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Aeropalynological survey in the city center of Aydın (Turkey)

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Abstract: Airborne pollen grains in Aydın, an important city for agriculture and tourism in the western part of Turkey, were studied for 2 years (2014 and 2015) using the volumetric method. During a 2-year study conducted in the city center, an average of 19,226 pollen grains belonging to 46 taxa were detected. Among these detected taxa, 29 (average 73.97%) belonged to arboreal plants and 17 (average 24.95%) to nonarboreal plants. The highest pollen concentrations belonged to *Olea europaea* (21.02%), *Quercus* (15.23%), Poaceae (11.89%), Pinaceae (11.47%), Cupressaceae/Taxaceae (11.11%), *Platanus*(4.12%), *Morus* (3.83%), and Urticaceae (3.58%), which were considered to be the dominant species. We used the Spearman correlation test to assess the relationship between the daily pollen concentrations belonging to these 8 taxa and the mean average temperature (°C), daily precipitation (mm), mean average relative humidity (%), and mean average wind speed (m/sec), which yielded significant results. A negative correlation was found between the average temperature and the pollen concentrations of Poaceae, Pinaceae, Cupressaceae/Taxaceae, *Morus*, and *Urtica* in both years. Furthermore, while the average wind speed only had a negative effect on the pollen concentrations of some taxa, the effects of relative humidity and precipitation on the pollen concentrations of dominant taxa varied from one taxon to another and between the 2 years. The results obtained in this study indicated that the top 3 dominant airborne pollen types (*Olea europaea*, *Quercus*, and Poaceae) in the atmosphere of Aydın generally had allergenic effects at high levels, and the highest pollen concentration during the study period was detected in May.

Key words: Aerobiology, airborne pollen, meteorological parameters

1. Introduction

According to the World Health Organization, allergic rhinitis affects 400 million people worldwide, and its global prevalence continues to increase (Pawankar et al., 2013). Aeroallergens play an important role in the development of respiratory diseases, especially asthma and rhinitis. The leading factors causing these disorders include pollen grains, fungal spores, dust mites, insect rashes, and animal epithelia (Singh and Mathur, 2012). Wind-transported pollen grains are among the major sources of atmospheric allergens. These pollen grains, released into the atmosphere in high quantities, are the main cause of pollinosis and allergic reactions (Ribeiro et al., 2008). Studies conducted in recent years have reported an increase in the prevalence of pollen allergies in Europe up to 40% (D'Amato et al., 2007).

Approximately 12,000 taxa of native plants are distributed in Turkey, which is divided into 3 phytogeographical regions. These regions have different characteristics in terms of climate and vegetation, with atmospheric pollen densities and the diversity of pollen grains showing regional variations (Bıçakçı et al., 2009). Aeropalynological studies in Turkey started in the 1960s, mostly using the gravimetric method. Today, the most common method for sampling pollen grains and sporesis the volumetric method; the Hirst-type trap is used worldwide for spore and pollen monitoring (Buters et al., 2018). In recent years, there has been a considerable increase in the number of studies using the volumetric method in Turkey (İnceoğlu et al., 1994; Guvensen and Ozturk, 2003; Potoğlu Erkara et al., 2007; Bicakci et al., 2017; Uguz et al., 2017).

Aerobiological investigations are important for studying the behavior of airborne allergens throughout the year. Pollen grains of different species have varying degrees of allergenic effects on humans. The atmospheric pollen data from different regions are important to clinicians for better management of the allergy symptoms of patients with hay fever (Subiza et al., 1995). Therefore, particularly in densely populated regions, the types of airborne pollen should be identified in order to study the flowering intensity and timing of these species (Boi and Llorens, 2013). A large number of studies have been carried out in different regions of the world to investigate

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allergenic pollen types, the pollination periods of plants producing these pollen types, and the relationship between pollen types and meteorological factors (Pınar et al., 1999; Gioulekas et al., 2004; Puljak et al., 2016; Majeed et al., 2018; Lo et al., 2019).

Aerobiological studies and studies on allergies show that pollen mapping in Europe has changed due to cultural factors, increased international travel, and climate change (D'Amato et al., 2007). The continuity of atmospheric monitoring studies not only leads to better planning of treatments for allergy patients but also provides valuable data for local authorities in selecting appropriate species to be planted in parks and gardens. Therefore, qualitative and quantitative pollen analysis inthe atmosphere of densely populated cities is crucial (Scevkova et al., 2010).

Aydın Province includes major tourism centers such as Kuşadası and Didim along the Aegean coast. Although several aeropalynological studies have been carried out by different researchers in these tourism centers (Bilisiket al., 2008; Tosunoğlu et al., 2013), there has been no aeropalynological study focusing on the populous city center of Aydın. The aims of our study are (1) to identify the airborne pollen types in Aydın's atmosphere, (2) to determine the start and end of pollen seasons for the dominant taxa, and (3) to observe the effects of meteorological parameters on the concentration of dominant airborne pollen types.

2. Materials and methods

2.1. Study area, flora, and climate

Aydın is located in the western part of Turkey, in the Aegean region (Figure 1). The city has important tourism centers such as Kuşadası and Didim along its coast. Agricultural is important further in land, where the city center is also located. Olives and figs are the major agricultural products of this region. The province of Aydın has large districts with high population densities, bringing the total population to over 1 million. The city center of Aydın itself hosts a population of more than 300,000 people; this number has multiplied annually by more than 10% in the last 5 years. The province covers an area of 8007 km² and is located on the Büyük Menderes Basin. The basin includes fertile plains in the west and in the center, and is surrounded by mountains in the north and south. The city

Figure 1. Location of the study area (Aydın) in Turkey and in the Euroasian continent.

center has an elevation of 65 m a.s.l. Although the province has a 150-km coastline along the Aegean Sea, most of its terrain is mountainous. The Aydın Mountains, which form a natural border in the north, and the Menteşe Mountains in the south are important elevations. The taxa identified in floristic studies around the study area are composed mainly of Mediterranean and Eastern Mediterranean elements (Çelik, 1995).

