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Airborne pollen in European and Asian parts of Istanbul

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Abstract Pollen concentrations in the atmosphere of Istanbul, a city located between two continents, has been monitored for 1 year as part of a larger research program. The sampling sites were located in two different continents: the Asian part (AS) and the European part (EP). The sampling was performed in AS and EP of the city by using Hirst type volumetric method, and pollen grains of 58 and 62 taxa were identified in the two parts, respectively. The pollen spectrum reflected the floristic diversity of the region. The main pollen producers at the sites were characterized by some allergenic pollen and were identified as Cupressaceae/Taxaceae, Urticaceae, *Pistacia* sp., *Quercus* sp., *Platanus* sp., *Fraxinus* sp., and *Xanthium* sp. These pollen types contributed to the total pollen sum with a percentage of more than 80% at both monitoring sites. The highest amount of pollen grains was recorded in April. The greatest number of species was recorded in May, when 42 types (AS) and 44 types (EP) were present.

Keywords Aerobiology · Euro-Asia · Pollen concentrations · Pollen types · Turkey

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Introduction

Airborne pollen grains are an important and potent source of aeroallergens. The number of individuals allergic to allergens contained in pollen has been steadily increasing, especially in large cities and industrial areas (Hofman and Michalik 1998; Nilsson and Persson 1981; Obtulowicz et al. 1996). Determining the concentration of pollen in the air can help people suffering allergic diseases by being a predictor of allergen dose. Airborne pollen grains have been evaluated all over the world for several years by various studies to determine their dispersal and concentrations. The principal aim of aeropalynologic studies is to assess the seasonal appearance of pollen grains in the air and to make quantitative and qualitative analyses of pollen concentrations. Atmospheric pollen has been measured for many years at various locations in the world. Pollen calendars for particular countries have been published in a number of national or regional pollen atlases (Nilsson et al. 1977; Horak and Jäger 1979; Stix 1981; D'Amato 1984; Driessen et al. 1988). In each biogeographical area, different species make up the characteristic airborne pollen calendar, the composition of which is controlled by meteorological conditions that are changeable among years and microclimates. In part, the amount and dispersion of pollen are dependent on specific microclimates that can help explain the differences observed with respect to the onset of flowering within the same species (Fernandez-Gonzalez et al. 1999; Garcia-Mozo et al. 1999). Therefore, to obtain reliable information on a whole area, it is important to increase the number of aerobiological monitoring stations to cover the many different climatic and/or phytogeographic areas.

Aytug et al. (1974) performed the first study on allergenic pollen distribution in Istanbul, Turkey. Additional atmospheric pollen surveys have been carried out in various cities of Turkey since 1966 (Bicakci and Akyalcin 2000; Bicakci et al. 2000; 2002a, b, 2003, 2004a, b; Celenk and Bicakci 2005; Bicakci 2006; Celenk et al. 2008).

The aims of this study are (1) to clarify which types of pollen are present in the air, (2) to identify the most representative pollen types, (3) to make a quantitative and qualitative analyses of pollen concentration in the atmosphere of Istanbul, and (4) to determine whether there were major differences in the seasonal incidence and abundance of pollen grains.

Study area

Istanbul is a city with more than ten million inhabitants; it is situated at 28°58′ E, 41°01′ N in Turkey. It is the only city in the world that spreads over two continents. The two sampling sites were located on rooftops; one at Istanbul Huzur Hospital located Asian part (AS) of the city and the other at Eresin Hotel, which is located on the European part (EP) of the city in a densely populated zone (Fig. 1).

Vegetation

The vegetation of Istanbul near the sampling area and in general is divided into two parts:

1. Forests and Maquis as native vegetation. (a) Forests: Arid forests cover the south of the city, while moist forests cover the north of Istanbul. On the Asian side of the Bosporus, "Alemdag Forest," and on the European side of the Bosporus, "Belgrad Forest", which

