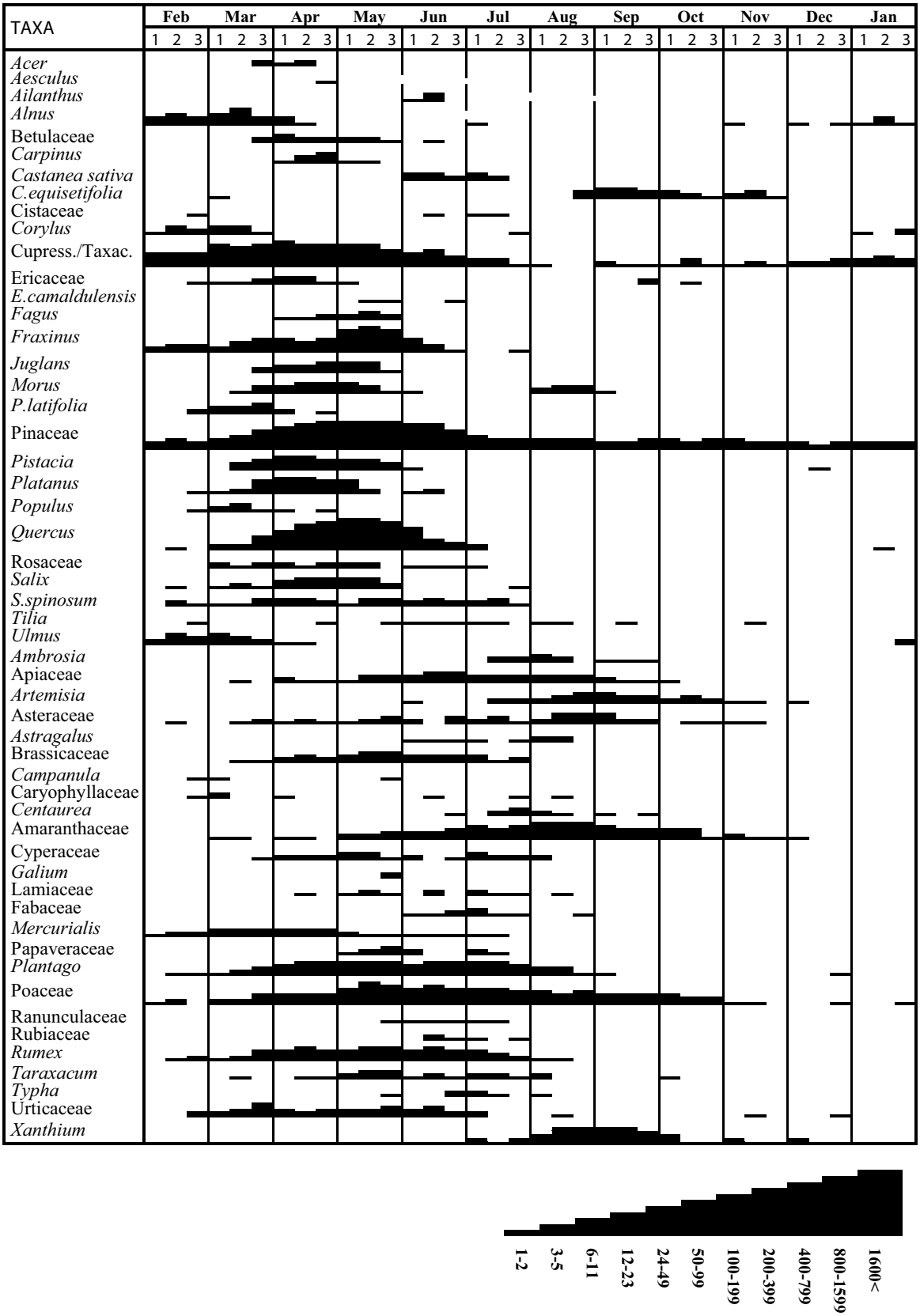


**Figure 5.** Pollen calendar of Uşak.

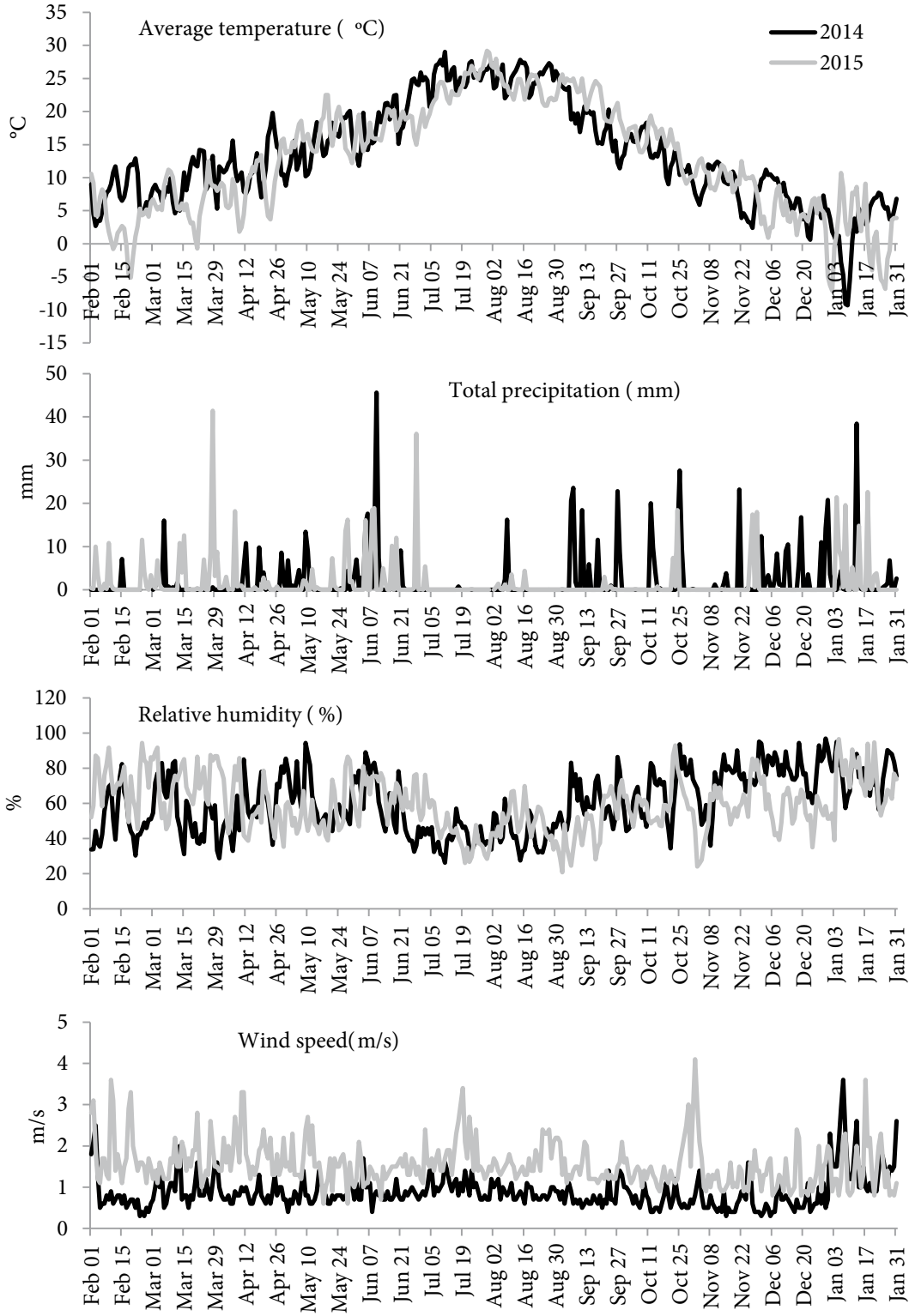


**Figure 6.** Seasonal variation of average temperature (°C), average relative humidity (%), total precipitation (mm), and average wind speed (m/s) in Uşak (2014–2015).

