Pollen counts and their relationship to meteorological factors in Ankara, Turkey during 2005–2008

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Abstract Pollen plays an important role in the development and exacerbation of allergic diseases. We aimed to investigate the days with highest counts of the most allergenic pollens and to identify the meteorological factors affecting pollen counts in the atmosphere of Ankara, Turkey. Airborne pollen measurements were carried out from 2005 to 2008 with a Burkard volumetric 7-day spore trap. Microscope counts were converted into atmospheric concentrations and expressed as pollen grains/m^3. Meteorological parameters were obtained from the State Meteorological Service. All statistical analyses were done with pollen counts obtained from March to October for each year. The percentages of tree, grass and weed pollens were 72.1% (n=24,923), 12.8% (n=4,433) and 15.1% (n= 5,219), respectively. The *Pinaceae* family from tree taxa (39% to 57%) and the *Chenopodiaceae/Amaranthaceae* family from weed taxa, contributed the highest percentage of pollen (25% to 43%), while from the grass taxa, only the *Poaceae* family was detected from 2005 to 2008. *Poaceae* and *Chenopodiaceae/Amaranthaceae* families, which are the most allergenic pollens, were found in high numbers from May to August in Ankara. In multiple logistic regression analysis, wind speed (OR=1.18, CI95%=1.02–1.36, P=0.023) for tree pollen, daily mean temperature (OR=1.10, CI95%=1.04–1.17, P=0.001) and sunshine hours (OR=1.15, CI95%=1.01–1.30, P=0.033) for grass pollen, and sunshine hours (OR= 3.79, CI95%=1.03–13.92, P=0.044) for weed pollen were found as significant risk factors for high pollen count. The pollen calendar and its association with meteorological factors depend mainly on daily temperature, sunshine hours and wind speed, which may help draw the attention of physicians and allergic patients to days with high pollen counts.

Keywords Allergy · Grass · Meteorology · Pollen · Tree · Weed

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Introduction

Aerobiology is the science dealing with the biological particles carried passively by airflow in the atmosphere.

Biological particles in the atmosphere are constituted by the pollen of plants that are pollinated by the wind, as well as viruses, bacteria, fungal spores, algae, ferns, fungal hyphea and other plant particles. These biological particles, especially pollen, can cause allergic symptoms. The pollen count is affected by meteorological factors like temperature, sunshine hours (daily sunshine duration), relative humidity, rainfall and wind (Ballero and Maxia 2003; Cariñanos et al. 2003; Gioulekas et al. 2004; Damialis et al. 2005; Estrella et al. 2006; Palacios et al. 2007). There are many studies reported in the literature dealing with the relationship between the pollen concentrations and distribution and meteorological factors (Riberio et al. 2003; Stennett and Beggs 2004; Alwadie 2008; Sahney and Chaurasia 2008).

Pollen plays an important role in the development of allergic diseases and in the exacerbation of allergic reactions. Allergic exacerbations caused by pollen exposure increase the social and economic burden of allergic diseases (Beggs 2004; Beggs and Bambrick 2005). Enhancement of protective measures against pollens may decrease the disease burden during periods when the pollen concentration rises. In order to develop such protective measures, it is necessary to study the effects of meteorological factors on the pollen counts.

The aims of this study were to investigate the days with high counts of the most allergenic pollens and to determine the meteorological factors affecting pollen counts as well as the types of pollen species found in the atmosphere of Ankara, Turkey.

Materials and methods

Sampling location

Ankara is the capital city of Turkey with a population of four and a half million people. It is located at 39° 55′ North, 32° 5′ East and situated in the Northwest of Central Anatolia at an altitude of 820 m above sea level (Inceoglu et al. 1994). The city has typical Irano-Turanien elements that are characterized by a continental type of climate with very cold winters and hot summers (Davis 1965).

Air sampling

Airborne pollen measurements were carried out in Ankara, during the pollen season from January to December of each year from 2005 to 2008 with a Burkard volumetric 7-day spore trap. The trap was placed on the roof of the Hacettepe Children's Hospital, 23 m above ground level.

A Burkard spore trap was used for 7 day sampling onto Melinex tape coated with a thin film of Lubriseal (Thomas Scientific, Swedesboro, NJ). Tapes were changed weekly,

cut into 48 mm segments, and mounted on microscope slides. Slides were colored with glycerin jelly containing basic fuchsine and examined microscopically at 400x magnification using a single longitudinal traverse lens. Microscope counts were converted into atmospheric concentrations and expressed as pollen grains/m^3.

