Environ Monit Assess (2009) 158:365–380
DOI 10.1007/s10661-008-0590-1

An aerobiological study on pollen grains in the atmosphere of North-West Turkey

Sevcan Celenk · Yakup Canitez · Adem Bicakci · Nihat Sapan · Hulusi Malyer

Received: 18 March 2008 / Accepted: 29 September 2008 / Published online: 26 October 2008
© Springer Science + Business Media B.V. 2008

Abstract A continuous aerobiological survey of the atmosphere of Bursa was carried out from 1st January 2003 to 31st December 2004 by means of the volumetric method using a Lanzoni trap. During 2 years, a total of 57,124 pollen grains/m^3, which belonged to 66 taxa and 869 unidentified pollen grains, were recorded. In the region investigated, *Pinus* sp., *Olea* sp., *Platanus* sp., Cupressaceae/Taxaceae, *Quercus* sp., Poaceae, Moraceae, Urticaceae, and *Castanea* sp. were responsible for the greatest amounts of pollen. During the study period, the pollen concentration reached the highest level in May. A correlation analyses was made between the daily fluctuations of the main pollen types and meteorological parameters.

Keywords Aeropalynology · Bursa · Meteorological factors · Pollen · Spearman correlation test · Turkey

S. Celenk (✉) · A. Bicakci · H. Malyer
Department of Biology, Faculty of Science, Uludag University, Gorukle, Bursa, Turkey
e-mail: sevcant@uludag.edu.tr

Y. Canitez · N. Sapan
Division of Pediatric Allergy, Faculty of Medicine, Uludag University, Bursa, Turkey

Introduction

In the last decades, the prevalence of pollen related allergies, rhinitis, and asthma has increased all around the world. Several causes of this phenomenon have been suggested. Allergic symptoms are related to the composition, timing, and abundance of airborne allergenic material, together with other environmental and genetic risk factors. The "hygiene hypothesis" was conceived as an attempt to explain rising trends in atopic disease over the last 30–40 years, particularly in industrialized/developed countries (Weiss 2002). Some pollen grains are known to cause allergic diseases in humans, including allergic asthma and allergic rhinitis (Leuschner et al. 2000). These diseases appear especially during the flowering periods of plants. Determination of the pollen types and their concentration is very important especially in the atmosphere of highly populated cities. These data prove helpful in the treatment of patients suffering from such diseases. For this reason, studies of the pollen content in the atmosphere of different areas have been carried out by researchers worldwide and in Turkey as well (Romano et al. 1988; Bicakci and Akyalcin 2000; Bicakci et al. 2002, 2004; Ballero and Maxia 2003; Jones and Harrison 2004; Stennett and Beggs 2004; Celenk and Bicakci 2005; Altunoglu et al. 2008).

In each geographic area, there is a succession of different flowering species throughout the year. Weather conditions probably have an important influence on the number of pollen grains in the atmosphere. Such conditions influence both the development of pollen grains and their dispersion. The relief and height of relatively close areas can produce local microclimates, which explain the differences observed regarding the onset of flowering within the same species. Airborne pollen grains in the Bursa atmosphere and their pollen season periods were examined by Bicakci et al. (2003).

The aim of this study is to present the results of the airborne pollen concentration in the atmosphere of Bursa during a 2-year period (2003–2004) and to correlate these with some meteorological parameters. This study is of importance for the preparation of a 10-year pollen calendar for the Bursa atmosphere.

Materials and methods

Bursa is a city with tree million inhabitants, situated at 41°11′ N, 29°04′ E in north-western Turkey at an altitude of about 100 m above the sea level, located on a plain flanked by Mount of Uludag to the south and the Samanli Range to the north. A localization map was given in Fig. 1. Bursa has a Mediterranean vegetation and climate in general. The plain near the metropolitan district comprises an agricultural land for vineyards, plum, quince, peach, olive groves, and a land suitable for the growth of sunflower, tobacco, etc. In the Mount of Uludag and in the city center, the following species are found as dominant: *Laurus nobilis*, *Olea europaea*, *Juniperus oxycedrus*, *Cercis siliquastrum*, *Erica arborea*, *Castanea sativa*, *Ulmus minor*, *Ulmusglabra*, *Ulmuslaevis*, *Juglans regia*, *Corylus avellana*, *Quercus* sp., *Fagus orientalis*, *Carpinus betulus*, *Pinus nigra*, *Pinuspinea*, *Pinusbrutia*, *Abies nordmanniana* subsp. *bornmuelleriana*, *Juniperus nana*, *Vaccinium myrtillus*, *Thymus* sp., *Daphne oleoides*, and *Digitalis ferruginea*. In the Samanli Range, the local flora features Mediterranean elements such as *P. nigra*, *J. oxycedrus*, *Quercus* sp., *O. europaea*, and *L. nobilis.*

The semi-arid climate of Bursa is characterized by warm and dry summers and cold and wet winters. The mean annual temperature at Bursa is 14.4°C, and the mean annual precipitation amounts to 710 mm with little snow during

