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Concentrations of airborne pollen grains in Sivrihisar (Eskisehir), Turkey

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Abstract Pollen grains in the atmosphere of Sivrihisar were studied for a continuous period of 2 years (1 January 2005–31 December 2006) using a Durham sampler. During this period, pollen grains belonging to 41 taxa were recorded, 24 of which belonged to arboreal plants and 17 to non-arboreal. From these, 23,219 were identified in 2005 and 34,154 in 2006. Of the total pollen grains, 90,46% were arboreal, 9,43% non-arboreal, and 0,1% unidentifiable. The majority of the investigated allergic pollen grains were from Pinaceae, Cupressaceae, *Fraxinus* spp., *Cedrus* spp., *Artemisia* spp., Poaceae, Chenopodiaceae/Amaranthaceae, *Populus* spp., *Quercus* spp., Urticaceae and Asteraceae, respectively. Pollen concentrations reached their highest levels in May. This information was then established into a calendar form according to the pollens determined in 2005–2006, in terms of annual, monthly and weekly numbers of taxa fall per cm^2. A comparison between the results and the meteorological factors revealed a close relationship between pollen concentrations in the air and meteorological conditions. An increase in pollination was also linked to increasing temperatures and the wind. It was therefore concluded that high temperatures and relative humidity were also effective in increasing the number of pollens in the air.

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Introduction

During the last decade clear evidence has emerged that there has been an increase in the incidence of pollen allergy in most European countries and that this trend is particularly noticeable in urban areas (D'Amato and Spieksma 1990). Pollen is the most important aeroallergen throughout Europe, although its relative contribution to pollinosis varies regionally in relation to local vegetation type, agriculture and climate (Nilsson and Palmberg-Gothard 1982; Lejoly-Gabriel and Leuschner 1983; Bousquet et al. 1984; Koivikko et al. 1986; Spieksma et al. 1989; D'Amato and Spieksma 1990; Banik and Chanda 1992; Mullins and Emberlin 1997; Molina et al. 2001). In Turkey, studies regarding airborne pollen grains are gradually gaining more importance (Aytug 1974; Inceoglu et al. 1994; Bicakci et al. 1996, 2000, 2002; Güvensen and Öztürk 2002; Kaplan 2004; Türe and Salkurt 2005; Potoglu Erkara et al. 2007).

Some pollen grains are known to cause allergic ailments in humans, including allergic asthma and hayfever. These diseases appear particularly during the flowering periods of plants. Determination of the type and concentration of pollen grains will be benefical for patients suffering from allergic diseases (D'Amato et al. 1998; D'Amato and Liccardi 2003).

For this reason, the evaluation of airborne pollen grains has gained momentum worldwide over the past few years with various studies being conducted to determine their dispersal (Charpin et al. 1974; Mandrioli et al. 1982; Chapman 1986; Nardi et al. 1986; Spieksma et al. 1989, 1991; Ribeiro et al. 2003).

The purpose of this study was to identify pollen grains in Sivrihisar, their percentage values, pollen season periods and pollen concentrations.

Materials and methods

Sivrihisar (Eskisehir) is situated at 39°27′ N, 31°32′ E Northwest of Turkey (Fig. 1) at an altitude 1,070 m. Sivrihisar has a Mediterranean, Irano-Turanion vegetation, and generally follows a typical Mediterranean climate. According to Emberger's (1952) bioclimate essentials, the study area is under the influence of a low-precipitation Mediterranean bioclimate level (Akman 1982). The annual average rainfall for the period 1963–2006 was 33.1 mm. and the average temperature for the same period was 10.9°C. The warmest month during this period was July with an average temperature of 21.8°C. The annual average humidity during this period was 60.4%. The predominant wind directions at the sampling site were south-southwesterly (Anonymous 2006). The station has rich flora; with Pinaceae, Asteraceae, Fabaceae, Brassicaceae, Lamiaceae, Boraginaceae, Poaceae and Rosaceae families being very common. It's Latitude is 39°26′42″ N and Longitude: 31°32′36.8″ E, with an Altitude of: 1,071 m. Distances between the research station and a meteorological station were measured with a GARMIN GPS 12 CX device (Global Positioning System; Made in Taiwan, under USA patent). This device was also used to measure the altitude of the research station.