Pinus brutia Ten., typically a member of forest vegetation, is widely distributed in the region. Other taxa found in this vegetation type include: *Astragalus depressus* L., *Campanula lyrata* Lam., *Centaurea urvillei* DC., *Cistus creticus* L., *Juniperusexcelsa*M.Bieb., *J. oxycedrus* L., *Pinus pinea* L., *P. nigra* Arn. subsp. *pallasiana* (Lamb.) Holmboe., *Quercus ithaburensis* Decne. subsp. *macrolepis* (Kotschy), *Q. cerris* L., *Q. infectoria* Olivier., and *Q. pubescens* Willd. On the other hand, the maquis include the following: *Amaranthus chlorostachys*Willd., *A. retroflexus* L., *Anthemistinctoria* L., *Arbutus unedo* L., *A. andrachne* L., *Chenopodium album* L. subsp. *album* L., *C. botrys* L., *C. murale* L., *Erica manipuliflora* Salisb., *Euphorbia anacampseros* Boiss., *Galiumpeplidifolium* Boiss., *Jasminum fruticans* L., *Mercurialisannua* L., *Olea europaea* L., *Paliurus spina-christi* Miller, *Pistaciaterebinthus* L., *Plantagocoronopus* L. subsp. *commutata* (Guss.) Pilger., *P. cretica* L., *P. lanceolata* L., *P. major* L. subsp. *major* L., *Q. coccifera* L., *Rosa canina* L., *Rumexacetosella* L., *R. bucephalophorus* L., *R. conglomeratus* Murray, *R. creticus*Boiss., *R. pulcher* L., *R. tuberosus* L. subsp. *tuberosus* L., *Sarcopoterium spinosum* (L.) Spach., *Spartiumjunceum* L., *Teucrium chamaedrys* L., and *Trifoliumcampestre* Schreb. Other species identified are: *Alnusglutinosa* L., *A. orientalis* Decne. var. *pubescens* Dippel, *Castanea sativa* Miller., *Nerium oleander* L., *Parietariajudaica* L., *P. lusitanica* L., *Platanusorientalis* L., *Salix alba* L., *Styrax officinalis* L., *Urticadioica* L., and *U. plilulifera* L. around rivers;*Bromusmadritensis* L., *Eruca sativa* Miller., *Hordeumbulbosum*L., *Papaver argemone* L., *Polygonum pesicaria*L., *Ranunculus arvensis* L., *Sinapis alba* L., *Silenebehen*L., S. *vulgaris* (Moench) Garcke var. *vulgaris* (Moench) Garcke, and *Sorghum halepense* (L.) Pers. in crop fields and fallow fields (Çelik, 1995; Özel, 1992).

Plants commonly found in parks and gardens include: *Acacia cyanophylla* Lindl., *Acer negundo* L., *Casuarina equisetifolia*L., *Citrus aurantium* L., *Cupressus sempervirens* L., *C. arizonica* Greene, *Cupressocyparis leylandii* Dallim., *Eucalyptus globulus* Labill., *E. camaldulensis* Dehnh., *Liquidambar orientalis* Miller., *Morus alba* L., *M. nigra*L., *Platanusorientalis* L., *Rosmarinus officinalis* L., and *Sophora japonica* L.

The province of Aydın is influenced by the Mediterranean climate, with hot, dry summers and warm and rainy winters. According to the Turkish Meteorological Data Archive System (TMDAS) covering many years (1950–2015), the highest average temperature in Aydın Province was recorded in July (28.4°C); the lowest, in January (8.2 °C). The mean number of rainy days was the highest in December (12.8 days) and the lowest in August (0.8 days). The highest and lowest monthly total precipitation rates were calculated as 120.9 mm in December and 2.3 mm in August, respectively. According to the data obtained from TMDAS, the mean annual temperature of Aydın is 17.7 °C and the average annual precipitation is 664.9 mm.

2.2. Aerobiological method

The present aerobiologicalstudy was carried out between February 2014 and January 2016 in AydınProvince, with a Hirst-type 7-day sampling volumetric pollen and spore trap (Lanzoni VPPS 2010; Lanzoni, Bologna, Italy). The device was placed on the roof of Adnan Menderes University's Faculty of Agriculture about 20 m a.g.l. and away from any obstacle that might prevent air circulation. The tape on the drum installed on the pollen capturing device completed its full rotation in a week at a speed of 2 mm/h. This tape was replaced weekly during the 2-year study period between February 2014 and January 2016. To identify and count the pollen grains, an Olympus light microscope (400× magnification) was used. For atmospheric sampling and analysis, we used the method described by the Spanish Aerobiological Network (Galán et al., 2007), transversally dividing slides into 12 intervals. We also followed the minimum requirements for pollen monitoring established by the European Aerobiology Society (EAS) (Galán et al., 2014). Pollen concentrations were expressed as daily average of pollen grains per cubic meter (pollen grains/m^3).

Any taxa with pollen grains constituting ≥3% of the total number of airborne pollen grains in Aydın during the study period were defined as dominant taxa. To determine the main pollen season (MPS) for these dominant taxa, we used the method proposed by Andersen (1991). According to this method, the start of MPS corresponds to the day when the sum of pollen concentration exceeded 2.5% of the annual pollen integral, and the end of it corresponds to when 97.5% of the annual pollen integral is reached. Because our study started on 1 February, the Urticaceae pollen season coincided with the middle of the pollen season. Therefore, in order to more accurately identify the main pollen season of this taxon, we used the data obtained from 1 January 2015 to 31 December 2015, determining that there was only one pollen season in the second year.