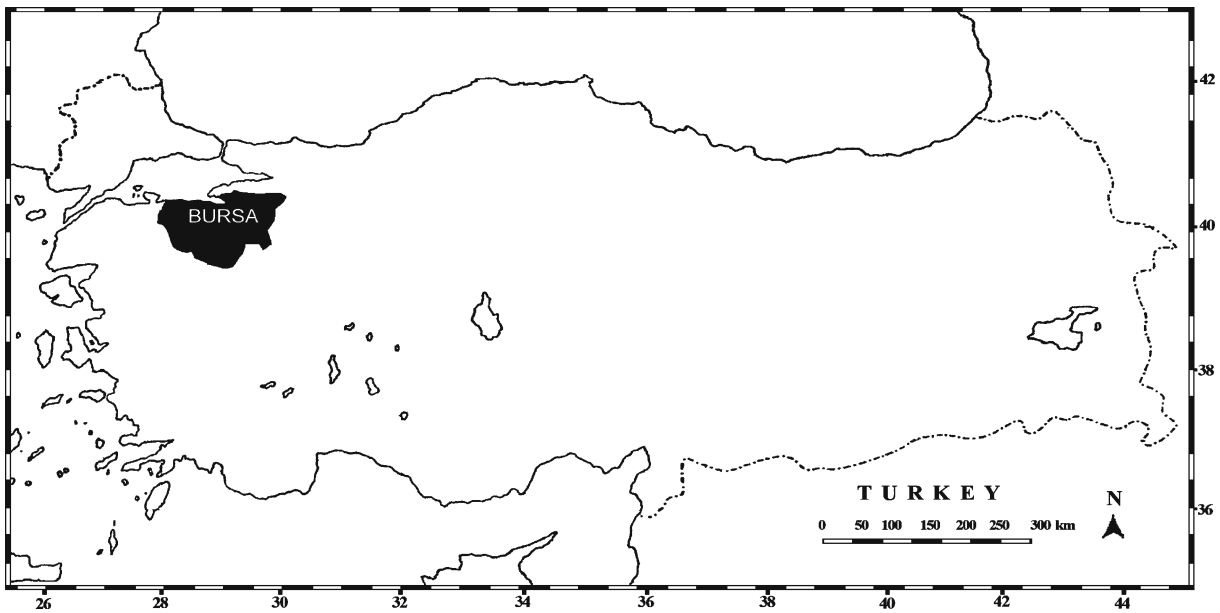


Fig. 1 Location map of Bursa

wintertime (Bulletin 1984; Bursa Valiligi 2007). The climate of Bursa is strongly influenced by the high elevation of Mount of Uludag. The major air movements over the city are observed mainly from northerly directions due to mountain–valley structure of the city. Climate in Bursa allows many plants to grow, flower, produce, and release pollen grains into the atmosphere at any time of the year.

Pollen sampling was carried out using a volumetric trap (VPPS 2000 Lanzoni, Bologna, Italy) placed about 25 m above ground level, on the roof of the Almira Hotel, which was located in the center of the city in a densely populated zone. The sampling method, slide preparation, and data interpretation were performed according to the standard method of the Italian Network for the Aerobiological Monitoring (D'Amato and Spieksma 1990), and pollen concentrations were expressed as number of pollen grains per cubic meter per day ($p/m^3/24$ h). The pollen was counted at a magnification of $\times 400$ in 24 transverse bands corresponding to every full hour, and total daily counts were converted into the number of pollen grains per cubic meter (m^3) of air. Pollen calendar for Bursa was given in the figures on the basis of 10-day means.

We have studied the characteristics of the pollination period of the nine most important and abundant allergenic pollen types by recording the dates of the beginning and end of the pollen season, maximum pollen counts, and duration of pollen season. In the study, daily mean air temperatures, daily amounts of precipitation, daily maximum wind speeds, and relative humidity were used. The relative humidity was measured at three climatological terms (at 7 A.M., 2 P.M., and 9 P.M. local time), and values were averaged as weighted means. To obtain the pollination period, we took into account the period covering 95% of total annual pollen, discarding the initial period until 2.5% is reached and the final period after reaching 97.5% (Andersen 1991). The meteorological data used for the study were supplied by the Turkish State Meteorological Service. Daily values of pollen and meteorological data for 2 years (2003–2004) were applied and analyzed together. The correlations between pollen concentrations during the main pollen season and the main meteorological parameters were calculated by means of the Spearman correlation test. SPSS 15.0 (2006) software packages were used for all statistical analyses (Longo et al. 2004; Docampo et al. 2007).

Results and discussion

During the 2-year period (2003–2004), a total of 57,124 pollen grains from 66 taxa (33,299 in 2003 and 23,825 in 2004) have been identified in the atmosphere of Bursa (Table 1). The highest percentages in relation to the annual total were obtained from April to June and peaked in May. Pollen grains of these months accounted for 83.94% of the recorded total pollen.

The main pollen producers in the atmosphere of Bursa were the following plants: *Pinus* sp. (21.37%), *Olea* sp. (12.55%), *Platanus* sp. (11.93%), Cupressaceae/Taxaceae (8.61%), *Quercus* sp. (8.10%), Moraceae (4.25%), and *Castanea* sp. (3.22%). Of herbaceous pollens, Poaceae (5.42%), Urticaceae (3.54%), and *Xanthium* sp. (1.54%) were also found in the atmosphere of Bursa (Table 1).

The earliest pollen grains in the atmosphere of Bursa were noted on the 1st of January. In January, pollen grains of *Corylus* sp. (0.36%), Cupressaceae/Taxaceae (0.27%), Poaceae (0.01%), Chenopodiaceae/Amaranthaceae (0.004%), and others (0.23%) were recorded. At the beginning of April, grasses (family Poaceae) began to blossom.

Number of pollen grains increased from February to April and reached its maximum level in May (40.81%). *Pinus* sp. (16.23%), *Quercus* sp. (6.25%), *Platanus* sp. (6.07%), Poaceae (2.23%), Cupressaceae/Taxaceae (1.95%), Moraceae (1.68%), *Olea* sp. (0.90%), Oleaceae (0.56%), Urticaceae (0.26%), and Chenopodiaceae/Amaranthaceae (0.03%) produced high amounts of pollen into the atmosphere throughout their pollination period and formed more than 40% of the total pollen grains in May. The pollen season identified in January was continued in February. Urticaceae and Cruciferae pollens were identified in the atmosphere, and *Corylus* sp. pollen reached high levels in the mid of February (Fig. 2).

Table 1 Annual totals of pollen counts, Bursa 2003–2004

	2003	2004	2003–2004	Percentage
Pinus	8,354	3,856	12,210	21.37
Olea	5,654	1,513	7,167	12.55
Platanus	3,893	2,922	6,815	11.93
Cupressaceae/Taxaceae	2,338	2,581	4,919	8.61
Quercus	3,501	1,128	4,629	8.10
Poaceae	1,611	1,486	3,097	5.42
Moraceae	768	1,660	2,428	4.25
Urticaceae	1,258	764	2,022	3.54
Castanea	982	857	1,839	3.22
Xanthium	205	673	878	1.54
Unidentified	282	587	869	1.52
Chenopodiaceae/Amaranthaceae	408	416	824	1.44
Oleaceae	344	432	776	1.36
Corylus	298	422	720	1.26
Plantago	164	383	547	0.96
Artemisia	238	292	530	0.93
Fraxinus	225	202	427	0.75
Fagus	137	282	419	0.73
Acer	28	388	416	0.73
Juglans	184	214	398	0.70
Rumex	147	249	396	0.69
Humulus	237	141	378	0.66
Asteraceae	135	221	356	0.62
Alnus	151	200	351	0.61
Mercurialis	185	166	351	0.61
Ericaceae	237	58	295	0.52
Salix	129	141	270	0.47
Leguminasae	43	227	270	0.47
Pistacia	97	93	190	0.33
Betulaceae	97	89	186	0.33
Umbelliferae	104	68	172	0.30
Rosaceae	30	130	160	0.28
Ailanthus	75	77	152	0.27
Cedrus	71	72	143	0.25
Cruciferae	60	74	134	0.23
Cyperaceae	64	65	129	0.23
Ulmus	66	50	116	0.20
Carpinus	63	50	113	0.20
Tilia	49	59	108	0.19
Populus	75	31	106	0.19
Betula	26	75	101	0.18
Typha	42	43	85	0.15
Taraxacum	24	55	79	0.14
Abies	21	48	69	0.12
Ostrya	26	30	56	0.10
Sanguisorba	11	31	42	0.07
Caryophyllaceae	14	24	38	0.07
Echium	15	22	37	0.06
Sophora	0	34	34	0.06
Papavearceae	10	24	34	0.06
Robinia	29	4	33	0.06
Rubiaceae	24	9	33	0.06
Ligustrum	18	14	32	0.06
Labiatae	0	28	28	0.05