In addition to the natural vegetation, some species (i.e. *P. nigra*, *Cedrus libani*, *Acer* spp., *Morus* spp.,

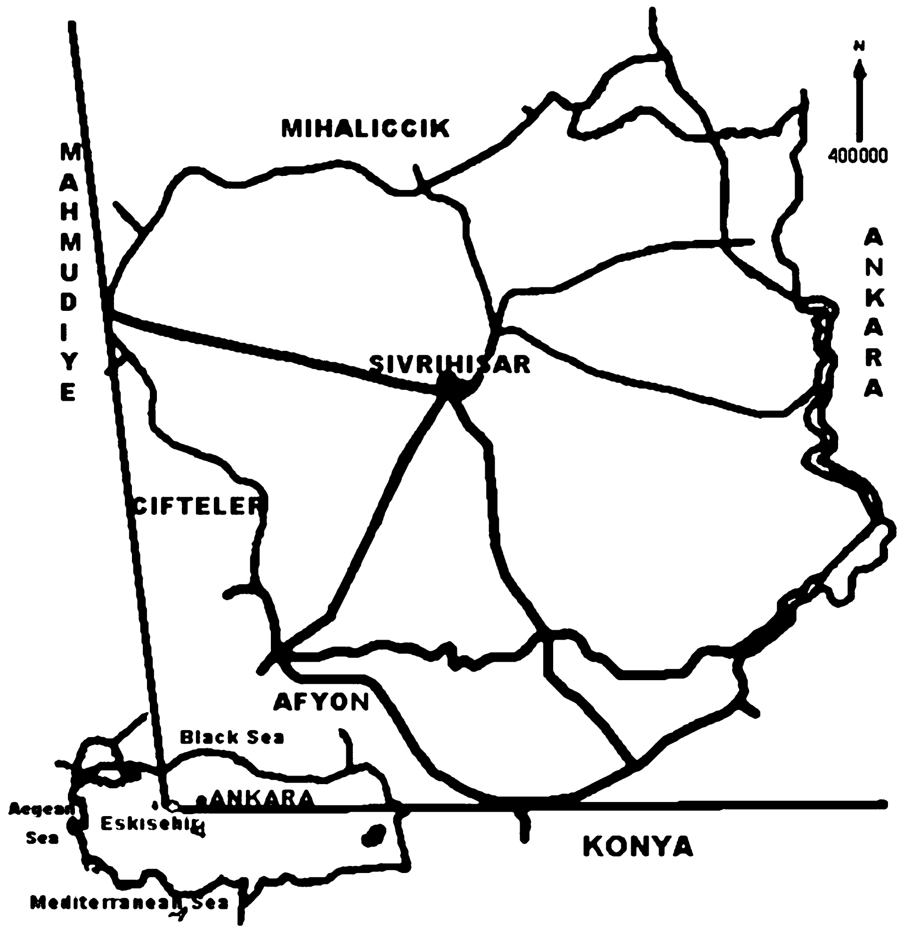


Fig. 1 A map of Sivrihisar city (Eskisehir, Turkey) showing the province of Sivrihisar

Tilia spp., *Alnus* spp., *Corylus* spp., *Fraxinus* spp., *Populus* spp., *Salix* spp., *Juglans* spp., and *Ulmus* spp.) can be seen frequently in the parks, gardens, and streets of Sivrihisar. Upon examination of the flora of Sivrihisar, it can be seen that plant taxa belonging to Asteraceae, Fabaceae, Lamiaceae, Poaceae, and Brassiceae are dominant (Türe 2002).

In the present study, gravimetric methods and a Durham sampler were used (Anderson 1985; Hansen and Wright 1987). The Durham sampler was placed at a height of 1.75 m above ground level in the garden of the Meteorology Station. The station is located in the center of Sivrihisar (Fig. 1). The position of the sampler allows air movement from all sides. Before exposure, slides were covered with glycerine jelly mixed with basic fuchsin (Charpin et al. 1974; Paiva and Teresa 1989). The number of pollen grains is expressed as grains per cm^2 of microscope cover glass (22 mm×22 mm). The grains were identified and counted under a light microscope, with identification at species, genus or family level. The grains that could not be identified were considered as unidentified types. Slides placed on the Durham sampler were changed weekly.

Results

During the 2 year period, a total of 57,373 pollen grains belonging to 41 taxa were identified and recorded in Sivrihisar's environment, 24 of which belonged to arboreal plants and 17 to non-arboreal. From these, 23,219 were identified in 2005 and 34,154 in 2006. In more specific terms, the breakdown occured thus: 51,902 pollen grains were found to be arboreal (90,46%), 5412 were non-arboreal (9,43%) and 59 unidentifiable (0,1%; Table 1). Arboreal pollen types were found to be dominant due to the vegetation and geographical location of the city. Monthly variations of total pollen grains recorded in the atmosphere of Sivrihisar during the years 2005–2006 are shown in Fig. 2. The seasonal variation of arboreal and non-arboreal pollen falls is given in Fig. 3. The main pollen producers in the atmosphere of Sivrihisar were found to be the following arboreal plants: Pinaceae (69,31%), Cupressaceae (9,82%), *Fraxinus* spp. (3,65%), *Cedrus* spp. (3,56%), *Populus* spp. (1.07%) and *Quercus* spp. (0,6%). They accounted for 90,46% of the total pollen fall. Herbaceous plants such as *Artemisia* spp. (2,91%), Poaceae (2,87%), Chenopodiaceae/Amaranthaceae (2,33%), Urticaceae (0.33%) and Asteraceae (0.21%) were discovered frequently in the atmosphere of Sivrihisar, making up 9,43% of the total (Table 1). Arboreal pollen grains were higher in numbers than the non-arboreal pollen grains in total pollen concentrations. Arboreal pollen grains reached maximum levels in May, while non-arboreal pollen grains reached maximum levels in September (Fig. 3, Table 1).

