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Atmospheric pollen spectrum in Stone City, Mardin; the northern border of Mesopotamia/SE-Turkey

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Abstract Airborne pollen distribution in Mardin city was measured volumetrically during three consecutive years, 2014–2016. Three thousand eight hundred fifty-seven pollen grains as a mean value belonging to 44 taxa were recorded annually during the study period, and pollen grains from woody plant taxa had the more substantial atmospheric contribution with 62.66% and with 23 taxa. Despite the differences between years, the highest pollen concentration was recorded in April. The main pollen producers of the pollen spectrum were Cupressaceae (27.79%), Poaceae (21.21%), *Platanus* (10.29%), *Morus* (6.19%), *Olea europaea* (5.01%), *Quercus* (4.91%), *Pinus* (3.84%), and Amaranthaceae (3.73%) and almost all dominant pollen types in the city atmosphere were previously stated to be allergic. The atmospheric sampling data was characterized by the high presence of woody plants in spring, as well as the high presentation of herbaceous plants in late spring to early winter. The main pollen season (MPS) and durations of dominated pollen types were analyzed and mostly found a little bit earlier or parallel with similar studies in Mediterranean basin, but found earlier than the east. Statistical analyses were performed to compare years with each other and for correlating daily pollen concentrations of dominated pollen types concurrent with the data of meteorological parameters; a number of significant correlations were found.

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Introduction

Pollen is the male gametophyte of seed plants and produced as a part of the sexual production, which is primarily dispersed by wind or insects. Among these, atmospheric pollen, which provides in high quantities especially by anemophilous plants, constitute an influential group regarding human health because of being the most common triggers of seasonal allergies. Worldwide, the rise in prevalence of allergic diseases has continued in the industrialized world, and pollen allergy is presently estimated to be 40% in Europe (D'Amato et al. 2007; Wallace et al. 2008). That is why aeropalynological studies are particularly important for patients affected by the threshold levels of pollen and for clinicians (Ribeiro et al. 2008). Therefore, detecting pollen types and their concentrations is very important, particularly in the atmosphere of highly populated cities. From this point of view, many aerobiological studies have been carried out around the world (Giner et al. 2002; Peternel et al. 2003; Ianovici et al. 2013; Ribeiro and Abreu 2014; Puljak et al. 2016), and the relationship between the amount of airborne pollen concentration and meteorological factors has been demonstrated in several studies in the literature (Ribeiro et al. 2003; Rodríguez-Rajo et al. 2003; Sahney and Chaurasia 2008; Kizilpinar et al. 2010).

In this study, we aimed (1) to assign the pollen types and their concentrations, (2) to represent pollen seasons, (3) to prepare a pollen calendar for Mardin city, and (4) to investigate the relationship between daily pollen concentrations and meteorological factors in Mardin city, which has an entirely different geography and climate.

Material and methods

The study area, climate, and flora

Situated in the Southeastern Anatolia Region of Turkey on the Syrian border, Mardin city [36° 55′–38° 51′ N–39° 56′–42° 54′ E] (Fig. 1) is a unique place in architectural, ethnographic, archeological, historical, and visual aspects and hosts mosques, mausoleums, churches, monasteries, and similar religious creations parallel to the different religious beliefs, all of which are

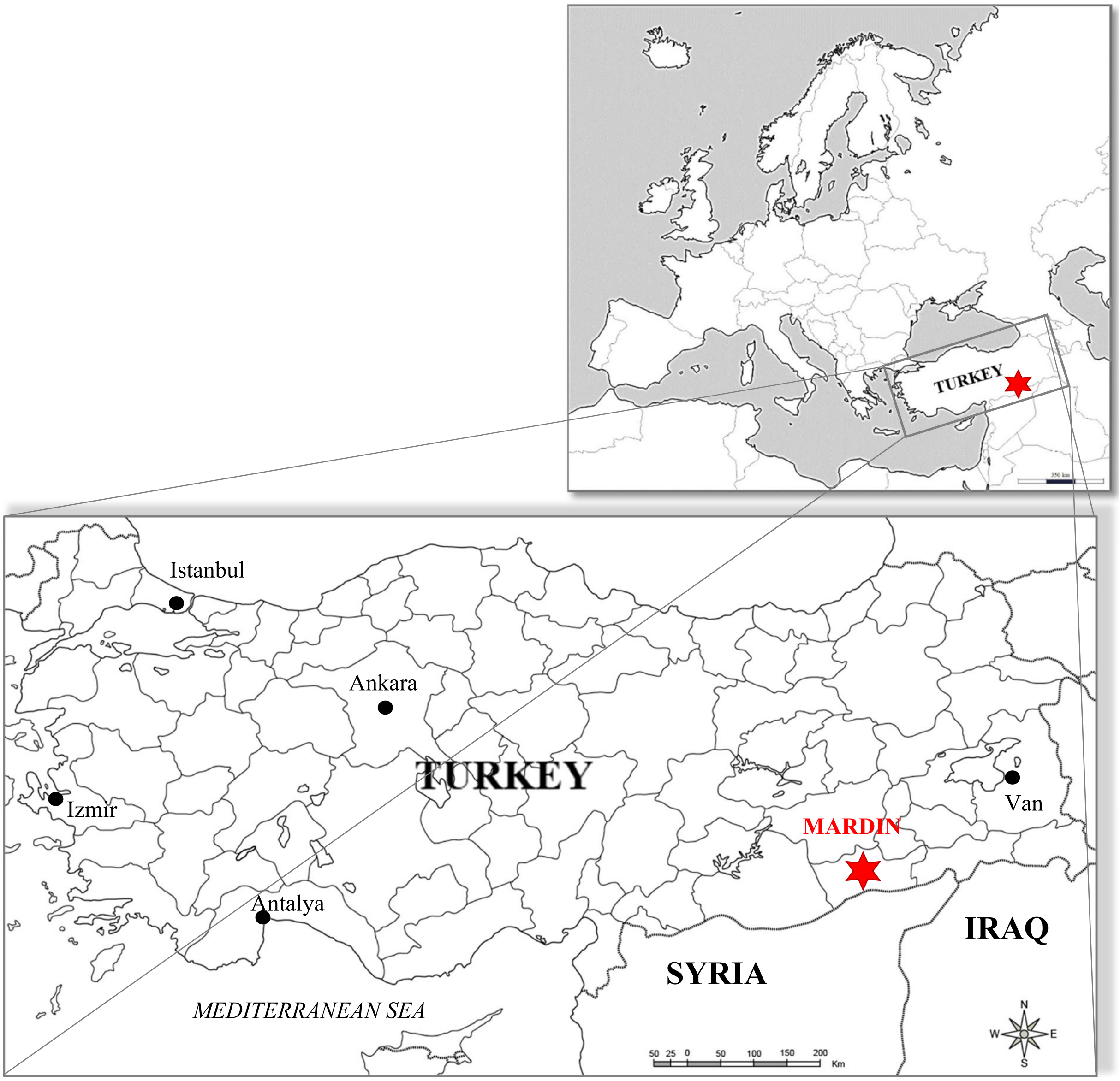

Fig. 1 Location of the study area (Mardin)

representing both artistic and historic values. The province of Mardin is located along the historical Silk Road and has a very mixed population; Turks, Assyrians, Aramean-Syriac people, Arabs, and Kurds all represent large groups. The capital of Mardin Province is known for its Arab-style architecture and has a strategic location on a bare, broad mass, rocky mountains, which covers 52.6% of the province and giving "Stone City" nickname to the area, overlooking the plains of northern Syria.