Table 1 (continued)

	2003	2004	2003–2004	Percentage
Aesculus	13	12	25	0.04
Sambucus	16	3	19	0.03
Zea	1	12	13	0.02
Ranunculaceae	3	10	13	0.02
Helianthus	4	8	12	0.02
Boraginaceae	4	4	8	0.01
Campanulaceae	0	8	8	0.01
Juncaceae	4	3	7	0.01
Centaurea	4	0	4	0.01
Luzula	1	2	3	0.01
Convolvulaceae	1	1	2	0.004
Cistus	1	0	1	0.002
Onobrychis	0	1	1	0.002
Total	33,299	23,825	57,124	100.00

The pollen of the *Alnus* sp. reached high levels in the mid of March. A high airborne concentration of Cupressaceae/Taxaceae was measured in March 31, 2003 and in April 13, 2004 (Fig. 2 and Table 2). In July, the pollen grains of weeds became dominant. The most important taxa were found as Urticaceae (0.78%), *Castanea* sp. (0.49%), and Poaceae (0.48%). In the second half of July, the highly allergenic *Artemisia* sp. pollen began to be detected, and the air temperature continued to be warm (Figs. 2, 3, and 4).

Pollen grains of *Xanthium* sp. (0.97%), Chenopodiaceae/Amaranthaceae (0.57%), and Urticaceae (0.53%) in August, Chenopodiaceae/Amaranthaceae (0.48%) and *Xanthium* sp. (0.48%) in September, and Chenopodiaceae/Amaranthaceae (0.08%) and Poaceae (0.07%) in October were recorded as predominant taxa. In November and December, only a few pollen grains, such as Cupressaceae/Taxaceae, were recorded (Figs. 2, 5, and 6).

Pollens in the atmosphere of Bursa are shown in the form of a pollen calendar (Fig. 2) based on the mean pollen counts concerning the years 2003 and 2004. The calendar shows each taxon's mean 10-day value during the study period, calculated on the basis of the 10-day averages of each year.

In the period examined, the following nine taxa produced the greatest (equal or more than 3%) amounts of pollen grains in the atmosphere of Bursa (Fig. 2 and Table 2).

Pinus sp. The pollen season started at the beginning of March and ended at the end of September. The highest values were noted from the middle of April to the middle of June.

Olea sp. The pollen season started in the middle of April and ended in the last days of July. The peak values were noted in the first days of June and mid-June.

Platanus sp. The pollen season was relatively short. It started in the last days of March and ended in the last days of May. The highest counts were recorded between the beginning of April and the middle of May.

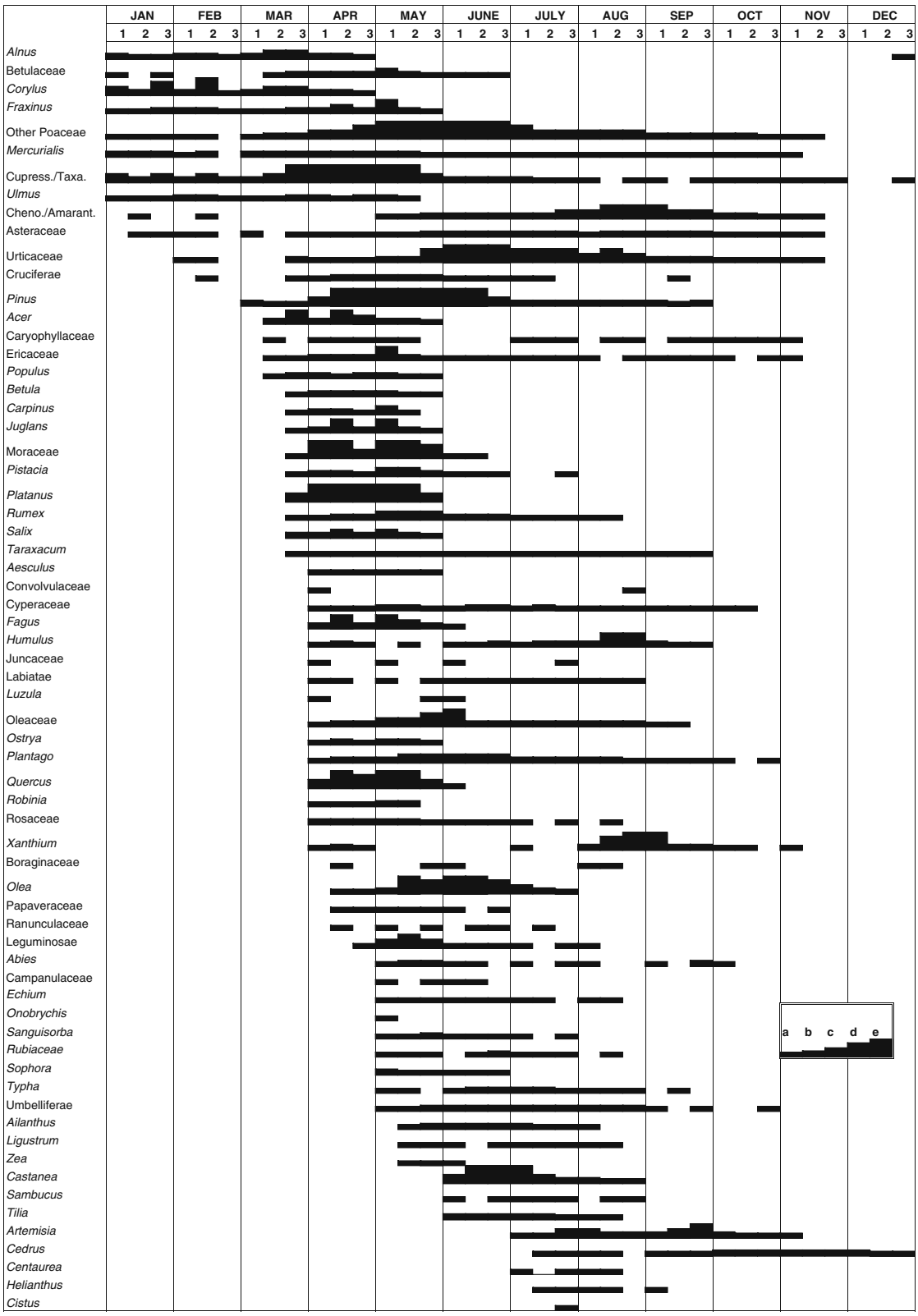
Cupressaceae/Taxaceae Pollen grains of these families were recorded thought all year. The highest counts were recorded from March to May.