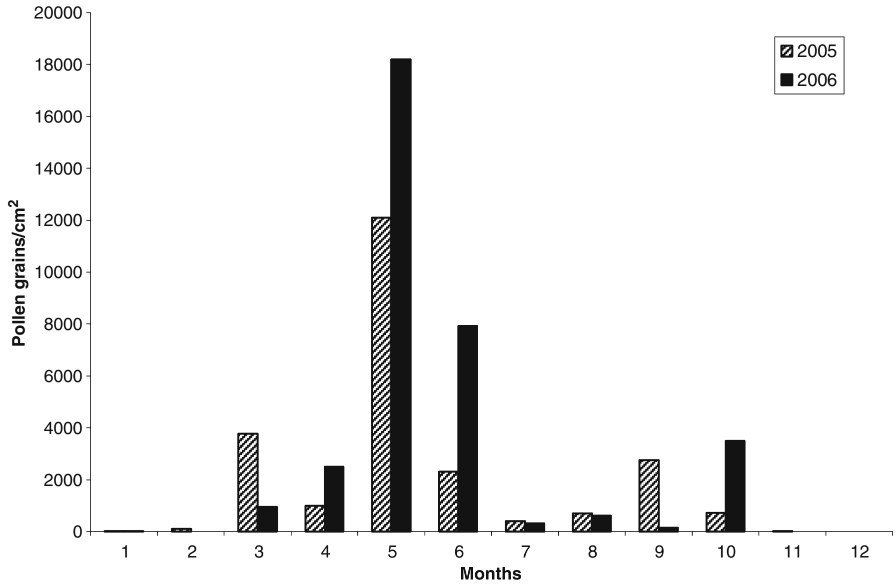
The earliest recorded pollen grains in the atmosphere of Sivrihisar, those of the predominant arboreals, were noted in January in 2005 (Fig. 4). Pollen grain numbers then began to increase in February, March and April and reached their maximum levels in May (18,204 pollen grains in 2006). *Pinus* spp., Cupressaceae, Poaceae, *Fraxinus* spp., Oleaceae, *Salix* spp. Brassicaceae, *Juglans* spp., Moraceae and Urticaceae disperse high amounts of pollen, more than 31,58%, into the atmosphere throughout their pollination period, especially in May. In June, non-arboreal pollen grains from Poaceae, Chenopodiaceae/Amaranthaceae Urticaceae, Asteraceae, *Rumex* spp. and Apiaceae were observed alongside arboreal pollen grains from *Ailanthus* spp., Cupressaceae, Pinaceae and *Fraxinus* spp. Like in May, the numbers of pollen grains were also at high levels in June. From the beginning of July, the pollen grains of weeds had become dominant; however the amount of pollen was lower than that in Spring. One reason for the decrease seen after June might be that this period of the year is the end of the pollination period of many arboreal plants, which produce and release a high level of pollen grains into the atmosphere (Fig. 3). High levels of pollen grains were also observed in July. High amounts of pollen grains of Chenopodiaceae/Amaranthaceae, Poaceae, Asteraceae, *Artemisia* spp. and *Cedrus* spp. were recorded in August–October and low quantities of *Cedrus* spp., Poaceae, Asteraceae, Chenopodiaceae/Amaranthaceae and *Artemisia* spp. pollen grains were recorded in November and December.

Pollen in the atmosphere of Sivrihisar was continuously observed between January and Decembe for the whole of the 2 year period. Total pollen grains reached maximum levels in May during this period. The types of pollen present in the atmosphere of Sivrihisar are shown in the form of a pollen calendar