2.3. Statistical analysis

For statistical analysis studies, we first ran a normality test by using the Kolmogorov–Smirnov test to find the most appropriate statistical method. We determined that the data did not show a normal distribution ($P < 0.05$). Therefore, the Spearman correlation test was applied to identify the relationship between the average daily pollen concentrations of the 8 dominant taxa (*Olea europaea*, *Quercus*, Poaceae, Pinaceae, Cupressaceae/Taxaceae, *Platanus*, *Morus*, and Urticaceae) in the atmosphere during the MPS and meteorological factors including average temperature (°C), average relative humidity (%), total precipitation (mm), and average wind speed (m/s). Statistical analysis was performed using the IBM SPSS program, version 20.0 (IBM Corp., Armonk, NY, USA).

3. Results and discussion

The annual pollen integral and percentage of taxa included in this study are presented in Table 1. During the study period, 46 taxa were identified, with a total of 38,451 pollen grains. Among these taxa, 29 were arboreal (73.97%) and 17 were nonarboreal plants (24.95%);11.89% of the nonarboreal plants were grasses. In both years, higher pollen concentrations were recorded in February, March, April, and May. Despite the differences between monthly pollen concentrations, the upward trend in these months showed similarities. Arboreal taxa particularly dominant in this period were the identifiers of airborne pollen concentrations (Figure 2). For example, the increase in airborne pollen concentrations, starting with February in both years, resulted from increasing Cupressaceae/Taxaceae pollen (Figure 3). However, in the second year, pollen concentrations of this taxon were higher in March due to differences in meteorological conditions.

The overall increase observed in March in the first year was mostly caused by *Morus*, Pinaceae, *Platanus*, and *Quercus*, the pollen of which started to appear in the atmosphere during this month. However, in the second year, pollen concentrations belonging to all of these taxa were higher in April. May was the month with the highest airborne pollen concentration in both years, constituting 40.84% of the total pollen concentration in the first year and 33.28% in the second year. On the other hand, the most noteworthy contrast observed between February and May was an unexpected decrease in the total pollen concentration in April during the first year (Figure 2). This decline may possibly be explained by the low temperatures in January and February in 2015. In addition, except for Urticaceae, pollination started later in 2015 than in 2014 (Figure 2). Pollen concentrations of *Morus*, *Pinus*,*Platanus*, Poaceae, and *Plantago* (which had the third highest pollen concentration after Poaceae and Urticaceae, although not shown in Figure 2) reached the highest levels in March during the first year and in April during the second year.

In the present study, the taxa whose pollen grains constituted ≥3% of the total number of airborne pollen grains according to 2-year average values were considered dominant. Arboreal taxa with the highest concentrations were *Olea europaea* (21.02%), *Quercus* (15.23%), Pinaceae (11.47%), Cupressaceae/Taxaceae (11.11%), *Platanus*(4.12%), and *Morus* (3.83%) (Table 2). These taxa cumulatively constituted 66.78% of the total pollen. Nonarboreal taxa with dominant pollen concentrations were Poaceae (11.89%) and Urticaceae (3.58%), accounting for 15.47% of the total pollen. The monthly distribution of these taxa in the atmosphere of Aydın, along with their main pollen seasons, are shown in Tables 2 and 3.

Among the 8 dominant taxa representing about 82.25% of the total pollen during the study period, *Olea europaea* had the highest mean daily airborne pollen concentrations (Table 3). Aerobiological studies conducted in different regions of Turkey have detected different ratios of this species' pollen in the atmosphere. Although pollen concentrations of olive show proportional differences due to the regional vegetation structure, it is one of the taxa with the highest pollen concentrations, especially along the Aegean and Mediterranean coasts of Turkey (Tosunoğlu et al., 2013; Bilişik et al., 2008). Our results are not surprising as the olive tree has a wide natural distribution in Aydın, and it is cultivated in this region. According to data from 2015(Uğuz and Güvensen, 2019), olive trees cover an area of 154,465 ha in Aydın Province. In the same study, its area of coverage was reported as 97,830 ha in Manisa and 94,432 ha in Muğla, two other major provinces in the Aegean region. Olive cultivation is one of the major economic practices in the Mediterranean basin (Galán et al., 2005). In the Mediterranean countries, pollen from olive trees is an important allergy concern for both patients and physicians (Bousquet et al., 1984, 1985).

In natural environments around Aydın, *Quercus* species have a native distribution. Therefore, the second highest annual pollen integral belongs to *Quercus* spp. (Table 1). We found pollen from these species in the atmosphere between February and July during the first year, and throughout the entire second year (Table 2). The total number of pollen grains was recorded at high rates in April and May during both years (Figure 3). Pollen from *Quercus* spp. was determined in many of the aeropalynological studies conducted in Turkey. This is because Turkey is one of the places in the world where this genus has a wide distribution and a high number of species. Scientists have identified 18 species of *Quercus* in Turkey (Seçmen et al., 1995). On the other hand, this taxon poses a moderate to high riskof allergy, based on the reported positive results from skin prick tests (Potoğlu Erkara et al., 2009).

Poaceae pollen accounted for 11.89% of all total pollen (the third most abundant pollen), and for 47.65% of all pollen grains from nonarboreal plants. Pollen belonging to this taxon was present in the atmosphere in different quantities throughout the year (Table 2). In both years, pollen concentrations started to increase in March and

Table 1. Annual pollen integrals (APIn) and percentage of pollen taxa recorded in Aydın atmosphere (2014–2015).