The pollens were identified from pollen atlases, reference books and the pollen collection of the local flora (Wodehouse 1935; Aytuğ et al. 1971; Moore and Webb 1983; Pehlivan 1995; Erik and Dogan 2002).

Pollen types and counts

Acer L., *Aesculus* L., *Ailanthus* Desf., *Alnus* Mill., Betulaceae, *Berberis* L., *Catalpa* Waltz, *Carpinus* L., *Crateagus* L., Cupressaceae/Taxaceae, Fabaceae, *Fagus* L., *Fraxinus* L., Juglandaceae, *Morus* L., Oleaceae, Pinaceae, *Platanus* L., *Populus* L., *Quercus* L., *Rosaceae*, *Salix* L., *Tilia* L. and *Ulmus* L. pollens in the atmosphere were classified in the tree taxa. Pollens belonging to Poaceae family were included in the grasses. Apiaceae, Asteraceae, Brassicaceae, Boraginaceae, Campanulaceae, *Carex* L., Caryophyllaceae, Chenopodiaceae/Amaranthaceae, Cistaceae, Ericaceae, *Globularia* L., Lamiaceae, Liliaceae, *Lonicera* L., *Luzula* DC., Onagraceae, *Plantago* L., Polygonaceae, *Rubiaceae*, *Rumex* L., *Sambucus* L., *Sanguisorba* L., Scrophulariaceae, *Taraxacum* F.H.Wigg., *Typha* L. and Urticaceae were classified in the weed taxa.

Since pollen was mostly absent from November to February, the pollen calendar was designed between March and October from 2005 to 2008. Total counts of tree, grass and weed pollens per day and per month were determined and grouped according to the American Academy of Allergy, Asthma and Immunology classification (Portnoy et al. 2004). In this classification, tree pollens were grouped as low (1–14), moderate (15–89), high (90–1,500) and very high (>1,500), grass pollens were grouped as low (1–4), moderate (5–19), high (20–200) and very high (>200), weed pollens were grouped as low (1–9), moderate (10–49), high (50–500) and very high (>500).

Meteorological data

Among the meteorological parameters, daily mean temperature, sunshine hours, mean relative humidity, mean wind speed and rainfall were all obtained from the Republic of Turkey Ministry of Environment and Forestry, State Meteorological Service.

Statistics

Statistical analyses were done with SPSS 15 for Windows (Chicago, IL). All data including pollen counts and

meteorological factors such as daily temperature, sunshine hours, relative humidity, wind speed and rainfall are given as mean and standard error of the mean. All statistical comparisons were done using the "one way ANOVA" test. For all analyses, values of $P < 0.05$ were considered significant. Spearman correlation analysis was performed to analyze the relationship between the daily meteorological parameters and daily counts of pollens. Logistic regression analysis was performed to analyze the effect of meteorological risk factors on high and very high counts of pollen for trees, grass and weeds.

Results

Pollen counts from 2005 to 2008

The 7-day trap experiment conducted in Ankara counted a total of 34,575 pollen grains (Table 1). In the 4-year period investigated, the total number and percentages of pollens for trees, grasses and weeds entrapped were 72.1% ($n=24,923$), 12.8% ($n=4,433$) and 15.1% ($n=5,219$), respectively.

The counts of tree, grass and weed pollen showed a significant difference from 2005 to 2008 (Table 1).

Classification of pollen counts of 23 trees, 1 grass and 29 weeds taxa is shown in Fig. 1. The Pinaceae family from the tree taxa, had the highest percentage of pollens 57%, 53%, 39%, 39% in 2005, 2006, 2007 and 2008; from the grasses, only the Poaceae family was detected in Ankara; and finally the Chenopodiaceae/Amaranthaceae family

from weed taxa showed the highest percentage of pollens as 43.4%, 25.4% and 28.5% from 2006 to 2008.

Meteorological parameters from 2005 to 2008

The daily mean temperature, mean relative humidity, mean wind speed, mean sunshine and mean rainfall showed significant differences from 2005 to 2008 (Table 1).

Association of meteorological parameters with pollens

The maximum counts of tree pollen were detected in May 2005 (Pinaceae 48.8%), April 2006 (*Populus* 22.8%), May 2007 (Pinaceae 29.5%) and June 2008 (Pinaceae 26.2%), when the mean temperature was 16.6, 13.1, 20.4 and 22.0°C, respectively (Fig. 2).