Table 1 Annual totals of weekly pollen counts

	2005	2006	Total	Total %
Arboreal plants				
Acer	24	–	24	0,04
Ailanthus	12	7	19	0,03
Alnus	3	3	6	0,01
Betulaceae	5	15	20	0,03
Carpinus	2	14	16	0,02
Castanea sativa	4	20	24	0,04
Cedrus	688	1359	2,047	3,56
Corylus	22	19	41	0,07
Cupressaceae	4,251	1386	5,637	9,82
Ericaceae	1	1	2	0
Fagus orientalis	209	18	227	0,39
Fraxinus	409	1,688	2,097	3,65
Juglans	56	30	86	0,14
Moraceae	128	126	254	0,44
Oleaceae	35	246	281	0,48
Pinaceae	12,817	26,950	39,767	69,31
Platanus orientalis	2	–	2	0
Populus	241	373	614	1,07
Quercus	344	5	349	0,6
Robinia pseudoacacia	31	70	101	0,17
Rosaceae	42	46	88	0,15
Salix	65	92	157	0,27
Tilia	13	3	16	0,02
Ulmus	7	20	27	0,04
Total grains from arboreal plants	19,411	32,491	51,902	90,46
Non-arboreal plants				
Apiaceae	11	8	19	0,03
Artemisia	1,564	111	1,675	2,91
Asteraceae	121	5	126	0,21
Bellis	28	24	52	0,09
Brassicaceae	61	65	126	0,21
Caryophyllaceae	38	28	66	0,11
Chenopodiaceae	912	427	1,339	2,33
Cyperaceae	13	6	19	0,03
Juncaceae	12	2	14	0,02
Linaceae	5	-	5	0
Plantago	23	25	48	0,08
Poaceae	804	846	1,650	2,87
Rubiaceae	1	-	1	0
Rumex	16	28	44	0,07
Taraxacum	4	4	8	0,01
Urticaceae	147	48	195	0,33
Xanthium	16	9	25	0,04
Total grains from non-arboreal plants	3,776	1,636	5,412	9,43
Unidentified	32	27	59	0,1
Total pollen number	23,219	34,154	57,373	100

Fig. 2 Monthly totals of atmospheric pollen in Sivrihisar, 2005–2006



(Fig. 4), based on the counts made in 2005–2006. The following is more taxa specific information regarding those taxa producing the highest amounts of pollens in the atmosphere of Sivrihisar.

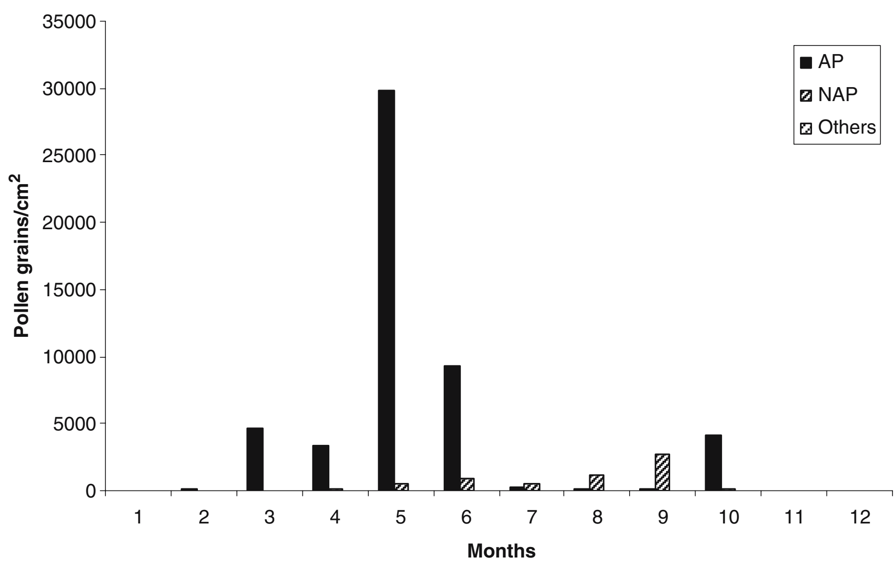
Pinaceae Pollen grains were recorded during the greater part of the year, from January to December. The pollen season began in the second week of January and ended in the second week of December. The highest value was noted in the second week of May (69,31%).

Cupressaceae The pollen season started in the last week of January and ended in the second week of June. The maximum value was recorded in the second week of March (9,82%).

Fraxinus spp. The pollen season started in the first week of March and ended in the second week of June. The maximum value was recorded in the second week of April (3,65%).

Cedrus spp. Pollen production continued from the first week of September to the second week of December. The maximum value was recorded in the second week of October (3,56%).

Fig. 3 Monthly variations of arboreal (AP) and non-arboreal (NAP) pollen grains in Sivrihisar, 2005–2006