	2014		2015		Mean 2014–2015	
	APIn	%	APIn	%	APIn	Mean %
Acacia	8	0.04	1	0.01	5	0,02
Acer	48	0.25	7	0.04	28	0,14
Ailanthus	-	-	36	0.19	18	0,09
Alnus	124	0.64	92	0.48	108	0,56
Castanea sativa	43	0.22	55	0.29	49	0,25
Casuarina equisetifolia	90	0.46	58	0.30	74	0,38
Cistaceae	5	0.03	2	0.01	4	0,02
Corylus	9	0.05	38	0.20	24	0,12
Cupressaceae/Taxaceae	1765	9.11	2505	13.14	2135	11,11
Ericaceae	42	0.22	42	0.22	42	0,22
Eucalyptus camaldulensis	194	1.00	153	0.80	174	0,90
Fraxinus	127	0.66	63	0.33	95	0,49
Juglans	44	0.23	49	0.26	47	0,24
Ligustrum vulgare	70	0.36	22	0.12	46	0,24
Liquidambar orientalis	106	0.55	32	0.17	69	0,36
Morus	432	2.23	1040	5.45	736	3,83
Olea europaea	5046	26.04	3036	15.92	4041	21,02
Phyllrea latifolia	122	0.63	99	0.52	111	0,57
Pinaceae	2277	11.75	2135	11.20	2206	11,47
Pistacia	46	0.24	256	1.34	151	0,79
Platanus	711	3.67	875	4.59	793	4,12
Populus	40	0.21	18	0.09	29	0,15
Quercus	2945	15.20	2911	15.26	2928	15,23
Rosaceae	8	0.04	26	0.14	17	0,09
Salix	134	0.69	167	0.88	151	0,78
Sarcopoterium spinosum	66	0.34	93	0.49	80	0,41
Sophora japonica	26	0.13	-	-	13	0,07
Tilia	8	0.04	4	0.02	6	0,03
Ulmus	36	0.19	56	0.29	46	0,24
Total arboreal	14572	75.19	13871	72.74	14222	73,97
Apiaceae	70	0.36	120	0.63	95	0,49
Artemisia	19	0.10	44	0.23	32	0,16
Asteraceae *	151	0.78	201	1.05	176	0,92
Brassicaceae	75	0.39	83	0.44	79	0,41
Campanula	-	-	4	0.02	2	0,01
Carex	32	0.17	70	0.37	51	0,27
Caryophyllaceae	8	0.04	1	0.01	5	0,02
Amaranthaceae	297	1.53	286	1.50	292	1,52
Lamiaceae	40	0.21	65	0.34	53	0,27
Mercurialis	224	1.16	292	1.53	258	1,34

Table 1. (Continued).

Plantago	355	1.83	347	1.82	351	1,83
Poaceae	2026	10.45	2547	13.36	2287	11,89
Rumex	242	1.25	348	1.82	295	1,53
Taraxacum	58	0.30	70	0.37	64	0,33
Typha	31	0.16	-	-	16	0,08
Urticaceae	868	4.48	507	2.66	688	3,58
Xanthium	45	0.23	68	0.36	57	0,29
Total Nonarboreal	4541	23.43	5053	26.50	4797	24,95
Unidentified	268	1.38	146	0.77	207	1,08
Total	19381	100.00	19070	100.00	19226	100,00

*: Other Asteraceae taxa except *Artemisia*, *Taraxacum* and *Xanthium.*

reached the highest levels in May. The most noteworthy point in the distribution of Poaceae pollen during the study was the decrease in concentrations during April of the first year, as mentioned above (Figure 3). Two factors were thought to be the cause of this decline. The first one was the presence of airborne pollen from numerous taxa belonging to the Poaceae family with different pollination periods. The second one was the amount of rainfall recorded during April in the first year (Figure 4), which is thought to have led to a decrease in the pollen concentration. Sahney and Chaurasia (2008) have suggested that if plants are exposed to precipitation during flowering periods, the amount of airborne pollen decreases due to the washing effect of the rain. Pınar et al. (2004) reported that the most important factors affecting the airborne pollen concentrations of Poaceae are rainfall and wind speed.

On the other hand, in the second year, the rainfall in February had a positive effect on Poaceae pollen concentrations. High rainfall was reported to encourage plant growth and flowering, and thus an increase in pollen production (Li et al., 2015). The data we obtained on Poaceae demonstrated that the high rainfall during April in the first year caused a low pollen count (0.73%), and the decrease in rainfall during May led to an increase in pollen concentrations (3.60%). Similarly, in the second year, the amount of rainfall was highest in February; thus, the amount of Poaceae pollen was low (0.53%), but exceeded 3% in the following months (March, April, May) due to a decrease in rainfall (Table 2 and Figure 4). These results suggest that precipitation in spring not only had a washing effect on the atmosphere, but also supported the vegetative development of some herbaceous plants. Recio et al. (2010) also reported similar results for Poaceae in their study conducted in Malaga (Spain). Poaceae had a long MPS in both years (Table 3). This long pollen season may have resulted from the different pollination periods of different plants in this family. In several other similar studies, the MPS of Poaceae was recorded as 134 days in the first year and 282 days in the second year in Çeşme (Uguzet al., 2017), and between 198 and 222 days in Toledo (Spain) (Vaquero et al., 2013). Tourism is an important economic activity on the western coast of Turkey. In Aydın Province, agricultural practices are also important for the economy, and Poaceae species are highly cultivated. However, Poaceae species are among the most important aeroallergens in the world (Puc and Puc, 2004; Belmonte et al., 1998).

Pinaceae species produce high amounts of pollen; they are found particularly in the forest vegetation around the region. Pollen grains of this taxon can be transported over long distances; they constituted 11.47% of the total pollen. Similar studies carried out in nearby areas reported pollen concentrations for this taxon as 45.58% in Didim (Bilişik et al., 2008) and as 19.71% in Kuşadası (Tosunoğlu et al., 2013). We recorded the pollen grains of this taxon measured between March and June as 92.3% in the first year and as 92.7% in the second year (Figure 3). During this period, the amount of Pinaceae pollen in the atmosphere increased in accordance with the pollination of this taxon. The pollen season lasted for a long time; thus, Pinaceae pollen was present in the atmosphere in all months during the 2-year study period. However, February and March were warmer in the first year, with a long rainless period, especially in the second half of March. These factors may have caused the MPS to start earlier in the first year. Pinaceae pollen typically has a low allergenic effect (Bousquet et al., 1984).

