

## Relationship between pollen counts and weather variables in the atmosphere of Mersin Province on the Eastern Mediterranean Coast of Turkey

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**Abstract:** This study researched atmospheric pollen from Mersin Province using the volumetric method between in 2016 and 2017. The daily, weekly, monthly, and annual distribution of the pollen obtained during the study was identified. The relationship between pollen and meteorological factors was researched using Spearman's rho analysis. During the two-year study, 32,336 pollen grains/m<sup>3</sup> from 40 different taxa [22 trees, 1 grass (Poaceae), and 17 other weeds] were identified. Of the total pollen, 82% belonged to trees, 6.8% to grasses, 11% to other weeds, and unidentified taxa accounted for 0.2%. In the first year, 17,070 pollen grains/m<sup>3</sup> were identified in the atmosphere and 15,266 pollen grains/m<sup>3</sup> were identified in the second year. The pollen concentration was at its peak between March and July. Pollen grains of the following taxa, listed according to density, were discovered in the atmosphere: Cupressaceae/Taxaceae (26.49%), Pinaceae (25.61%), *Olea* (12.76%), Urticaceae (7.00%), Poaceae (6.77%), and *Fraxinus* (5.06%). According to the statistical analysis while sunshine duration, relative humidity, and wind speed usually have a positive correlation, precipitation has a negative correlation with pollen concentration.

**Key words:** Aeropalynology, aerobiology, meteorological factor, Mersin, Turkey

### 1. Introduction

Pollen, spores, hyphae, algae, small seeds, insect larvae, insect fragments, and protozoa are the leading particles in the atmosphere that have a diameter of 0.5–100 µm (Sin et al., 2007). Studying these airborne particles is the main goal of aerobiology, a practice that attempts to understand the spread of allergenic and other diseases in humans, animals, and plants in order to prevent their possible destructive effects (Lacey and West, 2006). Aerobiology involves different fields that intend to diagnose and remedy biological and environmental problems in disciplines such as medicine, meteorology, entomology, environmental studies, phytopathology, agriculture, and criminology (Dopazo et al., 2000; Brown, 2004).

Anemophilous plants, especially grasses, gymnosperms, and some angiosperms, are the main sources of atmospheric pollen (Lacey and West, 2006). Pollen may contain tens of allergenic proteins and glycoproteins of different types. Pollen that reaches the human respiratory system can cause allergic rhinitis, allergic conjunctivitis, and allergic asthma in sensitive individuals by releasing the allergic protein in its structure (Tekat, 2002; Puc, 2003; Serbes and Kaplan, 2014). In order to help patients who complain of pollen allergies it is useful to detect the type and proportion of pollen grains in the atmosphere. Because pollen grains affect

health, pollen calendars have been prepared worldwide for many years (Stennett and Beggs, 2004; Jariwala et al., 2014; Makra et al., 2015; Martínez-Bracero et al., 2015; Guarín et al., 2015; Chakraborty et al., 2016; Žiarovská and Zelenáková, 2016). They have also been prepared for some Turkish cities (Bıçakçı and Akyalçın, 2000; Dursun et al., 2008; Kızılpınar and Doğan, 2010; Saatçioğlu et al., 2011; Yükselen et al., 2013; Tosunoglu and Bicakci, 2015; Acar et al., 2015; Türkmen et al., 2018).

Cases of pollen allergy are frequently reported, diagnosed, and described in temperate and seasonal areas. That is why most aerobiological studies have been performed in these areas (D'Amato et al., 2007). In the current study, pollen grains in the atmosphere of Mersin, which has a Mediterranean climate, were investigated for two years using the volumetric method.

Airborne pollen from the urban area of Mersin was analyzed to identify different types of pollen which have been reported as allergenic or likely to cause multiple diseases in other countries.

### 2. Materials and methods

#### 2.1. Study area and flora

Mersin is located in the Adana division of the Mediterranean region, between 34°47'30" north latitude

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and 34°38'00" east longitude. With a surface area of 15.853 km<sup>2</sup> Mersin province covers 2% of Turkey. The land border of Mersin is 608 km, the sea border is 321 km, and 108 km of the coastal line consists of natural sandy beaches<sup>1</sup>.

Located in the Mediterranean phytogeographic region, Mersin resides in squares C4 and C5, according to the Grid system of Davis (Davis, 1965). The C5 frame in particular constitutes one of Turkey's richest regions in terms of endemism (Davis, 1965–1985; Davis et al., 1988; Güner et al., 2000; Kutluk and Aytuğ, 2000). This region is of great importance worldwide due to its large number of endemic species and diverse habitats (Duran and Günek, 2010). According to Turkey's Plants Data Service (TUBİVES), the flora of Mersin is comprised of 1724 taxa, and 399 of these taxa are endemic (Everest and Ozturk, 2005).

Since the summers are hot and dry in Mersin, the vegetation is mostly xerophyte (arid). The lower parts of the region are covered with thick and bright leaves, evergreen shrubs, as well as shrubs and coniferous forests with high light and warmth. In the higher elevations of the region, only coniferous forests are found (Duran and Günek, 2010).

Topography is one of the most important factors determining the distribution and development of plant communities. Topographic factors such as altitude, view, and slope of the land create diverse vegetation and flora-influencing vegetation. The Bolkar Mountains offer the best place to observe the effect of topography on vegetation in Mersin. The Bolkar Mountains (3524 m) are located in the Taurus Mountains, a part of the Alpine–Himalayan system within the provincial borders of Mersin. The Bolkar Mountains, which have a length of about 150 km and a width of 40–50 km, are very rich in terms of plant species diversity (Ünaldı and Kömüçü, 2007). There are more than 1500 plant species in this area, and 300 of them were found to be endemic (Gemici, 1994).