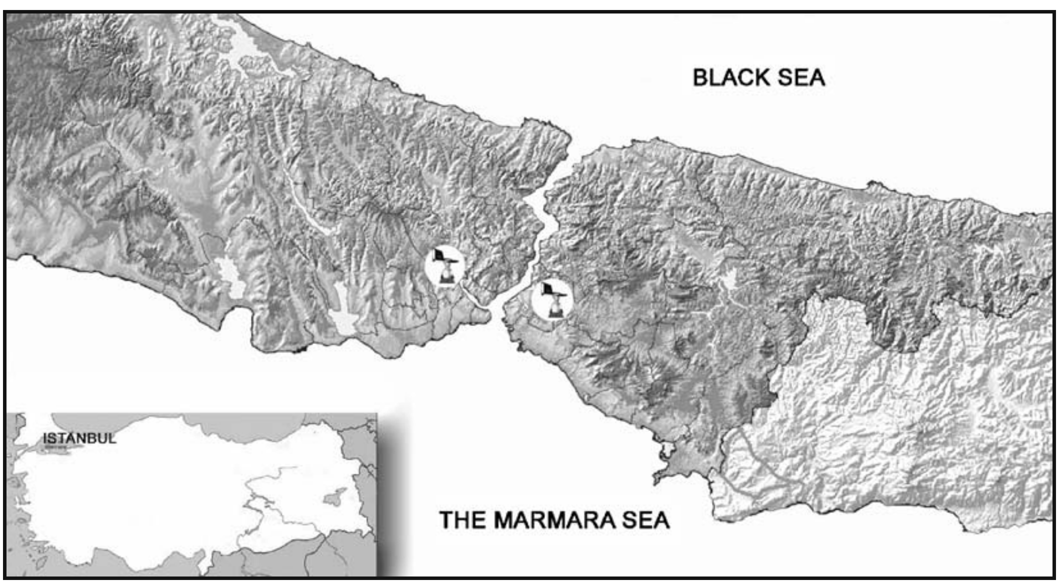


Fig. 1 Location map of Istanbul and two pollen-monitoring sites

contains *Quercus* sp. (*Quercus robur*, *Quercus frainetto*, and *Quercus petraea*), *Fagus orientalis*, *Carpinus betulus*, *Castanea sativa*, *Populus tremula*, *Corylus avellana*, *Acer campestre*, *Ulmus minor*, *Tilia argentea*, *Alnus glutinosa*, and *Salix caprea*. On either side, there are no significant differences in weather conditions or soil type. Relief has determined the character of the forests. (b) Maquis: Native vegetation is restricted to patches located on either side of the Bosporus and along the coast, represented by small forests larger forest and Pseudomaquis. On the EP of Istanbul, Pseudomaquis covers the destroyed forests and are also located throughout the AS. Dominant species of Maquis and Pseudomaquis are *Arbutus unedo*, *Erica arborea*, *Quercus coccifera*, *Phillyrea latifolia*, *Pistacia terebinthus*, *Cistus salvifolius*, *Cistus creticus*, *Juniperus oxycedrus*, *Sarcopoterium spinosum*, *Pyracantha coccinea*, *Lavandula stoechas*, *Calycotome villosa*, *Genista tinctoria*, *Osyris alba*, and *Olea europaea.*

2. Trees and shrubs planted in parks, gardens, groves, nurseries, arboretums, botanical gardens, small forests (coppices), and city streets like *Pistacia* sp., *Fraxinus* sp., *Quercus* sp., and *Cupressus* sp. On the EP, 29 coppices are found, and on the AS of the city, 18 coppices present. These small forests include native and non-native trees and shrubs (Davis 1965–1985; Yaltirik et al. 1997).

Climate

In Istanbul Bosporus and the surrounding area, the characteristic climate is Mediterranean. Average temperatures are 4 and 27°C. The dominant winds throughout the year are the cool and rainy from the north and warm from the south. The weather can be unpredictable in a region with such a blending of lands and seas. There are few days of frost or snow. According to long-term data, mean yearly atmospheric pressure was measured as 1,010.0 mb, mean temperature as 13.8°C, mean relative humidity as 76%, mean rainfall as 787 mm, and mean wind speed as 3.2 m/s in Istanbul (Turkish State Meteorological Service

Table 1 Mean annual meteorological data for Istanbul

Meteorological parameters	Asian part											
	Winter			Spring			Summer			Autumn		
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Mean number of rainy days	20	19	20	14	10	6	8	3	5	12	15	23
Rainfall (total mm)	109.0	139.6	134.5	44.7	18.1	17.3	26.2	40.0	22.5	65.2	74.5	144.7
Mean daily max temp (°C)	13.0	14.5	14.2	14.6	19.0	19.5	24.6	26.7	27.9	24.4	20.4	15.0
Mean daily min temp (°C)	0.3	0.4	−0.9	0.2	4.0	11.8	17.0	20.3	22.6	16.5	8.4	3.4
Mean 2 P.M. relative humidity (%)	65.6	68.9	60.7	56.4	49.4	58.0	43.2	49.8	47.7	54.7	65.0	70.0

Meteorological parameters	European part											
	Winter			Spring			Summer			Autumn		
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Mean number of rainy days	20	18	20	16	8	8	7	3	5	12	12	22
Rainfall (total mm)	88.2	113.0	111.4	45.1	21.7	21.5	20.2	67.5	27.4	54.9	42.7	75.9
Mean daily max temp (°C)	14.5	13.7	13.2	14.3	18.4	19.9	25.1	27.3	28.6	25.1	20.5	14.7
Mean daily min temp (°C)	0.3	0.3	−1.4	0.5	4.8	12.4	16.9	20.4	22.8	16.8	8.4	2.6
Mean 2 P.M. relative humidity (%)	68.9	72.8	63.8	63.5	53.8	62.5	49.2	56.3	52.1	55.3	59.2	70.3