The pollen of Cupressaceae/Taxaceae was observed in the atmosphere in all months during both years. The pollen concentration of this taxon, which has a long MPS, showed slight increases in the spring months and at certain times in the fall, but reached its highest level during February and March (Figure 3). These increases

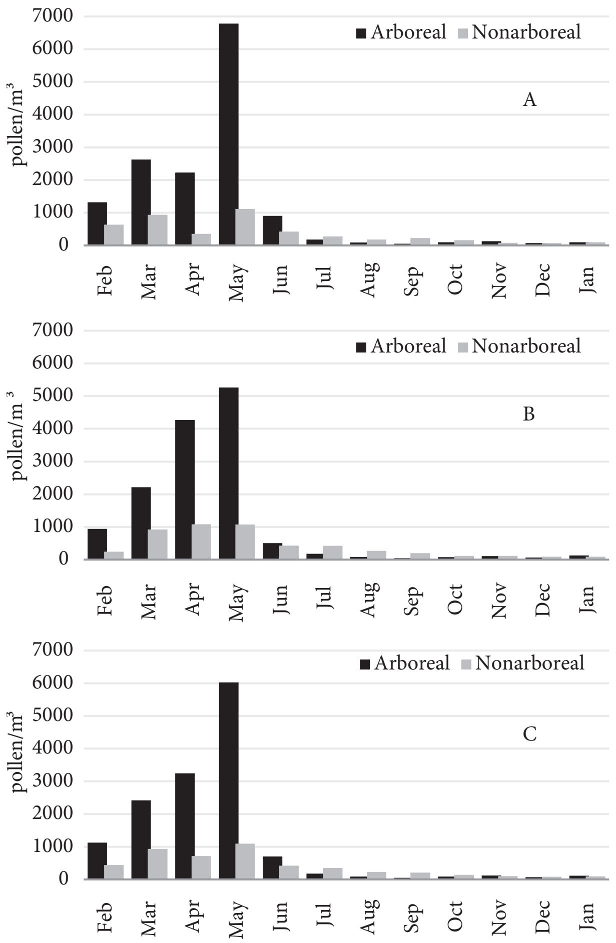

Figure 2. Annual dynamics of monthly pollen integrals of arboreal and nonarboreal pollen grains recorded in Aydın atmosphere, A: 2014, B: 2015 and C: the mean values 2014–2015.

in different periods were related to the presence of species such as *Cupressus sempervirens* L. which flowers in winter, *Juniperus oxycedrus* L. which flowers at the end of winter and early spring, and *Cupressus arizonica* Greene,which is reported to flower 20–23 days before *C. sempervirens* (Hidalgo et al., 2003). Most aeropalynological studies conducted in Turkey have indicated that pollen grains of this taxon are among the dominant pollen types in the atmosphere (Güvensen and Öztürk, 2002; Celenk et al., 2010; Tosunoglu et al., 2015). This is probably due to the fact that the species of this taxon release numerous pollen grains into the atmosphere, and that they are grown in parks and gardens as ornamental plants. The high airborne pollen concentration of this taxon in Aydın results from the natural distribution of *Juniperus excelsa* M.Bieb. and *J. oxycedrus* L. in nearby elevations, along with *Cupressus sempervirens* L. and *C. arizonica* grown in parks and gardens for ornamental purposes. Cupressaceae/Taxaceae

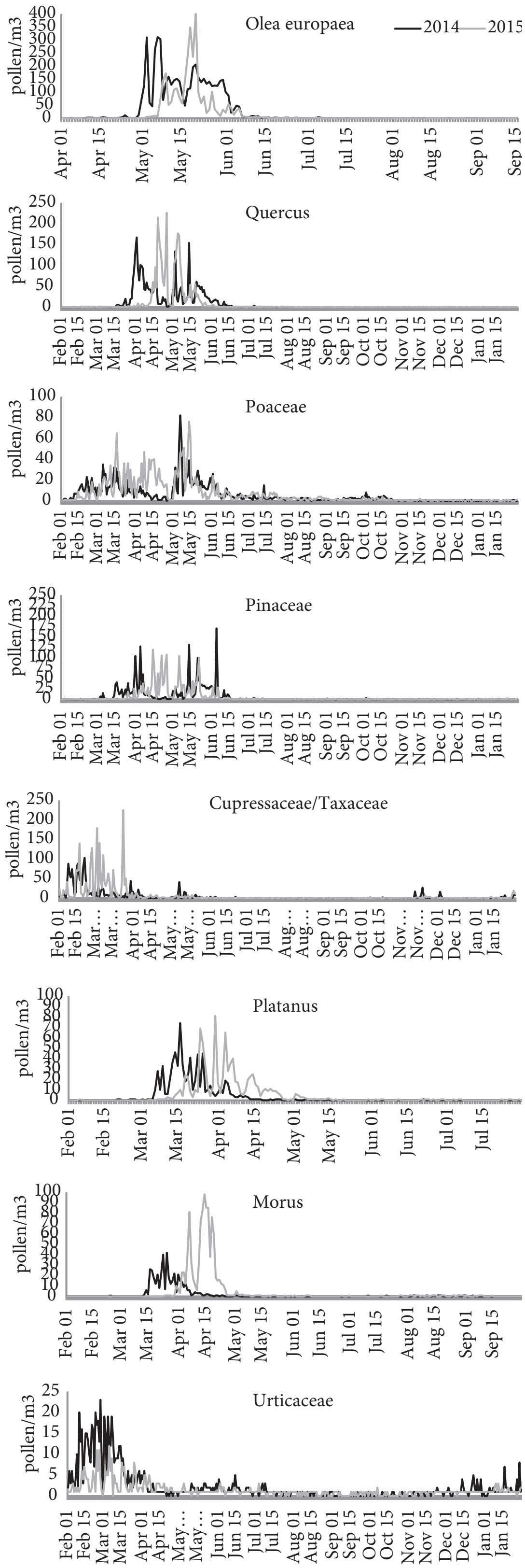

Figure 3. Annual distribution of the mean daily concentrations of the dominant pollen types in Aydın atmosphere, years 2014 and 2015.