Located in the northwest of Mersin, within the boundaries of Mezitli, Fındıklı is a plateau 1250 m high. In this region 85 endemic species have been identified. On the plateau, Fabaceae is represented by 62 species (13.4%), Lamiaceae by 43 (9.3%), Brassicaceae by 45 (9.7%), Asteraceae by 36 (7.7%), and Boraginaceae by 32 species (6.9%). *Trifolium* (12 species; 2.5%), *Alyssum* (11 species; 2.3%), and *Ranunculus* and *Euphorbia* (10 species; 2.1%) are the most common species in the region (Orcan et al., 2004).

The Taşeli Plateau is located to the north of Anamur (Mersin) and south of Ermenek at an altitude of 1500 m. Of the 1053 taxa which spread throughout the Taşeli Plateau 213 were found to be endemic. *Verbascum microcephalum* and *Astragalus talassaus* are listed among the endangered plants (Siler and Şengün, 2014).

Sorgun, Taurus, Aygadı, and Güzeloluk highlands are located on the high plateaus of the Central-Taurus-facing Mediterranean, and 462 species and subspecies which belong to 69 families were identified in these regions. Of these taxa 10.6% (49 species) are endemic. Asteraceae (57 species), Fabaceae (49 species), Lamiaceae (36 species), Brassicaceae (32 species), and Poaceae (28 species) are the families which have the most taxa in the area. *Achillea phrygia*, *Onosma mutabile*, *Astragalus pinetorum* ile *Alkanna pinardii*, *Alkanna macrophylla*, *Verbascum latisepalum*, *Euphorbia isaurica*, *Centaurea pseudoreflexa*, *Arabis androsacea*, *Petrorhagia lycica*, *Anthemis fimbriata*, and *Nepeta caesarea* species are endemic and endangered in the region according to the Red List categories (Yüceol et al., 2009).

## 2.2. Meteorological description

Distribution of pollen which causes allergy and is, in particular, pollinated by wind, depends on the climate parameters. July and August are the months when the mean temperature is highest, as it was during the two-year observation performed in 2016–2017 in Mersin. The coldest months are January, February, and December. The longest monthly sunshine duration was 340.1 h in July, and the shortest mean sunshine duration was 128.4 h in December. Maximum precipitation was observed in December. No precipitation was observed in July, and minimum precipitation was seen in August, September, and October. The highest monthly mean relative humidity observed during these two years was 66.2% in June, and the lowest mean relative humidity was 64.2% in November. According to the Beaufort wind scale, winds which have a speed less than 10.8 m/s (<6 Beaufort) are low speed winds. During the study period the wind speed in Mersin was low. The highest mean wind speed observed in these years was 1.60 m/s in May and July, and the lowest wind speed was 0.9 m/s in October. Wind direction is one of the essential parameters of climatic aspects. The winds blow mainly from the north. It was found that the wind was blowing from the north in January, February, March, April, October, November, and December. The wind was blowing from south and southeast in June, July, and August (Turkish State Meteorological Service). The meteorological data from Mersin is given in Table 1.

## 2.3. Aerobiological method

An aeropalynological study was performed in Mersin using a Hirst-type volumetric trap (Burkard Manufacturing Co. Ltd., UK) during a 2-year period (2016–2017) (Hirst, 1952). In the study, the guidelines of the IAA and recommendations proposed by the Spanish Aerobiology Network (Galán et al., 2007, 2014) were followed. The pollen trap used in the study was located on the roof of

<sup>1</sup> Turkish Statistical Institute (2013). Seçilmiş göstergelerle Mersin: Türkiye İstatistik Kurumu [online]. Website <http://www.mersin.gov.tr/kurumlar/mersin.gov.tr/Genel/depo/mersin2013.pdf> [accessed 18 July 2019].

the Healthcare Services Vocational High School of Mersin University, and all sides of it were left uncovered. The roof of the Mersin University Hospital is 25 m above ground and 3.5 km from the sea (Google Earth Pro, version 7.3) (Figure 1). Identification and counting of pollen grains was performed with a light microscope (400×) and based on 4 longitudinal transects along the slides. The pollen count obtained from the sampler was converted to the pollen concentration in 1 m<sup>3</sup> of air.

To determine the correlation of meteorological parameters with pollen concentration, meteorological data

including temperature, sunshine duration, precipitation, relative humidity, and wind speed for Mersin during 2016–2017 were kindly provided by the Turkish Meteorological Data Archiving System.

**2.4. Statistical analysis**

In this aeropalinologic study which was carried out at the Hacettepe University Department of Biology, Faculty of Science, daily pollen concentrations obtained from the sampler and their relationship with meteorological factors such as temperature, sunshine duration, precipitation, relative humidity, and wind speed were statistically

**Table 1.** Mean monthly meteorological data recorded in Mersin, obtained from the State Meteorological Service of Turkey.

Meteorological data	Year	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean temperature (°C)	2016	9.7	11.8	16.8	20.3	21.7	26.8	29.6	30.0	26.7	23.6	17.3	10.1
	2017	11.9	14.7	15.6	18.6	21.9	25.9	30.0	30.0	28.1	22.8	17.1	14.6
Sunshine duration (h)	2016	144.5	185.4	254.3	264.7	251.8	314.2	331.0	335.0	271.7	253.0	185.4	107.9
	2017	116.6	139.7	190.3	259.4	251.3	317.1	349.2	316.1	279.6	272.3	170.9	148.9
Precipitation (mm)	2016	95.2	0.8	74.0	1.8	16.0	11.4	0	6.6	12.2	0.4	12.2	366.4
	2017	201.4	49.8	153.6	87.2	11.4	7.8	0	7.4	12.4	11.8	123.2	29.8
Relative humidity (%)	2016	56.0	47.7	54.7	59.5	65.5	65.5	65.6	64.4	54.9	49.9	39.4	58.2
	2017	63.4	58.3	57.8	58.4	64.3	66.9	63.7	62.4	59.2	44.7	53.0	54.8
Wind speed (m/s)	2016	1.1	1.1	1.6	1.2	1.6	1.3	1.6	1.6	1.3	0.8	0.9	1.2
	2017	1.1	1.6	1.4	1.6	1.5	1.5	1.5	1.4	1.1	1.0	1.0	1.0



**Figure 1.** Location and geographical map of Mersin.



assessed through Spearman's rho analysis using IBM SPSS 23.0 software (IBM Corp., Armonk, NY, USA).

