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ORIGINAL PAPER

An aeropalynological survey in the city of Van, a high altitudinal region, East Anatolia-Turkey

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Abstract Pollen concentrations in the atmosphere of Van city has been monitored for two consecutive years (2010–2011). This was the first detailed aeropalynological study for the elevated East Anatolia Region of Turkey. The sampling was performed by Hirst-type volumetric sampler, and pollen grains of 35 taxa were identified. The main pollen producers of the pollen flora were recorded as: Poaceae (20.94 %), Cupressaceae (10.53 %), *Fraxinus* (8.56 %), Chenopodiaceae/Amaranthaceae (7.77 %), *Populus* (7.75 %), *Quercus* (6.70 %), *Platanus* (6.68 %), *Morus* (5.57 %), *Plantago* (3.03 %). The pollen spectrum reflected the floristic diversity of the region, and the highest pollen concentration was recorded in April. There were a great percentage of allergenic taxa found in the city atmosphere, otherwise many of them scored under threshold values for risk of pollinosis. Statistical analyses were performed for correlating daily pollen concentrations of dominated pollen types concurrent with the data of meteorological parameters in MPS periods and number of significant correlations found. In addition, comparing 2-year data in terms of pollen concentrations and meteorological factors in MPS durations, many variables were found explanatory and concordant with the data. MPS starting dates of many plant taxa were found nearly a month later compared with western sites and lower altitudes of the country as well as Mediterranean countries; this case is mostly thought the ecological factors of the study area which directly affects the plant growth about the timing.

Keywords Aeropalynology · Pollen calendar · Pollen concentration · Van · Turkey

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1 Introduction

Pollen is the male gametophyte of seed plants and produced as a part of sexual production which is primarily dispersed by wind or insects. Wind-pollinated plants are the main cause of pollen allergy on pollen-sensitive individuals, and symptoms may include allergic rhinitis (hay fever), allergic conjunctivitis and allergic asthma. Worldwide, the rise in prevalence of allergic diseases has continued in the industrialised world and pollen allergy is presently estimated to be 40 % in Europe (D'Amato et al. 2007; Wallace et al. 2008).

The length of seasonal exposure to bioaeroallergens is dependent on geographical location, local flora and climatic conditions. Thus, different aeropalynological compositions have seen on the atmosphere of different regions because of these variables. For this reason, many aeropalynological investigations have been performed worldwide about pollen dispersal and concentrations, especially in highly populated areas (Giner et al. 2002; Peternel et al. 2003; Ribeiro and Abreu 2014).

Mountain systems cover nearly 20 % of earth's land surface and inhabited except Antarctica. They are mostly characterised by extreme weather conditions, such as reduced air temperature, air density, cloudiness and increased wind velocity, precipitation, solar radiation . Thus, the altitude, geographical latitude, climatic factors, snow cover duration and physiological stress affect the vegetation on high elevations by forcing vascular plants to a very short growing season (Beniston and Fox 1995). On the other hand, there are relatively few studies, which aimed to monitor airborne pollen levels of high elevations; Durham samplers and pollen deposition method have been used for pollen sampling in neighbouring cities Bishkek-Kyrgyzystan and Bitlis-Turkey (Kobzar 1999; Celenk and Bicakci 2005), while volumetric traps have been used in three sites of Russia for the comparison of pollination seasons (Šaulienė et al. 2014), also in Swiss Alps-Switzerland pollen transportation monitored over tree line (Frei, 1997). For the purpose of shedding light on wind pollination of plants in such difficult conditions and to perform the first aeropalynological study for such a high altitudinal region of Turkey, we aimed to assign the pollen types and their concentrations present in the air, represent pollen seasons, prepare a pollen calendar for Van city, investigate the relationship between pollen concentrations and meteorological factors and above all to evaluate airborne pollen data in terms of high altitudinal vegetation and growing seasons.

2 Materials and methods

2.1 Study area, flora and climate

Van is situated at East Anatolia Region, where the Pontic and Anti-Taurus mountain ranges converge, is rugged country with high elevations, more severe climate and great precipitation found on Anatolian plateau. Van is the biggest city of the East Anatolia Region with population of more than one million people. City is located in the middle of Van lowland at an altitude of 1700 m. It is surrounded by Erek Mountain (3204 m) on the east, Sahbagı hill (1968 m) on the north and Musakent hill (2407 m) on the north-east. Borders of the city lie between neighbour Iran and Lake Van; this lake is the largest one in Turkey and one of the largest endorheic saline soda lakes in the world (Fig. 1).

The study area shows a semi-arid Mediterranean climate. In the Van plain, mainly two seasons seem: cold—long winter, and hot—short summer. According to 38-year data, frost in the plain begins in October and continues until the beginning of May; it takes nearly 4 months of the year, and there are 132 frost days per year. The average of snow cover stands 79 days per year, when rainfall is observed for 84 days. The weather starts to warm up in May. Very short time after the spring of May, June, July and August seems as hot summer months. In average, 87 summer days and 19 tropical days recorded for Van plain. After a short fall in September, winter begins with sudden cold (Kalelioglu 1991). According to 60 years of meteorological data, provided by Turkish State Meteorological Service, January is the coldest month (−3.4 °C), whereas July is the warmest month (22.2 °C). July is also the sunniest month with 12.1 h/day, April is the rainiest month with 12.6 rainy days with a total of 56 kg/m^2 rain, and August is the least rainy month with a total of 1.3 mm rain. Also meteorological parameters (mean daily relative humidity, mean daily temperature, mean daily wind speed and daily rainfall) of two studied years can be seen in Fig. 2.

Natural flora of Van highly was destroyed by local people, especially for agricultural activities and for urbanisation. That is why, no forests can be seen there except at remote and mountainous regions of the settlements. Present forests on the slopes particularly consist of oak trees and *Fraxinus, Alnus, Acer, Celtis, Crataegus* species frequently accompanied to these. Also *Salix* species and *Populus*, *Juglans* species and their cultivars can be seen especially around the rivers and streams along agricultural places.

According to floristic studies, 35.4–44 % of phytogeographical elements were found as Irano-

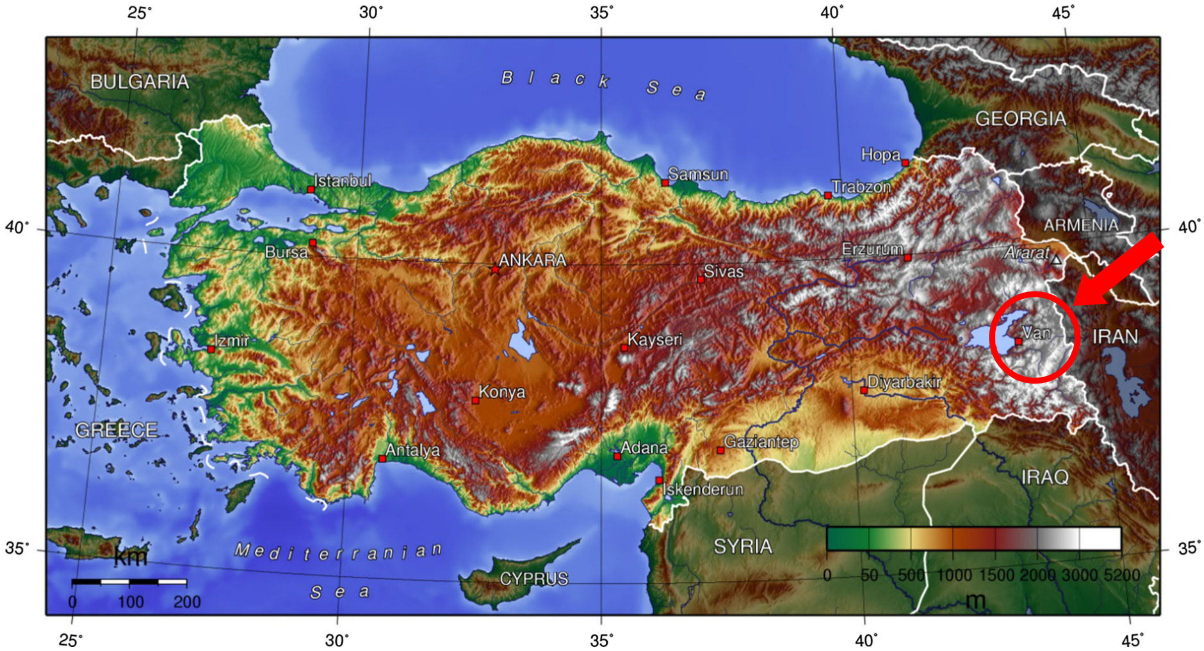


Fig. 1 Location map of Van (https://en.wikipedia.org/wiki/Geography_of_Turkey)

Turanian elements, 8–9.9 % of them as Europa-Siberian and 2–2.9 % as Mediterranean elements in the region. The biggest families of the flora were reported as Asteraceae (131–142 taxa), Brassicaceae (69–76 taxa) and Fabaceae (68–80 taxa) in descending order (Firat 2002; Karabacak and Behçet 2007).