Quercus sp. Pollen release continued from the beginning of April to the beginning of June. The highest counts were recorded from mid-April to mid-May.

Poaceae Pollen grains were recorded during the greater part of the year, from January to November. The highest counts were recorded in May and June.

Moraceae The pollen season started at the end of March and ended in the middle of June. The peak value was observed in April and May.

Urticaceae Pollen grains were recorded during the greater part of the year, from February to


JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEP
OCT
NOV
DEC
1 2 3
Alnus
Betulaceae
Corylus
Fraxinus
Other Poaceae
Mercurialis
Cupress./Taxa.
Ulmus
Cheno./Amarant.
Asteraceae
Urticaceae
Cruciferae
Pinus
Acer
Caryophyllaceae
Ericaceae
Populus
Betula
Carpinus
Juglans
Moraceae
Pistacia
Platanus
Rumex
Salix
Taraxacum
Aesculus
Convolvulaceae
Cyperaceae
Fagus
Humulus
Juncaceae
Labiatae
Luzula
Oleaceae
Ostrya
Plantago
Quercus
Robinia
Rosaceae
Xanthium
Boraginaceae
Olea
Papaveraceae
Ranunculaceae
Leguminosae
Abies
Campanulaceae
Echium
Onobrychis
Sanguisorba
Rubiaceae
Sophora
Typha
Umbelliferae
Ailanthus
Ligustrum
Zea
Castanea
Sambucus
Tilia
Artemisia
Cedrus
Centaurea
Helianthus
Cistus
a b c d e
a: 1-9
b: 10-49
c: 50-99
d: 100-199
e: 200>

◀ **Fig. 2** Pollen calendar of Bursa, 2003–2004 (*1–2–3*: first, second, and third decade of months; *a–e* number of pollen grains)

November. The highest counts were recorded from the end of May to the middle of August.

Castanea sp. The pollen season started in the first days of June and ended in the last days of August. The highest values were recorded from mid-June to the first days of July.

In April, there were 2 days of very high airborne pollen concentrations in 2004, which were due to the *Platanus* sp. and *Pinus* sp. pollen grains in the atmosphere (Table 2). In the year 2003, monthly mean air temperature of April was lower than the past 27-year average air temperature, and the total counts of pollen grains in April exceeded those recorded in the year 2004 (Figs. 5 and 6).

In May, pollen grains of *Pinus* sp. predominated with high airborne concentrations throughout the month. Forty-five pollen taxa in 2003 and 54 pollen taxa in 2004 were identified in May. Pollen concentrations of some taxa such as *Quercus* sp., Gramineae, and Moraceae reached maximum level on the 5th of May 2003, when the mean air temperature was 19.4°C (Fig. 4 and Table 2). Pollen of Urticaceae, *Castanea* sp., and *Olea* sp. reached their peak values in June (Table 2).

Concerning total pollen counts, in 2003, three peaks were observed, with the highest one at the beginning of May. On the other hand, in 2004, two peaks were observed with the highest one in April (Figs. 3 and 4). The observed synchronism related to the variations of pollen concentration, the mean temperature, and rainfall is important. During the sampling period, more dispersal rainfall was observed, which affected the continuity of the pollen spectrum. As it can be seen in Figs. 4 and 5, when it rains, there is a substantial decrease in the total quantity of pollen concentration.

Pollen concentrations throughout the study period were largely determined by meteorological differences during the flowering periods of the sampled years. Variations in the airborne pollen concentrations greatly depend on the weather conditions. The individual rhythms of plant pollination and phenological phenomena are modified by the effects of weather conditions (Bringfelt 1982; Emberlin et al. 1993; Frenguelli et al. 1991). In the year 2003, after the warmer period that started in May and continued till August, September was just 2°C colder than that of the 27-year average. In the first half of September, high *Xanthium* sp. pollen levels were still present in the air. From October 1 onward, concentrations of all the pollens (grass, herbaceous plants of the nettle family, and *Artemisia* sp.) were low. In this period, it rained steadily for days, and the temperature declined (Figs. 3 and 5).

Rainfall, wind speed, and relative humidity are the most influential meteorological parameters affecting the airborne pollen counts. While relative humidity was negatively correlated with *Platanus* sp., Poaceae, Urticaceae, and *Castanea* sp., it was positively correlated with Moraceae (Table 3). For pollen grains of Urticaceae family, there was a significant positive correlation between the pollen counts and mean temperature (99% probability) and wind speed (95% probability). For pollen grains of *Castanea* sp., the correlation was negative and significant with the mean temperature, wind speed, and relative humidity in 95% probability (Table 3). Since pollen grains are highly hygrophilous cells, 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, the amount of pollen in the atmosphere decreases. The correlation between the daily pollen concentration and relative humidity was often negative and weak; in fact, some of them were not significant (Table 3).

Rainfall was negatively correlated with most of the taxa (Table 3). Precipitation reduces the air pollen concentration both by passively dragging pollen to the ground and by hydrating them and consequently increasing their weight and deposing them to the ground by gravity. Figures 3 and 4 show that between March and July, when precipitation increases, the number of pollen grains suspended in the atmosphere decreases. In fact, the correlation between daily pollen concentration and precipitation are often negative.

The correlation between daily pollen concentration and temperature (daily mean) was negative except for *Platanus* sp., Poaceae, and Urticaceae. In relation to mean temperature, a

Table 2 Characteristics of the most important taxa: start and ending dates, length, maximum value and its date, total pollen count and number of days with pollen concentration over an allergenic significant value