Table 2. Monthly distribution, in percentage (%), of dominant taxa in Aydın atmosphere (February 2014–January 2016)

Taxa/month		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Annual (%)	Mean
Oleaeuropaea	*FY*	-		0.62	23.70	1.57	0.10	0.04	-	-	-	-	-	26.04	21.02
	SY	-	--	0.01	14.55	1.20	0.14	-	0.02	-	-	-	-	15.92	
Quercus	*FY*	0.05	2.10	6.49	5.75	0.70	0.10	-	-	-	-	-	-	15.20	15.23
	SY	0.04	0.17	7.45	7.13	0.17	0.08	0.03	0.04	0.04	0.06	0.05	0.02	15.26	
Pinaceae	*FY*	0.06	2.51	2.26	4.36	1.72	0.18	0.13	0.13	0.12	0.13	0.05	0.09	11.75	11.47
	SY	0.04	0.43	5.27	4.08	0.61	0.17	0.14	0.09	0.08	0.09	0.08	0.11	11.20	
Cupressaceae/Taxaceae	*FY*	5.28	1.63	0.34	0.71	0.17	0.06	0.03	0.02	0.07	0.39	0.20	0.21	9.11	11.11
	SY	4.40	6.98	0.46	0.38	0.06	0.05	0.05	0.03	0.07	0.23	0.09	0.34	13.14	
Platanus	*FY*	0.03	3.11	0.50	0.03	0.01	-	-	-	-	-	-	-	3.67	4.12
	SY	0.01	2.09	2.23	0.17	0.05	0.04	-	-	-	-	-	-	4.59	
Morus	*FY*	0.01	1.67	0.47	0.01		0.01	0.06	0.01	-	-	-	-	2.23	3.83
	SY	-	0.12	5.03	0.13	0.03	0.02	0.10	0.03	-	-	-	-	5.45	
Poaceae	*FY*	1.19	2.32	0.73	3.60	0.99	0.48	0.26	0.27	0.37	0.11	0.06	0.07	10.45	11.89
	SY	0.53	3.16	3.10	3.72	0.93	0.76	0.33	0.20	0.23	0.15	0.13	0.10	13.36	
Urticaceae	*FY*	1.54	1.30	0.22	0.25	0.25	0.15	0.10	0.02	0.04	0.11	0.23	0.27	4.48	3.58
	SY	0.50	0.62	0.32	0.17	0.19	0.14	0.09	0.07	0.05	0.13	0.16	0.22	2.66	
Others	*FY*	1.90	3.75	1.69	2.34	1.43	1.24	0.77	0.96	0.74	0.33	0.19	0.37	15.70	16.67
	SY	0.69	2.89	4.20	2.91	1.64	1.77	1.10	0.79	0.52	0.51	0.28	0.35	17.66	
Unidentified	*FY*	0.08	0.08	0.05	0.10	0.15	0.17	0.15	0.14	0.13	0.15	0.10	0.07	1.38	1.08
	SY	0.05	0.10	0.24	0.04	0.14	0.08	0.01	0.03	0.03	0.03	0.03	-	0.77	
Total	*FY*	10.13	18.47	13.36	40.84	6.99	2.50	1.55	1.55	1.47	1.23	0.83	1.08	100.00	100.00
	SY	6.26	16.55	28.31	33.28	5.02	3.25	1.85	1.31	1.02	1.19	0.83	1.14	100.00	
Mean	-	8.21	17.52	20.78	37.09	6.01	2.87	1.70	1.43	1.24	1.21	0.83	1.11		
FY: First year February 2014 to January 2015; SY: Second year February 2015 to January 2016.															

pollen is shown to be one of the major causes of seasonal respiratory diseases, especially in winter (D'Amato et al., 2007; Charpin et al., 2017). On the other hand, Subiza et al. (1995) reported that Poaceae pollen also contributed to a proportion of individuals diagnosed as susceptible to Cupressaceae pollen in skin tests. Therefore, Cupressaceae/Taxaceae pollen recorded in the atmosphere of Aydın Province is important, as it shows cross-reactivity with the high amount of Poaceae pollen.

Platanus and *Morus* are two other arboreal taxa with pollen grainsrecorded as dominant in the atmosphere of our study area. Species of these taxa are among the plants that are especially preferred in parks and gardens around city centers in Turkey. In addition,*Morus* is not naturally distributed in Turkey, but it is cultivated, andits fruit is consumed as food in Aydın. In studies performed in nearby areas and in most of the studies conducted in Turkey, the pollination period of *Morus* was reported to be short and mostly completed in the spring (Guvensen and Ozturk, 2003; Bilisik et al., 2008; Tosunoğlu et al., 2013). In our study, its pollen concentration reached the highest levels in March during the first year (1.67%) and in April during the second year (5.03%) (Table 2). Likewise, the pollen of *Platanus* was observed to be dominant in March during the first year (3.11%) and in April during the second year (2.23%) (Table 2). Studies conducted in different regions of Turkey have reported varying amounts of pollen belonging to this taxon. For instance, *Platanus* pollen concentration was recorded as 5.26% on the Asian side and as 23.76% on the European side of İstanbul, the largest city in Turkey (Celenk et al., 2010). Various studies have identified *Platanus* as a taxon with potential to cause allergies, yielding positive results in skin-prick tests (Varela et al., 1997; Potoğlu Erkara et al., 2009).

Urticaceae was the nonarboreal taxa with the second highest airborne pollen concentration after Poaceae (Table 2). Its pollen was detected in the air in all months during both years, possibly due to the long flowering period of

Table 3. Characteristics of the main pollen season for the dominant taxa; season length and maximum daily pollen concentrations (pollen grains/m³).