On the other hand, in the city centre of Van, *Pinus nigra, P. sylvestris, Picea orientalis, Abies* sp., *Platanus orientalis, Punica granatum* and especially along the side of Lake Van *Populus nigra, Populus alba* and rarely *Olea europea* cultivars can be seen in parks and gardens.

2.2 Aerobiological method

An aeropalynological study was performed in Van city with a Hirst-type volumetric pollen trap (Lanzoni VPPS 2010) during 2010 and 2011. The pollen trap was placed 8 m above the ground level on a roof of a building in dense city centre (38°30′27″N–43°22′46″E), which located on a dominating hill of the city and completely open to wind flow. The device is calibrated to aspirate 10 l min^{-1} air. Sampling was operated continuously except for the January–March period; the pollen sampler was swamped into snow cover in that term because of heavy snowfall, and it was not possible to get regular sampling in that period for studied years.

For preparation, silicone oil applied Melinex® tape was taken from the 7-day sampling drum weekly and was cut into daily fragments. The tape fragments were mounted to slides and covered with glycerine jelly mixed with basic fuchsine (Charpin et al. 1974) and examined by light microscopy at 400× magnification.

Atmospheric sampling and analysis were performed as described by the Spanish Aerobiology Network (REA), which ascertains intradiurnal variation by transversally dividing slides into 12 bi-hourly intervals (Galán et al. 2007). Pollen concentrations were stated as a number of pollen grains in one m^3 of air.

Pollen types that comprised more than 3 % of the annual total pollen concentration were considered to be dominant (Celenk et al. 2010). The main pollen season (MPS) for dominant pollen types was calculated according to Andersen (1991), using the 95 % method; the start date of the MPS is defined as the day when the daily pollen count reached 2.5 % of the annual pollen index (API) with starting from 1 April,

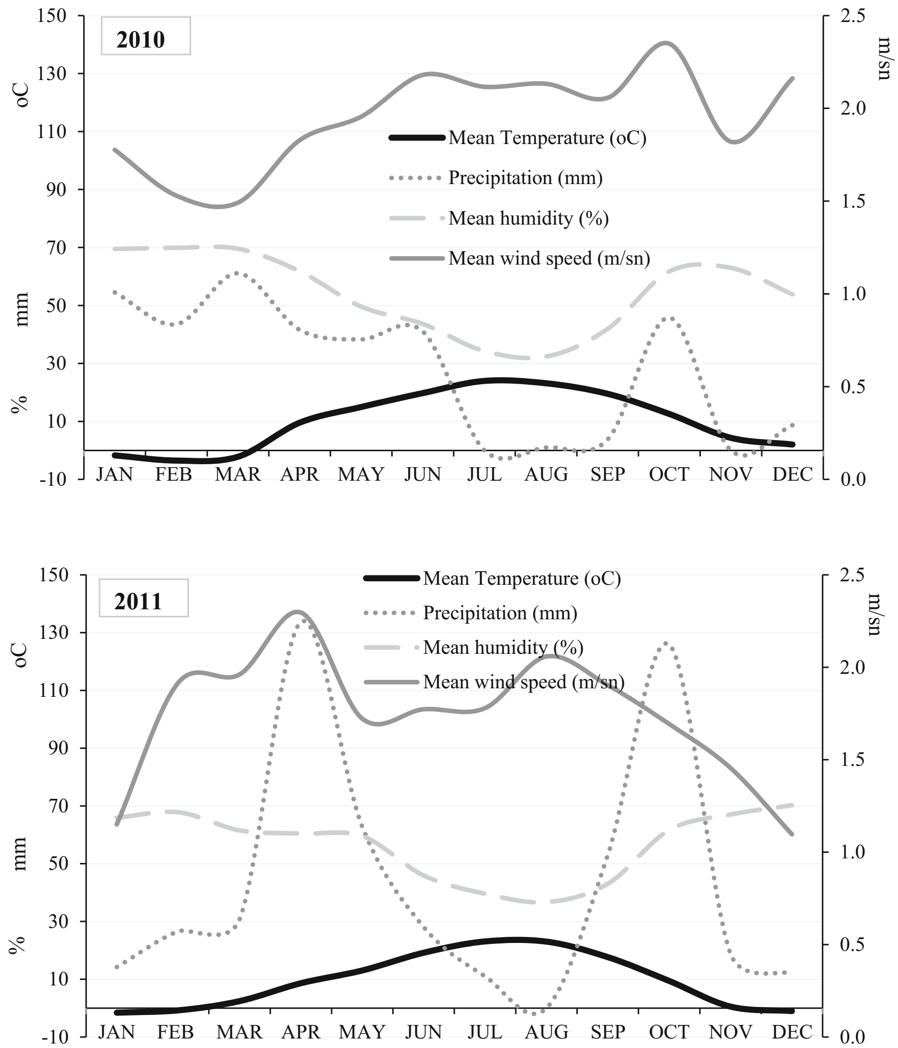


Fig. 2 Monthly variation in pollen concentration, mean temperature, mean wind speed, precipitation and mean humidity in Van for studied years

and the end occurs when 97.5 % of the annual pollen count had been reached.

The pollen calendar was constructed following the Spieksma model (Spieksma 1991); daily pollen counts from 10-day periods were summed and averaged for the years that were studied. These average sums were placed in 10-day mean pollen concentrations into a series of classes (Spieksma 1991) and were depicted by column growth heights in the calendar. Because of missing the beginning of the pollen season, it was not possible to determine starting dates of earliest pollen types found in the atmosphere. For this reason, starting and peak dates of these pollen types are not taken into account for comparison.

2.3 Statistical analysis

First, the Kolmogorov–Smirnov test was applied to the daily data for normality test and negative results found ($P < 0{,}05$). Spearman's correlation analysis was performed to correlate the daily pollen counts during the MPS periods of dominated pollen types (Poaceae, Cupressaceae, *Fraxinus*, Chenopodiaceae/Amaranthaceae, *Populus*, *Quercus, Platanus*, *Morus* and *Plantago*) with the concurrent data of meteorological parameters (mean daily relative humidity, mean daily temperature, mean daily wind speed and daily rainfall) using the same day data. To compare the two sampling years in terms of daily MPS pollen amounts of dominated taxa, and meteorological parameters in MPS periods, nonparametric Mann–Whitney *U* test has been prepared with the 95 % of confidence interval. The statistical tests were performed using the software package IBM SPSS version 22.0 (SPSS—Chicago, Illinois, USA).

3 Results

An annual total of 4163 pollen grains (3939 in 2010 and 4387 in 2011) recorded from 35 taxa were identified in the atmosphere of Van during the study period. Of these, 16 taxa were arboreal and the others were non-arboreal plants (Table 1). Pollen grains from arboreal plants were dominated in the atmosphere with the mean value of 58.20 % (67.40 % in 2010 and 49.94 % in 2011) of the annual pollen index (API). Moreover, 41.80 % (32.60 % in 2010 and 50.06 % in 2011) of the annual total pollen count was from non-arboreal plants (19 taxa)—14.95 % is belonging to Poaceae in 2010 and 26.30 % in 2011 (Table 1).

For both years, sampling started instantly with the removal of snow cover, namely when the device began to move freely in the wind. In the first year of the study, pollen concentration reached the highest level in early spring—April with the total of 1656 pollen per cubic metre, or 42.04 % of the annual total. These high levels also continued in May with 28.87 % of API and started to decrease with the start of summer, in June (Fig. 3). In the second year, pollen concentration was found in high levels in April–June period. In May, 1253 pollen grain were recorded and they reached the highest level in June with 1266 p/m^3 (28.86 % of the API) (Fig. 3). On the other hand, early spring peak in the pollen concentration was found as a result of arboreal plants' pollination season, which produces excessive amounts of pollen grains. In short spring and at the beginning of the hot summer, pollen grains from non-arboreal plants were noted, especially from Poaceae family in May–June period, and low pollen concentrations were recorded in summer accompanying other non-arboreal pollen grains through the end of the year. There was no pollen in the atmosphere in November and December of the year 2011 (Fig. 3).