Table 2 Monthly pollen counts in Istanbul atmosphere

		Asian part		European part	
		Total	Total %	Total %	Total
Arboreal pollen	Abies	–	–	4	0.01
	Acacia	2	0.01	–	–
	Acer	27	0.10	108	0.30
	Aesculus	78	0.28	13	0.04
	Ailanthus	29	0.10	186	0.51
	Alnus	121	0.44	92	0.25
	Betula	–	–	16	0.04
	Betulaceae	229	0.83	99	0.27
	Buxus	2	0.01	5	0.01
	Carpinus	24	0.09	20	0.05
	Castanea	482	1.74	157	0.43
	Cedrus	116	0.42	33	0.09
	Cistaceae	1	0.00	–	–
	Corylus	67	0.24	68	0.19
	Cupress./Taxa.	10093	36.52	12522	34.42
	Ericaceae	96	0.35	120	0.33
	Fagus	13	0.05	19	0.05
	Forsythia	–	–	6	0.02
	Fraxinus	990	3.58	1095	3.01
	Juglans	137	0.50	150	0.41
	Laurus	6	0.02	1	0.00
	Ligustrum	15	0.05	16	0.04
	Moraceae	563	2.04	737	2.03
	Olea	–	–	44	0.12
	Oleaceae	91	0.33	66	0.18
	Ostrya	7	0.03	16	0.04
	Pinus	1950	7.06	992	2.73
	Pistacia	2121	7.68	1282	3.52
	Platanus	1453	5.26	8643	23.76
	Populus	139	0.50	149	0.41
	Quercus	1771	6.41	1284	3.53
	Rosaceae	51	0.18	18	0.05
	Salix	51	0.18	175	0.48
	Sophora	–	–	4	0.01
	Tilia	32	0.12	21	0.06
	Ulmus	137	0.50	116	0.32
	Total	20894	75.61	28277	77.72
	Total %	75.61		77.7246	
Non-arboreal pollen	*Artemisia*	253	0.92	243	0.67
	Boraginaceae	22	0.08	19	0.05
	Campanulaceae	1	0.00	–	–
	Caryophyllaceae	1	0.00	5	0.01
	Centaurea	1	0.00	2	0.01
	Chenopod./Amaranth.	227	1.00	277	0.76
	Clematis	2	0.01	21	0.06
	Compositae	82	0.30	448	1.23
	Cruciferae	17	0.06	23	0.06
	Cyperaceae	24	0.09	23	0.06
	Gramineae	750	2.71	502	1.38
	Helianthus	6	0.02	6	0.02
	Humulus	161	0.58	90	0.25
	Labiatae	3	0.01	2	0.01
	Leguminasae	20	0.07	56	0.15

Table 2 (continued)

	Asian part		European part	
	Total	Total %	Total %	Total
Luzula	–	–	3	0.01
Mercurialis	46	0.17	102	0.28
Papaveraceae	12	0.04	15	0.04
Plantago	198	0.72	164	0.45
Ranunculaceae	12	0.04	7	0.02
Rubiaceae	12	0.04	15	0.04
Rumex	81	0.29	74	0.20
Sangisorba	3	0.01	8	0.02
Taraxacum	10	0.04	18	0.05
Typha	14	0.05	23	0.06
Umbelliferae	39	0.14	50	0.14
Urticaceae	2356	8.53	4629	12.72
Xanthium	1958	7.09	1023	2.81
Zea	–	–	4	0.01
Total NAP	6361	23.02	7852	21.58
Total%	23.02		21.5827	
Unidentified	379	1.37	252	0.69
Total	27634		36381	
Total %		100.00		100.00

2006). Some of the meteorological parameters recorded in 2005 are given in Table 1.

Material and methods

Aerobiological data were collected using two 7-day volumetric trap (VPPS 2000 Lanzoni®, Bologna, Italy) of the Hirst design (Hirst 1952) located in Altunuzade (AS) and Topkapi (EP), each approximately 25 m above the ground, from 1st March 2005 to 28th February 2006. The standard method of the Italian Network for the Aerobiological Monitoring (D'Amato and Spieksma 1990) was used, and analysis of each 24-h period was conducted by counting 24 transverse lines at ×400 magnification. Pollen counts were converted to grains per cubic meter of air and expressed as a daily mean value (Hirst 1952).