In the region, the summers are scorching hot and arid, and the winters are abundant and rainy. The high-pressure area in Mardin during the winter season leads to cold winter months. On the one hand, being under the influence of the desert climate of the south (Basra Low Pressure) and being prevented by the high mountains about the entry of cold air masses from the north, lowland of the region is extremely hot and dry in summer. According to 65 years of meteorological data provided by the Turkish State Meteorological Service, July is the hottest month (29.9 °C), whereas January is the coldest month (3.1 °C). July is the sunniest month, with 12.3 h/day and August is the least rainy month, with a total of 0.3 mm/m^2 rain; January is the wettest month with 11.5 rainy days and a total of 114.8 mm/m^2 rainfall. Moreover, according to the data of the last 35 years, Mardin city is known as a province and has the highest total evaporation amount in Turkey.

That is why the Mardin region is impoverished regarding plant and forest assets. The oak trees on the edge of the steppe are dry forests because the area has a continental climate with some similarities of the Mediterranean climate. The most common oak species are *Quercus infectoria* Olivier subsp. *boissieri* (Reuter) O. Schwarz and *Quercus brantii* Lindley. In the high sections where winters last long, the oaks are replaced by cold-resistant junipers. Besides, there are different trees such as willow, plane, walnut, poplar, and hackberry in the wells and wetland valley bases. The heads of steppe plants in the region are *Verbascum*, *Astragalus*, *Delphinium*, *Erygalum*, *Euphorbia*, *Gentiana*, *Silene*, *Trifolium*, *Bromus*, *Thymus*, *Achillea*, and *Convolvulus* species. The amount of arable land is minimal, and some of Mardin's anthropogenic steppes have been converted into cultivated areas of mechanized cropping in agriculture.

Aerobiological method

An aeropalynological study was performed in Mardin city center with a Hirst-type 7-day sampling volumetric pollen and spore trap (Lanzoni VPPS 2000) during 2014–2016 for 3 years. The device operated continuously and was calibrated to aspirate 10 l/min air in every sampling week. Melinex® tape, which was first placed by applying silicone oil, was taken from the sampling drum together with the adherent atmospheric particles and cut into daily fragments. The tape fragments were mounted to slides, covered with glycerin jelly mixed with basic fuchsine (Charpin et al. 1974) and examined by light microscopy. Atmospheric sampling and analysis were performed as described by the Spanish Aerobiology Network (REA), which ascertains intradiurnal variation by transversally dividing slides into 12 intervals (Galán et al. 2007). Pollen concentrations were stated as a number of pollen grains in 1 m^3 of air according to the technical specification CEN/TS 16868 (European Committee for Standardization 2015). The pollen grains that could not be identified were considered to be unidentified types.

Pollen types that comprised more than 3% of the annual total pollen concentration were considered to be dominant. The main pollen season (MPS) for predominant pollen types was calculated according to Andersen (1991) using the 95% method. The pollen calendar was constructed according to the Spieksma model, and 10-day mean pollen concentrations were placed into a series of classes and depicted by column height in the calendar (Spieksma 1991). Pollen types that annually represented under five pollen per cubic meter were not taken into the calendar.

Statistical analysis

First, the Kolmogorov-Smirnov test was applied to the daily data for normality testing and negative results found ($P < 0.05$). The Kruskal-Wallis test was used to assess whether daily concentrations of pollen were different between years for each dominated taxon and the Mann-Whitney U test was used to determine which years differed for concentrations of pollen per day. Spearman's correlation analysis was performed to correlate the whole daily pollen data of predominant pollen types and the daily pollen data of predominant pollen types in MPS periods with the concurrent meteorological parameters (mean daily temperature, mean daily wind speed, and daily rainfall) using data from the same day. The statistical tests were performed using the software package IBM SPSS version 22.0 (SPSS—Chicago, IL, USA).

Results

Pollen concentrations and groups

In Mardin, a total of 3857 pollen grains as a mean value were recorded annually during the study period (2014 to 2016). Pollen concentration was found the highest in the first sampling year (4456 in the year 2014) and the lowest in the second year (3023 in the year 2015) with a quarter drop (Table 1).

A total of 44 different types of pollen were recorded for 3 years; of these, 23 of them came from woody plants and 21 from herbaceous plants. Although the numerical superiority of pollen types varies according to years, pollen concentrations of woody plants were found to be higher than those of herbaceous plants for every 3 years. When considering the average of three sampling years, 62.66% of the total pollen concentration was recorded as from woody plants and 36.86% was derived from herbaceous plants—with a significant contribution of Poaceae pollen (21.21%); the highest pollen concentration of arboreal plants was recorded in 2016 with 70.93%, and the lowest herbaceous pollen concentration was recorded in 2015 (44.02%) (Table 1).

Variations in pollen concentrations

In the studied years, differences in monthly variation of pollen concentration were investigated as well as found in the annual pollen index (API). In the first year, the highest pollen concentration was recorded in March, and it has followed a gradual decrease until September. A smaller but noteworthy second peak was recorded in October. The precipitation peak recorded in parallel to the first pollen concentration peak in March 2014 is equally worthwhile, while the second pollen peak of the first year was recorded in October, when rainfall was lower than in the previous and subsequent months, after which the pollen concentration remained at the lowest level until the rise in February 2015 (Fig. 2). In the second year, unlike the previous year, the highest pollen concentration was recorded in May. The highest amount of rainfall here is in February, and the amount of pollen was the highest in late spring (May); what is noteworthy here is that the first peak concentration was quite low compared to that in the previous year. With the increase of mean temperature in summer of 2015, the amount of pollen dropped to low levels, and unlike the past year, there was no second peak recorded in October (Fig. 2). Once again, the pollen concentration started to increase in February of the following year (2016), but it reached its highest level in April. In the year 2016, when the highest amount of precipitation was recorded in February and compared with the other years, when the peak concentration of pollen reached the highest level in April, the amount of rainfall was lower. As in the first sampling year, October peak was also seen in the last year, but pollen concentration of the peak was found lower. In general, except spring months and mid-autumn (October), pollen concentration was found very low in Mardin atmosphere (Fig. 2).