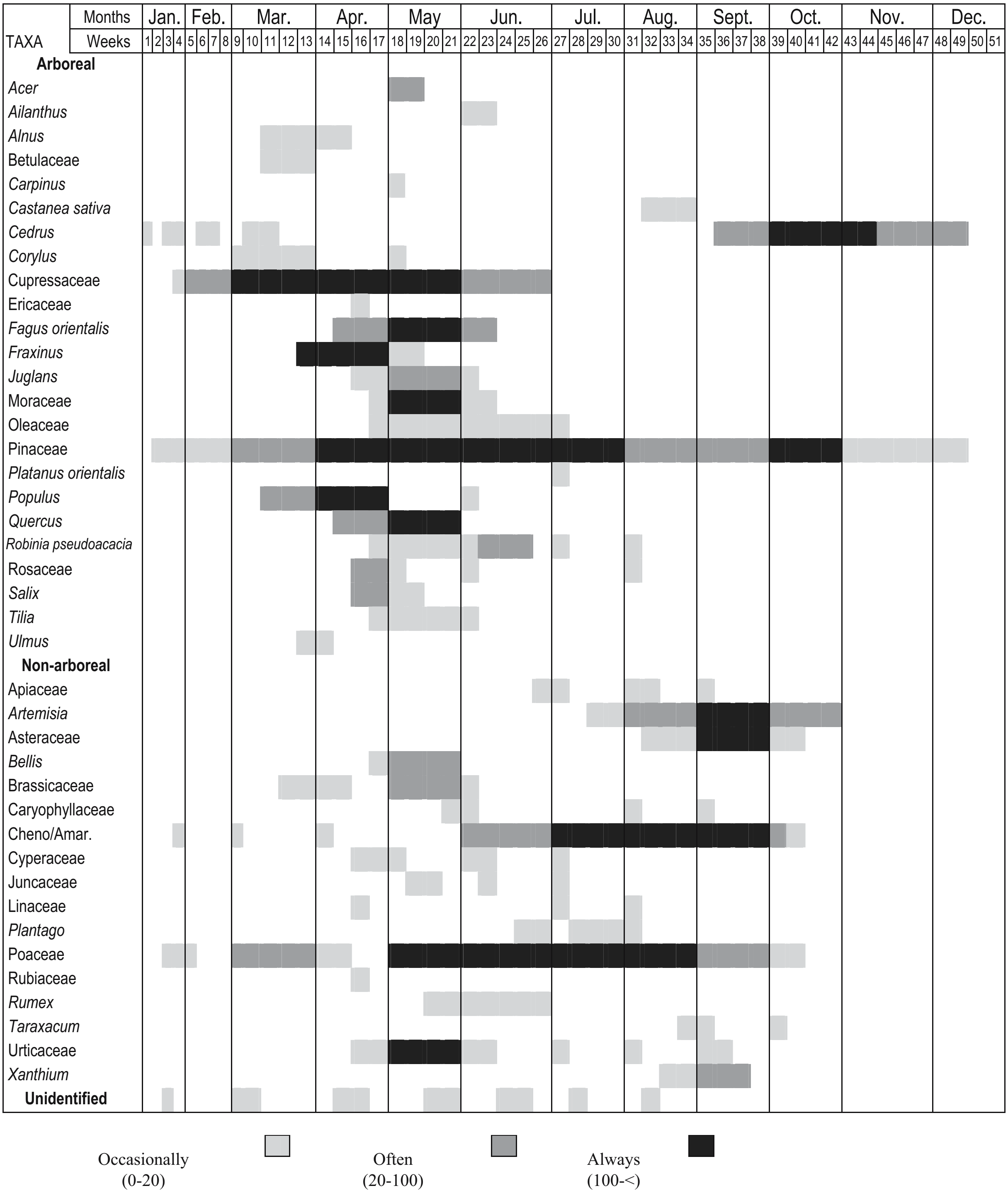


Fig. 4 Pollen calendar of Sivrihisar

Artemisia spp. Pollen production was continuous between the second week of July to the third week of October. The maximum value was recorded in the second week of September (2,91%).

Poaceae Pollen grains were recorded in the second week of January and ended in the first week of November. The highest count was recorded in the first week of June (2,87%).

Chenopodiaceae/Amaranthaceae The pollen season started in the third week of March and ended in the first week of October. Maximum pollen concentration occured in the first week of August (2,33%).

Populus spp. The pollen season commenced in the first week of March and ended in the first week of June. The highest pollen concentration was noted in the second week of April (1,07%).

Quercus spp. The pollen season started in the second week of April and ended in the first week of June. The highest pollen concentration was noted in the second week of May (0,6%).