Results

The total annual pollen catch registered during the studying period was 27,634 grains on the AS and 36,381 grains on the EP. The number of

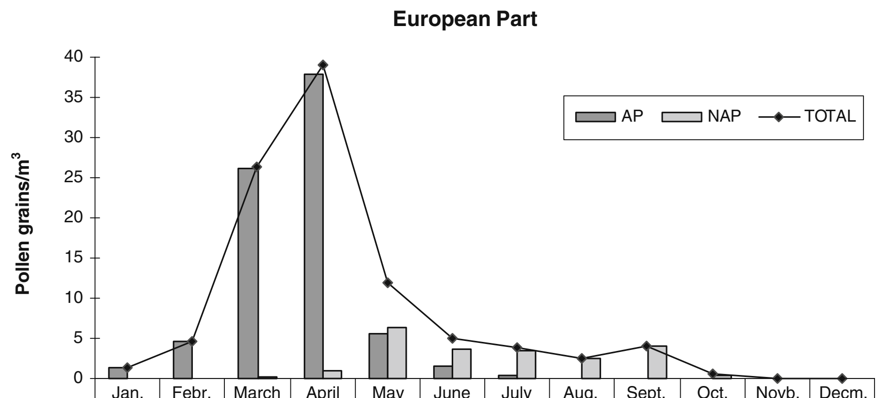
Table 3 Selected values of dominant taxa in Istanbul

Taxon	Asian part (AS)				European part (EP)			
	Period of occurrence	Duration (days)	Concentration in a peak day (grains per cubic meter)	Peak day	Period of occurrence	Duration (days)	Concentration in a peak day (grains per cubic meter)	Peak day
Fraxinus	08.12–26.05	126	134	13.04	14.01–23.05	101	127	17.04
Cupressaceae/ Taxaceae	18.01–09.12	214	1719	21.03	06.01–03.12	189	1,330	19.03
Pistacia	18.02–09.07	66	834	9.04	13.02–26.07	64	266	12.04
Urticaceae	26.02–28.10	188	119	28.06	20.02–12.10	217	178	18.05
Platanus	19.03–06.06	63	259	25.04	12.03–10.06	68	2,576	17.04
Pinus	19.03–21.07	145	137	11.05	–	–	–	–
Quercus	02.04–31.05	60	285	13.05	01.04–31.05	61	117	12.04
Xanthium	25.06–03.11	79	388	23.09	–	–	–	–

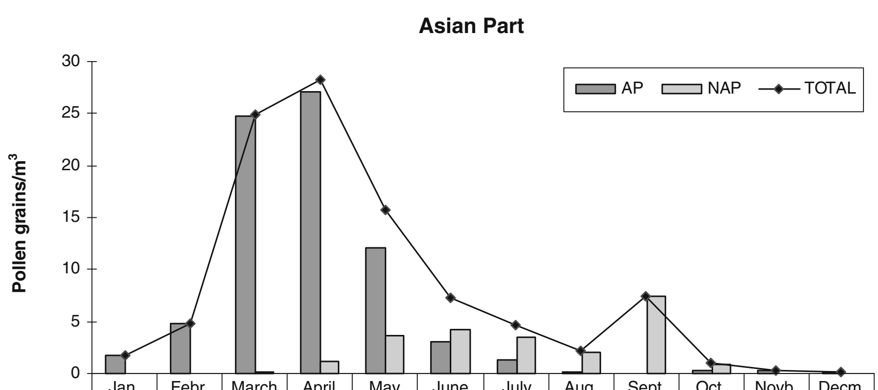
unidentified pollen grains was 379 (1.37%) on the AS and 252 (0.69%) on the EP. The results of pollen count for both sites are shown in Table 1. The counts include over 58 different pollen types [27 non-arboreal pollen (NAP) and 31 arboreal pollen (AP)] on the AS and 62 different pollen types (28 NAP and 34 AP) on the EP.

For the AS of Istanbul, 82.13% of the annual total pollen grains were represented by only eight taxa (up to 3% of the total pollen catch) with the remaining 17.87% composed of around 50 different pollen types seen only occasionally and in low numbers. Representative pollen types in decreasing order were Cupressaceae/Taxaceae, Urticaceae, *Pistacia* sp., *Xanthium* sp., *Pinus* sp., *Quercus* sp., *Platanus* sp., and *Fraxinus* sp. (Table 2). For the EP of Istanbul, 80.96% of annual total pollen grains were represented by only six taxa (up to 3% of the annual total pollen catch) with the remaining 19.04% composed of around 56 different pollen types seen only occasionally and in low numbers. In decreasing order of representative pollen types for the EP are Cupressaceae/Taxaceae, *Platanus* sp., Urticaceae, *Quercus* sp., *Pistacia* sp., and *Fraxinus* sp. (Table 2). Quantitative trends of dominant pollen types (period of occurrence, duration, concentration in a peak day, and peak day) are given in Table 3.