**Table 4.** The results of Spearman's correlation analysis between daily pollen concentrations of dominant taxa and meteorological parameters.

| Correlations | Year | Mean daily temperature (°C) | Mean daily humidity (%) | Total daily rainfall (mm) | Mean daily wind speed (m/s) |
|---|---|---|---|---|---|
| *Quercus* | 2014 | 0.371** | –0.398** | –0.426** | 0.194 |
| | 2015 | 0.409** | –0.152 | –0.076 | –0.061 |
| Pinaceae | 2014 | 0.194 | –0.048 | –0.192 | –0.048 |
| | 2015 | –0.618** | 0.367** | 0.194* | 0.014 |
| Cupress./Taxaceae | 2014 | 0.042 | –0.247** | –0.307** | –0.023 |
| | 2015 | 0.484** | –0.379** | –0.087 | –0.151 |
| *Fraxinus* | 2014 | 0.386** | 0.005 | –0.130 | –0.220 |
| | 2015 | 0.262 | –0.011 | –0.028 | 0.135 |
| Poaceae | 2014 | 0.041 | 0.024 | –0.054 | 0.114 |
| | 2015 | –0.162* | 0.154* | 0.085 | 0.102 |
| Amaranthaceae | 2014 | 0.530** | –0.404** | –0.233** | 0.119 |
| | 2015 | 0.561** | –0.477** | –0.069 | 0.112 |
| *Plantago* | 2014 | 0.062 | 0.058 | –0.090 | –0.046 |
| | 2015 | 0.078 | –0.122 | –0.270** | 0.090 |
| *Rumex* | 2014 | 0.237* | –0.022 | –0.126 | –0.060 |
| | 2015 | 0.231** | –0.161 | –0.130 | –0.044 |
| *Platanus* | 2014 | - | - | - | - |
| | 2015 | 0.375* | –0.065 | –0.212 | 0.015 |

* Correlation is significant at the 0.05 level (2-tailed), $P < 0.05$.
** Correlation is significant at the 0.01 level (2-tailed), $P < 0.01$.

not only have a natural spread in the region's vegetation but also are intensively planted in gardens as decorative plants. Similar results were obtained in most of the studies conducted in different regions of Turkey, such as Eskişehir (Erkara et al., 2007), Kastamonu (Çeter et al., 2012), and Antalya (Tosunoglu et al., 2015a). Although the proportion of woody pollen in the majority of these studies varied from one region to another, it was always higher than that of herbaceous pollen.

The results related to herbaceous and woody taxa with the highest amount of airborne pollen in Uşak are very similar to the results recorded in studies conducted in the Mediterranean phytogeographic region in general (Table 5). Our results show that, unlike many Mediterranean countries, *Fraxinus* pollen is among the dominant pollen types in the region. This is probably due to the fact that the Mediterranean climate in Uşak Province is under the influence of the continental climate. Similarly, in provinces such as Eskişehir, Afyon, and İstanbul, where the transition climate reigns, *Fraxinus* pollen concentrations were higher than were Oleaceae pollen concentrations.

On the other hand, the analysis of all of the pollens indicated that, although not in high amounts, there was pollen belonging to plants of three different phytogeographical regions (Mediterranean, Irano-Turanian, and Euro-Siberian) (Figure 1). This result can be related to the fact that Uşak province is located between Western Anatolia and Central Anatolia, and that the elevations constituting the boundaries of the province in particular consist of elements belonging to all three phytogeographical regions.

The comparison of the results obtained in the present study with the results of the gravimetric study carried out in Uşak in 2000 (Bıcakcı et al., 2004) showed that the amount of woody pollen increased while that of herbaceous pollen decreased. While the dominant airborne pollen of the woody taxa constituted 74.13% of the total pollen in Bıcakcı et al.'s study, this rate increased to 81.37% in the present study. In addition, the rates of the *Quercus* and *Pinus* pollen in Bıcakcı et al.'s study, which were 11.18% and 29.67%, respectively, increased to 32.60% and 31.96% in the present study. On the other hand, while the pollen concentrations of Cupressaceae/Taxaceae and *Platanus*