Pollen seasons, intensities, variations and identified taxa put into a calendar, which was prepared using the average values of 2 years (Fig. 4). The earliest pollen grains of Van were mostly belonging to arboreal plant species such as *Ulmus, Fraxinus,* Cupressaceae, *Acer, Platanus* and *Populus*. Pollen grains of arboreal plants were abruptly decreased in the atmosphere together with summer dry in the study area, and the number of non-arboreal type pollen grains started to increase such as *Urticaceae,* Poaceae, *Plantago, Rumex, Artemisia* and Chenopodiaceae/Amaranthaceae. Pollen concentration and diversity were found in very low levels in October–December term (Fig. 4).

Nine different plant taxa comprised more than 3 % of the total pollen content and taken as predominant pollen types with the greatest influence in Van atmosphere during the study period. These pollen types belonged to Poaceae, Cupressaceae, *Fraxinus*, Chenopodiaceae/Amaranthaceae, *Populus*, *Quercus*, *Platanus Morus* and *Plantago* (Table 1).

Poaceae pollen could be identified at the family level in this study and may originate from many wild grass species with different flowering times over several months, and long pollination period of this taxon is most likely due to limited identification. Looking up to MPS durations, the most abundant pollen type—Poaceae has the longest duration probably because of above-listed reasons. Also in this study, MPS durations were found longer for non-arboreal plants than for arboreal ones; all MPS durations of dominated pollen types (Poaceae, *Plantago* and Chenopodiaceae/Amaranthaceae) were found to be meanly up to 100 days. From arboreal contributors, the longest MPS duration belonged to Cupressaceae, followed by *Quercus* and *Fraxinus*, as well as *Populus* has the shortest duration (Fig. 5). In addition, comparing the peak dates of predominated pollen types, peaks of arboreal pollen types were mostly found in April and May, while non-arboreal types in June–August period (Fig. 5). But on the other hand, because of being capable of putting forward the data of 9 months for both years, it may not be appropriate to calculate MPS durations from the beginning of April, especially for pollen grains of early flowering arboreal plants. As seen at the top of Fig. 4, head portion of pollination seasons could not be monitored and nobody can know whether there were any pollen grains of these plants in the air in lacking days. We put forward MPS durations of all taxa according to the sampling data, and as seen in Fig. 5 with asterisks, MPS durations of Cupressaceae and

Table 1 Annual pollen counts and percentage of pollen taxa recorded in Van atmosphere (2010–2011)

Taxa	2010		2011		Mean	
	Total	%	Total	%	Total	%
Cupressaceae	**420**	**10.66**	**457**	**10.42**	**439**	**10.53**
Fraxinus	**212**	**5.38**	**501**	**11.42**	**357**	**8.56**
Populus	**517**	**13.13**	**128**	**2.92**	**323**	**7.75**
Quercus	**445**	**11.30**	**113**	**2.58**	**279**	**6.70**
Platanus	**411**	**10.43**	**145**	**3.31**	**278**	**6.68**
Morus	**141**	**3.58**	**323**	**7.36**	**232**	**5.57**
Pinus	116	2.94	129	2.94	123	2.94
Juglans	114	2.89	100	2.28	107	2.57
Ulmus	87	2.21	125	2.85	106	2.55
Salix	64	1.62	34	0.78	49	1.18
Acer	31	0.79	39	0.89	35	0.84
Rosaceae	44	1.12	25	0.57	35	0.83
Betula	29	0.74	31	0.71	30	0.72
Oleaceae	20	0.51	33	0.75	27	0.64
Cedrus	2	0.05	8	0.18	5	0.12
Ericaceae	2	0.05	–	–	1	0.02
Arboreal plants	*2655*	*67.40*	*2191*	*49.94*	*2423*	*58.20*
Poaceae	**589**	**14.95**	**1154**	**26.30**	**872**	**20.94**
Chenopod./Amaranthaceae	**308**	**7.82**	**339**	**7.73**	**324**	**7.77**
Plantago	**101**	**2.56**	**151**	**3.44**	**126**	**3.03**
Urticaceae	87	2.21	145	3.31	116	2.79
Artemisia	51	1.29	85	1.94	68	1.63
Rumex	54	1.37	64	1.46	59	1.42
Xanthium	6	0.15	65	1.48	36	0.85
Fabaceae	5	0.13	48	1.09	27	0.64
Apiaceae	31	0.79	17	0.39	24	0.58
Asteraceae	14	0.36	18	0.41	16	0.38
Lamiaceae	9	0.23	22	0.50	16	0.37
Boraginaceae	2	0.05	23	0.52	13	0.30
Cyperaceae	11	0.28	12	0.27	12	0.28
Taraxacum	6	0.15	17	0.39	12	0.28
Brassicaceae	3	0.08	17	0.39	10	0.24
Juncaceae	1	0.03	9	0.21	5	0.12
Rubiaceae	–	–	7	0.16	4	0.08
Mercurialis	2	0.05	3	0.07	3	0.06
Humulus	4	0.10	–	–	2	0.05
Non-arboreal plants	*1284*	*32.60*	*2196*	*50.06*	*1740*	*41.80*
Total	3939	100.00	4387	100.00	4163	100.00

Dominated pollen types are shown in bold

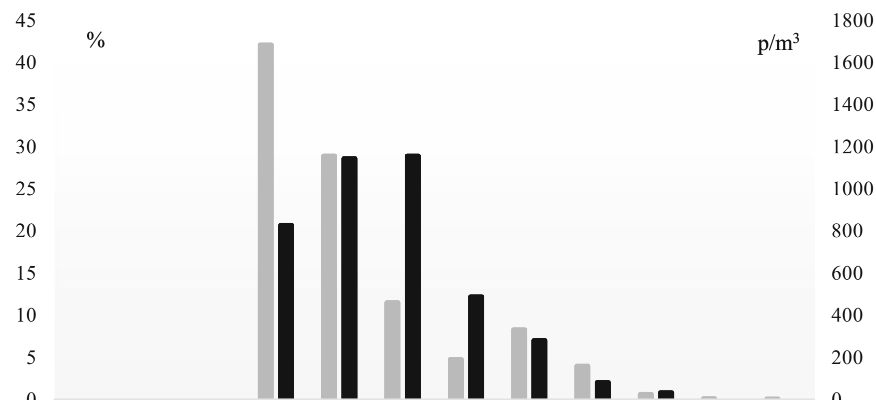
Fraxinus for both monitoring years and *Platanus* and *Plantago* MPS periods for the year 2011 were found in doubt.

Comparing the sampling years, Mann–Whitney *U* test showed that pollen amounts in MPS periods displayed some similarities and differences, but comparison of pollen concentrations of Poaceae, *Fraxinus, Populus, Quercus, Platanus* and *Morus* pollen grains in MPS periods was found significantly different between two sampling years (Table 2).

On the other hand, there were a number of significant correlations ($P < 0.05$) between daily mean pollen concentrations of nine dominated pollen types and meteorological data in MPS periods (Table 2). We obtained a negative correlation with Poaceae and *Plantago* pollen concentrations in 2010 and with *Fraxinus* pollen in 2011 with main daily temperature. Also, we found a positive correlation between Cupressaceae and *Morus* pollen concentrations in 2010 and between Chenopodiaceae/Amaranthaceae and *Plantago* pollen concentrations in 2011 with mean daily temperature (Table 2). With mean daily wind speed, a significant positive correlation was obtained for *Populus* and *Platanus* pollen concentrations in 2010 and Chenopodiaceae/Amaranthaceae pollen concentration in 2011. We found negative correlations between daily pollen amounts of Cupressaceae, *Fraxinus* and *Populus* in 2010 with daily mean relative humidity and *Plantago* pollen concentrations in 2011. Mean daily relative humidity was positively correlated in our study just with *Morus* in 2011 (Table 2). Looking up to the statistical data between pollen concentrations and daily rainfall, there were significant negative correlations obtained for Cupressaceae, Chenopodiaceae/Amaranthaceae and *Platanus* in 2010 and with *Quercus* in 2011 (Table 2).