Pollen grains in the atmosphere of Istanbul were present all year round. The general trend shows an increase in pollen counts and species



	Jan.	Febr.	March	April	May	June	July	Aug.	Sept.	Oct.	Novb.	Decm.
AP	1,31	4,63	26,17	37,97	5,55	1,45	0,32	0,08	0,06	0,09	0,04	0,06
NAP	0,03	0,04	0,13	0,97	6,32	3,65	3,48	2,46	4,04	0,41	0,02	0,03
TOTAL	1,34	4,67	26,30	38,95	11,87	5,10	3,80	2,54	4,10	0,50	0,06	0,09



	Jan.	Febr.	March	April	May	June	July	Aug.	Sept.	Oct.	Novb.	Decm.
AP	1,76	4,73	24,79	27,15	12,06	3,05	1,26	0,10	0,04	0,25	0,25	0,14
NAP	0,01	0,04	0,09	1,09	3,70	4,28	3,46	2,04	7,41	0,83	0,04	0,01
TOTAL	1,78	4,78	24,88	28,24	15,77	7,34	4,72	2,14	7,45	1,07	0,29	0,16

Fig. 2 Yearly percentage of airborne arboreal pollen (*AP*) and non-arboreal pollen (*NAP*) recorded at the two pollen-monitoring sites in Istanbul

richness in spring, reaching a maximum level at the end of the spring. In summer, pollen concentration begins to decrease. The very small numbers of grains observed from late autumn until early spring is noticeable. Monthly pollen concentrations measured at both monitoring sites showed two peaks in April and September. From March to May, 69.44% and 77.43% of the total pollen catch were recorded. The month with the highest pollen total was April with 14,204 grains and 7,804 grains in the AS and the EP, respectively. The month with the lowest pollen total was November with 25 grains on the EP and December with 44 grains on the AS. Maximum peak of daily concentration was on the 21st of March with 1,738 grains cubic meter in AS (corresponded to Cupressaceae/Taxaceae) and the 17th of April with 2,576 grains per cubic meter on the EP (corresponded to *Platanus* sp.; Table 3 and Figs. 2, 3, and 4).