Pollen calendar

Pollen seasons, intensities, and variations in pollen concentrations and identified taxa were put into a calendar, which was prepared using the average values from 3 years (Fig. 3). The pollen calendar showed that the earliest pollen types in the atmosphere of Mardin mostly belonged to winter flowering arboreal plants like Cupressaceae and *Fraxinus* and early bird Poaceae and Urticaceae members. On the other hand, pollen grains of some prominent families like Cupressaceae, Poaceae, Urticaceae, and Amaranthaceae showed a very long-term abundance in the atmosphere of Mardin, probably due to their sizeable extended group and different flowering terms of many belonging species. The pollen calendar was characterized by demonstrating many types of pollen grains in late winter, like *Pinus*, *Salix*, *Morus*, and *Ulmus* together with herbaceous *Mercurialis* and *Plantago*. The number of pollen types was recorded at the highest level in April (Fig. 3). A significant decline in pollen concentration and a gradual decline in the number of pollen types towards summer months has been recorded. The pollen grains that appear in the atmosphere during summer were mostly from herbaceous plants like Poaceae, Amaranthaceae, *Xanthium*, and *Artemisia*. In autumn, besides pollen grains of herbaceous taxa, which have been seen in summer, pollen grains of woody plants like *Betula* (with a second peak) and *Cedrus* that bloom in the autumn were also encountered (Fig. 3).

Table 1 Annual pollen counts and percentage of pollen taxa recorded in Mardin atmosphere (2014–2016)

	2014		2015		2016		Mean	
	Total	%	Total	%	Total	%	Total	%
Cupressaceae	**1468[a]**	**32.94**	**755[b]**	**24.98**	**1041[c]**	**25.44**	**1088**	**27.79**
Platanus	**335**	**7.52**	**235**	**7.77**	**637**	**15.58**	**402**	**10.29**
Morus	**201**	**4.52**	**168**	**5.57**	**347**	**8.48**	**239**	**6.19**
Olea europaea	**191**	**4.28**	**170**	**5.61**	**210**	**5.14**	**190**	**5.01**
Quercus	**132**	**2.97**	**128**	**4.24**	**308**	**7.53**	**190**	**4.91**
Pinus	**138**	**3.09**	**84**	**2.79**	**231**	**5.65**	**151**	**3.84**
Cedrus	120	2.68	–	–	4	0.10	62	1.39
Salix	27	0.62	32	1.05	2	0.04	20	0.57
Populus	29	0.66	9	0.28	29	0.72	22	0.55
Ulmus	24	0.55	13	0.42	–	–	19	0.49
Fraxinus	10	0.21	20	0.65	23	0.55	17	0.47
Abies	40	0.89	6	0.20	10	0.24	19	0.44
Betula	6	0.14	11	0.36	23	0.57	13	0.36
Juglans	1	0.03	15	0.50	15	0.37	11	0.30
Rosaceae	7	0.15	13	0.44	9	0.21	10	0.27
Ligustrum	1	0.03	8	0.26	–	–	5	0.14
Pistacia	7	0.16	3	0.10	–	–	5	0.13
Acer	1	0.01	4	0.12	9	0.21	4	0.11
Alnus	2	0.05	4	0.14	2	0.06	3	0.09
Aesculus	1	0.03	–	–	–	–	1	0.03
Myrtaceae	1	0.03	–	–	–	–	1	0.03
Ericaceae	–	–	–	–	1	0.01	1	0.01
Ostrya	–	–	–	–	1	0.01	1	0.01
Woody plants	**2743**	**61.56**	**1678**	**55.50**	**2902**	**70.93**	**2441**	**62.66**
Poaceae	**720**	**16.16**	**873**	**28.88**	**760**	**18.58**	**784**	**21.21**
Amaranthaceae	**289[a]**	**6.49**	**74[b]**	**2.44**	**93[b]**	**2.27**	**152**	**3.73**
Urticaceae	145	2.34	73	2.42	90	2.19	102	2.32
Xanthium	157	3.52	31	1.01	12	0.28	66	1.60
Artemisia	109	2.44	46	1.53	25	0.61	60	1.53
Apiaceae	43	0.96	61	2.02	43	1.04	49	1.34
Fabaceae	21	0.47	73	2.42	31	0.76	42	1.22
Plantago	79	1.78	12	0.40	51	1.25	48	1.15
Rumex	26	0.59	26	0.87	17	0.42	23	0.62
Mercurialis	11	0.25	16	0.54	14	0.34	14	0.38
Brassicaceae	13	0.30	13	0.44	–	–	13	0.37
Echium	16	0.37	–	–	14	0.34	15	0.36
Taraxacum	16	0.37	4	0.12	–	–	10	0.25
Boraginaceae	10	0.23	9	0.28	8	0.19	9	0.24
Asteraceae	12	0.26	7	0.22	5	0.13	8	0.21
Rubiaceae	1	0.03	7	0.24	4	0.10	4	0.12
Lamiaceae	9	0.19	1	0.04	2	0.06	4	0.10
Caryophyllaceae	3	0.08	–	–	4	0.09	4	0.08
Cannabaceae	1	0.03	2	0.08	–	–	2	0.05

Table 1 (continued)

	2014		2015		2016		Mean	
	Total	%	Total	%	Total	%	Total	%
Cyperaceae	3	0.07	1	0.04	1	0.03	2	0.05
Papaver	1	0.01	–	–	–	–	1	0.01
Herbaceous plants	**1687**	**37.87**	**1330**	**44.02**	**1174**	**28.70**	**1397**	**36.86**
Unidentified	26	0.57	15	0.48	15	0.37	19	0.48
Total	**4456**[a]	**100.00**	**3023**[b]	**100.00**	**4091**[c]	**100.00**	**3857**	**100.00**

For each taxon shown in bold, the values shown as superscripts with different letters were found to be significantly different statistically. The taxa which were not different between years are not marked (the significance level is 0.05)

Dominated pollen types and MPS periods

According to the 3-year average, eight plant taxa comprised more than 3% of the total pollen content, taken as the predominant pollen types with the most significant influence in Mardin atmosphere (Table 1): Cupressaceae (27.79%), Poaceae (21.21%), *Platanus* (10.29%), *Morus* (6.19%), *Olea europaea* (5.01%), *Quercus* (4.91%), *Pinus* (3.84%), and Amaranthaceae (3.73%). These eight dominated taxa represented 77.97% of the annual pollen index in 2014, 82.28% in 2015, and 88.67% in 2016 (Table 2).