		1st year	2nd year
Olea europaea	Main pollen season	30/04– 01/06	07/05– 04/06
	Season length (days)	33	29
	Max. dailypollen/m³-date	311– 06/05	400– 20/05
Quercus	Main pollen season	23/03– 07/06	08/04– 12/06
	Season length (days)	77	66
	Max. daily pollen/m³-date	167– 01/04	226– 25/04
Poaceae	Main pollen season	15/02– 27/10	25/02– 11/11
	Season length (days)	256	261
	Max. daily pollen/m³-date	82– 06/05	76– 13/05
Pinaceae	Main pollen season	15/03– 01/11	26/03– 02/11
	Seasonlength (days)	232	222
	Max. daily pollen/m³-date	170– 04/06	119– 14/04
Cupressaceae/Taxaceae	Main pollen season	07/02–28/12	06/02– 04/01
	Season length (days)	326	334
	Max. daily pollen/m³-date	103– 21/02	225– 23/03
Platanus	Main pollen season	06/03– 12/04	15/03– 14/05
	Season length (days)	38	61
	Max. daily pollen/m³-date	74– 16/03	81– 30/03
Morus	Main pollen season	15/03– 03/05	02/04– 09/06
	Season length (days)	50	69
	Max. daily pollen/m³-date	42– 25/03	98– 14/04
Urticaceae	Main pollen season	13/01/2015– 20/12/2015	
	Season length (days)	341	
	Max. daily pollen/m³-date	12– 05/03	

Parietaria and the presence of different *Urtica* species in the study area. However, its pollen was recorded in higher concentrations during February and March in both years (Table 2 and Figure 3). Other studies have also reported a peak in Urticaceae pollen counts several times throughout the year, but particularly during the spring and summer months (Garcia-Mozo et al., 2006; Melgar et al., 2012). In the present study, higher pollen concentrations were determined at the start of spring. A similar result was obtained by Guardia and Belmonte (2004) in Catalonia (northeastern Spain). *Parietaria* pollen has been reported to cause pollinosis in many countries (Bousquet et al., 1986).

During this study, changes in the concentration of the dominant taxa determined in the main pollen season showed a correlation with the meteorological parameters of the same days (Table 4). Most of the aeropalynological studies have indicated that temperature and wind had a positive effect on airborne pollen concentrations, while rainfall and humidity had a negative effect (Ribeiro et al., 2003; Rodriguez-Rajo et al., 2003; Garcia-Mozo et al., 2007). In this study, the Spearman correlation test results showed that average temperature had a negative effect on pollen concentrations of all dominant taxa except for *Olea europaea*. Similarly, wind speed had a significant negative effect on the pollen concentrations of dominant taxa. However, the effect of average humidity and precipitation on the pollen distribution of dominant taxa varied between taxa, and from one year to the other. We determined a remarkable negative correlation between the average temperatures in both years and the pollen concentrations of Poaceae, Cupressaceae/Taxaceae, *Morus*, Urticaceae, and Pinaceae. With the exception of *Morus*, the MPSs of these taxa in Aydınwere much longer, and the species had different pollination periods. The comparison of pollen distributions demonstrated that although pollen was present in the atmosphere for a long period, the highest concentrations were recorded during the spring.