The maximum count of grasses was detected in July 2005, June 2006, June 2007 and June 2008, when the mean temperature was 25.0, 21.6, 20.4 and 22.0°C, respectively (Fig. 2).

The maximum count of weed pollens was always detected in August, when the mean temperature was 25.4–27.2°C from 2005 to 2008 (Fig. 2).

The correlation analysis of daily pollen counts and meteorological parameters showed that tree, grass and weed pollen counts were significantly correlated with mean temperature ($r=0.155$, $P<0.001$; $r=0.278$, $P<0.001$; $r=0.319$, $P<0.001$) and sunshine hours ($r=0.140$, $P<0.001$, $r=0.250$, $P<0.001$; $r=0.212$, $P<0.001$), respectively (Fig. 3). The wind speed showed a positive correlation with grass ($r=0.174$, $P<0.001$) and weed pollens ($r =$

Table 1 Pollen counts (mean ± standard error of the mean) and meteorological parameters between 2005 and 2008

	2005	2006	2007	2008	F	P*
Total pollen counts	56.51±5.27 [a,c]	25.77±2.53 [a,d]	49.15±7.16 [d,f]	19.50±1.63 [c,f]	13.45	<0.001
Tree	35.15±4.61 [c]	21.68±2.29	38.22±6.74 [f]	14.98±1.45 [c,f]	6.15	<0.001
Grass	16.08±1.03 [a,b,c]	1.97±0.29 [a,d]	5.12±0.57 [b,d,f]	1.53±1.17 [c,f]	37.78	<0.001
Weed	11.28±1.12 [a,b,c]	2.13±0.23 [a,d]	5.80±0.59 [b,d,f]	2.99±0.26 [c,f]	35.23	<0.001
Temperature, °C	16.7±0.5 [b]	18.1±0.5	18.7±0.5 [b]	18.3±0.4	2.87	<0.001
Humidity, %	58.1±0.7 [a,b,c]	54.1±0.8 [a,d,e]	42.8±1 [b,d,f]	58.0±1.5 [c,e,f]	55.07	<0.001
Wind speed, m/sec	2.3±0.1 [b]	2.3±0.1 [d]	4.7±0.1 [b,d,f]	2.0±0.1 [f]	254.67	<0.001
Sunshine hours, hour	8.7±0.2 [c]	9.4±0.3 [d,e]	8.2±0.2 [d,f]	7.1±0.3 [c,e,f]	14.87	<0.001
Rainfall, mm	1.4±0.3 [b]	0.7±0.2 [e]	0.6±0.1 [b,f]	2.2±0.4 [e,f]	6.96	<0.001