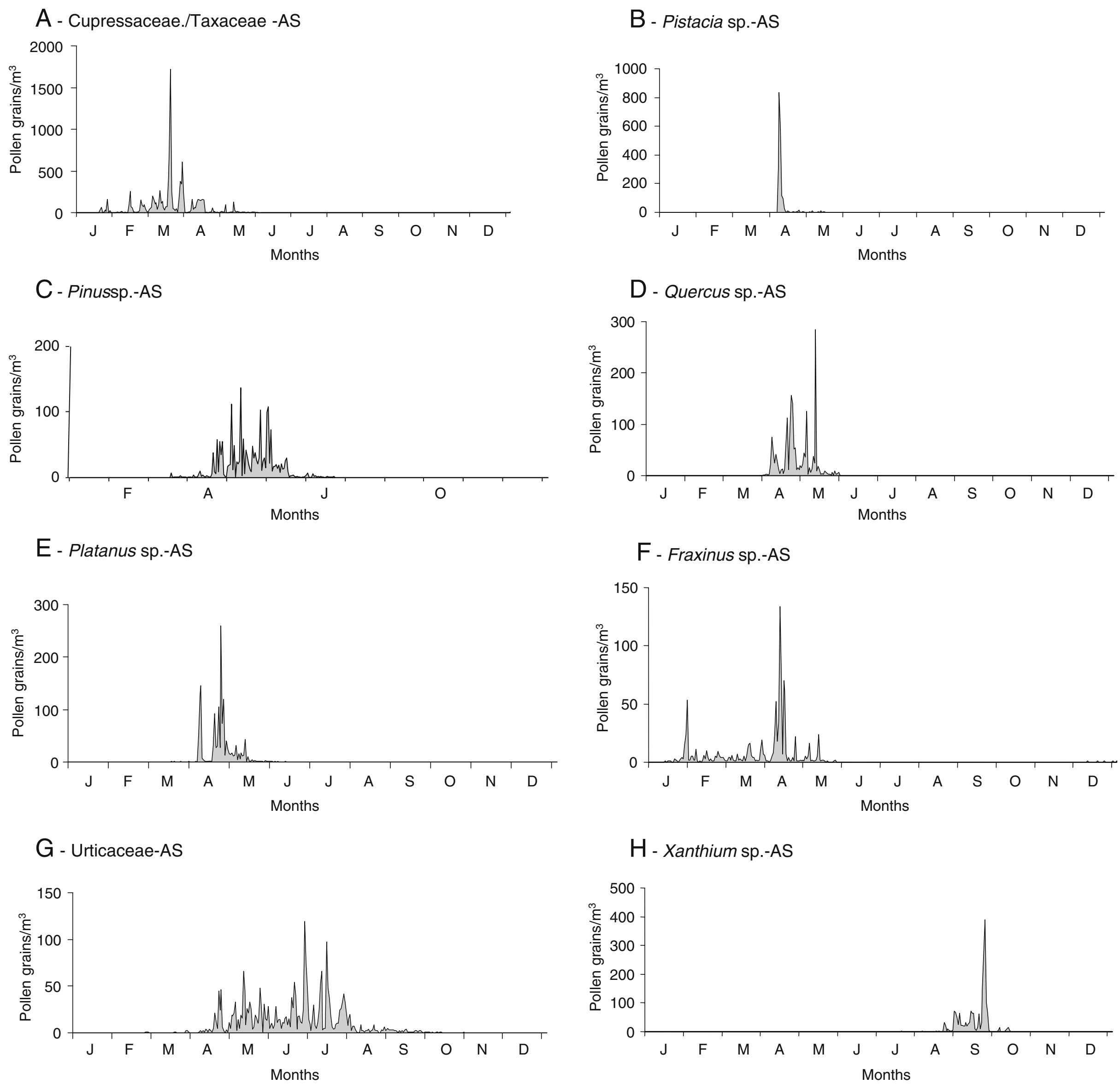


Fig. 3 Seasonal variation for eight dominant taxa on the Asian part (*AS*) of Istanbul

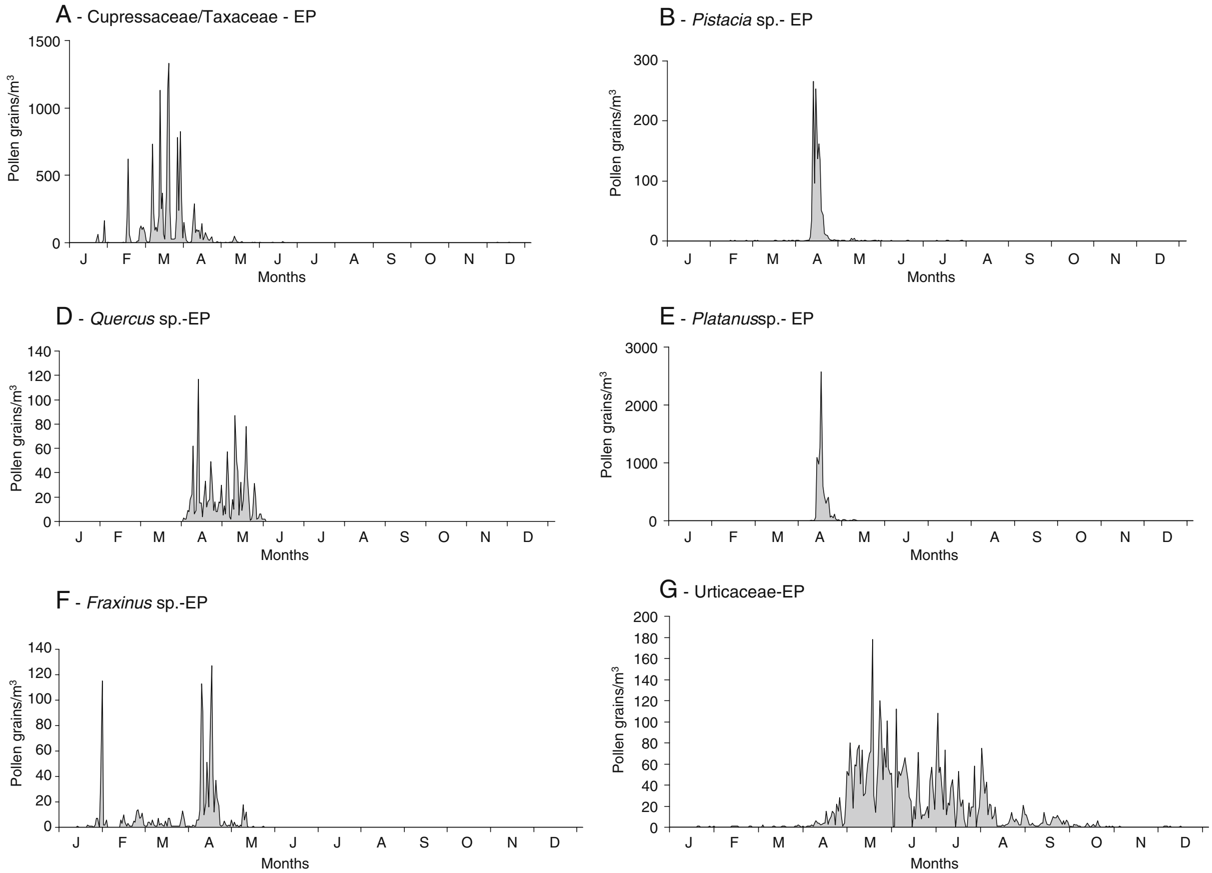


Fig. 4 Seasonal variation for 6 dominant taxa on the European part (EP) of Istanbul

The airborne pollen patterns of each taxon showed marked seasonality, although pollen grains of Cupressaceae/Taxaceae were present in the air throughout the year at both sites. Pollen grains of these families constituted 36.52% of the total pollen catch on the AS and 34.42% of the total amount of pollen on the EP (Tables 2 and 3 and Figs. 3 and 4).