Species	Characteristics	2003	2004
Olea spp.	Pollen season	11May–23Jul	12Apr–30Jul
	Duration of pollen season	74	110
	Maximum—day	1,347—9Jun	237—4Jun
	Total pollen counts	5,654	1,513
	Days, 1–15 pollen/m^3	25	35
	Days, 16–90 pollen/m^3	10	22
	Days, 91–1,500 pollen/m^3	13	3
Platanus spp.	Pollen season	12Apr–30May	23Mar–27May
	Duration of pollen season	49	66
	Maximum—day	687—3May	436—12Apr
	Total pollen counts	3,893	2,922
	Days, 0–15 pollen/m^3	15	29
	Days, 16–90 pollen/m^3	14	9
	Days, 91–1,500 pollen/m^3	8	11
Cupress./Taxaceae	Pollen season	1Jan–23Nov	7Jan–29Dec
	Duration of pollen season	328	357
	Maximum—day	745—31Mar	575—13Apr
	Total pollen counts	2,324	2,581
	Days, 1–15 pollen/m^3	131	125
	Days, 16–90 pollen/m^3	27	23
	Days, 91–1,500 pollen/m^3	3	6
Quercus ssp.	Pollen season	11Apr–29May	1Apr–2Jun
	Duration of pollen season	49	63
	Maximum—day	719–5May	241–13Apr
	Total pollen counts	3,501	1,128
	Days, 1–15 pollen/m^3	23	44
	Days, 16–90 pollen/m^3	10	14
	Days, 91–1,500 pollen/m^3	11	3
Graminea	Pollen season	4Feb–1Nov	8Jan–14Nov
	Duration of pollen season	271	311
	Maximum—day	75—5May	83—24May
	Total pollen counts	1,611	1,486
	Days, 1–5 pollen/m^3	137	118
	Days, 6–20 pollen/m^3	41	86
	Days, 21–200 pollen/m^3	22	12
Moraceae	Pollen season	26Apr–11Jun	21Mar–13Jun
	Duration of pollen season	47	85
	Maximum—day	96—5May	313—12Apr
	Total pollen counts	768	1,660
	Days, 1–15 pollen/m^3	25	26
	Days, 16–90 pollen/m^3	14	13
	Days, 91–1,500 pollen/m^3	1	5
Urticaceae	Pollen season	1Feb–26Sep	14Feb–13Nov
	Duration of pollen season	208	273
	Maximum—day	48—23Jul	33—3Jun
	Total pollen counts	1,258	797
	Days, 1–10 pollen/m^3	90	142
	Days, 11–50 pollen/m^3	41	29
Castanea sp.	Pollen season	8Jun–29Aug	1Jun–22Aug
	Duration of pollen season	83	83
	Maximum—day	109–18Jun	82–14Jun
	Total pollen counts	982	857
	Days, 1–15 pollen/m^3	50	30
	Days, 16–90 pollen/m^3	20	18
	Days, 91–1,500 pollen/m^3	1	–

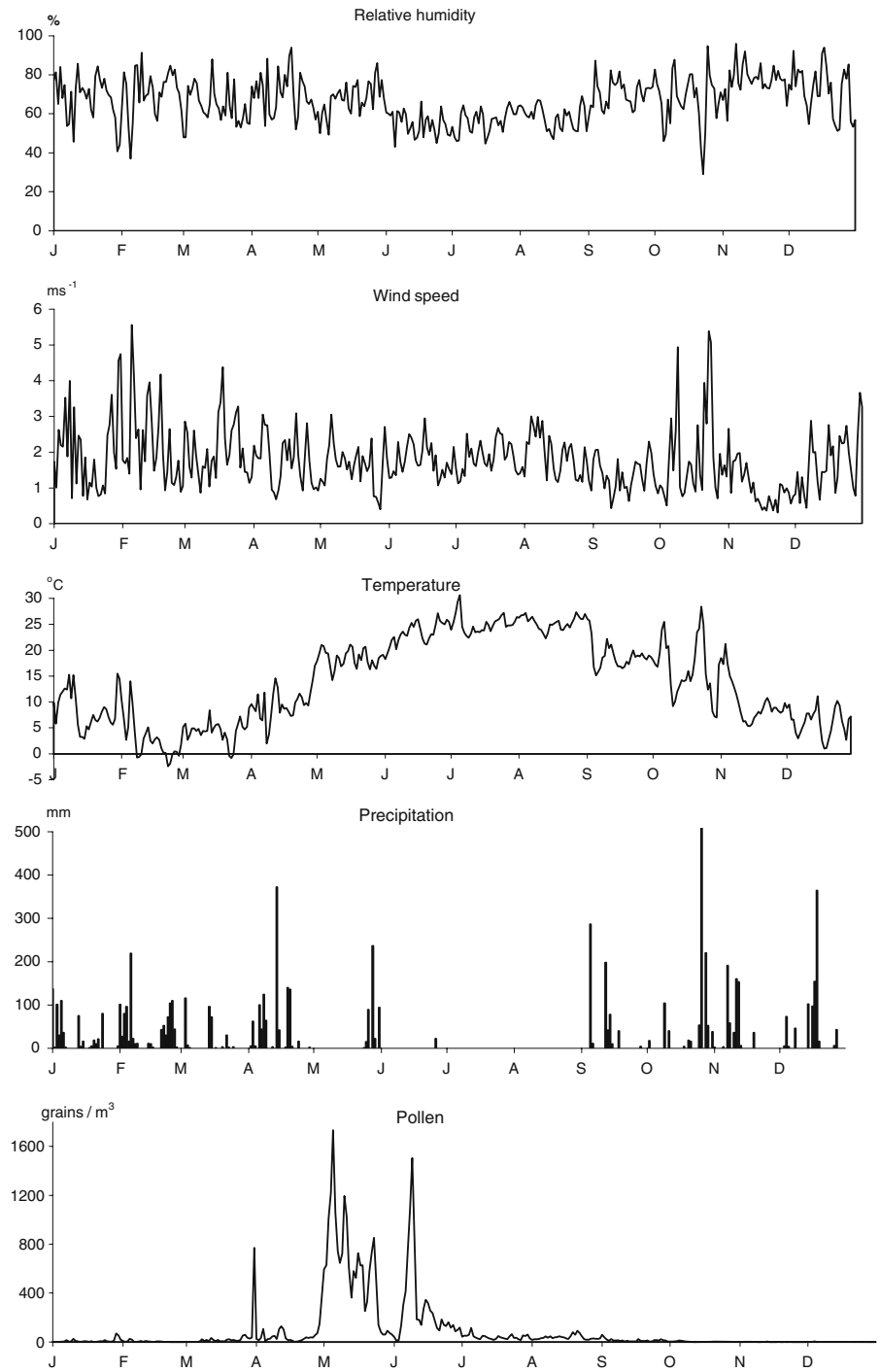


Fig. 3 Annual variation of relative humidity, wind speed, temperature, rainfall, and pollen concentrations of the year 2003

positive correlation and 99% significant values were obtained in the case of the main pollination periods of Urticaceae. On the other hand, a negative correlation and 95% significant values were obtained in the case of the main pollination period of *Castanea* sp. (Table 2). Consequently, the source of pollen has practically been exhausted due to the longer duration of its post-peak period in relation to other taxa. Similarly, Rodriguez-Rajo et al. (2003) found a positive