* Comparison of four groups by one way ANOVA

[a] Significant P value when 2005 and 2006 data are compared

[b] Significant P value when 2005 and 2007 data are compared

[c] Significant P value when 2005 and 2008 data are compared

[d] Significant P value when 2006 and 2007 data are compared

[e] Significant P value when 2006 and 2008 data are compared

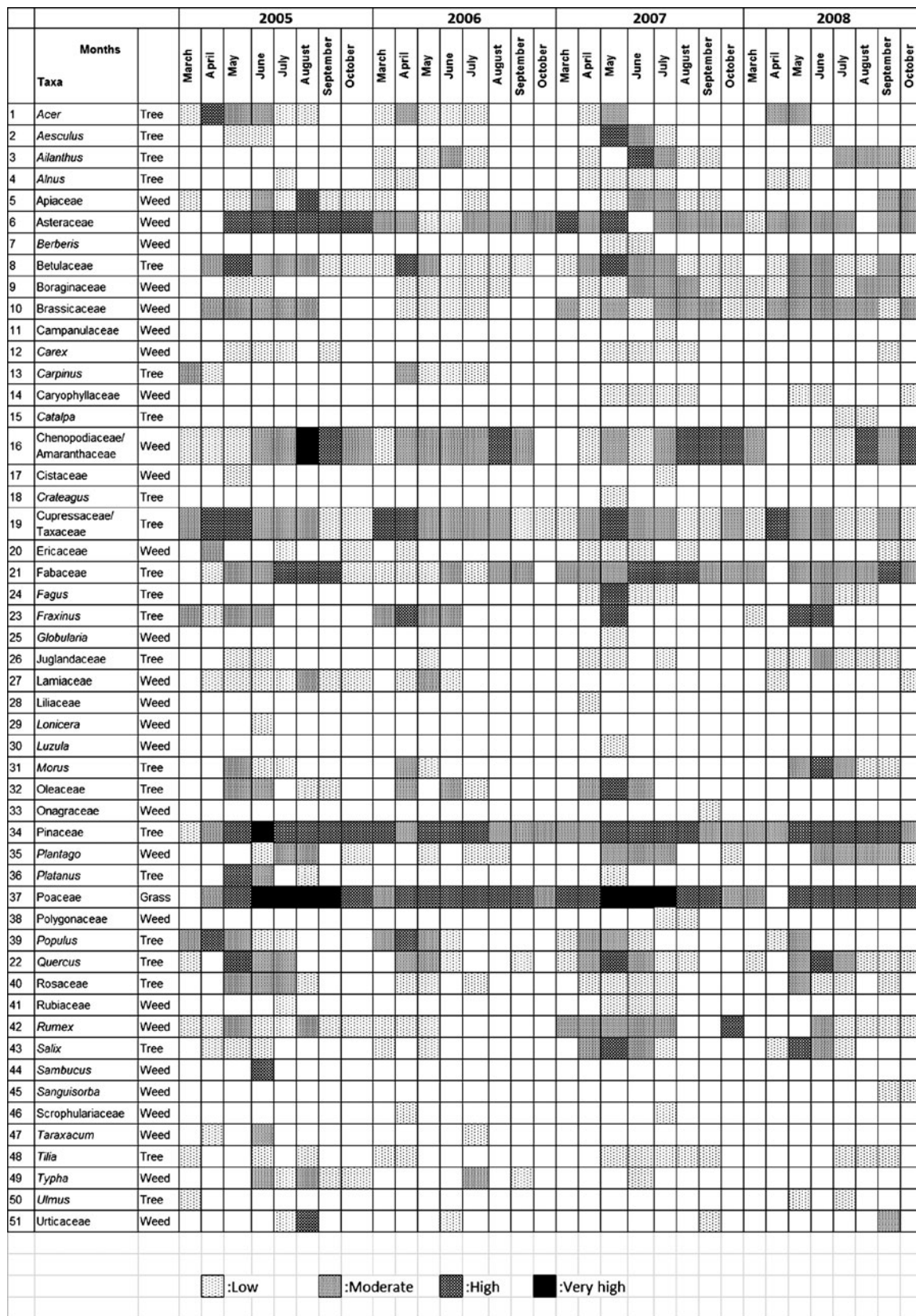[f] Significant P value when 2007 and 2008 data are compared

			2005								2006								2007								2008							
	Months Taxa		March	April	May	June	July	August	September	October	March	April	May	June	July	August	September	October	March	April	May	June	July	August	September	October	March	April	May	June	July	August	September	October
1	*Acer*	Tree																																
2	*Aesculus*	Tree																																
3	*Ailanthus*	Tree																																
4	*Alnus*	Tree																																
5	Apiaceae	Weed																																
6	Asteraceae	Weed																																
7	*Berberis*	Weed																																
8	Betulaceae	Tree																																
9	Boraginaceae	Weed																																
10	Brassicaceae	Weed																																
11	Campanulaceae	Weed																																
12	*Carex*	Weed																																
13	*Carpinus*	Tree																																
14	Caryophyllaceae	Weed																																
15	*Catalpa*	Tree																																
16	Chenopodiaceae/ Amaranthaceae	Weed																																
17	Cistaceae	Weed																																
18	*Crateagus*	Tree																																
19	Cupressaceae/ Taxaceae	Tree																																
20	Ericaceae	Weed																																
21	Fabaceae	Tree																																
24	*Fagus*	Tree																																
23	*Fraxinus*	Tree																																
25	*Globularia*	Weed																																
26	Juglandaceae	Tree																																
27	Lamiaceae	Weed																																
28	Liliaceae	Weed																																
29	*Lonicera*	Weed																																
30	*Luzula*	Weed																																
31	*Morus*	Tree																																
32	Oleaceae	Tree																																
33	Onagraceae	Weed																																
34	Pinaceae	Tree																																
35	*Plantago*	Weed																																
36	*Platanus*	Tree																																
37	Poaceae	Grass																																
38	Polygonaceae	Weed																																
39	*Populus*	Tree																																
22	*Quercus*	Tree																																
40	Rosaceae	Tree																																
41	Rubiaceae	Weed																																
42	*Rumex*	Weed																																
43	*Salix*	Tree																																
44	*Sambucus*	Weed																																
45	*Sanguisorba*	Weed																																
46	Scrophulariaceae	Weed																																
47	*Taraxacum*	Weed																																
48	*Tilia*	Tree																																
49	*Typha*	Weed																																
50	*Ulmus*	Tree																																
51	Urticaceae	Weed																																