**Table 5.** Comparison of dominant pollen taxa in Uşak province with other Mediterranean cities.

| | *Quercus* | Pinaceae | Cupress./Taxa. | *Fraxinus* | Poaceae | Amaranthaceae | *Plantago* | *Rumex* | *Platanus* |
|---|---|---|---|---|---|---|---|---|---|
| Bodrum (1) | 15.95% | 9.78% | 42.73% | 0.80% | 5.50% | 0.90% | 1.28% | 0.43% | 0.89% |
| Cagliari (2) | - | 20.39% | 51.13% | - | 2.10% | 1.54% | - | - | - |
| Estepona (3) | 17.33% | 2.96% | 20.52% | 0.40% | 10.46% | 1.86% | 3.33% | 0.93% | 1.88% |
| Split (4) | 5.6% | 10.6% | 49.9% | 0.5% | 2.2% | 0.2% | 0.5% | 0.4% | 1.1% |
| Salamanca (5) | 26.4% | 3.8% | 10.8% | - | 21.4% | 1.2% | 3.9% | 3.5% | 3.6% |
| Thessaloniki (6) | 20.8% | 8.9% | 24.9% | - | 6.3% | 2.5% | - | - | 5.4% |
| Uşak * | 32.60% | 31.96% | 10.22% | 5.47% | 4.74% | 1.82% | 1.59% | 1.18% | 1.12% |

Numbers refer to references: (1) Tosunoglu and Bıcakcı, 2015; (2) Ballero and Maxia, 2003; (3) Recio et al., 2006; (4) Puljak et al., 2016; (5) Rodríguez de la Cruz et al., 2010; (6) Gioulekas et al., 2004a; (*) Present study.

were lower in the present study than those in Bıcakcı et al.'s study, the pollen concentration of *Fraxinus* was higher.

Comparison of the monthly pollen distribution within a year revealed a similarity between the results of Bıçakçı et al.'s study (2004) and the results of the present study. The total amount of pollen, which started to increase in March and April in both studies, peaked in May. In similar aeropalynological studies conducted in Turkey, the months with the high airborne pollen concentrations were May, April, and March in İzmir (Guvensen and Ozturk, 2003) and May, April, and June in Afyon (Bıçakçı et al., 2002). That the months with high pollen concentrations in these studies were similar to the months in the present study is due to the similar climate types and vegetation in these regions. High pollen concentrations recorded in these months were due to the high amounts of pollen from woody taxa whose pollination season is spring.

The nine taxa whose pollen grains comprised more than 1% of the total number of pollen grains each during the two-year study period were *Quercus*, Pinaceae, Cupressaceae/Taxaceae, *Fraxinus*, Poaceae, Amaranthaceae, *Plantago*, *Rumex*, and *Platanus.* A pollen calendar showing the periods during which the pollen of these taxa is present in the air is given in Figure 5. On the other hand, the main pollen seasons of dominant taxa are given in Table 3. Of the woody taxa, *Quercus* had the highest pollen count, which accounted for 32.60% of all the pollen. This rate is considerably higher than the rates in similar studies. In Bıçakçı et al.'s gravimetric study (2004) conducted in this region, the rate of *Quercus* pollen was 11.18%. Similarly, in some other studies in which the amount of pollen of *Quercus* was high, the rates and places were as follows: 18.86% in Büyükorhan (Bursa) (Tosunoglu et al., 2015b) and 15.95% in Bodrum (Tosunoglu and Bıcakcı, 2015). The most important cause of the high airborne pollen concentration of *Quercus* in Uşak is the fact that it is an element of the Mediterranean macchie, densely growing evergreen shrubs, which have a widespread distribution in the region. On the other hand, the floristic studies conducted in the region detected the following species belonging to this genus: *Quercus cerris*, *Q. coccifera*, *Q. infectoria, Q. ithaburensis*, *Q. libani*, *Q. pubescens*, and *Q. vulcanica* (Çırpıcı, 1989; Dönmez Şahin and Serin, 2009). *Quercus* pollen started to appear (51 pollen grains) in March, significantly increased in April (2189 pollen grains), and peaked in May (5219 pollen grains) (Table 2). Similarly, the pollination period of *Quercus* started in the third week of March and peaked in the first week of May in Bıçakçı et al.'s (2004) study conducted in Uşak, Turkey. The increase in the average temperatures in the region with spring led to an increase in pollen concentrations. However, because the spring season in the second year was rainier, *Quercus* pollen concentrations in this period were lower than those in the first year. Similarly, that *Quercus* pollen concentrations declined suddenly in the first week of May of the first year was due to the fact that this period was rainy (Figure 6). The positive relationship between the total pollen concentration for *Quercus* and the average temperature was considered statistically significant in both years. However, the negative effect of total rainfall and relative humidity on *Quercus* pollen concentration in the first year was statistically significant (Table 4). This taxon, reported to have moderate to high allergenic effects, yielded positive results in skin prick tests (Subiza et al., 1995; Potoglu Erkara et al., 2009).