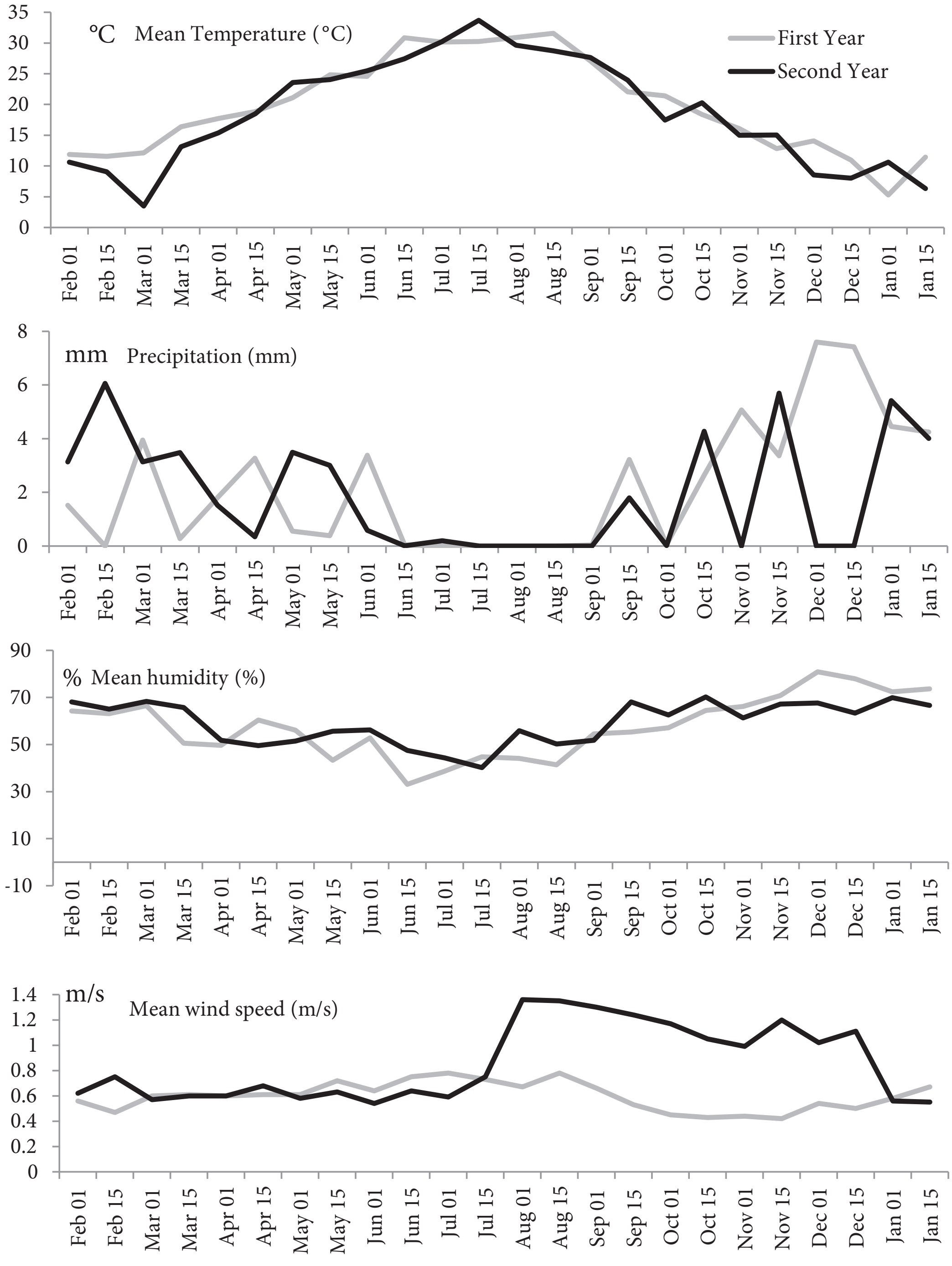

Figure 4. Variations of mean temperature (°C), precipitation (mm), mean humidity (%) and mean wind speed (m/s) in Aydın. First Year: February 2014–January 2015; Second Year: February 2015–January 2016.

The statistical results suggest that rainfall during this period may have led to a decrease in the airborne pollen concentrations. On the other hand, the main pollen seasons of these taxa extended to summer months and early fall; however, the recorded pollen concentrations were not very high in these months although temperatures were high. Similar studies also recorded a negative correlation between the pollen concentrations of these taxa and the average temperature (Tosunoğlu and Bicakci, 2015; Tosunoglu et al., 2018; Uguz et al., 2017). Results from a study conducted in Kastamonu, a province in the Black Sea region of Turkey, suggest that high temperatures

Table 4. Spearman's correlation coefficients between daily values of pollen concentrations of main taxa and meteorological parameters during MPS of each studied year in Aydın.

Year	Correlations	*Oleaeuropaea*	Poaceae	*Quercus*	Pinaceae	Cupressaceae /Taxaceae	*Platanus*	*Morus*	Urticaceae
2014	Mean temperature (°C)	0.093	−0.448**	−0.024	−0.396**	−0.422**	−0.202	−0.320*	
	Mean humidity (%)	0.006	0.115	−0.505**	−0.013	0.175**	0.024	−0.266	
	Rainfall (mm)	0.259	0.020	−0.274*	0.105	0.011	−0.441**	−0.300*	
	Mean wind velocity (m/s)	−0.047	−0.096	0.131	0.064	−0.115*	−0.303	0.058	
2015	Mean temperature (°C)	0.413*	−0.261**	−0.165	−0.306**	−0.445**	−0.547**	−0.722**	−0.272**
	Mean humidity (%)	−0.388*	−0.184**	−0.356**	−0.199**	0.124*	0.272*	−0.054	−0.001
	Rainfall (mm)	−0.059	0.188**	−0.206	0.168*	0.215**	0.148	0.108	0.100
	Mean wind velocity (m/s)	0.285	−0.417**	0.145	−0.356**	−0.334**	−0.146	−0.014	−0.347**

*: Correlation is significant at the 0.05 level (2-tailed).

**: Correlation is significant at the 0.01 level (2-tailed).

may have prevented flowering and thus caused a decrease in pollen counts (Çeter et al., 2012).

Seasonal precipitation was another factor affecting the amount of airborne pollen in the atmosphere during spring, causing quantitative differences between the 2 years. Reductions were clearly seen, particularly in the taxa with the highest densities in the atmosphere during these periods. In the first year, the rains in April caused a significant decrease in pollen belonging to taxa with long pollination periods, such as Pinaceae and Poaceae. However, investigation of data from the 2 years suggest that during the first year both the high temperatures in March and the rainfall in April had an effect on the MPS of taxa with short pollination periods, such as *Platanus* and *Morus*. The MPS of *Platanus* lasted for 38 days between March 6 and April 12 in the first year, and for 61 days between March 15 and May 14 in the second year (Table 3). The high amount of precipitation during April in the first year and the high number of rainless days in the same month, particularly in its second half, may have caused the MPS to last longer in the second year. Accordingly, the rainfall observed in the first year was thought to have an effect on the pollen concentration and the MPS of *Morus*, as with other taxa (Figure 4). Similar studies have stated a negative correlation between the pollen concentration of this taxon and the amount of rainfall (Garcia-Mozo et al., 2007; Tosunoglu and Bicakci, 2015).Furthermore, the decreasing pollen amounts of Cupressaceae, Poaceae, and Urticaceae in February of the second yearwere also affected by precipitation (Table 2).

4. Conclusion

Pollen grains belonging to 46 taxa were detected in the atmosphere of Aydın during the 2-year study period, and the pollen of arboreal taxa were more dominant than that of nonarboreal plants. Pollen concentration in the atmosphere was higher between February and May, the highest pollen concentration being detected in May. We identified 8 taxa, each of which produced pollen grains constituting ≥3% of the total amount of airborne pollen. Cumulatively, they accounted for 82.25% of the total pollen concentration. Among these 8 taxa, the pollen grains of Poaceae, Pinaceae, Cupressaceae/Taxaceae, and Urticaceae were observed in the air in all months, and they all had a long MPS in both years. We determined that *Olea europaea* had the highest airborne pollen concentration in the atmosphere of Aydın, and the shortest MPS compared to other taxa. However, the widespread distribution of olives and their cultivation in this region pose a risk for allergy sufferers. The long MPS of other dominant taxa such as Poaceae and Cupressaceae/Taxaceae may also increase the risk of allergy and of crossreaction. Rainfall had a washing effect on airborne pollen, especially in the spring when pollination was high in Aydın, leading to periodic reductions in pollen concentrations. On the other hand, the negative effect of average temperature and average wind speed on the pollen concentrations of many dominant taxa were statistically significant. Based on the results obtained in this study, we evaluated the annual pollen distribution in the province of Aydın for the first time, and introduced data with potential importance for both allergic patients living in the region and the doctors working on this issue.

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