:Low   :Moderate   :High   :Very high
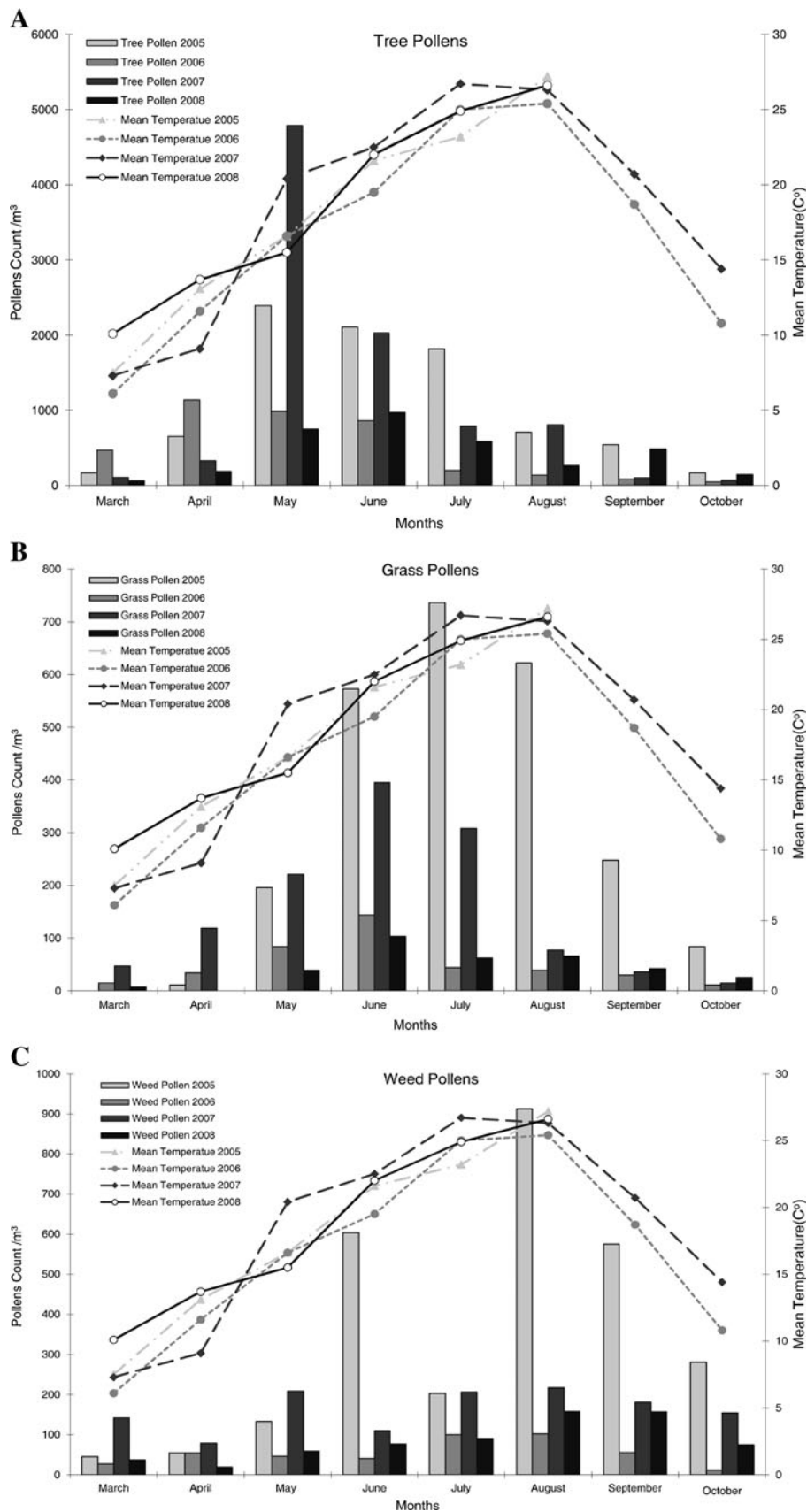