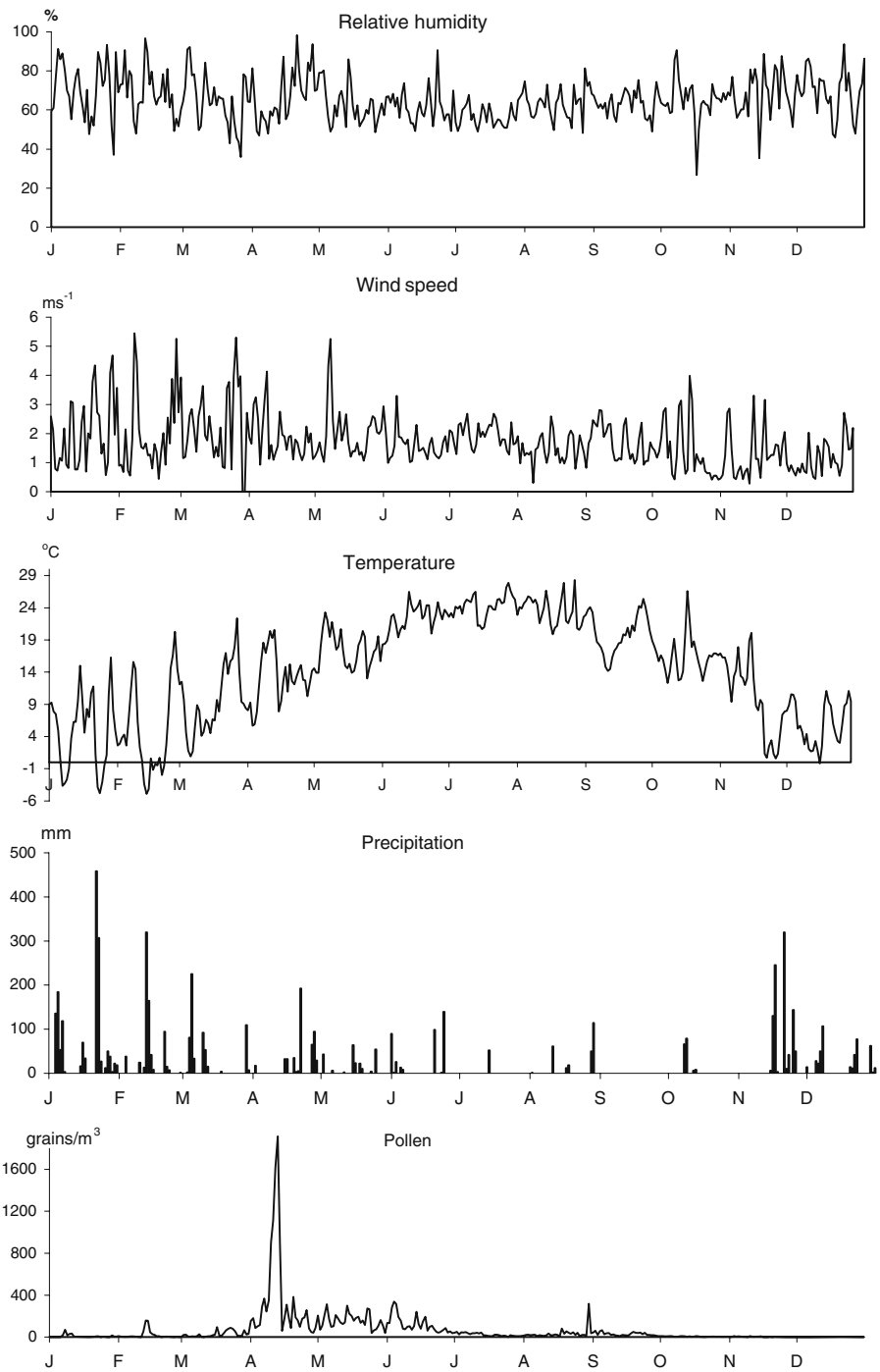
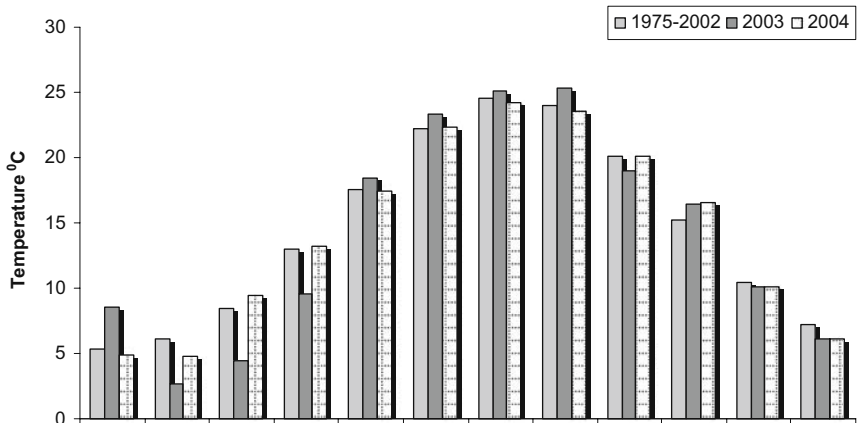


Fig. 4 Annual variation of relative humidity, wind speed, temperature, rainfall, and pollen concentrations of the year 2004

correlation with temperature and main pollination periods of Urticaceae. In relation to wind speed, there was a significant positive correlation concerning Urticaceae and a significant but negative correlation concerning *Castanea* sp. (Table 3).

There were year-on-year differences in weather conditions, with higher rainfall and more rainy days in 2004 between January and April; this may have exerted the washing-out effect on airborne pollen frequently noted in aerobiological studies.

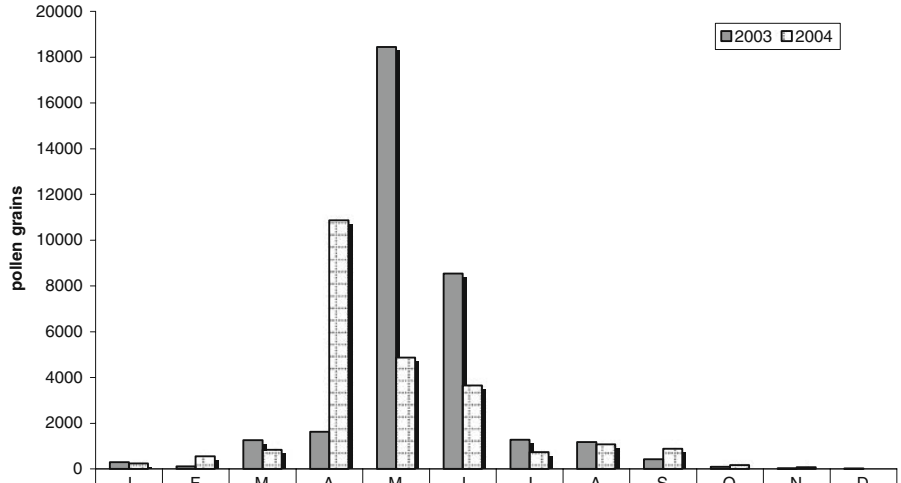


	J	F	M	A	M	J	J	A	S	O	N	D
1975-2002	5,37	6,06	8,43	13,03	17,53	22,23	24,52	24,01	20,13	15,26	10,43	7,26
2003	8,55	2,70	4,39	9,60	18,45	23,33	25,06	25,35	18,97	16,39	10,14	6,16
2004	4,89	4,80	9,47	13,18	17,45	22,38	24,28	23,53	20,11	16,54	10,06	6,11

Fig. 5 Monthly average air temperatures in Bursa in 2003–2004 (from January to October) compared to the long-term means (1975–2002)

The total annual pollen count was lower in 2004 (Table 1). Fluctuations in pollen production may account for the biannual or triennial cycles widely reported for airborne pollen (Detandt and Nolard 2000; Latalowa et al. 2002). Weather conditions during the flowering period in 2003 were more favorable for the release and dispersal of pollen grains.