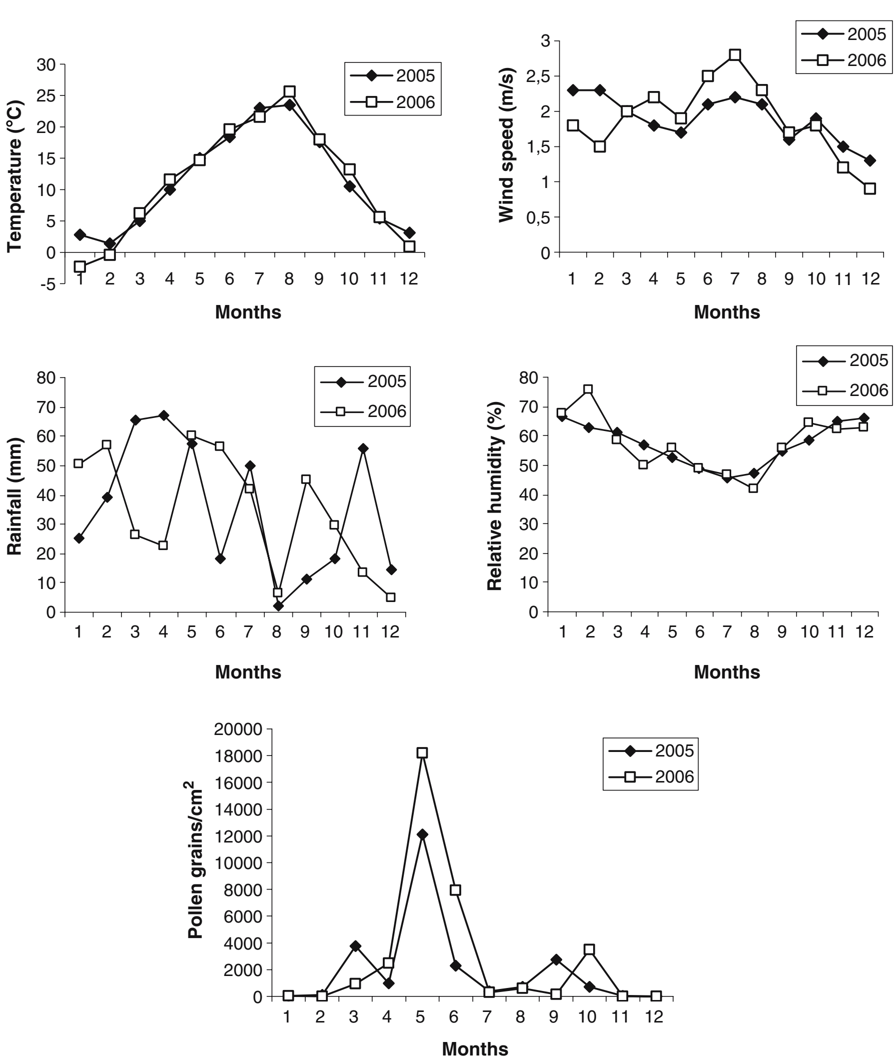
Urticaceae Pollen grains were recorded in the first week of May and ended in the first week of September. The highest count was recorded in the second week of June (0,33%).

Asteraceae The pollen season started in the second week of April and ended in the second week of October. Maximum pollen concentration occured in the second week of September (0,21%).

The correlation between the monthly pollen concentration and the monthly meteorological factors over the period January–December 2005 is shown in Fig. 5.

In January and February, since the temperature and wind speed were low, pollen counts were low. Low temperatures caused a drop in the concentration of pollen (Minero et al. 1999; Norris-Hill 1999). However, this was followed in March by a significant

Fig. 5 Monthly variations in atmospheric pollen and weather conditions in the atmosphere of Sivrihisar from 1 January 2005 to 31 December 2006



increase in the number of pollen grains. This can also be correlated with higher temperatures and wind speed in comparison with the previous months.

Pollen concentrations in April were different from those in March. A small decline was seen in pollen concentration in April, with heavy rain, high temperatures and lower wind speed and humidity in the third week of April all contributing to a lowering in the amount of pollen. This can be explained by the fact that the wind speed and the relative humidity were lower in April than in March (Fig. 5).

The highest level of pollen concentration was observed in May. Lower rainfall and humidity and higher temperature and wind speed contributed to increasing pollen concentration in May (Fig. 5).

In June, the increase in the total pollen amount was caused by the beginning of the pollination of herbs and the maximum pollen dispersal of Chenopodiaceae/Amaranthaceae, Poaceae, Urticaceae, Asteraceae, *Rumex* spp. and Apiaceae. The low humidity and rainfall, high temperature and wind speed seen during this month raised the pollen counts. In addition, rainfall in April increased flowering intensity (Mc Donald 1980; Inceoglu et al. 1994; Potoglu Erkara et al. 2007). The lower pollen concentration in July is attributed to a decline in pollen production by trees at the end of the flowering season rather than to weather conditions.

There was a small increase in the pollen concentration of herbs between August and October (Fig. 5). The higher temperature and wind speed increased the amount of pollen dispersed by herbs. In November and December, the extremely low airborne pollen values recorded were due to higher rainfall levels and the lower temperatures than those of the other months.