4 Discussion

Different aeropalynological studies issue many types of habitats, arctic, temperate and tropical regions in the world and also as in our study concerning about its location, altitude and flora. In altitudinal zones, climate is very rigid and winter conditions, physiological drought, day–night changes in temperature and solar irradiance are very stringent for plants. In these kind of places, the growing season of plants confined to short summer and peak flowering period is tighten only around in a short period as in Tenerife-Canary Islands (ca. 2000 m) (Dupont et al. 2003). In another aeropalynological monitoring studies, performed in Bishkek-Kyrgyzstan (alt. 700–900 m) in the NE of Central Asia, pollen sampling could began in April and in Bitlis-Turkey (alt. 1500 m) in March according to the botanical activity and weather conditions (Kobzar 1999; Celenk and Bicakci 2005). The difference between pollination season starting dates can be thought as a result of meteorological conditions, but especially air temperature is found responsible (Frenguelli et al. 1991; Rodríguez-Rajo et al. 2004). For example, pollination starting date is recorded nearly 15 days later (April) than in Riga-Latvia, Vilnius-Lithuania, and Moscow-Russia for some early flowering spring tree pollen types (Šaulienė et al.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2010	0	0	0	42.04	28.87	11.47	4.72	8.25	3.94	0.58	0.08	0.05
2011	0	0	0	20.63	28.56	28.86	12.17	6.98	2.01	0.80	0	0
2010	0	0	0	1656	1137	452	186	325	155	23	3	2
2011	0	0	0	905	1253	1266	534	306	88	35	0	0

Fig. 3 Annual monthly variation in pollen concentrations in Van

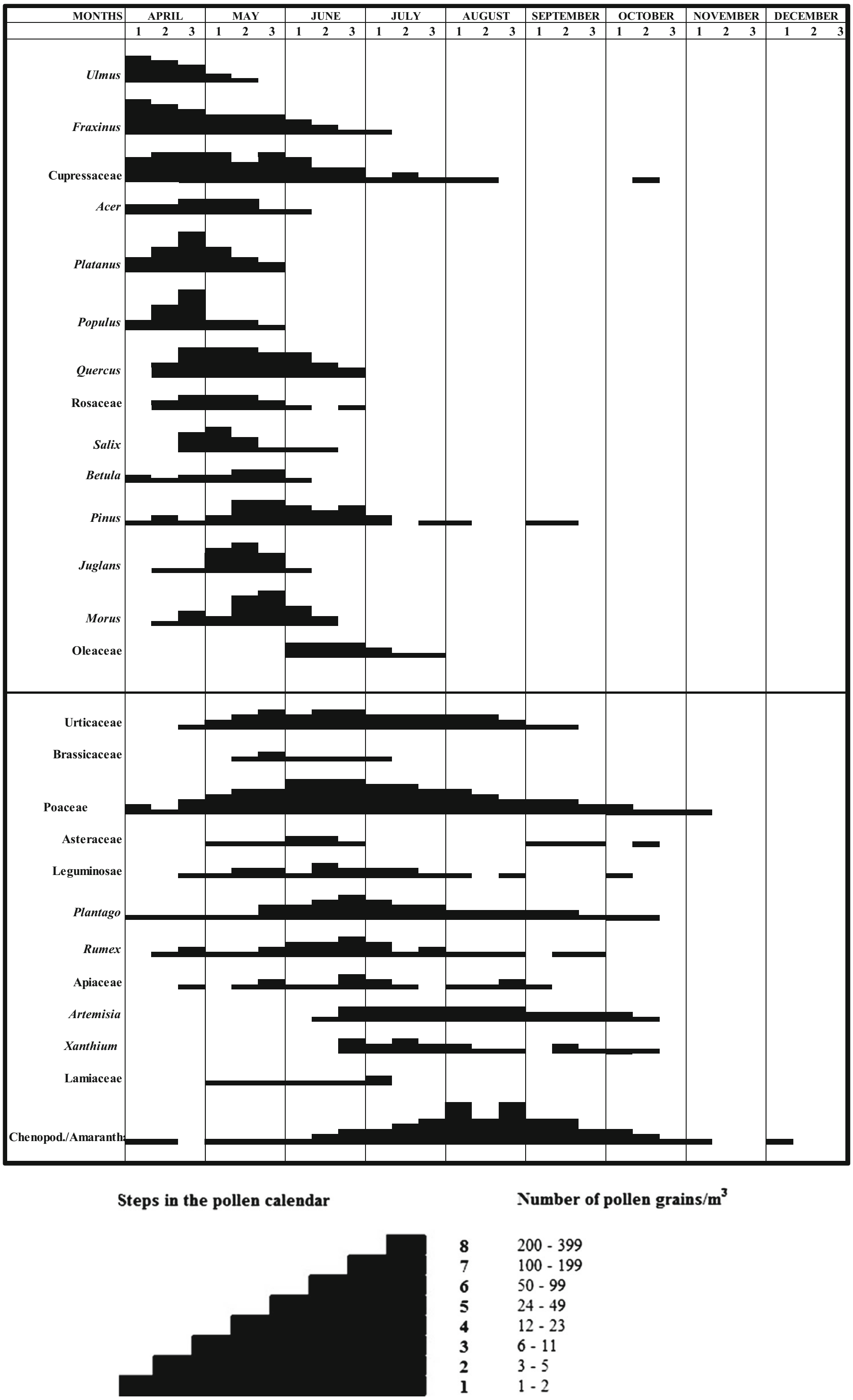


Fig. 4 Pollen calendar of Van (average values of 2010–2011)

2014). Also in this study, it has shown that pollination starting dates of many taxa postponed nearly 3–4 weeks later compared with western cities of Anatolia or Greece (Gioulekas et al. 2004; Tosunoglu et al. 2009; Tosunoglu and Bicakci 2015; Tosunoglu et al. 2015a).

In epitome, in the first year the highest pollen concentration was found in April and in June in the second year in Van city. In the first year, unlike the second year, precipitation was very high in January–March term and temperature was lower. Together with sudden reduction in rainfall and rise of temperature to positive values, pollen concentration reached the highest level in the first year. Contrary to the first year, precipitation was the highest and probably in parallel with that, pollen concentration remained at lower level in April. With a decrease in rainfall, number of pollen grains in the air started to increase and reached the highest levels in May–June term (Figs. 2, 3).

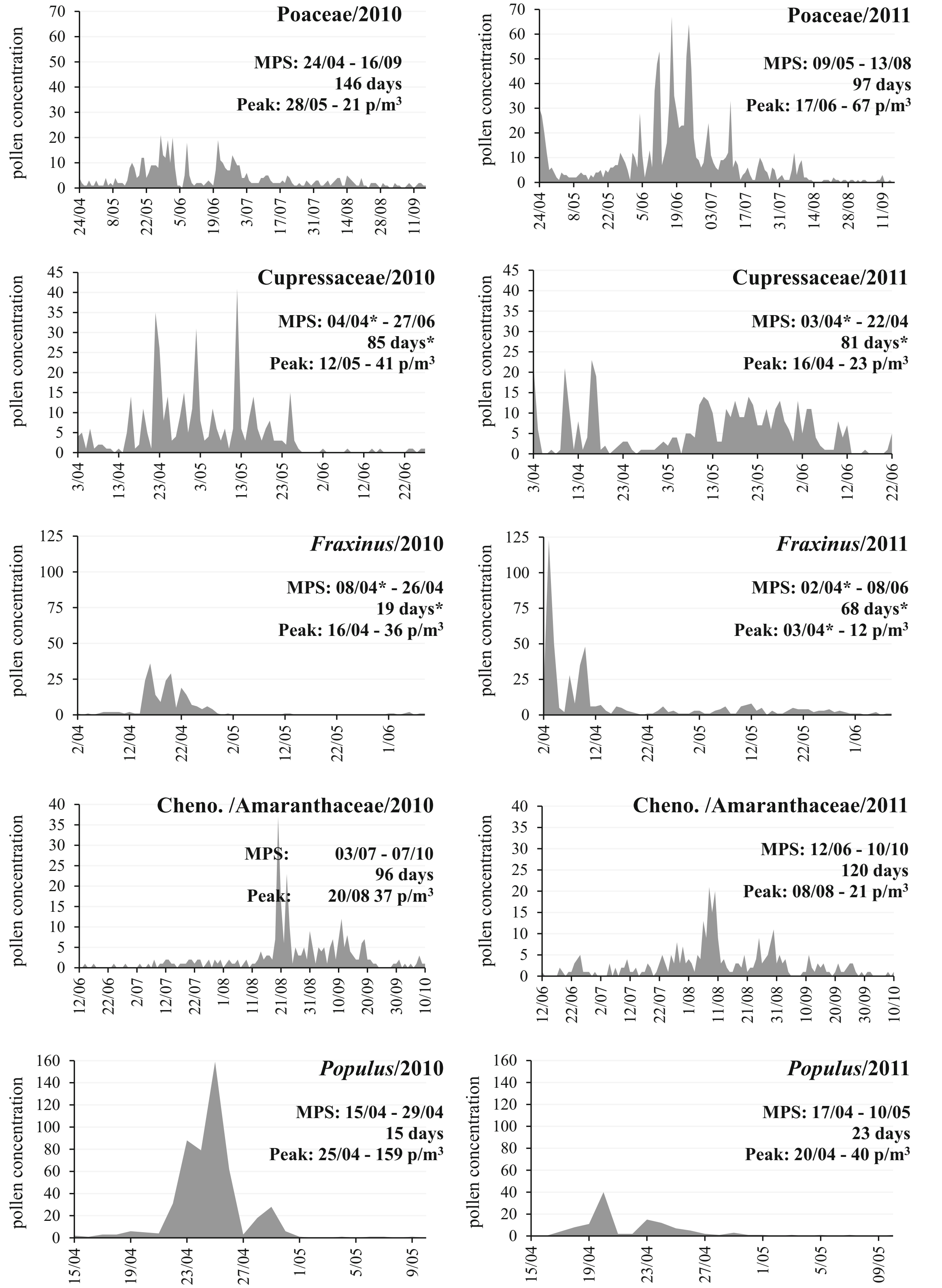
Nine plant taxa were taken as predominant pollen types with the greatest influence in Van atmosphere during the study period. Many of these dominated pollen types are found in parallel with the nearest aeropalynologically investigated place Turkey-Bitlis (Celenk and Bicakci 2005). Also dominated Chenopodiaceae/Amaranthaceae, *Quercus,* Poaceae, *Populus* and Cupressaceae pollen quantities were found very similar to Bishkek-Kyrgyzystan (Kobzar 1999).