**3. Results**

As a result of the 2-year aeropalynological survey, 32,336 pollen grains/m<sup>3</sup> from 40 different taxa, including 22 trees (woody perennials and shrubs), 1 grass, and 17 other weeds were detected. Of the pollen collected, 82% belonged to trees, 6.8% to grasses, 11% to other weeds, and unidentified taxa accounted for 0.2% of all pollen collected. In the first

year, 17,070 pollen grains/m<sup>3</sup> were identified in the air; 15,266 pollen grains/m<sup>3</sup> were detected in the second year (Table 2). It was observed that the pollen concentration was at its peak in March, April, and May (Table 3).

The total number of taxa represented in the identified pollen began to increase in February and reached its peak in April. The total number of taxa in the pollen decreased to its minimum level in December (Figure 2).

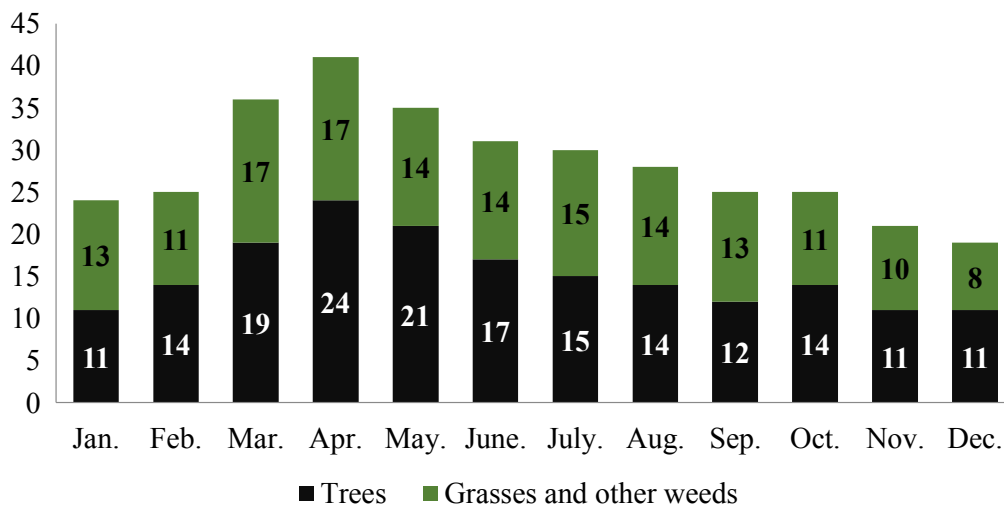
In the samples for 2016 from Mersin the pollen from 33 different taxa was identified, including 19 trees, 1 grass,

**Table 2.** Yearly pollen concentration (pollen grains/m<sup>3</sup>) and percentage (%) values of pollen grains belongs to trees, grasses, other weeds, and unidentified taxa observed in Mersin atmosphere (2016–2017).

	2016		2017		Total	
	Pollen grains/m <sup>3</sup>	%	Pollen grains/m <sup>3</sup>	%	Pollen grains/m <sup>3</sup>	%
Trees	14259	83.5	12248	80.2	26507	82.0
Grasses	1116	6.5	1073	7.1	2189	6.8
Other weeds	1672	9.9	1896	12.4	3568	11.0
Unidentified	23	0.1	49	0.3	72	0.2
Total pollen	17070	100	15266	100	32336	100

**Table 3.** Taxa of the pollen observed during 2 years in Mersin and monthly pollen concentrations belonging to these taxa (pollen grains/m<sup>3</sup>) (2016–2017).

Year	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Total pollen
2016	140	418	8734	4873	876	882	536	211	75	54	77	194	17,070
2017	68	508	3961	3920	4368	926	546	294	163	380	93	39	15,266
Total	208	926	12695	8793	5244	1808	1082	505	238	434	170	233	32,336



**Figure 2.** Variation in number of trees, grasses, and other weeds according to mean values of sampling years in Mersin atmosphere (2016–2017).

and 13 other weeds. Of the total pollen collected from these samples, 14,259 pollen grains/m<sup>3</sup> were from trees, 1116 pollen grains/m<sup>3</sup> were from grasses, 1672 pollen grains/m<sup>3</sup> came from other weeds, and 23 pollen grains/m<sup>3</sup> were from unidentified taxa (Table 4). When the monthly pollen concentrations in 1 m<sup>3</sup> of air in the Mersin atmosphere were examined, it was found that maximum pollen concentration occurred in March (Table 3). The minimum pollen concentration was in October. For the year 2016, the highest pollen concentrations were observed in the atmosphere between March and June (Table 3). The Cupressaceae/Taxaceae and Pinaceae family members were the taxa with the most commonly observed pollen, and the members of *Aesculus*, *Bellis*, and *Taraxacum* were the taxa with the least commonly observed pollen in the Mersin atmosphere (Table 4).

The pollen represented a total of 38 different taxa; 22 were trees, 1 was a grass, and 15 other weeds were identified in the samples from 2017. Among these samples, 12,248 pollen grains/m<sup>3</sup> were from trees, 1073 pollen grains/m<sup>3</sup> were from grasses, 1896 pollen grains/m<sup>3</sup> came from other weeds, and 49 pollen grains/m<sup>3</sup> were from unidentified taxa (Table 2). The number of taxa with pollen grains in the atmosphere reached its peak value in May in 2017 and decreased to a minimum value in December (Table 3). The highest pollen concentrations in the atmosphere were observed between March and June in Mersin for the year 2017 (Table 3). Pinaceae and *Olea* were the taxa whose pollen was observed most frequently, and *Alnus*, Rutaceae, and *Xanthium* were the taxa whose pollen was observed least frequently in the Mersin atmosphere (Table 4).