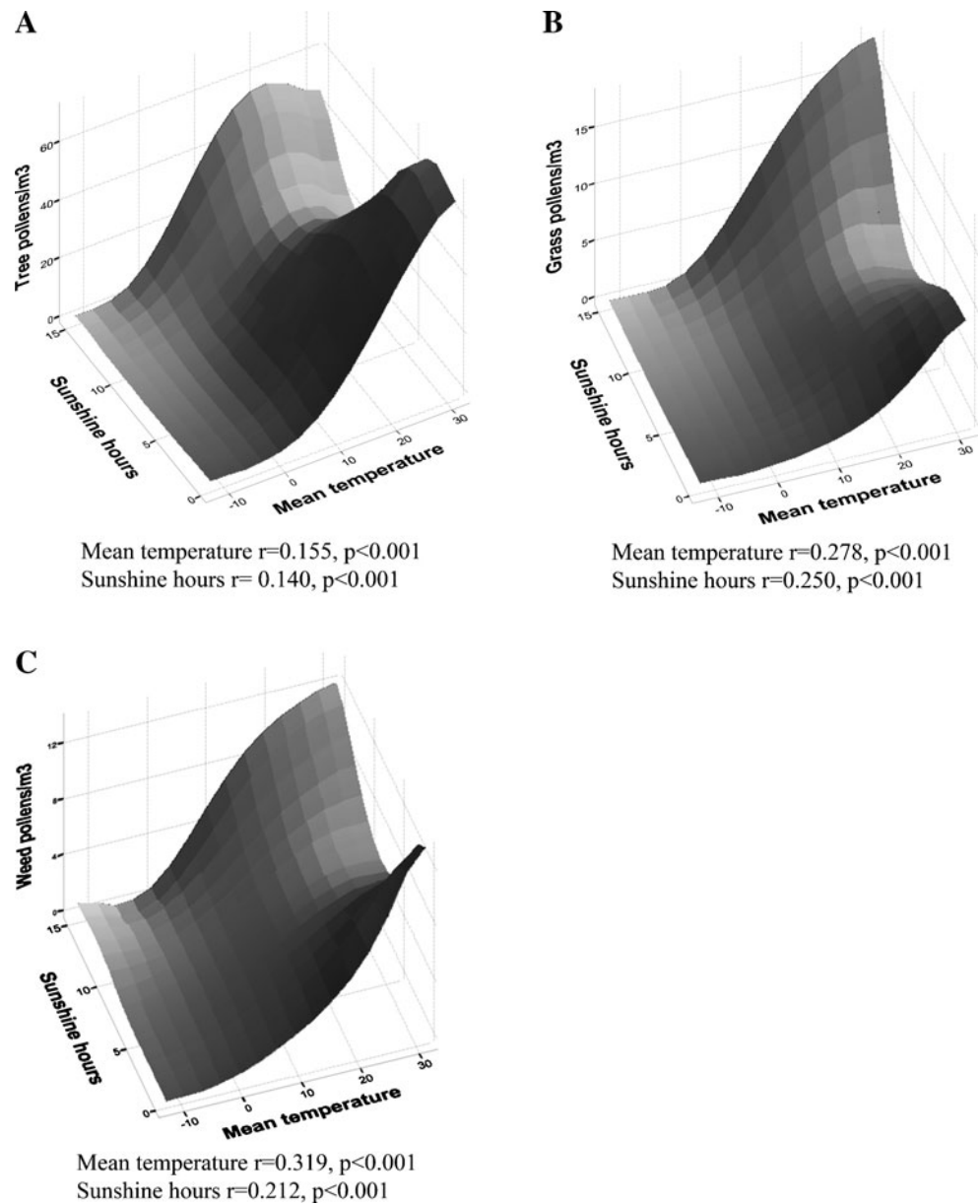
Fig. 1 Pollen counts of tree, grass and weed, 2005–2008