Urticaceae represented the dominant NAP type in the atmosphere of Istanbul at both sites. While the concentrations of Urticaceae pollen were consistent, they occurred in low numbers and peaked in June on the AS; they were intermittent, occurred in high numbers (two times greater than those on the AS), and peaked in May on the EP. The Urticaceae pollen season was characterized as running from the last 10 days of February until the last 10 days of October (Tables 2 and 3 and Figs. 3 and 4).

Pollen concentrations of *Quercus* sp., *Pistacia* sp., and *Platanus* sp. were different between the sites. However, concentrations of *Platanus* sp. on the EP were recorded as being six times greater than that of the AS, although concentration of *Quercus* sp. and *Pistacia* sp. pollen were recorded as being two times lower on the EP than those of the AS of the city (Table 2 and Figs. 3 and 4).

Pollen grains of *Fraxinus* sp. were twice as common on the EP as on the AS of the city. The pollen season of this taxon started in the first 10 days of December and lasted until the last 10 days of May (Table 2 and Figs. 3 and 4).

Pollen grains of *Xanthium* sp. and *Pinus* sp. were identified at both monitoring sites. Since concentrations of these taxa were lower than 3% on the EP, these taxa were not identified as dominant for the EP. Pollen grains of *Xanthium* sp. and *Pinus* sp. constituted 7.09% and 7.06% of the total pollen catch and registered as the fourth and fifth dominant taxa on the Asian side of the city, respectively. The pollen season of *Xanthium* sp. started in the last 10 days of June and lasted until the first 10 days of November, and the highest values were noted on the 23rd of September (Tables 2 and 3 and Fig. 3). The pollen season of *Pinus* sp. started in the second decade of March and lasted until the third decade of July. The highest values were noted on the 11th of May (Tables 2 and 3 and Fig. 3).

Discussion

Pollen concentrations in the atmosphere of Istanbul are mostly specific to the region. The two sites show broad similarities in the timing of peak pollen concentration, although the composition of the pollen is subtly different. At the investigated sites, a smaller number of pollen grains were counted on the AS than on the EP (Table 2). This was probably a result of slight differences in vegetation and weather conditions (such as wind speed and/or rainfall) between these two sites. The number of identified taxa showed variation between the sites (Table 2, Fig. 5). On the AS, fewer taxa were identified than on the EP.

Aytug et al. (1974) did the first study on atmospheric pollen analysis for Istanbul from 1966 to 1968. In that study, a Hirst trap was located at ground level in the Belgrad forest. According to their results, the main pollen producers were recorded as Cupressaceae/Taxaceae, *Platanus* sp., Gramineae, *Fraxinus* sp., *Quercus* sp., and *Pinus* sp. The difference between the results of two studies is probably due to the composition of vegetation in the sampling area and the location of the Hirst traps at different levels.

The symptoms of pollen related allergies confirm correlation with the airborne pollen count (Samolinski et al. 1996). Trees are among the main pollen producers because of their common incidence and large pollen production per anther and inflorescence (Molina et al. 1996). AP types were dominant in the atmosphere of Istanbul; this is due to the characteristics of the vegetation and geographical location of the city. Most of the dominant pollen types identified in this study were placed on the list of the most important plants causing pollinosis in Europe (Erickson et al. 1984; Spieksma 1990).

It was observed that Cupressaceae/Taxaceae pollens were the most common types in the atmosphere of Istanbul and reached their peak level in April. Different authors have cited Cupressaceae pollen as an important allergen (Caiaffa