Discussion

The present study will contribute to our knowledge of airborne pollen grains in Sivrihisar. The dominance of arboreal pollen types in the atmosphere of Sivrihisar is due to the character of vegetation and geographical location of the study area. The important tree pollen types were Pinaceae (69,31%), Cupressaceae (9,82%), *Fraxinus* spp. (3,65%), *Cedrus* spp. (3,56%), *Populus* spp. (1,07%) and *Quercus* spp. (0,6%). Grass pollen appeared with the maximum flowering period lasting from the second week of January to the first week of December, with the highest count recorded in the first week of June. The herb pollen season was recorded from the second week of January to the last week of October. The peak of herbaceous pollen production was recorded from the beginning of May to the beginning of the November, when *Artemisia* spp. (2,91%), Poaceae (2,87%), Chenopodiaceae/Amaranthaceae (2,33%), Urticaceae (0,33%) and Asteraceae (0,21%) were very abundant in the atmosphere. According to other studies carried out in Europe, arboreal pollen types are also dominant in other regions for the same reason, i.e. 82% in Finland (Koivikko et al. 1986), 76.51% in Burdur-Turkey (Bicakci et al. 2000), 94% in Zonguldak-Turkey (Kaplan 2004), 55.0% in Ascoli piceno-Italy (Romano et al. 1988), and 73.0% in Ostrawiec Swietokryzyski-Poland (Kasprzyk 1995).

From the main pollination period of the various types recorded, three groups could be distinguished: (1) pollen with a short principal period <9 weeks: *Acer* spp., *Ailanthus* spp., *Alnus* spp., Apiaceae, *Bellis* spp., Betulaceae, *Carpinus*, spp. Caryophyllaceae, *Castanea sativa*, *Corylus* spp., Cyperaceae, Ericaceae, *Fraxinus* spp., *Juglans* spp., Juncaceae, Linaceae, Moraceae, *Plantago* spp., *Platanus orientalis*, *Populus* spp., *Quercus* spp., Rosaceae, Rubiaceae, *Rumex* spp., *Salix* spp., *Taraxacum* spp., *Tilia* spp., *Ulmus* spp. and *Xantium* spp.; (2) pollen with a medium principal period, between 9 and 15 weeks: *Artemisia* spp., Asteraceae, Brassicaceae, *Fagus orientalis*, Oleaceae, *Robinia pseudoacacia* and Urticaceae; (3) pollen with a long principal period >15 weeeks: *Cedrus* spp., Cupressaceae, Pinaceae, Chenopodiaceae/Amaranthaceae and Poaceae. However, the pollen grains of some plants found in city flora could not be distinguished (Türe 2002). This may be down to many factors, such as different flowering periods, meteorological factors, the location of the durham sampler, anthesis, and dispersion (Potoglu Erkara et al. 2007).

The concentration of pollen in the atmosphere is closely related to the flowering period of plants, as well as meteorological characteristics (Türe and Salkurt 2005). There is a significant correlation between the temperature increase seen in April and May and the pollen count (Fig. 5; Mc Donald and O'Driscoll 1980; Minero et al. 1999; Molina et al. 2001). It can be seen that the atmospheric pollen concentration in February, March, September, October, and November is less than that of the other months because of relatively low temperatures and more precipitation (Fig. 5; Kaplan 2004; Türe and Salkurt 2005; Potoglu Erkara et al. 2007). Even though they represented only a small proportion of the airborne particles present in the atmosphere, pollen grains can be the cause of allergic responses in susceptible humans, and pollinosis (ocular rhinitis and asthma) is now a public health problem. *Acer* spp., *Alnus* spp., Apiaceae, *Artemisia* spp., Asteraceae, Chenopodiaceae/Amaranthaceae, Cupressaceae, *Fraxinus* spp., *Juglans* spp., Moraceae, Oleaceae, Pinaceae, *Plantago* spp., *Platanus orientalis*, Poaceae, *Quercus* spp., *Rumex* spp. and Urticaceae, all detectable in the atmosphere of Sivrihisar, may cause asthma and allergic rhinitis in susceptible individuals (D'Amato and Spieksma 1990; Bousquet et al. 1984; Spieksma 1990; Lewis and Vinay 1979; Buck and Levetin 1980; Eriksson et al. 1984; Bousquet et al. 1986; Gioulekas et al. 1991). The pollen grains of *Salix* spp., *Populus* spp., Rosaceae, Cyperaceae, *Cedrus* spp., *Ailanthus* spp. and Caryophyllaceae taxa have also been shown to produce milder allergic pollen grains in Sivrihisar (Koivikko et al. 1986; Lewis and Vinay 1979; Buck and Levetin 1980; Eriksson et al. 1984; Bousquet et al. 1985).