When monthly pollen percentages are taken into account according to the 3-year average values, the highest concentration of pollen in the Mardin atmosphere was recorded in April (35.73% of the annual pollen index), although it varies between years (31.68% of the annual pollen index in March 2014, 30.43% in May 2015, 65.01% in April 2016) (Table 2).

For the dominant pollen types detected in the study, main pollen seasons and durations based on daily data are shown in Table 3. The most extended main pollen seasons were belonging to the Cupressaceae, Poaceae, and Amaranthaceae families. On the other hand, the

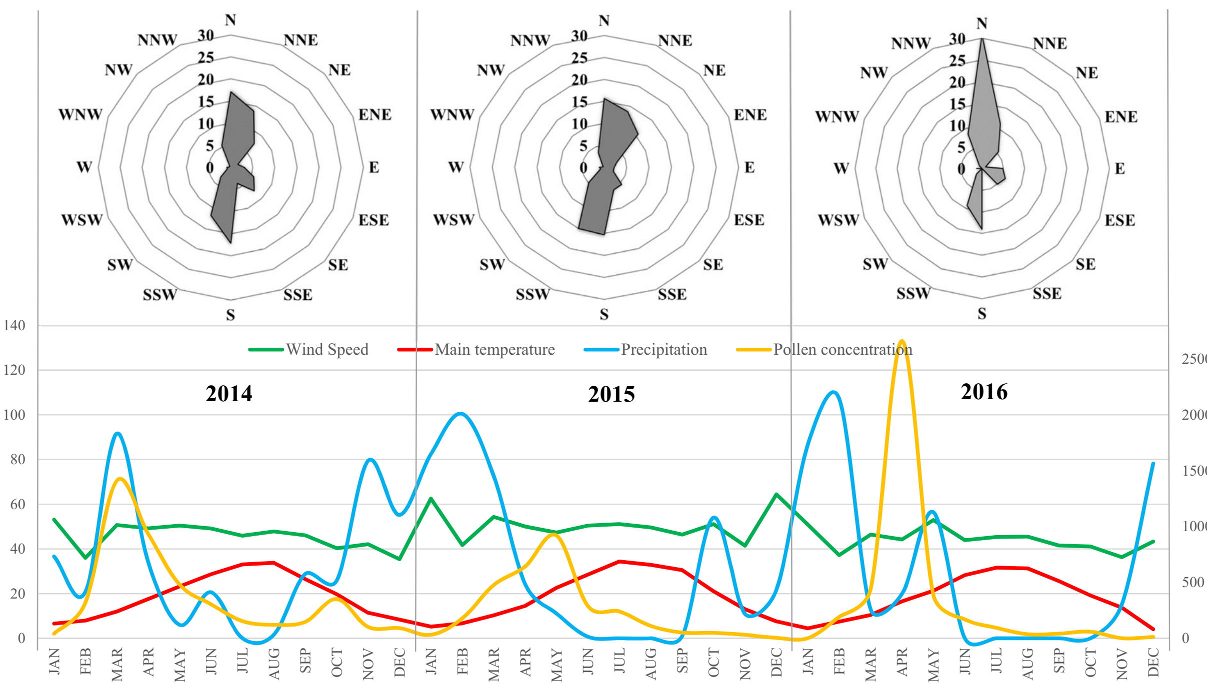

Fig. 2 Three-year variations on pollen concentration (p/m^3—*secondary axis*) and meteorological parameters [wind speed (m/s), main temperature (°C), precipitation (kg/m^2)—*primary axis*] and prevailing winds in web graphs (*with percentages of wind directions*) in Mardin atmosphere

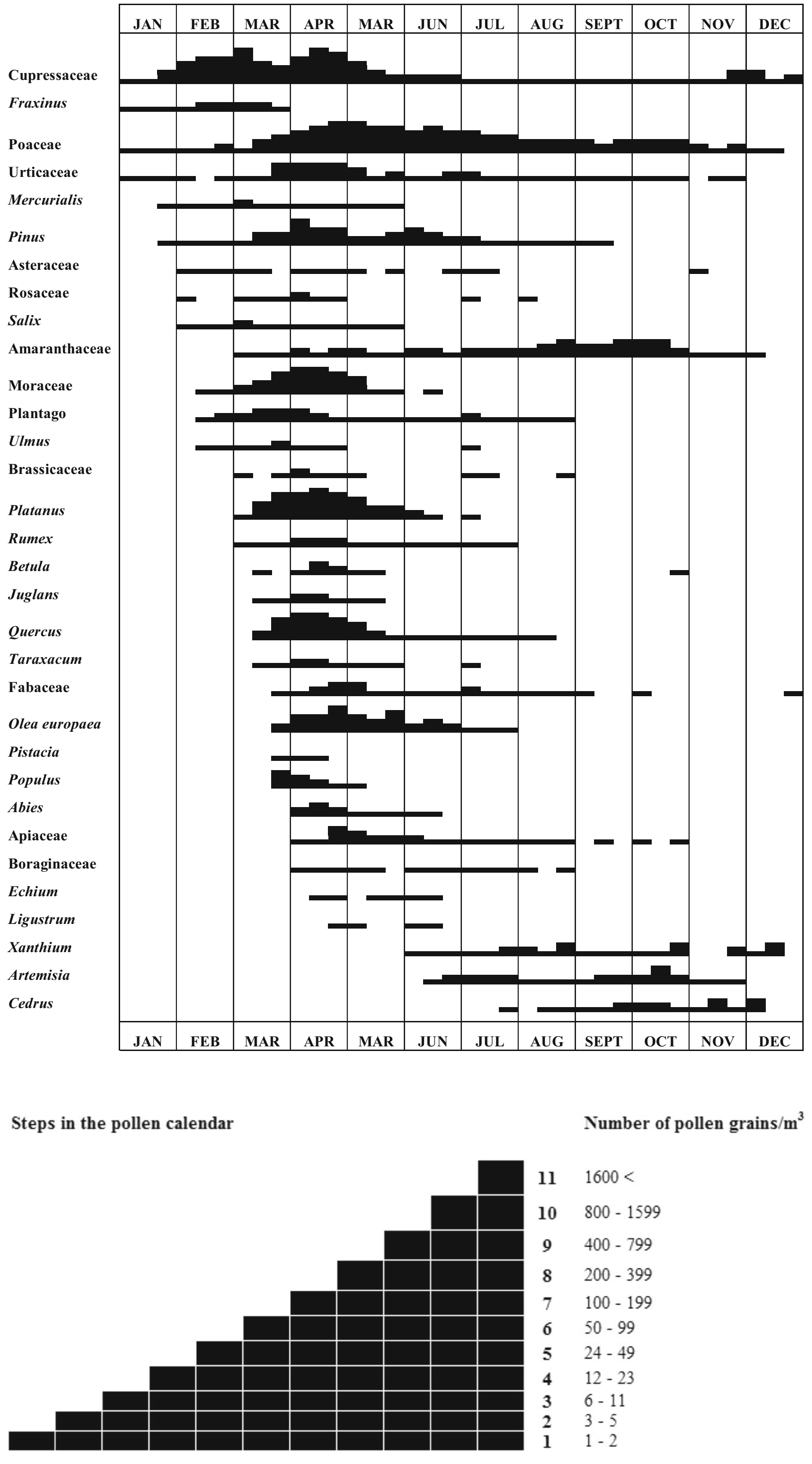

Fig. 3 Pollen calendar of Mardin atmosphere, based on the 3-year average data

Table 2 Dominated pollen types and their annual percentage in Mardin atmosphere in years 2014–2016