Aerobiological research must take into account not only the phenological data but also other environmental variables, including topographical factors, pollen production, ability of the pollen grain to be transported over long distances, distance of the sampler from the source, and their contribution to airborne pollen counts in space and time. Topographical characteristics must also be taken into account when considering pollen transport; a sampling station located at a high altitude can detect pollen transported from lower areas (Gehrig and Peeters 2000). The topography of the study area is characterized by high mountains (up to 2,500 m) with a steep slope down to the



	J	F	M	A	M	J	J	A	S	O	N	D
2003	302	115	1263	1627	18443	8542	1274	1175	419	93	30	20
2004	234	543	841	10866	4867	3644	732	1073	874	163	74	2

Fig. 6 Monthly average pollen grains in Bursa atmosphere, 2003–2004

Table 3 Correlation coefficients between the pollen concentration and the main meteorological parameters by using the Spearman correlation test

	Pinus	Olea	Platanus	Cupress/Tax.	Quercus	Graminea	Moraceae	Urticacea	Castanea
Mean temp.	−0.081	−0.074	0.168	−0.108	−0.055	0.053	−0.031	0.186**	−0.146*
Relative humidity	0.022	−0.142	−0.229*	0.056	0.126	−0.178**	0.190*	−0.272**	−0.229*
Rainfall	−0.190	−0.168	−0.346	−0, 099	0.234	−0.077	0.061	−0.122	0.125
Wind speed	0.046	0.009	0.040	−0.001	−0.055	0.053	−0.031	0.153**	−0.226*

* $p = 0.95$ significance; ** $p = 0.99$ significance

Nilufer River. The marked variations in altitude give rise to considerable climatic diversity over relatively short distances. In that manner, pollen from plants located at lower altitudes, even at some distance from the trap, may be transported into the sampling area, prompting the start of the airborne pollen season prior to the onset of flowering period.

Some of pollen grains found in high concentrations in Bursa were also found as dominant in the other European cities (Spieksma et al. 1991; Romano et al. 1988; Koivikko et al. 1986; Kasprzyk 1996; Jato et al. 2002, Table 4). The frequency of pollen grains in the atmosphere of Bursa generally depends on the distribution and density of the local vegetation and the rate of pollen production. According to the other studies carried out in neighbor cities to Bursa, similar pollen types such as *Pinus* sp., Cupressaceae/Taxaceae, Gramineae, *Platanus* sp., *Quercus* sp., *Olea* sp., *Salix* sp., Urticaceae, Moraceae, *Plantago* sp., Chenopodiaceae/Amaranthaceae, *Ailanthus* sp., *Juglans* sp., *Carpinus* sp., and Rosaceae in Balikesir (Bicakci and Akyalcin 2000), Gramineae, *Pinus* sp., Quercus sp., Cupressaceae/Taxaceae, *Salix* sp., *Platanus* sp., *Populus* sp., *Carpinus* sp., *Fagus* sp., Chenopodiaceae/Amaranthaceae, *Xanthium* sp., Moraceae, *Corylus* sp., *Fraxinus* sp., and Urticaceae in Sakarya (Bicakci 2006), and *Pinus* sp., Gramineae, Cupressaceae/Taxaceae, *Platanus* sp., Chenopodiaceae/Amaranthaceae, *Quercus* sp., *Ailanthus* sp., Moraceae, *Juglans* sp., *Salix* sp., *Cedrus* sp., and Rosaceae in Afyon (Bicakci et al. 2002) were found as dominant.

Although pollen causes a wide range of reactions in allergy sufferers, different values have been pointed out as thresholds for triggering allergic symptoms. These values, attained in the atmosphere of Bursa during 2003–2004, were shown in Table 5. For trees, the values of 16 to 90 grains/m^3, which produce symptoms in many individuals sensitive to these pollens, were attained in 52 days during 2003 and 49 in days during 2004. For grasses, the values of 6 to 20 grains/m^3, which produce symptoms in many individuals sensitive to these pollens, were attained in 47 days during 2003 and in 80 days during 2004. For weeds, the values of 11 to 50 grains/m^3 were attained in

Table 4 Dominant pollen taxa in Bursa and other European cities (the numbers refer to references, 1: Spieksma et al. 1991; 2: Romano et al. 1988; 3: Koivikko et al. 1986; 4: Kasprzyk 1996; 5: Jato et al. 2002)

Taxa	City							
	Bursa—2007	Leiden (1)	Brussels (1)	Vienna (1)	Ascoli and Piceno (2)	Jyvaskylan (3)	Ostrowiec (4)	Santiago de Compostela (5)
Pinus sp./Pinaceae	+	–	+	–	–	+	–	+
Olea sp./Oleaceae	+	–	–	–	+	–	–	–
Platanus sp.	+	–	+	–	–	–	–	+
Cupressaceae/ Taxaceae	+	–	–	–	–	–	–	–
Quercus sp.	+	–	–	+	–	+	–	+
Graminea	+	+	–	+	+	+	+	+
Moraceae	+	–	–	–	–	–	–	–
Urticaceae	+	+	–	+	+	–	–	–
Castanea sp.	+	–	–	–	–	–	–	–

Table 5 The days of pollen density of different pollen types for Bursa, 2003–2004 (according to Forsyth County Environmental Affairs Department Pollen Rating Scale; Weber (1998)

Pollen grains/m^3	Trees								Grasses						Weeds					
	1–15[a]		16–90[b]		91–1,500[c]		>1,500[d]		1–5[a]		6–20[b]		21–200[c]		1–10[a]		11–50[b]		51–500[c]	
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
January	25	17	4	10	10	–	–	–	–	6	–	–	–	–	25	10	–	–	–	–
February	17	21	2	–	–	2	–	–	5	1	–	–	–	–	13	7	–	–	–	–
March	18	19	12	1	1	–	–	–	11	19	–	1–	–	–	18	23	–	1	–	–
April	8	–	16	6	–	19	–	2	21	11	1	19	1–	–	26	17	–	13	–	–
May	–	–	6	24	6	18	1	–	2	3	15	22	14	6	4	2	21	29	6	–
June	2	1	10	18	–	8	–	–	1	4	22	20	7	6	3	–	24	30	3	–
July	21	29	10	–	24	–	–	–	23	17	8	14	–	–	3	17	26	13	2	–
August	31	25	–	–	18	–	–	–	30	28	1	3	–	–	1	8	27	20	3	3
September	21	25	–	–	–	–	–	–	27	29	–	1	–	–	19	5	11	22	–	3
October	16	26	–	–	–	–	–	–	14	21	–	–	–	–	21	31	–	–	–	–
November	19	21	–	–	–	–	–	–	1	4	–	–	–	–	–	12	–	–	–	–
December	14	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

[a]Low

[b]Moderate

[c]High

[d]Very high

109 days during 2003 and in 128 days during 2004 (Table 2 and 5).