The following airborne types of pollen are responsible for many cases of pollinosis in Europe: *Cupressus* spp. (Buck and Levetin 1980; Bousquet et al. 1984; Spieksma 1990), *Pinus* spp. (Newmark and Itkin 1967), *Quercus* spp. (Eriksson et al. 1984), Moraceae (Aytug et al. 1990), and *Juglans* spp. (Aytug and Peremeci 1987). When the data are related to the allergic effects of these plant taxa, it can be seen that the Poaceae family is very important in terms of its long period of pollination (Fig. 4) and strong allergic effect, especially on patients with hayfever, and plants from this family can cause allergic reactions (Chapman 1986). Poaceae pollens have been reported to be the cause of pollinosis (D'Amato and Spieksma 1990). *Platanus* spp. (Chapman and Williams 1984), Chenopodiaceae (Buck and Levetin 1980), Asteraceae and Caryophyllaceae (Lewis and Vinay 1979; Aytug et al. 1990), Urticaceae (Bousquet et al. 1984; Wallin et al. 1991), *Fagus* spp. and *Salix* spp. (Ince 1994), again all detected in the atmosphere of Sivrihisar, may cause asthma and allergic rhinits. Some important allergic pollens, such as *Pinus* spp., Cupressaceae, *Quercus* spp., Poaceae, and *Platanus orientalis* were also found in high concentrations in the atmosphere around Sivrihisar.

The correlation between the monthly airborne pollen counts and the monthly meteorological factors over the period 1 January 2005–31 December 2006 clearly indicated that pollen concentration was affected by all meteorological parameters (wind speed, temperature, rainfall and humidity).

The lower pollen concentration found in April can be attributed to high rainfall and humidity and low temperature. The high and continuous level of rainfall depressed pollen dispersal. In addition, the lower wind speed slowed down pollen dispersal in the atmosphere (Aytug 1974; Inceoglu et al. 1994; Mc Donald 1980; Norris-Hill 1999; Ribeiro et al. 2003).

The higher quantity of pollen in the air samples in 2006 is attributed to greater wind speed, lower rainfall and higher temperature in spring. The mean wind speed in the spring of 2006 was 2.2 m/s, with the mean temperaturefor the same period 14.7°Cand mean humidity 55.7%. Another reason for the greater amount of pollen recorded in 2006 is the lower amount of precipitation recorded between May and August 2006 (60.3–6.6 mm). Storage of water in the soil during the winter caused plant growth and increased flowering intensity in spring (Mc Donald 1980).

Seasonal totals of weekly concentrations for grass pollen were highest in 2006 (846 grains/cm^2) This was probably caused by the higher wind speed in July 2006 (2.8 m/s). Mc Donald (1980) has showed that wind velocity has the greatest influence on the numbers of grass pollen in the atmosphere.

We determined an increase in the total number of pollens in 2005–2006, which we attributed to the high amount of rainfall that Sivrihisar received over the 2 years. Both sunny and rainy weather have been reported to have a positive effect upon an increase in the total number of pollens, as humidity also increases with a rise in temperature. Heavy rain is known to hamper pollination, which results in a far slower increase in pollen in the area affected (Mc Donald 1980; Inceoglu et al. 1994). A corresponding rise in the number of pollens was recorded with a rise in both temperature and humidity in the entire study area in the aftermath of rain (Figs. 1 and 5). Furthermore, periods with zero pollen concentrations in the air are attributed to the fact that a heavy rain cleanses the air (Aytug 1974).

The study area is significant in that it is north-northeasterly situated in terms of exposure to the wind and dissemination of pollination from both nearby and remote places. (Figs. 1 and 5).

We suggest that such studies as ours should be conducted routinely in consideration of changes in meteorological conditions, vegetation and cultivation areas. Some of the most important allergenic pollen grains, such as Pinaceae, Cupressaceae, *Artemisia* spp., Chenopodiaceae/Amaranthaceae, Poaceae and *Cedrus* spp. were also found in high concentrations in the study area. These pollen types are responsible for many cases of pollinosis in the Mediterranean region and other parts of the world (Nilsson and Palmberg-Gothard 1982; Koivikko et al. 1986; D'Amato and Spieksma 1990; Banik and Chanda 1992; Bousquet et al. 1986; Jager et al. 1991; Kosiski and Carpenter 1997; Hallsdottir 1999; Nitiu and Mallo 2002; Potoglu Erkara et al. 2007). It has been suggested that if these types of studies are undertaken during certain periods, data obtained from the studies will help us to determine the distribution mechanisms of pollens and minimize the negative impact on the health of pollen-sensitive people (Bringfelt et al. 1982).

Pollens occurring in the atmosphere of the study area were determined and identified, as a result of which a concept was formed in relation to the flora of this, the study area. Our study aims to both shed light on this area of systematic botany and to aid the establishing of a pollen calendar for the city of Sivrihisar (Eskişehir). The pollen calendar for the city of Sivrihisar (Eskişehir) presented in this paper may be useful for allergologists in establishing a precise diagnosis, as well as helping to eleviate the suffering caused by allergic diseases.

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