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014												
Cupressaceae	33	296	827	196	30	29	8	6	2	10	13	17
Poaceae	4		5	134	260	141	68	21	31	34	21	2
Platanus			178	109	45	4						
Morus			131	66	4							
Olea europaea			4	68	60	6						
Quercus			90	41	1							
Pinus			29	135	11	12	2	2	1			
Amaranthaceae			2	15	4	9	13	35	56	142	12	1
Others (%)	0.09	0.53	3.27	3.79	1.48	2.35	1.41	1.27	1.27	3.70	1.26	1.60
Total (%)	***0.92***	***7.17***	***31.68***	***20.94***	***10.77***	***6.84***	***3.44***	***2.71***	***3.30***	***7.89***	***2.29***	***2.04***
2015												
Cupressaceae	18	143	433	43	77	4	6	5	1	1	23	1
Poaceae	6	4	2	103	402	147	115	40	21	26	5	2
Platanus			6	149	74	5	1					
Morus			5	97	65	1						
Olea europaea				7	100	54	8					
Quercus				75	44	2	5	2				
Pinus	1	4	2	30	15	15	15	1	2			1
Amaranthaceae			1	2	2	7	14	29	10	9	1	
Others (%)	0.20	0.93	0.91	4.52	4.67	1.76	2.56	1.13	0.52	0.42	0.08	0.02
Total (%)	***1.03***	***5.89***	***15.76***	***21.25***	***30.43***	***9.55***	***7.95***	***3.67***	***1.70***	***1.61***	***1.03***	***0.12***
2016												
Cupressaceae		160	131	713	23	4						10
Poaceae		4	45	282	224	101	53	15	9	27		
Platanus			65	540	31	2						
Morus		4	41	296	5							
Olea europaea			3	179	29							
Quercus			37	262	9	1						
Pinus			20	137	23	46	3	2				
Amaranthaceae			4	8	11	8	9	12	20	20		
Others (%)	0.03	0.58	2.28	5.92	0.79	0.19	0.70	0.18	0.31	0.30	0.01	0.03
Total (%)	***0.03***	***4.70***	***10.72***	***65.01***	***9.47***	***4.14***	***2.30***	***0.88***	***1.01***	***1.45***	***0.01***	***0.28***

shortest pollen season was recorded for *Morus* pollen (Table 3) probably because of the most precise identification of the single genus, which is commonly planted in the area.

Daily data, difference between years, and correlation with meteorological factors

When statistical analyses were conducted to examine the difference in daily pollen concentrations of dominated taxa between years, only significant differences were found for Cupressaceae and Amaranthaceae families (Table 1). For Cupressaceae, the daily pollen concentrations were found different in all sampling years; but for Amaranthaceae, only the data for 2015 and 2016 were compatible with each other, which differs from 2014 (Table 1). While the reason for this difference was investigated, in the statistical study, only the average daily wind data was found different for all the years among the meteorological factors, and there

Table 3 Characteristics of the main pollen season (MPS) for the most essential taxa (start and end dates), season length (days), and maximum values of monthly pollen concentration (p/m^3)

		2014	2015	2016
Cupressaceae	Main pollen season	11/02–14/10	02/02–30/10	17/02–01/05
	Season length (days)	246	271	74
	Max. pollen/month	827/March	433/March	713/April
Poaceae	Main pollen season	08/04–06/11	16/04–12/10	20/03–10/10
	Season length (days)	213	180	204
	Max. pollen/month	260/May	402/May	282/April
Platanus	Main pollen season	23/03–22/05	02/04–30/05	20/03–04/05
	Season length (days)	61	59	46
	Max. pollen/month	178/March	149/April	540/April
Morus	Main pollen season	20/03–28/04	02/04–19/05	14/03–26/04
	Season length (days)	40	48	44
	Max. pollen/month	131/March	97/April	540/April
Olea europaea	Main pollen season	01/04–09/06	22/04–16/07	03/04–07/05
	Season length (days)	70	86	35
	Max. pollen/month	68/April	100/May	179/April
Quercus	Main pollen season	25/03–21/04	07/04–07/07	24/03–30/04
	Season length (days)	28	92	38
	Max. pollen/month	90/March	75/April	262/April
Pinus	Main pollen season	25/03–25/06	17/04–06/08	18/03–17/06
	Season length (days)	93	112	92
	Max. pollen/month	135/April	30/April	137/April
Amaranthaceae	Main pollen season	17/04–16/11	01/05–21/10	25/03–20/10
	Season Length (days)	214	174	210
	Max. pollen/month	142/October	29/August	20/Sept–Oct

was no significant difference between the years for the other meteorological parameters.

When the daily total pollen concentrations and daily meteorological factors were correlated for 3-year data, significant positive correlation with temperature and significant negative correlation with precipitation were found. Statistically, a significant difference was found between sampling years. It was found that there was a correlation between meteorological factors and dominantly detected pollen; Cupressaceae and *Pinus* pollen were negatively correlated in the first 2 years, but Cupressaceae pollen showed a significant positive correlation in the last sampling year with mean daily temperature. Also, Poaceae pollen concentration showed a significant negative correlation in 2015–2016 like Cupressaceae with mean daily temperature, but the only significant negative correlation was found in *Quercus* pollen concentration with mean daily temperature in 2015 (Table 4).

When the daily mean wind speed and the daily pollen concentrations were compared, there was generally no correlation found, and only a significant positive correlation between the Poaceae pollen and the wind speed was observed in the year 2016. When the relation between total rainfall and pollen concentration was examined, Cupressaceae pollen concentration was significantly correlated in the first 2 years, while *Morus* and *Platanus* pollen showed a significant negative correlation in the same years and negative correlation recorded with daily Amaranthaceae pollen concentration in 2015 (Table 4).