In the atmospheric pollen studies of Turkey, mostly Pinaceae or Cupressaceae/Taxaceae pollen grains were found as the most abundant pollen type (e.g. Celenk et al. 2010; Çeter et al. 2012; Tosunoglu et al. 2013; Tosunoglu et al. 2015b). On the contrary, high frequency of Poaceae pollen in the atmosphere of Van is not a surprising data even found parallel with flora and also a similar result was noted in another study from the east part of Turkey (Celenk and Bicakci 2005). Also Poaceae pollen reported as a main pollen type from Madras City-India (Satheeshkumar and Vittal 1998) and reported as a dominated type from the other Mediterranean cities such as Nicosia-Cyprus (Gucel et al. 2013), Zarqa-Jordan (Abu-Dieyeh and Ratrout 2012), Thessaloniki-Greece (Gioulekas et al. 2004), Alexandria-Egypt (El Ghazaly et al. 1991), Kefar Sava-Israel (Keynan et al. 1991). But unlike the study area, the highest levels of pollen grains of this family were mostly recorded in March–May period surrounding the Mediterranean coast. The MPS of Poaceae family pollen grains was found very long (146–97 days), but much shorter compared with the other studies; 17–26 days long in southern Antalya-Turkey (Tosunoglu et al. 2015a), 21–76 days Córdoba, 11–52 days in Priego and 25–66 days in Ciudad Real-Spain (Sánchez Mesa et al. 2003). This case can be viewed by different angles: It is known that pollination in high elevations is mainly constrained by ecological factors and generally alpine plants maintain their flowers longer; some studies especially on insect-pollinated plants showed that longer period of stigma receptivity can be comparable between populations of high and low elevations (Bingham and Orthner 1998; Fabbro and Körner 2004). Thus, in our study longer pollination periods of especially non-woody plant families may be the result of ecological components of the study area as well as the species diversity of the family.

Fig. 5 Seasonal variation, MPS starting–ending–peak dates ▶ and MPS durations of dominated pollen types in Van atmosphere for studied years (*MPS starting dates, durations or peak dates of these taxa found suspicious due to MPS calculation from 1 April as a result of missing dates)

Most of the dominated airborne pollen types in this study were found similar to those in the surrounding countries, but compared the flowering times and peak months, there can be seen a clear delay about the timing of pollen release, especially from western countries such as Greece, Cyprus, Egypt, Jordan and Israel (El Ghazaly et al. 1991; Keynan et al. 1991; Gioulekas et al. 2004; Abu-Dieyeh and Ratrout 2012; Gucel et al. 2013).

Cupressaceae/Taxaceae family pollen grains are mostly reported as a main pollen type in early spring and also seen in winter (Papa et al. 2001; Docampo et al. 2007; Tosunoglu et al. 2013), but in our study the second-winter peak was absent, even there were no any pollen records in last 2 months in the second sampling year as different from the west part of the country. Although pollination terms were nearly a month later from the Mediterranean coastal zone (Keynan et al. 1991; Gioulekas et al. 2004; Abu-Dieyeh and Ratrout 2012; Gucel et al. 2013), similar MPS durations were recorded from Nerja-Spain (Docampo et al. 2007) and Antalya-SW Turkey (Tosunoglu et al. 2015a) for Cupressaceae pollen, but longer MPS is reported from Istanbul-NW Turkey (Celenk et al. 2010). *Fraxinus* pollen grains also were


Poaceae/2010
MPS: 24/04 - 16/09
146 days
Peak: 28/05 - 21 p/m³
pollen concentration
24/04 8/05 22/05 5/06 19/06 3/07 17/07 31/07 14/08 28/08 11/09
Poaceae/2011
MPS: 09/05 - 13/08
97 days
Peak: 17/06 - 67 p/m³
24/04 8/05 22/05 5/06 19/06 03/07 17/07 31/07 14/08 28/08 11/09
Cupressaceae/2010
MPS: 04/04* - 27/06
85 days*
Peak: 12/05 - 41 p/m³
3/04 13/04 23/04 3/05 13/05 23/05 2/06 12/06 22/06
Cupressaceae/2011
MPS: 03/04* - 22/04
81 days*
Peak: 16/04 - 23 p/m³
3/04 13/04 23/04 3/05 13/05 23/05 2/06 12/06 22/06
Fraxinus/2010
MPS: 08/04* - 26/04
19 days*
Peak: 16/04 - 36 p/m³
2/04 12/04 22/04 2/05 12/05 22/05 1/06
Fraxinus/2011
MPS: 02/04* - 08/06
68 days*
Peak: 03/04* - 12 p/m³
2/04 12/04 22/04 2/05 12/05 22/05 1/06
Cheno. /Amaranthaceae/2010
MPS: 03/07 - 07/10
96 days
Peak: 20/08 37 p/m³
12/06 22/06 2/07 12/07 22/07 1/08 11/08 21/08 31/08 10/09 20/09 30/09 10/10
Cheno. /Amaranthaceae/2011
MPS: 12/06 - 10/10
120 days
Peak: 08/08 - 21 p/m³
12/06 22/06 2/07 12/07 22/07 1/08 11/08 21/08 31/08 10/09 20/09 30/09 10/10
Populus/2010
MPS: 15/04 - 29/04
15 days
Peak: 25/04 - 159 p/m³
15/04 19/04 23/04 27/04 1/05 5/05 9/05
Populus/2011
MPS: 17/04 - 10/05
23 days
Peak: 20/04 - 40 p/m³
15/04 19/04 23/04 27/04 1/05 5/05 09/05