In the atmosphere of Mersin there were 9 dominant taxa whose pollen concentrations were above 1%, and their percentage has been given at Table 5. These taxa were Cupressaceae/Taxaceae (26.49%), Pinaceae (25.61%), *Olea* (12.76%), Urticaceae (7.00%), Poaceae (6.77%), *Fraxinus* (5.06%), *Platanus* (4.43%), *Quercus* (2.40%), and Arecaceae (1.18%).

The highest pollen concentrations were detected from March to June in both of the study years. The pollen grains belonging to Cupressaceae/Taxaceae, Pinaceae, Urticaceae, and *Fraxinus* taxa showed a dramatic increase in the atmosphere in March (Table 5, Figure 3).

The relationship between meteorological factors and the pollen concentrations of trees, grasses, and other weeds was examined by Spearman's rho analysis (Table 6). Accordingly, the total pollen concentration detected in the Mersin atmosphere showed a significant and positive correlation with sunshine duration, relative humidity, and wind speed in 2016 (sig. < 0.01; P = 0.222, 0.234, and 0.349, respectively). There was no significant relationship with temperature and precipitation. In 2017, total pollen concentration showed a positive relationship

with temperature, sunshine duration, relative humidity, and wind speed (sig. < 0.01; P = 0.216, 0.301, 0.152, and 0.305, respectively), while it indicated a negative and significant correlation with precipitation (sig. < 0.01; P = -0.146).

The pollen concentration of grasses (Poaceae) showed a positive and significant correlation with the temperature, sunshine duration, relative humidity, and wind speed (Table 6). In the first year of the study, no significant relationship was seen between the pollen concentrations of grasses and precipitation, while a negative correlation was observed in the second year of the study.

The pollen concentrations of trees in the Mersin atmosphere showed a positive correlation with relative humidity and wind speed in the first year of the study and showed a negative and significant correlation with temperature (Table 6). In the second year, a positive and significant correlation with sunshine duration and wind speed was found.

Pollen concentrations of other weeds detected in the atmosphere showed a slightly positive and significant correlation with sunshine duration and wind speed in the first year of the study (Table 6). In the second year of the study, pollen concentrations of other weeds indicated a slightly positive correlation with the temperature, sunshine duration, relative humidity, and wind speed and a slightly negative and significant correlation with precipitation.

Pollen concentrations of the taxa that were detected at levels over 1% within total concentrations as well as their interaction with temperature, sunshine duration, precipitation, relative humidity, and wind speed were statistically evaluated using SPSS software (Table 7).

In the atmosphere of the region, the highest pollen concentrations belong to Cupressaceae/Taxaceae (26.49%) (Table 5). There was a slightly positive correlation between wind speed and pollen concentration, and there was a slightly significant negative correlation with temperature (Table 7). However, no significant relationship was found between pollen concentration and sunshine duration, precipitation, relative humidity, and wind speed.

Pollen concentrations of Pinaceae were ranked second, accounting for 25.61% in the atmosphere of the region (Table 5), and showed a positive and significant correlation with temperature, sunshine duration, relative humidity, and wind speed (Table 7). No significant relationship was found between pollen concentration and precipitation.

*Olea* is one of the taxa whose pollen is most intensely observed in the Mersin atmosphere (Table 5). Pollen concentrations of this taxa showed a positive and significant relationship with temperature, sunshine duration, relative humidity, and wind speed (Table 7). No significant relationship was found with precipitation.

**Table 4.** Annual pollen concentrations and percentages of pollen taxa recorded in Mersin (pollen grains/m<sup>3</sup>) (2016–2017).

Taxa	2016		2017		Mean	
	Total	%	Total	%	Total	%
<i>Acer</i>	8	0.06	62	0.51	70	0.22
<i>Aesculus</i>	1	0.01	15	0.12	16	0.05
<i>Ailanthus</i>	7	0.05	91	0.74	98	0.30
<i>Alnus</i>	13	0.09	1	0.01	14	0.04
Arecaceae	286	2.01	96	0.78	382	1.18
<i>Carpinus</i>	27	0.19	21	0.17	48	0.15
Cupressaceae/Taxaceae	6538	45.85	2027	16.55	8565	26.49
Ericaceae	-	-	9	0.07	9	0.03
<i>Eucalyptus</i>	56	0.39	72	0.59	128	0.40
<i>Fagus</i>	20	0.14	285	2.33	305	0.94
<i>Fraxinus</i>	1215	8.52	422	3.45	1637	5.06
Juglandaceae	7	0.05	135	1.10	142	0.44
<i>Olea</i>	840	5.89	3287	26.84	4127	12.76
Pinaceae	4072	28.56	4208	34.36	8280	25.61
<i>Platanus</i>	600	4.21	833	6.80	1433	4.43
<i>Populus</i>	152	1.07	80	0.65	232	0.72
<i>Quercus</i>	387	2.71	390	3.18	777	2.40
Rutaceae	12	0.08	1	0.01	13	0.04
<i>Salix</i>	3	0.02	109	0.89	112	0.35
<i>Tilia</i>	15	0.11	43	0.35	58	0.18
<i>Ulmus</i>	-	-	22	0.18	22	0.07
<i>Vitis</i>	-	-	39	0.32	39	0.12
Trees	14,259	100.00	12,248	100.00	26,507	
Poaceae	1116	40.03	1073	36.14	2189	6.77
Apiaceae	22	0.79	63	2.12	85	0.26
<i>Artemisia</i>	-	-	177	5.96	177	0.55
Asteraceae	21	0.75	61	2.05	82	0.25
<i>Bellis</i>	1	0.04	-	-	1	0.00
<i>Carex</i>	13	0.47	26	0.88	39	0.12
Caryophyllaceae	6	0.22	22	0.74	28	0.09
<i>Centaurea</i>	2	0.07	-	-	2	0.01
Chenopodiaceae/Amaranthaceae	107	3.84	212	7.14	319	0.99
Lamiaceae	4	0.14	4	0.13	8	0.02
Liliaceae	65	2.33	17	0.57	82	0.25
<i>Plantago</i>	78	2.80	105	3.54	183	0.57
Rubiaceae	-	-	7	0.24	7	0.22
<i>Rumex</i>	25	0.90	95	3.20	120	0.37
<i>Sambucus</i>	-	-	148	4.98	148	0.46
<i>Taraxacum</i>	1	0.04	22	0.74	23	0.07
Urticaceae	1327	47.60	936	31.53	2263	7.00
<i>Xanthium</i>	-	-	1	0.03	1	0.00
Otherweeds	2788	100.00	2969	100.00	5757	
Unidentified	23	0.13	49	0.32	72	0.22
Total	17,070	100.00	15,266	100.00	32,336	100.00