On the other hand, if the pollen concentrations of dominant pollen in only MPS periods and the meteorological parameters recorded on the same dates were taken into consideration, daily Cupressaceae and Amaranthaceae pollen concentrations were positively correlated with daily mean temperature, while Poaceae,

Table 4 Correlation between daily pollen concentrations in sampling years ( ), daily pollen concentrations in whole MPS periods (*in italic*) of the taxa and concurrent meteorological parameters for Mardin atmosphere

	Mean temperature (°C)				Wind speed (m/s)				Total rainfall (mm)			
	2014	2015	2016	MPS periods	2014	2015	2016	MPS periods	2014	2015	2016	MPS periods
Cupressaceae	− .584**	− .591**	.274*	.613**	.079	− .011	.067	.073	.139*	.232**	.184	.210**
Poaceae	− .134	− .342**	− .309**	− .243**	.120	.081	.306**	.023	.051	.142	− .007	.169
Platanus	− .110	− .031	.058	− .182*	.148	.058	.118	.086	− .449**	− .305*	.247	− .193*
Morus	− .252	.201	.231	− .007	− .170	.119	.022	− .052	− .356*	− .299*	.067	− .182*
Olea europaea	.009	.007	.121	− .019	.211	.101	− .174	− .058	− .186	− .152	− .006	− .059
Quercus	− .191	− .452**	.112	− .525**	.201	.070	.140	.021	− .307	.055	.041	.138
Pinus	− .401**	− .279**	− .014	− .307**	− .004	.057	− .145	.118*	− .006	− .029	.135	− .032
Amaranthaceae	.081	.308**	− .049	.113**	− .011	.065	.053	− .035	− .039	− .177*	− .036	− .096*

Statistically significant values are shown in bold

*Correlation is significant at the 0.05 level—two-tailed

**Correlation is significant at the 0.01 level—two-tailed

Pinus, *Quercus*, and *Platanus* pollen correlated negatively. In the MPS period, daily *Pinus* and *Platanus* pollen concentrations were positively correlated with mean wind speed and were negatively correlated with *Morus* pollen. Moreover, it was also found that daily Cupressaceae pollen concentration showed significant positive correlation with daily total precipitation while daily Amaranthaceae, *Morus*, and *Platanus* pollen concentration correlated negatively in their MPS periods (Table 4).

Discussion

In the Mardin atmosphere, 3857 pollen grains were determined over the average of 3 years. Although there is not any volumetric data from surroundings of the study area, it is clear that the lowest concentration of pollen was recorded in Mardin at least from the East Mediterranean basin (Gioulekas et al. 2004; Altintas et al. 2004; Tosunoglu et al. 2015; Bicakci et al. 2017). The only exciting finding was coming from the Kızıltepe town of Mardin city, which is nearly situated 20 km south of the city center, with the higher pollen counts of gravimetric sampling (Potoğlu Erkara et al. 2016). There may be several reasons for the low pollen concentration of Mardin Province like the highest amount of evaporation fame, being one of the regions with the strongest wind, having the high-temperature difference in day-night, and being one of the driest places in the area about the annual average amount of moisture. In relation with all these, as the Stone City name implies, the floristic structure of Mardin is also feeble, and low annual pollen concentrations are not surprising data from this point of view.

Forty-four types of pollen were detected despite low annual pollen concentration, and pollen grains of woody plants were found dominated in the atmospheric spectrum with the 3-year mean of 62.66%. The high dominance of pollen grains of woody plants in the air is prevalent in western Turkey (Bicakci et al. 2000; Altunoglu et al. 2008; Bilisik et al. 2008a; Guvensen and Ozturk 2003). However, it was an unexpected result to encounter with higher pollen concentrations of woody taxa on the east, on the contrary of other eastern and northern studied cites from the same phytogeographical region (Celenk and Bicakci 2005; Bicakci et al. 2017). The pollen spectrum of Eastern Anatolia was characterized before with high herbaceous plant pollen in the air, mainly with grass pollen with high percentages (Celenk and Bicakci 2005; Bicakci et al. 2017) (Table 1).

When the pollen calendar prepared for the region is evaluated, it can be seen that the number of taxa belonging to the woody plants is found higher in spring and that the herbaceous taxa are numerically dominant in the summer (Fig. 3). It was an expected result because anemophilous trees start their vegetation period earlier, but the annual herbs shed their pollen during the mid or late summer period depending on the seed development time and life cycle. It has been determined that woody plants such as Cupressaceae, *Fraxinus*, *Pinus*, and herbaceous Poaceae, Urticaceae, and *Mercurialis* are the earliest flowering plant taxa, as they are characteristics of many parts of the Mediterranean periphery (Altintas et al. 2004; Tosunoglu et al. 2009; Tosunoglu et al. 2015; Tosunoglu and Bicakci 2015). Here, Cupressaceae, Poaceae, Urticaceae, and Amaranthaceae pollen deserve a particular emphasis because of having very long and uninterrupted pollen seasons, probably because of including many taxa and as a result of limited identification.

Cupressaceae was the most frequent pollen type with 27.79% of the annual pollen index with parallel to many studies, conducted in the Mediterranean basin (Table 5). These pollen types are known as an essential cause of respiratory allergies in the region (Felice et al. 1994; D'Amato 1998) and the prevalence of allergic sensitization to Cupressaceae pollen grains is increasing worldwide (D'Amato 1998). In Mardin, cypress type pollen dominancy is probably due to the extensive use for gardening of *Cupressus arizonica* and large plantation of *Cupressus sempervirens* in graveyards, especially culturally in the city center. However, it should be reminded that there are natural populations of *Juniperus* at high altitudes on the northern part of the region, although there are no planted or spread juniper trees in the city center. When viewed from this angle, while the first peak in the pollen calendar in March is probably from the cypress, the second peak in April may be from juniper (Fig. 3). Cupressaceae pollen was recorded in March when the maximum monthly mean temperature started to rise in the first 2 years, and in April in the last sampling year (Table 2). On the other hand, the high concentration of pollen recorded in March and April 2016 may be tied to the earlier spring, which is drier than in previous years, or the more intense transport of *Juniperus* pollen by north winds, relative to the first 2 years (Fig. 2). The reason for the lower amount of pollen in January and February 2015 than in 2014 may be the excessive rainfall in these months. MPS duration of Cupressaceae pollen was very short in the year 2016, just 74 days, different from previous years (Table 3); this may be since no pollen was recorded in a dry summer. As far as the timing of the main pollen season, Cupressaceae pollen again showed similarities about MPS periods with the Istanbul city in Turkey (Celenk et al. 2010). However, the start of the MPS was 2 months earlier than the high-altitude areas in the east (Bicakci et al. 2017), 2 weeks more prior than the western Mediterranean coast (Tosunoglu and Bicakci 2015; Tosunoglu et al. 2015) (Table 3).