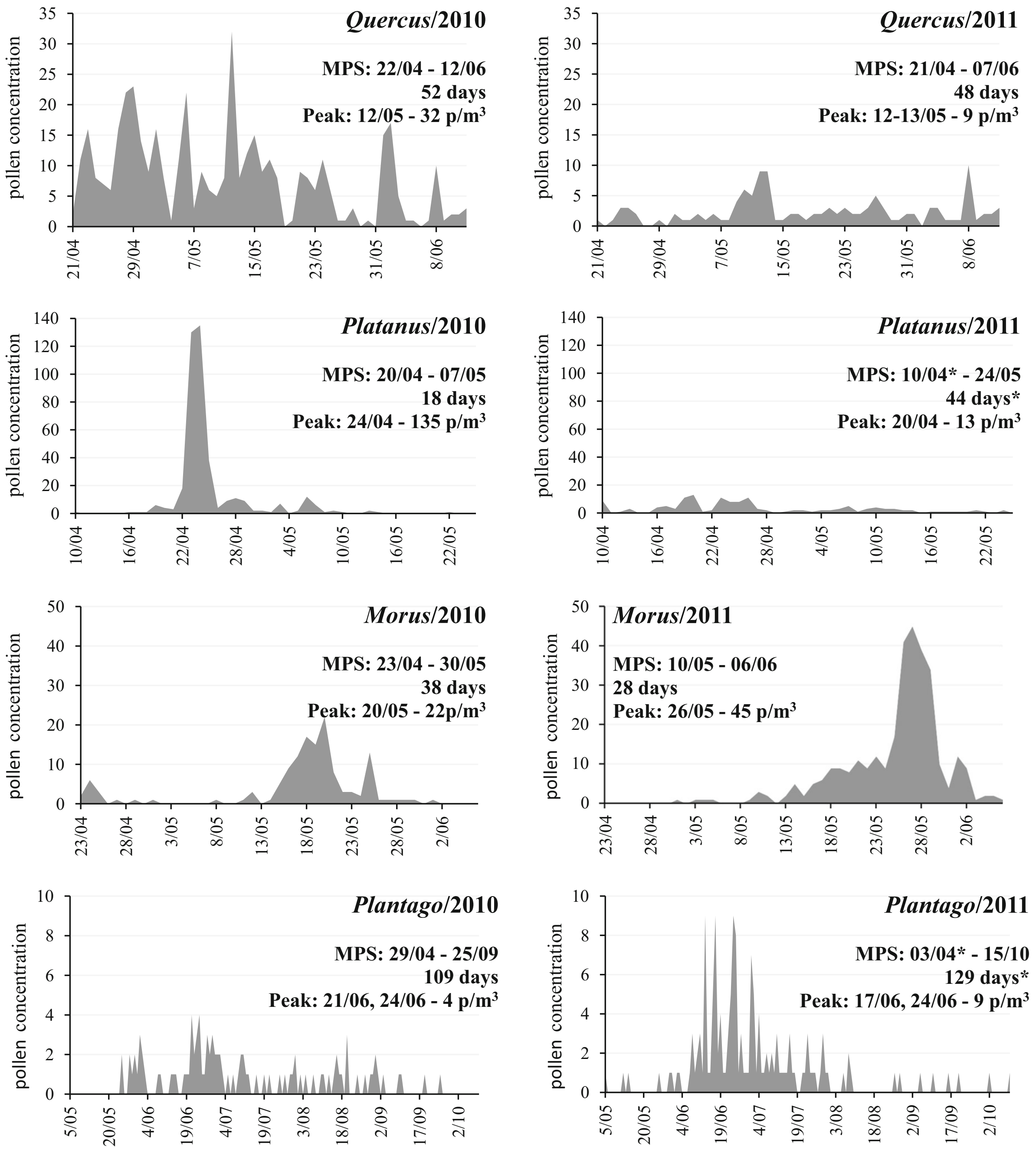


Fig. 5 continued

found dominant in Bitlis-E Turkey (3.67 %) (Celenk and Bicakci 2005), in Koycegiz, Mugla-SW Turkey (3.36 %) (Tosunoglu et al. 2009), in Konya-mid Turkey (4.77 %) (Altunoglu et al. 2010) and in Istanbul-NW Turkey (3.58 % in Asian part, 3.01 % in European part) (Celenk et al. 2010). Interestingly, pollination starting date of *Fraxinus* pollen grains was reported as at the end or beginning of year in many studies from the west part of Anatolia (Bilisik et al. 2008; Celenk et al. 2010; Tosunoglu and Bicakci

Table 2 Results of Spearman's correlation analysis and results of Mann–Whitney *U* test—*P* values

Taxa	Correlation between daily pollen concentrations in MPS period and concurrent meteorological parameters								Comparison of sampling years in terms of pollen amounts in MPS periods				
	Mean daily temperature		Mean daily wind speed		Mean daily relative humidity		Daily rainfall		MPS	Mean daily temperature	Mean daily wind speed	Mean daily relative humidity	Daily rainfall
	2010	2011	2010	2011	2010	2011	2010	2011					
Poaceae	**−0.245****	−0.089	−0.110	−0.007	0.150	0.052	0.148	0.107	**0.000**†	0.486	**0.001**$^{\blacktriangle}$	**0.002**$^{\blacktriangle}$	0.056
Cupressaceae	**0.384****	0.124	0.107	0.243	**−0.470****	−0.235	**−0.296***	0.014	0.110	**0.000**$^{\blacktriangle}$	**0.047**$^{\blacktriangle}$	0.339	0.216
Fraxinus	0.408	**−0.392****	−0.371	0.224	**−0.554***	0.184	−0.258	0.092	**0.026**†	0.056	0.329	0.555	0.311
Chenopodiaceae/ Amaranthaceae	0.036	**0.462****	0.083	**0.208***	−0.112	−0.155	**−0.219***	−0.141	0.843	**0.000**$^{\blacktriangle}$	**0.034**$^{\blacktriangle}$	**0.000**$^{\blacktriangle}$	**0.013**$^{\blacktriangle}$
Populus	0.453	−0.148	**0.784****	0.310	**−0.576***	−0.247	−0.218	−0.013	**0.002**†	0.578	0.592	0.202	**0.020**$^{\blacktriangle}$
Quercus	−0.224	0.231	−0.289	0.038	0.213	−0.213	0.080	**−0.307***	**0.000**†	**0.001**$^{\blacktriangle}$	0.942	0.939	0.123
Platanus	0.016	0.113	**0.555***	0.303	−0.169	−0.215	**−0.517***	−0.117	**0.002**†	**0.047**$^{\blacktriangle}$	0.807	**0.008**$^{\blacktriangle}$	0.175
Morus	**0.357***	0.074	0.068	−0.269	−0.122	**0.493****	−0.276	0.304	**0.000**†	0.471	0.551	**0.004**$^{\blacktriangle}$	0.581
Plantago	**−0.303****	**0.517****	−0.112	−0.015	0.040	**−0.477****	0.084	−0.169	0.100	**0.000**$^{\blacktriangle}$	**0.000**$^{\blacktriangle}$	**0.000**$^{\blacktriangle}$	**0.000**$^{\blacktriangle}$

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

† and $^{\blacktriangle}$ The significance level is 0.05

2015), which is probably due to flowering periods of different *Fraxinus* species.

Main pollen season starting dates of many plant taxa were found later in our study compared with the other sites; this case mostly thought the ecological factors and particularly low temperatures of the study area, which directly affects the plant growth about the timing. MPS of *Populus* in Van was found in parallel with the pollination season of this genus in high-altitude city Bishkek-Kyrgyzstan (Kobzar 1999), but found much later in sea-level city Zonguldak-N Turkey (Kaplan 2004). MPS starting dates of *Quercus* were also nearly 3 weeks before in NW Turkey (Tosunoglu et al. 2015a), 4 weeks before in SW Turkey (Celenk et al. 2010). On the other hand, *Platanus* pollen was detected nearly a month earlier than found in this study on mid-March in SW and NW Turkey (Celenk et al. 2010; Tosunoglu et al. 2015a), as well as different and earlier MPS durations were recorded for *Morus* genus in SW Turkey; starting dates were more than a month before, mainly in March (Tosunoglu and Bicakci 2015; Tosunoglu et al. 2015a). In addition, similar pollination starting dates but shorter MPS lengths were recorded in SW Turkey for atmospheric *Plantago* pollen grains (Tosunoglu and Bicakci 2015).

Also considering this case statistically, we found significant difference ($P < 0.05$) between years and pollen amounts of grass family in MPS periods. Comparing the meteorological parameters of two studied years, we found significant decrease in mean daily wind speed and significant increase in mean daily relative humidity in year 2011. Only negative significant correlation was found between mean daily temperature and pollen amount in 2010. Considering all these factors, to explain the changes by just using meteorological data that occurred between the 2 years is very difficult for Poaceae pollen. By the other way, only frequently applied follow technique can even cause the difference between years about amounts of grass pollen. Comparing pollen concentrations of 2 years in MPS periods for Cupressaceae, we could not find a statistically significant difference. It is thought that, although there are significant differences between 2 years in terms of meteorological factors, it is not reflecting to the pollen amounts together with weak correlation of Cupressaceae pollen as well as Chenopodiaceae/Amaranthaceae. Although there was not a significant difference in meteorological parameters between years in MPS period of *Fraxinus*, differences were found significant in pollen amounts of 2 years. The negative correlation between pollen concentrations and mean temperatures in 2011 and negative effect of mean daily relative humidity in 2010 may be responsible for this case. Parallel to this, an increase in *Morus* pollen concentrations in the MPS period of 2011 may be the result of significantly positive correlation ($P < 0.01$) for main daily relative humidity and pollen amounts (Table 2). Considering the increasing mean daily relative humidity in 2011, significantly negative correlation with mean daily relative humidity and significantly positive correlation with main daily wind speed may be the reasons for the increase in pollen concentration in MPS duration of *Populus* in year 2010. On the other hand, differences were found in significant in pollen concentrations of *Quercus* for MPS periods between years and increasing levels of mean daily rainfall in 2011 may be explanatory for the decrease in pollen concentrations (Table 2). Also a decrease in *Platanus* pollen concentration in 2011 is an expected result when correlation coefficients and differences between meteorological parameters were assessed together (Table 2). It can be thought that, according to correlation coefficients between pollen amounts of *Plantago* and meteorological parameters, significantly positive correlation with mean daily temperature and significantly negative correlation with mean daily relative humidity in the second year may have resulted with increasing pollen concentrations (Table 2).