**Table 5.** The highest pollen concentrations (pollen grains/m<sup>3</sup>) in consecutive months and their yearly composition (%), Mersin.

Taxa	Total	%	Year	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
Cupressaceae/ Taxaceae	8565	26.49	2016	61	395	4760	1171	71	18	14	4	16	6	6	16
			2017	27	413	597	410	316	156	30	29	18	9	16	6
Pinaceae	8280	25.61	2016	44	5	1385	1384	456	423	96	53	39	30	45	112
			2017	16	7	2061	900	416	312	134	85	27	199	35	16
<i>Olea</i>	4127	12.76	2016	-	-	-	804	29	6	1	-	-	-	-	-
			2017	-	-	3	1209	1990	68	9	6	2	-	-	-
Urticaceae	2263	7.00	2016	-	3	1118	173	7	16	9	-	1	-	-	-
			2017	2	15	595	175	132	14	-	-	-	-	-	3
Poaceae	2189	6.77	2016	3	-	69	95	168	329	322	98	1	5	6	20
			2017	11	5	49	105	276	257	192	77	45	37	16	3
<i>Fraxinus</i>	1637	5.06	2016	-	-	1030	171	4	0	3	-	3	1	-	3
			2017	-	-	53	179	189	0	1	-	-	-	-	-
<i>Platanus</i>	1433	4.43	2016	1	1	44	456	45	43	4	3	1	1	-	1
			2017	-	7	91	297	401	-	8	2	10	8	6	3
<i>Quercus</i>	777	2.40	2016	-	-	110	247	14	2	7	2	-	-	-	5
			2017	-	-	162	42	177	1	4	2	-	1	1	-
Arecaceae	382	1.18	2016	-	4	9	205	57	11	-	-	-	-	-	-
			2017	-	-	20	58	18	-	-	-	-	-	-	-

The pollen concentrations of Urticaceae were affected by relative humidity and wind speed in a positive way (Table 7). The pollen concentrations of the taxon decreased with an increase in temperature. No effects from sunshine duration and precipitation were observed in the pollen concentrations of Urticaceae (Table 7).

Temperature and sunshine duration were the most important climatic factors affecting pollen concentrations of the Poaceae (Table 7). It was also found that pollen concentration was affected in a positive way with an increase in relative humidity and wind speed. Furthermore, a negative correlation was detected between pollen concentrations of Poaceae and precipitation.

A positive correlation was detected between pollen concentrations of *Fraxinus* and wind speed; a negative correlation was found with temperature (Table 7). Additionally, no significant relationship was found between pollen concentration and sunshine duration, precipitation, and relative humidity (Table 7).

The relationship between pollen concentrations of *Platanus* and sunshine duration, relative humidity, and wind speed was positive and significant in statistical terms (Table 7). There is a negative and significant relationship between pollen concentrations and precipitation.

The relationship between the pollen concentrations of *Quercus* and relative humidity and wind speed is

significant in statistical terms (Table 7). There was a slightly positive correlation between pollen concentrations and the specified meteorological data.

The pollen concentrations of Arecaceae had a positive and significant relationship with relative humidity and wind speed (Table 7).

#### 4. Discussion

Distribution of pollen through the atmosphere substantially depends on climatic parameters. In general, the amount of pollen in the atmosphere reaches peak concentration during the days which are the sunniest and dry with high temperatures and moderate winds (Bıçakçı and Tosunoğlu, 2016). Many studies found that there was a significant and positive relationship between pollen concentration in the atmosphere and temperature. Therefore, the pollination period of plant taxa starts 3–4 weeks later than in taxa which originate at sea level because the temperature is lower in areas with high altitudes. On the other hand, the pollination period starts earlier because mild winters affect the evolution of plants in a positive way (Gemici, 2011; Tosunoglu and Bicakci, 2015). In this study, it was found that the maximum pollen concentrations in the atmosphere occur in March, April, and May when the temperature rises. In the region of the study, a strong positive relationship was detected in particular between