Fig. 2 Relationship of pollen counts of tree (**a**), grass (**b**) and weed (**c**) with daily mean temperature

Fig. 3 Correlation of tree (**a**),
grass (**b**) and weed (**c**) pollen
counts with daily temperature
and sunshine hours

Mean temperature r=0.155, p<0.001
Sunshine hours r= 0.140, p<0.001

Mean temperature r=0.278, p<0.001
Sunshine hours r=0.250, p<0.001

Mean temperature r=0.319, p<0.001
Sunshine hours r=0.212, p<0.001

0.148, $P<0.001$). A negative correlation was observed with relative humidity for tree pollens ($r=-0.083$, $P=0.012$), with relative humidity ($r=-0.117$, $P<0.001$) and rainfall ($r=-0.114$, $P=0.001$) for grass pollens and finally with relative humidity ($r=-0.154$, $P<0.001$) and rainfall ($r=-0.121$, $P=0.001$) for weed pollens.

Multiple logistic regression analysis showed that the wind speed [odds ratio (OR)=1.18, confidence interval (CI) 95%=1.02–1.36, $P=0.023$] for tree pollens daily mean temperature (OR=1.10, CI95%=1.04–1.17, $P=0.001$) and sunshine hours (OR=1.15, CI95%=1.01–1.30, $P=0.033$) for grass pollen, and sunshine hours (OR=3.79, CI95%=

1.03–13.92, $P=0.044$) for weed pollen, were the significant risk factors for high pollen count (Table 2).

Discussion

This study examined pollen found in the atmosphere of Ankara, Turkey, in the period 2005–2008. From a total of 53 taxa identified, 23 were trees, 1 was grass and 29 were weeds. Pollen counts of these taxa differed from year to year depending on meteorological factors, and the total pollen counts of tree, grass and weed taxa showed a large

Table 2 Risk factors for high and very high levels of pollen of trees, grass and weeds

	Univariate			Multivariate		
	OR	95%CI	P	OR	95%CI	P
Tree						
Temperature	1.028	0.992-1.066	0.129			
Humidity	0.986	0.969-1.004	0.129			
Wind speed	1.182	1.023-1.366	0.023	1.18	1.02-1.36	0.023
Sunshine hours	1.017	0.949-1.089	0.637			
Rainfall	1.028	0.967-1.094	0.372			
Grass						
Temperature	1.131	1.077-1.189	<0.001	1.10	1.04-1.17	0.001
Humidity	0.991	0.972-1.010	0.338			
Wind speed	1.097	0.929-1.294	0.276			
Sunshine hours	1.301	1.153-1.467	<0.001	1.15	1.01-1.30	0.033
Rainfall	0.792	0.610-1.029	0.081			
Weed						
Temperature	1.084	0.993-1.184	0.072			
Humidity	1.011	0.974-1.049	0.559			
Wind speed	0.819	0.527-1.273	0.375			
Sunshine hours	1.200	0.976-1.474	0.083	3.79	1.03-13.92	0.044
Rainfall	0.595	0.195-1.814	0.361			

variation in different years. Weeks with high and very high pollen counts were within the same periods during the 4 years of the study. High and very high counts of tree and grass pollen were detected in spring and summer; for weeds late summer and fall were the periods with high and very high number of pollen. Pollen counts and distribution in the atmosphere are affected by geographic location, vegetation and other environmental conditions (Arobba et al. 2000; Alwadie 2008). Within each group of taxa, the mean temperature and sunshine hours were significantly correlated with the increase in tree, grass and weed pollen. Moreover, wind speed for tree, temperature and sunshine hours for grass, and sunshine hours for weed pollens were significant risk factors for increased pollen counts.

A significant percentage of pollen in the Ankara atmosphere came from trees. The reason for this is both the natural distribution of many pollen flowering trees in the hills and mountains of the surrounding rural area, and plantation of these trees in parks, gardens and refuges. The dominance of tree pollen in the atmosphere of the cities has also been noted by other studies (Inceoglu et al. 1994; Guvensen 2006; Al-Qura'n 2008; Sahney and Chaurasia 2008).

Meteorological factors affect growing and flowering of plants, along with the amount, distribution and carriage of pollen in the atmosphere. Among these factors, daily temperature has an effect on the vegetative growth, formation and maturation of the organs and fertility of plants (Thuzar et al. 2010). In addition, daily temperature acts on the formation of pollen grains, and the opening of the anthers regulates the presence of bioparticles suspended in the air both numerically and heterogeneously. In our study, we showed a positive correlation between the daily temperature and tree, grass and weed total pollen grain counts. Several studies have found a positive correlation between pollen grain counts and daily temperature (Riberio et al. 2003; Gioulekas et al. 2004; Alwadie 2008). In addition, a study from Italy has reported that a 1°C increase (decrease) in surface daily temperature caused a 1-week earlier (later) start of the pollination season for olive trees (Avolio et al. 2008). A correlation between the start of the pollination season for *Cryptomeria japonica* (L.) D. Don and average daily temperature was found in Japan (Teranishi et al. 2006). In another study, a positive correlation between Ericaceae pollens and daily temperature was found throughout the entire year in Northwest Spain, when limited to months with maximum pollen counts, in which a positive correlation was found with daily temperature and Southwest wind (Rodríguez-Rajo et al. 2005).