The pollen spectrum obtained in Van city relates well to the local flora and vegetation of the area. East Anatolia generally has steppe formation; non-woody taxa are dominated in the region. In this aeropalynological survey, Poaceae pollen grains were the most dominant types, and considering the floral structure, this was the possible result. Also woody plants such as *Quercus* and *Fraxinus*, in which pollen grains found to be a dominant in the air, are mostly distributing around the slopes of Van Lake, and the other dominated pollen types such as Cupressaceae, *Populus, Platanus* and *Morus* are mostly planted ones in the city centre, especially in graveyards, parks and gardens.

In addition to all these, dominated pollen types that were recorded in Van were reported formerly as aeroallergens worldwide. In this survey, we recorded important allergenic pollen such as Poaceae (Bousquet et al. 1984; D’Amato and Spieksma 1992; D’Amato et al. 2007; Mandal et al. 2008), Cupressaceae (D'Amato and Liccardi 1994; D'Amato et al. 2007), *Fraxinus* (D'Amato and Spieksma 1990; Guerra et al. 1995; Hemmer et al. 2000), Chenopodiaceae/Amaranthaceae (Bousquet et al. 1984; Fang et al. 2001; Sanches-Mesa et al. 2005), *Populus* (Fang et al. 2001; Weber 2003; Calabria and Dice 2007), *Quercus* (Levétin and Buck 1980; Spieksma 1990; D'Amato et al. 1991), *Platanus* (Subiza et al. 1994; Varela et al. 1997; D'Amato et al. 2007), *Morus* (Chapman and Williams 1984; Benito Rica and Soto Torres 2001) and *Plantago* (Krilis et al. 1985; D'Amato and Lobefalo 1989). But above all, looking up to highly recorded pollen grains in Van city, from an allergenic point of view, the concentration levels have not been found high. This may be the result of low total pollen amount and frequently recorded pollen grains' peak counts mostly found under threshold concentrations for risk of pollinosis (Galán et al. 2007; González-Díaz et al. 2010; Piotrowska-Weryszko and Weryszko-Chmielewska 2014). Only Poaceae, *Fraxinus* and *Morus* pollen grains were found above these threshold values in the year 2011.

In conclusion, this study is the first aeropalynological study in such a high-elevation plain for Turkey, and when compared with pollen profile with entire country and Mediterranean basin, it has shown that especially predominated pollen types and their pollination periods were found quite different. Pollen grains of 35 taxa and their concentrations were determined during the pollen season in the atmosphere of Van, nine of which were defined as predominant types and formed 74.50 % of the API. In the region investigated, pollen grains were recorded during 9 months for both years in April–December period because of the heavy snow cower. Pollen grains reached their maximum concentration in April almost when the snow melted.

It is approved in this study that, in this kind of high elevational areas, vegetation pinched to a short growing season and pollination seasons of plants was postponed to a later date most likely due to geographical latitude, extreme meteorological factors, long snow cover duration, and physiological stress. This study showed that MPS starting dates of many taxa were recorded more than a month later from the western part of the country and particularly much later than Turkish and European cities, which coasted to Mediterranean Sea. In addition, determination of pollen types in the atmosphere, variations in pollen types set forth and the presented pollen calendar will be useful for local patients suffering from pollen allergies and/or visitors of the city for timing and may be useful for allergologists to establish an exact diagnosis.

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References

Abu-Dieyeh, M. H., & Ratrout, Y. S. (2012). Seasonal variation of airborne pollen grains in the atmosphere of Zarqa area, Jordan. *Aerobiologia, 28*, 527–539.

Altunoglu, M. K., Toraman, E., Temel, M., Bicakci, A., & Kargıoglu, M. (2010). Analysis of airborne pollen grains in Konya, Turkey, 2005. *Pakistan Journal of Botany, 42*(2), 765–774.

Andersen, T. B. (1991). A model to predict the beginning of the pollen season. *Grana, 30*, 269–275.

Beniston, M. & Fox, D. G. (1995). Impacts of climate change on mountain regions. In R. T. Watson, M. C. Zinyowera, & R. H. Moss (Eds.), *Climate change 1995: Impacts, adaptations and mitigation of climate change: Scientific-technical analyses*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. IPCC, 191–213.

Benito Rica, V., & Soto Torres, J. (2001). Pollinosis and pollen aerobiology in the atmosphere of Santander. *Allergología e Immunolología Clínica, 16*, 84–90.

Bilisik, A., Bicakci, A., Malyer, H., & Sapan, N. (2008). Analysis of airborne pollen concentrations in Fethiye-Mugla, Turkey. *Fresenius Environmental Bulletin, 17*(6), 640–646.

Bingham, R. A., & Orthner, A. R. (1998). Efficient pollination of alpine plants. *Nature, 391*, 238–239.

Bousquet, J., Cour, P., Guerin, B., & Michel, F. B. (1984). Allergy in the Mediterranean area: I. Pollen counts and pollinosis of Montpellier. *Clinical Allergy, 14*, 249–258.

Calabria, C. W., & Dice, J. (2007). Aeroallergen sensitization rates in military children with rhinitis symptoms. *Annals of Allergy Asthma Immunology, 99*, 161–169.

Celenk, S., & Bicakci, A. (2005). Aerobiological investigation in Bitlis, Turkey. *Annals of Agricultural and Environmental Medicine, 12*, 87–93.

Celenk, S., Bicakci, A., Tamay, Z., Guler, N., Altunoglu, M. K., Canitez, Y., et al. (2010). Airborne pollen in European and Asian parts of Istanbul. *Environmental Monitoring and Assessment, 164*, 391–402.

Ceter, T., Pinar, N. M., Güney, K., Yildiz, A., Aşçı, B., & Smith, M. (2012). A 2-year aeropalynological Survey of Allergenic Pollen in the Atmosphere of Kastamonu, Turkey. *Aerobiologia, 28*, 355–366.