Poaceae pollen was the second dominated taxon and also found as the most frequent pollen type of herbaceous plants in the air of Mardin with 21.21% mean (Table 1). The long pollen season was probably due to the limited identification of family members, which may originate from many cultivars or wild species. Grass pollen is also the primary cause of pollinosis in many parts of the world (D'Amato et al. 2007). The highest Poaceae pollen peak was recorded in May 2015 in Mardin atmosphere, but looking up to the mean value of 3 years, the maximum values were recorded in mid-April–mid-May terms (Fig. 3). The MPS periods were found very long due to the long pollen season of grass pollen in Mardin with low concentrations (Table 3), also found nearly a week earlier from western and eastern cites (Tosunoglu and Bicakci 2015; Bicakci et al. 2017).

Platanus was the third abundant pollen type in the atmosphere of Mardin with 10.29% of the annual pollen index (Table 1). *Platanus* pollen were found dominant also in Istanbul, NW; Kusadasi, SW Turkey; Denizli, SW Turkey; and Usak, W Turkey (Table 5). According to the 3-year average, *Platanus* pollen concentration reached the highest level in April (Fig. 3), and if the studied years were considered separately, the most prominent peak can be seen in the year 2016 (Table 2) within the highest pollen peak of 3 years (Fig. 3), which corresponds to the time without precipitation. A relative short pollen season started parallel to western coastal parts of Anatolia (Tosunoglu et al. 2015; Celenk et al. 2010; Uguz et al. 2018).

Mardin is on the route of the southern branch of the historic Silk Road, and for this reason, mulberry trees are still traditionally planted in gardens for their economic importance. Not only on the Silk Road, *Morus* pollen grains were previously reported as a predominant pollen type also from İzmir, W Turkey; La Plata, Argentina; and Köycegiz, SW Turkey (Table 5) and this pollen type previously reported as the leading cause of pollen allergy (Targow 1971; Murioz et al. 1995). Quite short main pollen season durations in Mardin for *Morus* pollen were found parallel with those of the previous studies (Tosunoglu et al. 2015; Bicakci et al. 2017), but the starting dates of MPS periods (Table 3) were found nearly a month later from Mediterranean

Table 5 Comparison and quantities of predominated taxa in the atmosphere of Mardin and other sampling sites

Sampling method	Sampling sites	Dominated taxa (%)								References
		Cupressaceae/ Taxaceae	Poaceae	*Platanus*	Morus/ Moraceae	*Olea europaea*/ Oleaceae	*Quercus*	*Pinus*/ Pinaceae	Amaranthaceae/ Chenopodiaceae	
Volumetric	Present study	27.79	21.21	10.29	6.19	5.01	4.91	3.84	3.73	
	Antalya (Turkey)	38.33	4.89	4.67	5.18	6.87	4.58	24.19	–	Tosunoglu et al. 2015
	Istanbul (A–E parts)	36.52–34.42	2.71–1.38	5.26–23.76	2.04–2.03	–	6.41–3.53	7.06–2.73	1.00	Celenk et al. 2010
	Bodrum (Turkey)	42.73	5.50	–	1.72	9.04	15.95	9.78	–	Tosunoglu and Bicakci 2015
	Çeşme (Turkey)	33.07	4.32	–	–	12.51	8.38	8.41	–	Uguz et al. 2018
	Van (Turkey)	10.53	20.94	6.68	5.57	–	6.70	–	7.77	Bicakci et al. 2017
	Kastamonu (Turkey)	20.60	9.70	–	–	–	5.50	42.90	–	Çeter et al. 2012
	Uşak (Turkey)	10.22	4.74	1.12	–	–	32.6	31.96	1.82	Uguz et al. 2017
	Yalova (Turkey)	21.22	10.01	29.08	–	2.50	3.07	7.34	–	Altunoglu et al. 2008
	Denizli (Turkey)	15.99	6.63	5.68	2.58	11.35	6.08	24.19	2.27	Guvensen et al. 2013
	Cagliari (Italy)	23.58	10.98	–	–	7.29	–	5.50	4.89	Ballero and Maxia 2003
	Cordoba (Spain)	1.10	13.20	–	–	10.99	59.81	1.85	–	Garcia-Mozo et al. 2007
	Thessaloniki (Greece)	25.5	8.30	6.30	–	10.20	16.00	7.50	2.90	Damialis et al. 2005
	Vinkovci (Croatia)	–	11.01	–	–	–	4.89	1.59	–	Stefanic et al. 2007
Gravimetric	Didim (Turkey)	13.49	6.33	7.62	3.81	9.19	2.02	45.58	–	Bilisik et al. 2008b
	Koycegiz (Turkey)	5.09	8.70	4.64	5.53	3.91	2.64	48.01	1.17	Tosunoglu et al. 2009
	Kuşadası (Turkey)	30.04	3.70	4.41	1.22	34.46	–	19.71	–	Tosunoglu et al. 2013
	İzmir (L–H levels) (Turkey)	2.60 4.80	7.70 6.00	–	− 2.40	5.30 4.40	11.70 12.00	57.30 57.00	1.30 1.70	Guvensen and Ozturk 2003
	Sivrihisar (Turkey)	9.82	2.87	–	–	–	–	69.31	2.33	Potoglu Erkara 2008
	Sakarya (Turkey)	10.31	18.95	5.98	1.86	–	10.50	14.1	2.13	Bicakci 2006

coast Antalya, Turkey (Tosunoglu et al. 2015), a month earlier from such a high altitudinal region Van, E Turkey (Bicakci et al. 2017).

Olea europaea pollen is considered as one of the most important causes of respiratory allergies in the Mediterranean basin (Liccardi et al. 1996), but even so, the economic prosperity of this tree makes it an indispensable cultural heritage in the Mediterranean. In addition to the cultivars, the wild *O. europaea* also spreads intensely in the Mediterranean flora. A relatively short pollen season of olive trees recorded with a small peak in April according to the 3-year mean pollen concentrations (Fig. 3). It was reported before that pollen season duration of *Olea europaea* depends upon both temperature and rainfall; high temperature and low precipitation may shorten the MPS period (González Minero and Candau 1997) and rain during the vegetative period has a positive effect on pollen production (González Minero and Candau 1997; González-Minero et al. 1998; Galán et al. 2001). In our study, recorded higher percentage in dry April and short pollen season of the third sampling year may be thought as parallel to this hypothesis. The MPS duration of *Olea europaea* in Spain was reported as 44–75 days in Málaga, 26–62 days in Córdoba, 28–63 days in Seville, and 32–57 days in Jaén (González Minero and Candau 1997; Diaz de la Guardia et al. 2003) and 28–39 days in Bodrum, 28–60 days in Çeşme from W-NW Turkey (Tosunoglu and Bicakci 2015; Uguz et al. 2017) and was found parallel to our MPS durations (Table 3).