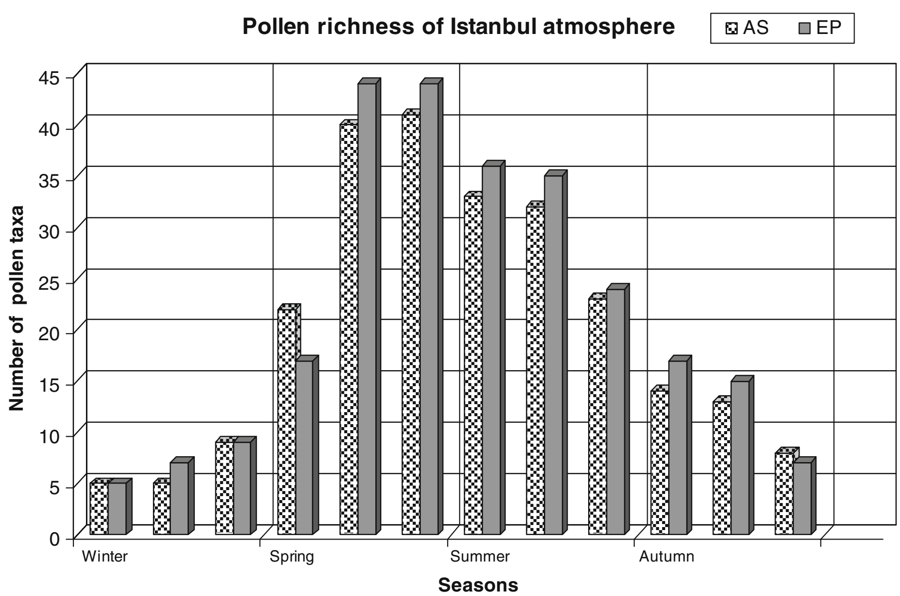


Fig. 5 Pollen types recorded during the sampling period in two monitoring sites (Asian part, *AS*; European part, *EP*)

et al. 1988; Cimignoli et al. 1992; D'Amato and Liccardi 1994; Nardi et al. 1996). These families are frequently used for ornamental purposes in parks and gardens in many cities (Galán et al. 1998; Hirotaka et al. 1996; Levetin 1998; Naito et al. 1998).

In Istanbul, since *Pistacia* sp. trees were planted in gardens or distributed naturally all around the city, their pollen grains were recorded as one of the most important pollen types for air of Istanbul. Pollen grains of *Pistacia* sp. were found in abundance as the fifth predominant pollen on the EP, and this pollen type was found as the third most predominant pollen on the AS, reaching the maximum level of concentration in April (Table 2 and Figs. 3 and 4). Keynan et al. (1987) described the *Pistacia* sp. tree genus as a very important source of respiratory hypersensivity. Similarly, pollen grains of this taxon dominated in Southern Croatia; in March, the *Pistacia* sp. trees start producing enormous amounts of pollen and continue until the end of April (Cvitanovic et al. 2004).

Urticaceae, *Quercus* sp., *Platanus* sp., *Fraxinus* sp., and *Xanthium* sp. are well-known allergenic pollens (Newmark and Itkin 1967; Erickson et al. 1984; Bousquet et al. 1986; Jaggi and Sharad 1987). In our study, they were also present in high values in the atmosphere of Istanbul. Although pollen grains of *Quercus* sp., *Platanus* sp. and *Fraxinus* sp. were identified at both of the monitoring sites as more than 3% of the total pollen catch, *Xanthium* sp. and *Pinus* sp. constituted more than 7.0% of the total amount of pollen on the AS of the city. According to other studies carried out in cities neighboring Istanbul, similar pollen types were found to be dominant (Table 4). Some of pollen grains found in high concentrations in Istanbul were also found as dominant in the other European cities (Spieksma et al. 1990; Romano et al. 1988; Koivikko et al. 1986; Kasprzyk 1996; Jato et al. 2002) (Table 4).

According to the results of studies related to meteorological parameters and pollen dispersion, the factors influencing pollen concentrations are pre-seasonal precipitation and pre-seasonal maximum temperature (Green et al. 2004).The current data set for Istanbul is still inadequate for such an analysis, as it does not capture all the possible yearly variations in regional pollen concentration. However, ongoing monitoring and analysis will eventually address some of these issues, which are ultimately essential for producing predictive models that can be applied to the management of respiratory health.

Conclusion

Pollen grains of 58 (AS) and 62 (EP) taxa were identified during the investigated period in Istanbul. Among them, eight (AS) and six (EP) taxa produced the greatest amount of pollen and were recorded in concentrations of up to 3% of the total pollen catch. The two monitoring sites revealed that all of the dominant pollen types could be connected to allergenic pollinosis and formed 82.13% (AS) and 80.96% (EP) of the total pollen catch. In the region investigated, pollen grains reached their maximum levels in April. This

Table 4 Comparison of dominant pollen taxa in Istanbul, neighbor cities, and other European cities

	Pinus/Pinaceae	Cupressaceae/Taxaceae	*Fraxinus*	*Platanus*	*Quercus*	Urticaceae	*Xanthium*
Balıkesir(1)	+	+	+	+	+	+	−
Bursa (2)	+	+	+	+	+	+	+
Sakarya (3)	+	+	+	+	+	+	+
Yalova (4)	+	+	−	+	+	−	−
Edirne (5)	+	+	+	+	+	−	−
Ascoli and Piceno (6)	−	−	−	−	−	+	−
Santiago de Compostela (7)	+	−	−	+	+	−	−

Numbers refer to references: 1 Bicakci and Akyalcin 2000, 2 Bicakci et al. 2003, 3 Bicakci 2006, 4 Altunoglu et al. 2008, 5 Bicakci et al. 2004a, b, 6 Romano et al. 1988, 7: Jato et al. 2002) preliminary study underscores the need for long-term research to be undertaken in the future.

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