The airborne pollen with the second highest concentration (31.96%) in Uşak belonged to the Pinaceae. The number of airborne pollen grains belonging to this taxon is high, not only because it is in the natural flora of the region but also because it is used for planting

and decorative purposes in the settlement areas. Of the members of Pinaceae, *Pinus nigra* J.F.Arnold, *P. brutia*, *P. sylvestris*, and *Cedrus libani* are distributed in the elevations around the region, whereas *Pinus pinea*, *Cedrus atlantica*, and *C. deodara* are used for decorative purposes in parks and gardens. That the concentrations of Pinaceae airborne pollen detected in aeropalynological studies are high is due to the fact that the Pinaceae taxon produces high amounts of pollen, and its pollen can be transported long distances in the air. On the other hand, the pollen of this taxon has a low allergenic effect (Puc, 2003). In Uşak, the plant responsible for the pollination in the atmosphere between late July and January is most likely *Cedrus*. However, in the present study, pollen belonging to the genus *Pinus* and *Cedrus* was considered Pinaceae. Pinaceae pollen was observed in the atmosphere all year round and the highest concentration was recorded in May. Similar to the *Quercus* pollen, the amount of Pinaceae pollen increased with the increase in temperature in both years; however, because the spring months in the second year were rainier, the amount of Pinaceae pollen was lower in the second year (Figure 6). Similarly, in Bıçakçı et al.'s (2004) study, May was reported as the month with the highest amount of Pinaceae pollen.

The Cupressaceae/Taxaceae taxon (*Cupressus*, *Juniperus*, *Taxus*, and *Thuja*) is used for decorative purposes in parks and gardens in Uşak. Pollen from this taxon, which has been shown to be a cause of seasonal respiratory illnesses, especially in winter months in Mediterranean countries, has low or moderate allergenic effect (Charpin et al., 2005; D'Amato et al., 2007). Cupressaceae/Taxaceae, which releases a large amount of pollen into the air during its pollination period, was the taxon with the third highest concentration of airborne pollen (10.22%) in the present study. Bıçakçı et al. (2004) reported the rate of the airborne pollen belonging to this taxon in Uşak as 19.47%. Nevertheless, they also reported that its pollination period was between February and July and that the highest amount of pollen belonging to this taxon was recorded in the first week of May. In the present study, Cupressaceae/Taxaceae pollen was observed in the air more or less every month of the year, but the higher rates were recorded between February and June. During the course of the present study, the factor significantly affecting the amounts of airborne Cupressaceae/Taxaceae pollen was precipitation. In the second study year, the period during which this taxon pollinates was rainier, which caused a decrease in the total amount of pollen in the second year. On the other hand, the increase in the amount of airborne pollen especially in late April and early May in the second year due to low level of rainfall supports this view (Figure 6). The negative correlation between the amount of pollen and rainfall and humidity in the first year and the positive correlation between the amount of pollen and the mean temperature and negative correlation between humidity and the amount of pollen in the second year was statistically significant (Table 4). The sudden decline in pollen concentrations in March in the second year could be attributed to the fact that the temperatures dropped below 0 °C in this period.

*Fraxinus* pollen, which constituted 5.47% of the total airborne pollen in Uşak in the present study, has an allergenic effect at medium and high levels. In Austria, 17.6% of the pollen-allergic patients were allergic to *Fraxinus* pollen (Hemmer et al., 2000). However, that pollen belonging to this taxon shows cross-reactivity with other members of the family is of importance (Vara et al., 2016a). In some of the aeropalynological studies carried out in Turkey, the amount of pollen belonging to this taxon was 3.67% in Bitlis (Celenk and Bicakci, 2005), 3.58% in the Asian part of İstanbul, and 3.01% in the European part of İstanbul (Celenk et al., 2010). In gravimetric studies performed by Bıçakçı et al. (2004) in Uşak, the rate of the pollen belonging to this taxon was 1.48%. The results obtained in the present study indicated an increase in the amount of pollen of this taxon. Until May in the second year of the study, *Fraxinus* pollen was not dominant in the air. This is thought to be due to the fact that the second year was rainier than the first year and the average temperature was higher. The increase in the amount of pollen in the middle and at the end of May of the second year was attributed to the fact that the temperature peaked twice during this period (Figure 6). However, there was a statistically significant positive correlation between the total *Fraxinus* pollen concentration in the first year and the average temperature (Table 4). While Jato et al. (2004) report that flowering of *Fraxinus* depends on meteorological factors, mostly precipitation and maximum temperature, Vara et al. (2016b) report that there is a negative correlation between rainfall and the amount of *Fraxinus* pollen. *Fraxinus angustifolia* Vahl, which has a natural spread of the region, *F. excelsior* L., *F. americana* L., and *F. ornus* L., species planted especially in parks and gardens, were thought to be effective in increasing the amount of pollen in the atmosphere. However, these plants have different flowering times. Therefore, *Fraxinus* pollen was present in the atmosphere for a long time.