Quercus pollen is another potential aeroallergen (Levétin and Buck 1980; D'Amato et al. 1991) and is frequently reported as a dominated pollen type in the air of Europe and Turkey (Table 5). Uninterrupted pollen season peaked in April (Fig. 3) and similar MPS durations and starting dates noted for *Quercus* pollen from many cites (Celenk et al. 2010; Tosunoglu et al. 2015; Bicakci et al. 2017; Uguz et al. 2017).

According to the previous aeropalynological studies from middle and north Anatolia, the abundant pollen type was mostly reported as *Pinus* (Table 5) but in the south, the most frequent pollen type was recorded as Cupressaceae many times (Table 5) as well as the Mediterranean basin (Papa et al. 2001; Docampo et al. 2007). Many researchers identified pollen grains of Pinaceae members in family level in aeropalynological studies because of their similar pollen morphology. However, some contradictions can be seen in the literature about the allergenicity of Pinaceae type pollen; some authors previously have suggested low allergenicity because of the large size of pollen grains, while some older studies supported important allergenicity (Harris and German 1985). Pollen season of *Pinus* was relatively long and nearly took 8 months according to 3-year mean (Fig. 3). Also, pine pollen was most visible in April for every 3 years (Table 2) as reported from many aeropalynological studies from Turkish cites (Table 5). The MPS duration for Pinaceae/*Pinus* pollen in Mardin atmosphere was found longer than Bodrum, SW Turkey (Tosunoglu and Bicakci 2015); Çeşme, W Turkey (Uguz et al. 2017); and Antalya, SW Turkey (Tosunoglu et al. 2015) but found shorter than Istanbul, NW Turkey (Celenk et al. 2010) and similar with Usak, W Turkey (Uguz et al. 2018). Also, similar MPS results for starting and ending dates were found from Perugia, Italy (Frenguelli et al. 2002); Brisbane, Australia (Green et al. 2003); and Nerja, S Spain (Docampo et al. 2007) for pine pollen.

Amaranthaceae was the second most frequent airborne pollen type from herbaceous plants in Mardin atmosphere (Table 1) and this group of pollen was also recorded as a dominated type from many cites (Table 5). Pollen grains of this family were mostly seen in the atmosphere in low levels due to their long pollen season and were found comparatively higher in late summer and autumn (Fig. 3, Table 2). Many members of the family Amaranthaceae were reported as responsible for allergic respiratory diseases (Galan et al. 1989; Colas et al. 2005). MPS durations found longer than those reported in previous studies but also starting dates of MPS were found nearly a month earlier than W Turkey and 2 months earlier than high altitudinal E Turkey (Bicakci et al. 2017; Uguz et al. 2018).

When the statistical analyses carried out to determine the differences between the years on dominated pollen types were observed, some hypotheses can be suggested about the differences in the daily concentrations of Cupressaceae and Amaranthaceae taxa over the years. The first of these is that the average daily wind speed was similar to that of the Cupressaceae pollen in years. It is expected that Cupressaceae pollen, which is represented by 27.79% in 3-year average and ranked first among the dominants, changes parallel to wind change, which is also determinant for the total pollen concentration per day. On the other hand, this may be due to differences in the short-term meteorological factors mentioned above during the three sampling years, which were coincided with the flowering periods of the taxa. Amaranthaceae pollen concentration was found statistically different from other years in 2014; the rainfall in September may be the main reason for this. In other years, the amount of pollen could have been suppressed by the high precipitation at the October in 2015 and the long arid summer in 2016.

Although there is a general discourse that temperature and wind increase the atmospheric pollen concentration and that humidity and rainfall reduce it (Ballero and Maxia 2003; Rodríguez-Rajo et al. 2003; Ribeiro et al. 2003; Gioulekas et al. 2004; Ščevková et al. 2015), within the scope of this study, contrary to previous studies, harmonious results were observed. Significant negative correlations were found between daily *Cupressus* pollen concentration and mean daily temperature (Table 4), as reported before from the western coastal part of Turkey (Tosunoglu and Bicakci 2015). On the contrary, the positive correlations were recorded between the same parameters in the last sampling year, as it was notified before from closer high altitudinal eastern province (Bicakci et al. 2017) and the northern Euro-Siberian region of Turkey (Çeter et al. 2012). Significant negative correlations on daily Poaceae pollen concentration and daily mean temperature were also found concordant with previous studies (Bicakci et al. 2017; Uguz et al. 2018). Similarly, significant negative correlations were reported for *Platanus* pollen concentrations and daily total rainfall before in Van, Turkey (Bicakci et al. 2017) and positive correlation with mean daily temperature in Usak (Uguz et al. 2018). The only significant negative correlation was found on daily *Morus* pollen concentration and daily total rainfall in 2014–2015 as well as the daily pollen concentration in MPS periods and daily rainfall (Table 4), but on the contrary, previous studies reported the daily *Morus* pollen concentration and daily relative humidity with positive significant correlations (Celenk et al. 2009; Bicakci et al. 2017). It was interesting that there were no any significant correlations found for any meteorological parameters in studied years for olive pollen (Table 4). The similar statistical results between daily mean temperature and daily pollen concentration were found previously for Quercus pollen also in Bodrum, SW Turkey (Tosunoglu and Bicakci 2015), but in contrast to Uşak, W Turkey (Uguz et al. 2018). Similar statistical results for *Pinus*/Pinaceae pollen concentrations were also reported from Bodrum, SW Turkey (Tosunoglu and Bicakci 2015); Kastamonu, N Turkey (Çeter et al. 2012); and Usak, W Turkey (Uguz et al. 2018). Positive correlations were found between the daily Amaranthaceae pollen concentration and daily mean temperature together with daily total rainfall in the year 2015 and MPS periods and this result was found to be parallel with previous studies (Bicakci et al. 2017; Uguz et al. 2018).

In conclusion, 3857 pollen grains over the average of 3 years belonging to 44 taxa were determined in the atmosphere of Mardin, and woody taxa (23) were higher than herbaceous taxa (21) in this spectrum. The annual pollen concentration in Mardin city was found to be very low; the highest amount of evaporation, the high differences in temperature between day and night, and drought were considered as the main reasons of sparse vegetation and low pollen concentrations. The atmospheric sampling data are characterized by the high presence of woody plants in spring, as well as the high presentation of herbaceous plants in late spring to early winter. The highest pollen peak was recorded in 2016 in April, arider than previous years. Although it varies between years, the highest concentration of pollen in the average was recorded in April. The MPS and durations of dominated pollen types were analyzed and mostly were found to be a little bit earlier or parallel from similar studies in Mediterranean basin, but found earlier than the east. Many significant correlations were found between daily pollen concentrations of dominant taxa and daily meteorological parameters. On the other hand, almost all of the taxa detected dominantly in this study have been reported by various authors to cause allergic reactions in susceptible individuals.

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