Photoperiod is defined as the period of sunshine hours necessary for flowering. Thus, daily and total sunshine hours are correlated directly with the photoperiod (Vázquez et al. 2003). In the present study, we found a positive correlation between sunshine hours and tree, grass and weed pollen counts due to the increased incidence of plant flowering.

Pollen grains are highly hygrophilous cells and they hydrate in the presence of a high percentage of relative

humidity in the air, thus gaining weight and falling to the ground by gravity. In this way, pollen counts in the atmosphere decrease (Ballero and Maxia 2003; Sahney and Chaurasia 2008). Moreover, high humidity inhibits anther opening and also makes the pollen heavier, preventing the pollen grains from remaining suspended in the air (Sahney and Chaurasia 2008). In several studies, including ours, humidity and rainfall exerted a negative influence on tree, grass and weed pollen counts (Stach 2000; Puc and Puc 2004; Alwadie 2008; Sahney and Chaurasia 2008).

The wind plays an important role in bioparticle distribution. Wind speeds of over 10 km/h for most of the year cause pollen grains from plants to spread in the atmosphere. Moreover, the wind lifts non-vital pollen grains that are dehydrated and partially damaged from the ground and distributes these to different layers of the atmosphere (Ballero and Maxia 2003). In our study, we found a positive correlation with grass and weed pollen counts. A study by Puc and Puc (2004) found a positive correlation between Poaceae pollens and wind speed. In another study from Thessaloniki, Greece, the effect of wind direction, speed and duration on the distribution of pollen belonging to different plant taxa was investigated for a period of 4 years. The results showed that, in every taxa, pollen counts were correlated with at least one of the aforementioned three components of the wind (Damialis et al. 2005).

Precipitation causes the so-called "rain washing" phenomenon (Sahney and Chaurasia 2008), and reduces the air pollen concentration both by passively dragging the particles to the ground and by hydrating them and consequently increasing their weight and depositing them on the ground by means of gravity. Our results determined a negative correlation between rainfall and daily tree, grass and weed total counts. A negative correlation between rainfall and pollen count has been found in a number of studies (Rodríguez-Rajo et al. 2003; Sahney and Chaurasia 2008).

The allergy potential of pollen plays an important role in the severity of allergy symptoms such as "asthma and allergic rhinitis exacerbations" in patients who are sensitive to pollen. The pollen families with high allergenicity found in Turkey are Poaceae, Chenopodiaceae, Astraceae, Oleaceae, Cupressaceae and Betulaceae. The Poaceae and Chenopodiaceae/Amaranthaceae families, which comprise the highest percentage of grass and weed taxa, have the highest capacity to induce an allergic immune response in individuals with allergic diseases (D'Amato et al. 2007; Metz-Favre et al. 2007; Gálan et al. 1989; Barderas et al. 2007). The months with maximum counts of pollen of the Poaceae and Chenopodiaceae/Amaranthaceae family, i.e., May, June, July and August, are the periods when pollen allergic patients must take precautions. In other words, the months with the longest sunshine hours and highest mean temperature are the periods when most allergenic pollens reached maximum levels in the atmosphere. Patients with suspected pollen allergy living in Ankara and central Anatolia should be analyzed with a panel of allergens including pollens with high allergenicity and/or high/very high number including Poaceae, Chenopodiaceae/Amaranthaceae, Asteraceae, Cupressaceae, *Quercus*, *Fraxinus*, *Fagus*, Oleaceae, *Platanus*, Poaceae, *Populus*, *Salix* (Dursun et al. 2008; Gioulekas et al. 2004).

In this study, it was shown that meteorological parameters have a significant, mild-to-moderate influence on the occurrence and distribution of pollen grains in the atmosphere. In addition, this study gives an indication of the airborne pollen types present in the atmosphere in Ankara and provides also an indication of their main flowering seasons. Pollens are important because they affect human health. It is known that pollens trigger allergic respiratory diseases such as asthma and hay fever. The pollen calendar and the association with meteorological factors may be useful to physicians in helping to diagnose and treat allergic patients, and advise precautions.

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