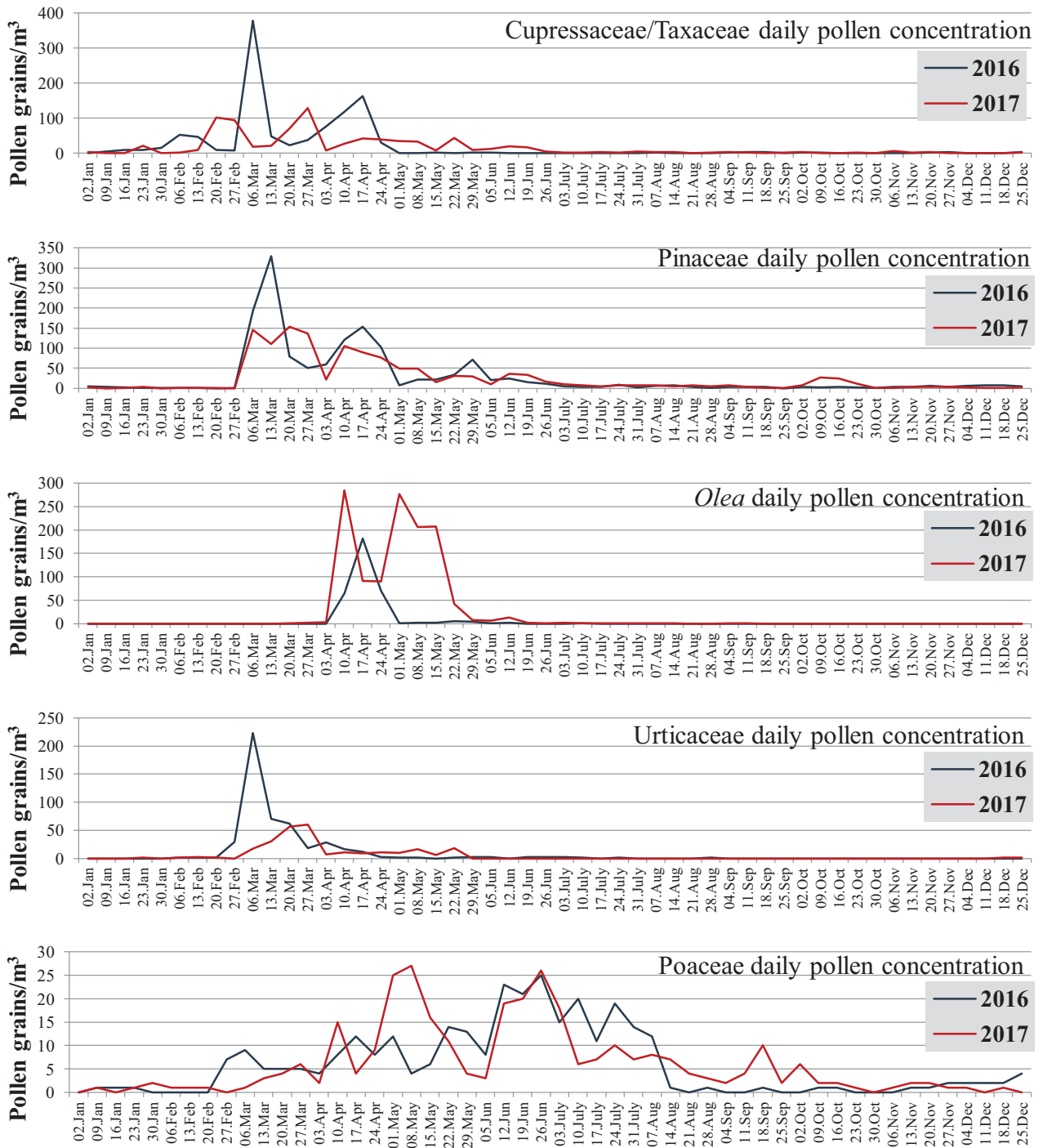


Figure 3. Daily pollen concentration of 5 most dominant taxa for the atmosphere of Mersin.

the pollen concentrations of grasses (Poaceae) and mean temperature.

It is known that precipitation and relative humidity create a negative correlation in the concentration and distribution of pollen grains in the atmosphere. High relative humidity prevents the mature anthers from blooming and delays the spreading process of the pollen.

During periods when relative humidity is high in the atmosphere, pollen obtains water from the environment, becomes heavier, and falls on the soil due to gravity (Sin et al., 2007; Gemici, 2011; Tosunoglu and Bicakci, 2015). In our study, no significant relationship was found between precipitation and pollen concentrations in 2016. In 2017, it was observed that precipitation had a negative correlation,



**Table 6.** The result of Spearman's correlation analysis between daily pollen concentrations (pollen grains/m<sup>3</sup>) of trees, grasses, other weeds, and meteorological parameters.

	Mean daily temperature (°C)		Main daily sunshine duration (hour)		Daily precipitation (mm)		Mean daily relative humidity (%)		Mean daily wind speed (m/s)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Pollen concentrations										
Trees	<b>-0.138**</b>	<b>0.094</b>	0.092	<b>0.229**</b>	.057	<b>-0.101</b>	<b>0.173**</b>	<b>0.122*</b>	<b>0.268**</b>	<b>0.278**</b>
Grasses	<b>0.431**</b>	<b>0.496**</b>	<b>0.469**</b>	<b>0.454**</b>	-0.057	<b>-0.218**</b>	<b>0.395**</b>	<b>0.271**</b>	<b>0.360**</b>	<b>0.319**</b>
Other weeds	0.096	<b>0.246**</b>	<b>0.225**</b>	<b>0.286**</b>	-0.050	<b>-0.192**</b>	0.118*	<b>0.145**</b>	<b>0.196**</b>	<b>0.296**</b>
Total	0.019	<b>0.216**</b>	<b>0.222**</b>	<b>0.301**</b>	0.018	<b>-0.146**</b>	<b>0.234**</b>	<b>0.152**</b>	<b>0.349**</b>	<b>0.305**</b>

Statistically significant values are shown in bold;

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

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

**Table 7.** The result of Spearman's correlation analysis between daily pollen concentrations of dominant taxa and meteorological parameters in 2016 and 2017.

Pollen concentrations (pollen grains/m <sup>3</sup> )	Mean daily temperature (°C)	Main daily sunshine duration (hour)	Daily precipitation (mm)	Mean daily relative humidity (%)	Mean daily wind speed (m/s)
Cupressaceae/ Taxaceae	<b>-0.170**</b>	0.035	0.001	0.023	<b>0.158**</b>
Pinaceae	<b>0.163**</b>	<b>0.258**</b>	-0.06	<b>0.213**</b>	<b>0.286**</b>
<i>Olea</i>	<b>0.147**</b>	<b>0.221**</b>	-0.058	<b>0.232**</b>	<b>0.211**</b>
Urticaceae	<b>-0.138**</b>	0.054	-0.004	<b>0.078*</b>	<b>0.169**</b>
Poaceae	<b>0.457**</b>	<b>0.457**</b>	<b>-0.126**</b>	<b>0.342**</b>	<b>0.341**</b>
<i>Fraxinus</i>	<b>-0.116**</b>	0.024	-0.05	0.035	<b>0.139**</b>
<i>Platanus</i>	0.005	<b>0.111**</b>	<b>-0.079*</b>	<b>0.145**</b>	<b>0.143**</b>
<i>Quercus</i>	-0.056	0.025	-0.014	<b>0.160**</b>	<b>0.195**</b>
Areaceae	-0.058	0.037	-0.025	<b>0.136**</b>	<b>0.176**</b>

Statistically significant values are shown in bold;

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

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

in general, and relative humidity had a positive impact on pollen concentration.