Of the herbaceous taxa in Uşak, Poaceae was the taxon with the highest pollen concentration (4.74%). In similar studies conducted around Uşak, the amount of pollen belonging to this taxon was 11.0% in Afyon (Bıçakçı et al., 2002) and 5.02% in Kütahya (Bıçakcı et al., 1999). This family, considered one of the most important aeroallergens in the world (D'Amato and Lobefalo, 1989), includes a variety of species; thus, its pollination period is long. In the present study, Poaceae pollen was detected in the air in

Uşak in every month of the year in different amounts, but reached the highest amount in May. In a study conducted by Bıçakçı et al. (2004), the highest amount of Poaceae pollen was recorded in the second week of June. With the increase in the air temperature, there was an increase in the amount of pollen, especially in late May, and more Poaceae pollen was recorded in the second year than in the first year. This difference between the two years is thought to be due to the high rainfall observed during the spring in the second year (Figure 6). In a similar study by Jato et al. (2009), spring rainfall was an important factor affecting the amount of Poaceae pollen. In Uşak Province, the Poaceae species, which are not only among the members of natural flora but also cultivated, are the source of pollen belonging to this family.

Amaranthaceae (1.82%), which constituted more than 1% of the total pollen concentration during the present study, was distributed at the roadsides, in the median strips, and in different parts of the city of Uşak. Pollen belonging to this taxon is reported to cause an allergic action at low, moderate, and high rates and yielded positive results in skin tests in 18.3% of the individuals with respiratory allergies in Thessaloniki (Gioulekas et al., 2004b). The highest levels of pollen belonging to this taxon were recorded in August in the atmosphere of Uşak. The amounts of pollens in the air were particularly affected by rainy periods. After the rainy season in the first week of August in the second year, the amount of pollen increased in the last period, which had no precipitation. Similarly, that the period without precipitation continued in September in the second year caused the amount of pollen to be higher than that in September in the first year, which was rainy (Figure 6). In the present study, the positive relationship between Amaranthaceae pollen concentrations and mean temperature values and the negative relation between Amaranthaceae pollen concentrations and mean values of humidity and rainfall were statistically significant (Table 4). The results recorded in the studies performed in Salamanca, Spain (Rodriguez de la Cruz et al., 2012) and Porto, Portugal (Ribeiro and Abreu, 2014) are similar to the results obtained in the present study.

*Plantago* pollen, which comprised 1.59% of the total airborne pollen, has low, moderate, and high allergenic effects. According to Rodriguez-Rajo et al. (2004), despite its low count, *Plantago* pollen is an important taxon causing pollinosis. In a study performed by Bıçakçı et al. (2004) in Uşak, the rate of the pollen belonging to this taxon was 0.77% between April and August. In our study, the *Plantago* pollen was detected between February and September in the air in Uşak, but its amount reached the highest levels between April and July. The amount of pollen belonging to this taxon increased noticeably in late June and in July compared to the previous month. It is thought that the amount of pollen belonging to this taxon this year was affected by the May–June rains (Figure 6). Statistical data support these results too. The inverse proportion between the amount of *Plantago* pollen and total rainfall in the second year was statistically significant (Table 4).