Chapman, J. A., & Williams, S. (1984). Aeroallergens of the southeast Missouri area, A report of skin test frequencies and air sampling data. *Annals of Allergy, 52*, 411–417.
Charpin, J., Surinyach, R., & Frankland, A. W. (1974). *Atlas of European allergenic pollens*. Paris: Sandos Editions.
D'Amato, G., Cecchi, L., Bonini, S., Nunes, C., Annesi-Maesano, I., Behrendt, H., et al. (2007). Allergenic pollen and pollen allergy in Europe. *Allergy, 62*, 976–990.
D'Amato, G., & Liccardi, G. (1994). Pollen related allergy in the European Mediterranean area. *Clinical and Experimental Allergy, 24*, 210–219.
D'Amato, G., & Spieksma, F Th M. (1990). Allergenic pollen in Europe. *Grana, 30*, 67–70.
D'Amato, G., & Spieksma, F Th M. (1992). European allergenic pollen types. *Aerobiologia, 8*, 447–450.
D'amato, G., Spieksma, F. T. M., & Bonini, S. (1991). *Allergenic pollen and pollinosis in Europe*. Oxford: Blackwell Scientific Publications.
D'Amato, G., & Lobefalo, G. (1989). Allergenic pollens in the southern Mediterranean area. *Journal of Allergy and Clinical Immunology, 83*, 116–122.
Docampo, S., Recio, M., Trigo, M. M., Melgar, M., & Cabezudo, B. (2007). Risk of pollen allergy in Nerja (southern Spain): A pollen calendar. *Aerobiologia, 23*, 189–199.
Dupont, Y. L., Hansen, D. M., & Olesen, J. (2003). Structure of a plant-flower-visitor network in the high-altitude sub-alpine desert of Tenerife, Canary Islands. *Ecography, 26*, 301–310.
El Ghazaly, G., Yusef, H., Ahmed, M., & El-Ghazaly, P. K. (1991). Study of aerobiology of Alexandria, Egypt. *Qatar University Science Journal, 11*, 161–182.
Fabbro, T., & Körner, C. (2004). Altitudinal differences in flower traits and reproductive allocation. *Flora, 199*, 70–81.
Fang, R., Shuqing, X., & Fang, W. (2001). Pollen survey and clinical research in Yunnan, China. *Aerobiologia, 17*, 165–169.
Firat, M. (2002). *Bahçesaray (Van) çevresi florası*. Van: Yüzüncü Yıl Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi.
Frei, T. (1997). Pollen distribution at high elevation in Switzerland: Evidence for medium range transport. *Grana, 36*, 34–38.
Frenguelli, G., Spieksma, F. T. M., Bricchi, E., Romano, B., Mincigrucci, G., Nikkels, A. H., et al. (1991). The influence of air temperature on the starting dates of the pollen season of Alnus and Populus. *Grana, 30*(1), 196–200.
Galán, C., Cariñanos, P., Alcázar, P. & Dominguez-Vilches, E. (2007). *Spanish aerobiology network (REA) management and quality manual*. Servicio de Publicaciones Universidad de Córdoba. ISBN 978-84-690-6353-8.
Giner, M. M., Garcia, J. S. C., & Camacho, C. N. (2002). Seasonal fluctuations of the airborne pollen spectrum in Murcia (SE Spain). *Aerobiologia, 18*, 141–151.
Gioulekas, D., Balafoutis, C., Damialis, A., Papakosta, D., Gioulekas, G., & Patakas, D. (2004). Fifteen-year records of airborne allergenic pollen and meteorological parameters in Thessaloniki, Greece. *International Journal of Biometeorology, 48*, 128–136.
González-Díaz, S. N., Rodríguez-Ortiz, P. G., Arias-Cruz, A., Macías-Weinmann, A., Cid-Guerrero, D., & Sedo-Mejia, G. A. (2010). Atmospheric pollen count in Monterrey, Mexico. *Allergy and Asthma Proceedings, 31*(4), 341–348.
Gucel, S., Guvensen, A., Ozturk, M., & Celik, A. (2013). Analysis of airborne pollen fall in Nicosia (Cyprus). *Environmental Monitoring and Assessment, 185*, 157–169.
Guerra, F., Carmen, C. G., Daza, J. C., Miguel, R., Moreno, C., González, J., et al. (1995). Study of Sensitivity to the Pollen of Fraxinus spp. (Oleaceae) in Cordoba, Spain. *Journal of Investigational Allergology and Clinical Immunology, 5*(3), 166–170.
Hemmer, W., Focke, M., Wanke, F., Götz, M., Jarisch, R., & Jäger, S. (2000). Ash (Fraxinus excelsior)—pollen allergy in central Europe: Specific role of pollen panallergens and the major allergen of ash pollen, Fra e 1. *Allergy, 55*(10), 923–930.
Kalelioğlu, E. (1991). Van ovasının iklim özellikleri. *Ankara Üniversitesi Dil Tarih ve Coğrafya Fakültesi Dergisi, 35*(2), 155–166.
Kaplan, A. (2004). Airborne pollen grains in Zonguldak, Turkey, 2001-2002. *Acta Botanica Sinica, 46*(6), 668–674.
Karabacak, O., & Behçet, L. (2007). The Flora of Akçadağ (Van-Turkey). *Turkish Journal of Botany, 31*, 495–528.
Keynan, N., Waisel, Y., Shomer-Ilan, A., Goren, A., & Brener, S. (1991). Annual variations of airborne pollen in the Coastal Plain of Israel. *Grana, 30*, 477–480.
Kobzar, V. N. (1999). Aeropalynological monitoring in Bishkek, Kyrgyzstan. *Aerobiologia, 15*, 149–153.
Krilis, S., Baldo, B. A., & Basten, A. (1985). Detailed analysis of allergen specific IgE responses in 341 allergic patients. Associations between allergens and between allergen groups and clinical diagnoses. *Australian and New Zealand Journal of Medicine, 15*, 421–426.
Levétin, E., & Buck, P. (1980). Hay fever plants in Oklahoma. *Annals of Allergy, 45*, 26–32.
Mandal, J., Chakraborty, P., Roy, I., Chatterjee, S., & Gupta-Bhattacharya, S. (2008). Prevalence of allergenic pollen grains in the aerosol of the city of Calcutta, India: A two year study. *Aerobiologia, 24*, 151–164.
Papa, G., Romano, A., Quaratino, D., Di Fonso, M., Viola, M., Artesani, M. C., et al. (2001). Prevalence of sensitization to *Cupressus sempervirens*: a 4 year retrospective study. *The Science of the Total Environment, 270*, 83–87.
Peternel, R., Čulig, J., Mitić, B., Vukušić, I., & Šostar, Z. (2003). Analysis of airborne pollen concentrations in Zagreb, Croatia, 2002. *Annals of Agricultural and Environmental Medicine, 10*, 107–112.
Piotrowska-Weryszko, K., & Weryszko-Chmielewska, E. (2014). Plant pollen content in the air of Lublin (central-eastern Poland) and risk of pollen. *Annals of Agricultural and Environmental Medicine, 21*(4), 693–696.
Ribeiro, H., & Abreu, I. (2014). A 10-year survey of allergenic airborne pollen in the city of Porto (Portugal). 2014. *Aerobiologia, 30*, 333–344.
Rodríguez-Rajo, F. J., Dopazo, A., & Jato, V. (2004). Environmental factors affecting the start of pollen season and concentrations of airborne Alnus pollen in two localities of Galicia (NW Spain). *Annals of Agricultural and Environmental Medicine, 11*(1), 35–44.
Sánchez Mesa, J. A., Serrano, P., Carinanos, P., Prieto-Baena, J. C., Moreno, C., Guerra, F., et al. (2005). Pollen allergy in Cordoba city: Frequency of sensitization and relation with

antihistamine sales. *Journal of Investigational Allergology and Clinical Immunology, 15*, 50–56.

Sánchez Mesa, J. A., Smith, M., Emberlin, J., Allitt, U., Caulton, E., & Galán, C. (2003). Characteristics of grass pollen seasons in areas of southern Spain and the United Kingdom. *Aerobiologia, 19*, 243–250.

Satheeshkumar, S., & Vittal, B. P. R. (1998). A preliminary survey of airborne pollen in Madras City. *Aerobiologia, 14*, 69–73.

Šauliené, I., Šukiené, L., Severova, E., & Kalnina, L. (2014). Comparison of Alnus, Corylus, Betula pollen seasons in Riga, Moscow and Vilnius. *Aerobiologia, 30*, 423–433.

Spieksma, F Th M. (1990). Pollinosis in Europe: New observations and developments. *Review of Paleobotany and Palynology, 64*, 35–40.

Spieksma, F. T. M. (1991). Regional European pollen calendars. In G. D'Amato, F. T. M. Spieksma, & S. Bonini (Eds.), *Allergenic Pollen and Pollinosis in Europe* (pp. 49–65). Oxford: Blackwell Scientific Publications.

Subiza, J., Cabrera, M., Valdivieso, R., Subiza, J.-L., Jerez, M., Jiménez, J. A., et al. (1994). Seasonal asthma caused by airborne Platanus pollen. *Clinical and Experimental Allergy*, *24*, 1123–1129.

Tosunoglu, A., & Bicakci, A. (2015). Seasonal and intradiurnal variation of airborne pollen concentrations in Bodrum. SW Turkey. *Environmental Monitoring and Assessment*, *187*(4), 167.

Tosunoglu, A., Altunoglu, M. K., Bicakci, A., Kilic, O., Gonca, T., Yilmazer, I., et al. (2015a). Atmospheric pollen concentrations in Antalya, South Turkey. *Aerobiologia, 31*, 99–109.

Tosunoglu, A., Babayigit, S., & Bicakci, A. (2015b). Aeropalynological survey in Buyukorhan, Bursa. *Turkish Journal of Botany, 39*, 40–47.

Tosunoglu, A., Bicakci, A., Malyer, H., & Sapan, N. (2009). Airborne Pollen Fall in Koycegiz Specially Protected Area (SW Turkey). *Fresenius Environmental Bulletin, 18*(10), 1860–1865.

Tosunoglu, A., Yenigün, A., Bicakci, A., & Eliacik, K. (2013). Airborne pollen content of Kusadasi. *Turkish Journal of Botany, 37*, 297–305.

Varela, S., Subiza, J., Subiza, J. L., Rodríguez, R., García, B., Jerez, M., et al. (1997). Platanus pollen as an important cause of pollinosis. *Journal of Allergy and Clinical Immunology, 100*, 748–754.

Wallace, D. V., Dykewicz, M. S., Bernstein, D. I., Joann Blessing-Moore, M. D., Linda Cox, M. D., David, A., et al. (2008). The diagnosis and management of rhinitis: An updated practice parameters. *Journal of Allergy and Clinical Immunology, 122*, 1–84.

Weber, R. W. (2003). Cottonwoods. *Annals of Allergy, Asthma and Immunology, 91*(2), A6.