Wind speed plays a determining role in conveyance of pollen grains during the pollination period of anemophilous plants. Light winds normally allow pollen to exist densely in the atmosphere in the immediate vicinity of the plant, while moderate winds enable distribution of pollen in a low concentration throughout the atmosphere (Gemici, 2011; Seinfeld and Pandis, 2012; Bıçakçı and Tosunoğlu, 2016). In our study, it was detected that pollen concentration in the atmosphere increased even with low wind speed because the plants in the environment were close to the Burkard trap. A stronger positive correlation was identified between Poaceae (meadow) pollen and wind speed.

On the Eastern Mediterranean coast of Turkey, airborne pollen levels were studied in relation to single meteorological conditions; daily variations in total pollen concentrations were not significantly related to any of the variables studied (humidity, precipitation, temperature, and wind). Some positive correlations were observed between both grasses and other weeds, and humidity and precipitation from March to July. In addition, some positive correlations were detected between tree counts and temperature and humidity in May and June (Altıntaş et al., 2004). Similarly, in our study, trees showed a positive correlation with sunshine duration, relative humidity, and light wind speed, and a negative correlation with precipitation. Grasses and other weeds displayed a positive correlation with temperature, sunshine duration,

humidity, and light wind speed and a negative correlation with precipitation.

During the study period 40 pollen types were determined, and 22 of these made up 82% of total pollen concentration. In the atmosphere of Mersin trees were dominant, and this is due to the character of the vegetation and geographical location of the town. Trees are also dominant in Turkey, i.e. 82.5% in Adana (Altıntaş et al., 2004), 85.4% in Kastamonu (Çeter et al., 2012), 87.06% in Kayseri (Acar et al., 2015), 85.6% in Gümüşhane (Türkmen et al., 2018), and 81.9% in Hatay (Tosunoglu et al., 2018).

It is known that plants belonging to Urticaceae, *Olea*, and Cupressaceae show dense distribution in mild regions with a Mediterranean climate in Turkey (Altıntaş et al., 2004). In a study conducted by Bıçakçı (2011) in the Mediterranean region, pollen grains belonging to Cupressaceae/Taxaceae, *Platanus*, Pinaceae, *Olea*, and Poaceae were dense in the atmosphere during the spring months, while pollen grains of Poaceae and Chenopodiaceae/Amaranthaceae taxa were present in the atmosphere during summer. Our study also found that pollen grains belonging to Cupressaceae/Taxaceae (26.49%), Pinaceae (25.61%), *Olea* (12.76%), Urticaceae (7.00%), Poaceae (6.77%), and *Fraxinus* (5.06%) were dense in the atmosphere during the spring months.

Because pollen grains belonging to Cupressaceae and Taxaceae families have similar characteristics, they are specified jointly under the Cupressaceae/Taxaceae heading. In an aeropalynological study conducted in Granada in Southern Spain, pollen grains of Cupressaceae/Taxaceae were among the allergens that have originated heavily in the atmosphere in the Mediterranean Region in recent years (Díaz de la Guardia et al., 2006). Moreover in studies carried out in Turkey, Cupressaceae/Taxaceae family members are widespread in the Mediterranean region. In an aeropalynological study conducted in Hatay, which has Mediterranean climatic conditions, the pollen grains belonging to Cupressaceae/Taxaceae were among the most commonly observed taxa (50.86%) (Tosunoglu et al., 2018). In another aeropalynological study carried out in Adana, the pollen grains of Cupressaceae were dense in the atmosphere of the city (Altıntaş et al., 2004). In this study, pollen grains belong to Cupressaceae/Taxaceae were encountered during almost the entire study period in the atmosphere of the region. In addition, the taxa with the most commonly represented pollen in the Mersin atmosphere was Cupressaceae/Taxaceae (26.49%). According to the statistical analysis, pollen concentrations of Cupressaceae/Taxaceae showed a slightly positive correlation with wind speed and a slightly negative correlation with temperature. No significant relationship was found with sunshine duration, precipitation, relative humidity, and wind speed. No significant relationship

could be found between the pollen concentration of Cupressaceae/Taxaceae and meteorological data in 2017.

Members of Pinaceae family produce large amounts of pollen grains. In various aeropalynological studies conducted throughout Turkey, it was found that the pollen grains of Pinaceae exist in the atmosphere at approximately 30% (Bıçakçı et al., 2011). The pollen grains of Pinaceae were encountered in all of the 59 regions in Turkey where aeropalynological studies have been conducted (Bıçakçı et al., 2011). Because the current study area, Mersin University, is situated within a black pine forest, Pinaceae was the taxon with the second most common pollen density in the atmosphere. The pollen grains of this taxon were dense in every period, as was seen in the samples taken during our study in Mersin. According to the statistical results of this study, the pollen concentrations of Pinaceae indicated a positive and significant correlation with temperature, sunshine duration, relative humidity, and wind speed. However, no significant relationship was found between pollen concentration and precipitation.

Pollen grains of *Olea* are assumed to be one of the essential causes of allergic diseases of the respiratory system in countries around the Mediterranean (D'Amato et al., 2007). Smith et al. (2014) investigated the atmospheric pollen of Europe at 13 different stations over 20 years. As a result of these investigations, the authors reported that *Olea* was the taxon which had the second most dominant pollen grains in the atmosphere of Europe. The pollen concentration of *Olea* in the Mersin atmosphere shows a slightly positive and significant relationship with temperature, sunshine duration, relative humidity, and wind speed; no significant relationship was found with precipitation. In 2017, no significant relationship could be found between the pollen concentrations of *Olea* and meteorological data.