In the floristic studies performed, the following species belonging to the genus *Rumex* were in the natural flora of the region: *Rumex acetosella* L., *R. angustifolius* Campd. subsp. *angustifolius*, *R. conglomeratum* Murray, *R. crispus* L., *R. gracilescens* Rech. fil., *R. nepalensis* Sprengel, *R. olympicus* Boiss., *R. pulcher* L., *R. scutatus* L., and *R. tuberosus* L. subsp. *horizontalis* (Koch) Rech. In aeropalynological studies carried out in Turkey, pollen concentrations of this taxon were mostly below 1%. The rate of pollen belonging to *Rumex*, which constituted 1.18% of the total pollen in the present study, was 2.50% in Bitlis (Celenk and Bicakci, 2005) and 1.42% in Van (Bicakci et al., 2017). The pollen of this taxon, known to have a moderate allergenic effect (Chapman and Williams, 1984), existed in the air between February and August in Uşak. The increase in *Rumex* pollen was in line with the increase in temperature, but the decrease in pollen in late May and in June in the second year indicated that precipitation was effective (Figure 6). Statistical data revealed a positive correlation between the amount of pollen and temperature in both years (Table 4). In a similar study conducted in Lublin by Piotrowska (2012), temperature was noted to be the most important factor in determining the *Rumex* pollen season.

In various studies, *Platanus* has been described as a taxon that has allergic potential and gives positive results in skin prick tests (Verela et al., 1997). *Platanus* is planted in parks and gardens in the city center, and pollen belonging to *Platanus* was recorded in the Uşak atmosphere between February and June, with the highest amount in April. The rate of pollen belonging to this taxon, which constituted 1.12% of the total pollen in the present study, was 7.34% in Bıçakçı et al.'s study (2004), with the highest amount in April. The amount of *Platanus* pollen was affected by temperature and precipitation during the study period. The *Platanus* pollen was first seen in late February in the first year and in late March in the second year. This delay in the second year was thought to be due to lower temperatures and a rainier March in the second year (Figure 6). In the second year, there was a sudden increase in the amount of pollen in the middle of April, when the temperature rose and there was no precipitation, and a positive significant relation was determined between the average temperature and the amount of pollen in this year (Table 4).

In the study period, other than during their pollination periods, *Alnus* and *Corylus* pollen was very low in July, *Morus* pollen in August and September, *Quercus* pollen in January and February, and *Tilia* pollen in February and April. The pollen of these taxa found on the soil surface

or vegetation may most likely have been caught by the volumetric trap after floating in the air because of the increase in wind intensity (Figure 6).

In the present study, 19 pollen grains of *Ambrosia* were detected. Presence of airborne pollen of *Ambrosia*, an invasive species, in Uşak is important for people allergic to it. It is reported that the pollen belonging to this taxon, especially found in agricultural areas and road sides, can travel far distances. Although there is no record of this plant in Uşak, that its pollen is found in the atmosphere is probably due to the fact that the plant could be present in agricultural areas, or it may be carried by winds from the northern regions such as Büyükorhan (Bursa) (Tosunoglu et al., 2015b). Similarly, it has been reported that the *Ambrosia* plant is not distributed in these provinces. However, *Ambrosia* pollen detected in the atmosphere of this province is thought to come here from the Black Sea Region (Düzce), where the plant is distributed, through long-distance pollen transport (Serbes and Kaplan, 2014).

The results obtained in the present study indicate that the dominant types of airborne pollen recorded in Uşak between 2014 and 2016 were generally moderately and highly allergenic. On the other hand, of the taxa with the dominant airborne pollen, Pinaceae was the only taxon with low allergic effect, although it had the airborne pollen with the second highest count. That the pollen of this taxon constituted 31.96% of the total airborne pollen reduced the proportion of allergenic airborne pollen to a certain extent in Uşak. The highest pollen concentrations of *Quercus*, *Fraxinus*, Poaceae, and *Plantago*, which are highly allergenic taxa, were recorded in May. Therefore, in Uşak, May is the riskiest month for individuals allergic to pollen. The decrease in the total number of woody taxa in the spring months of the second year during which these taxa pollinate indicates that high rainfall and high humidity in the second year caused washing effects on pollen. The comparison of data obtained in the two years revealed that the temperature had a positive effect on the amount of pollen in Uşak atmosphere, and precipitation and humidity had a negative effect; the mean wind speed was higher in all months of the second year but its effect was not statistically significant. While some of the taxa whose pollen was dominant during the study are in the natural flora of the region, other taxa are planted in parks and gardens. The results and pollen maps in the present study will help individuals susceptible to pollen to organize their daily activities more effectively and will guide local authorities to select more suitable plants in afforestation activities within Uşak Province.

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