The family Urticaceae extends through widespread areas in coastal Mediterranean countries such as Spain, France, Italy, Albania, and Greece (D'Amato and Spiekma, 1992; Rodríguez-Rajo et al., 2004; Camacho, 2015). The pollen grains of this family instigate the formation of allergic symptoms during the entire year in some Mediterranean countries such as Italy, because they can remain suspended in the atmosphere for a long time (D'Amato et al., 1992). The pollen grains of Urticaceae were found at high density in the Mersin atmosphere in March for both years and at medium density in April 2016 and April–May 2017. According to the statistical results, the pollen concentration of Urticaceae in the atmosphere is affected by wind speed in a positive way. Pollen concentration of Urticaceae in the atmosphere decreased with the increase in temperature in May, June, and July; relative humidity led to an increase in the aforementioned pollen concentration. However, no effects of sunshine duration and precipitation on Urticaceae pollen concentration were detected.

Throughout the world the pollen grains of Poaceae are accepted as one of the essential allergens originating in the atmosphere (Burbach et al., 2009). The pollen grains of the family exist in high concentrations in the atmosphere because they are used in agriculture and planted in parks and gardens; because they are wind pollinated, they produce large amounts of pollen (D'Amato et al., 2007). The pollen concentration of Poaceae showed a slightly positive correlation with temperature and wind speed. Precipitation and relative humidity decreased the pollen concentration (Adeniyi et al., 2017). Asthma and allergic rhinitis patients frequently showed sensitivity towards the pollen grains of this family. The pollen grains of Poaceae have always been encountered in regions where aeropalynological studies have been conducted in Turkey, and the proportion of Poaceae pollen concentrations as related to the total varies 1.38%–35% (Bıçakçı et al., 2009). In the aeropalynological study conducted by Tosunoglu et al. (2018) in Hatay, the pollen concentration of Poaceae was detected at the highest frequency (5.99%) among other weeds. In accordance with our study, it was determined that temperature and sunshine duration were the meteorological factors affecting pollen concentration of Poaceae in the atmosphere. In addition, the pollen concentration of this family was positively affected by an increase in temperature, sunshine duration, relative humidity, and wind speed. There was a negative relationship between pollen concentration and precipitation. The pollen grains of Poaceae were found in the atmosphere of Mersin during all study periods except February of 2016. In addition, the Poaceae pollen concentration began to rise in March and reached the highest values in May for 2016 and in June for 2017.

D'Amato and Spieksma (1991) and D'Amato et al. (2007) examined the atmospheric pollen of Europe and indicated that the pollen grains of *Fraxinus* caused allergic symptoms. In a study conducted in the atmosphere of Buenos Aires, Argentina, the pollen grains of *Fraxinus* were dominant and made up 56.39% of the total (Majas et al., 1992). The pollen grains of *Fraxinus* in the Mersin atmosphere were at their peak in March 2016 and were at medium density in April and in the period between March and May 2017. According to the statistical data, there was no significant relationship between the pollen concentration of *Fraxinus* in the atmosphere and sunshine duration, precipitation, and relative humidity. However, the pollen concentration of this taxon showed a slightly negative correlation with temperature and a slightly positive correlation with wind speed.

Members of *Fagus* and *Quercus* (Fagaceae) are grown as ornamental plants along roads and in parks and gardens. Benito Rica and Soto Torres (2001) reported that the pollen grains of *Quercus* in the atmosphere of Santander,

Spain constituted 5.7% of the total. In the present study, the pollen grains of *Quercus* represented 2.40% in the Mersin atmosphere. In addition, there is a significant positive correlation between the pollen concentration of *Quercus* and relative humidity and wind speed.

Taxa of the Arecaceae family have been among the most important plants used by people worldwide for centuries. Male plants of Arecaceae family can produce pollen sufficient to fertilize up to 50–100 female date trees. According to one report the pollen grains of Arecaceae family that spread due to sand storms in Saudi Arabia may cause serious allergic diseases (Kwaasi et al., 1992). In an aeropalynological study conducted in India, the pollen grains of Arecaceae were among the dominant aeroallergens (Chowdhury et al., 1998; Benito Rica and Soto Torres, 2001). In the atmosphere of Mersin, the pollen grains of this family were detected at a high concentration in April during both study years. Taking into account the statistical results, the pollen concentration of Arecaceae had a positive relationship with relative humidity and wind speed.

In Mersin, *Citrus* (Rutaceae) agriculture is widespread. It is possible that the pollen grains of Rutaceae may have reached the pollen trap on the wind from the *Citrus* gardens.

In the current study periods of maximum concentrations of atmospheric pollen grains belonging to the taxa detected were identified. We hope that more efficient treatment plans will be developed for those who complain of allergic symptoms that result from pollen sensitivity.

In our study, pollen concentrations were at their peak between March and July. Pollen grains of following taxa were discovered in the atmosphere, according to density: Cupressaceae/Taxaceae (26.49%), Pinaceae (25.61%), *Olea* (12.76%), Urticaceae (7.00%), Poaceae (6.77%), and *Fraxinus* (5.06%). According to statistical analysis, while sunshine duration, relative humidity, and wind speed usually have a positive correlation, precipitation has a negative correlation on pollen concentration.

It is important to know the types of pollen grains that may be encountered, as well as their seasons in different geographic regions in Turkey, in order to protect against pollen allergies. Specifying the threshold values for allergic diseases created by airborne pollen grains and their relationship with clinical and laboratory parameters is required. The data obtained from this study may contribute to the fields of medicine and pharmacology and other sciences as well. We expected that this study will be beneficial for diagnosis and treatment of allergic diseases caused by pollen grains, for allergy patients looking to take the required measures, and as guidance for collecting the pollen grains needed to prepare the extracts used in treatment and skin tests.

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