Concerning the values of average daily concentrations of pollen, we can highlight two periods of special importance for people allergic to pollens (Figs. 3 and 4). The first corresponds to the spring and beginning months of summer in which there is an important presence in the atmosphere of *Platanus* sp., *Pinus* sp., *Quercus* sp., and Cupressaceae/Taxaceae all of which are highly allergenic. The second corresponds to the last of summer (August) and the beginning of autumn (September).

In the city of Bursa, the risk for individuals sensitive to pollens begins in January, when moderate to high concentrations of allergenic tree pollens (*Alnus* sp., *Corylus* sp., plants of the families Cupressaceae/Taxaceae, Poaceae, Betulaceae) are present in the air. The results of the present study are consistent with those taken in central Italy and Switzerland, where pollens of the trees of the Betulaceae family predominate at this time of year (Lejoly-Gabriel and Leuschner 1983; Spieksma et al. 1989a). The pattern continues in February and March. During the study years, pollen concentrations in the city of Bursa have gradually increased starting from March, attaining a maximum peak in May, due to high concentrations of *Pinus* sp. Many rainy days reduced the airborne pollen concentrations in April. The highly allergenic grass pollen predominated with very high air concentrations in May and June, causing great problems to those allergic to this pollen type, as in other central and eastern European countries, where grass pollen accounts for as much as 50% of the total airborne pollen (Spieksma et al. 1989b). The extremely long grass pollen season results from the variable timing of the blossom for numerous genera of the Poaceae family. A similar situation arises with a member of the Urticaceae family. Because of its long pollen season and high levels of pollen, sensitive patients experience long-lasting symptoms that can be quite severe and difficult to treat (Cvitanovic et al. 1986; Cvitanovic and MaruÐic 1994; Makra et al. 2004, 2006, 2007). Pollen of the herbaceous plants of the Urticaceae predominated in July, whereas pollen of the most allergenic plant in the area, *Artemisia* sp., prevailed in August and September.

Conclusion

This study consists of some preliminary results of a project, which was planned for a 10-year period. In the coming article, we aim to make a 10-year calendar and correlation analysis with meteorological parameters for important allergenic pollen taxa, a model for forecasting airborne pollen and predicting days of high allergenic risk for Bursa. The presence of atmospheric pollen in the city of Bursa throughout the year shows seasonal variability. More than half of the total annual pollen was recorded in the months of April and May. Pollen grains of 66 taxa were identified during the pollen season in the atmosphere of Bursa, and nine of them constituted about 78.99% of the spectrum. The pollen calendar for the region presented in this paper may be useful for allergologists to make an exact diagnosis.

Acknowledgements We are grateful to Mr. Hasan Tatlidil, Mr. Fahrettin Celenk, and the staff of the Almira Hotel for various kinds of help.

References

Altunoglu, M. K., Bicakci, A., Celenk, S., Canitez, Y., Malyer, H., & Sapan, N. (2008). Airborne pollen grains in Yalova, Turkey, 2004. *Biologia*, *63*(5), 658–663. doi:10.2478/s11756-008-0118-8.

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

Ballero, M., & Maxia, A. (2003). Pollen spectrum variations in the atmosphere of Calgari, Italy. *Aerobiologia*, *19*, 251–259. doi:10.1023/B:AERO.0000006601.64507.3f.

Bicakci, A. (2006). Analysis of airborne pollen fall in Sakarya, Turkey. *Biologia*, *61*, 457–461. doi:10.2478/s11756-006-0076-y.

Bicakci, A., & Akyalcin, H. (2000). Analysis of airborne pollen fall in Balikesir, Turkey, 1996–1997. *Annals of Agricultural and Environmental Medicine*, *7*, 5–10.

Bicakci, A., Ergun, S., Tatlidil, S., Malyer, H., Ozyurt, S., Akkaya, A., et al. (2002). Airborne pollen grains of Afyon, Turkey. *Acta Botanica Sinica*, *44*(11), 1371–1375.

Bicakci, A., Koc, R. D., Tatlidil, S., & Benlioglu, O. N. (2004). Analysis of airborne pollen in Usak, Turkey. *Pakistan Journal of Botany*, *36*(4), 711–717.

Bicakci, A., Tatlidil, S., Sapan, N., Malyer, H., & Canitez, Y. (2003). Airborne pollen grains in Bursa, Turkey, 1999–2000. *Annals of Agricultural and Environmental Medicine*, *10*, 31–36.

Bringfelt, B. (1982). An evaluation of some models to predict airborne pollen concentration from meteorological conditions in Stockholm, Sweden. *Grana*, *21*, 59–64.

Bulletin (1984). *Ortalama, Ekstrem Sıcaklık ve Yağış Değerleri. T.C. Basbakanlik Devlet Meteoroloji Isleri Genel Mudurlugu*, Ankara, pp. 152–156.

Bursa Valiligi, T. C. (2007). Retrieved September 27, from http://www.bursa.gov.tr/tanitim/cografi.asp.

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

Cvitanovic, S. & MaruÐic, M. (1994). Hypersensitivity to pollen allergens on the Adriatic coast. *J Invest Allergol. Clinical Immunology (Orlando, Fla.)*, *4*, 96–100.

Cvitanovic, S., MaruÐic, M., Zekan, L., & Kohler-Kubelka, N. (1986). Allergy induced by *Parietaria* pollen in Southern Croatia. *Allergy*, *41*, 543–545. doi:10.1111/j.1398-9995.1986.tb00341.x.

D'Amato, G., & Spieksma, F. T. M. (1990). Allergenic pollen in Europe. *Grana*, *30*, 67–70.

Detandt, M., & Nolard, N. (2000). The fluctuations of the allergenic polen content of the air in Brussels (1982 to 1997). *Aerobiologia*, *16*, 55–61. doi:10.1023/A:1007619724282.

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. doi:10.1007/s10453-007-9063-1.

Emberlin, J., Savage, M., & Woodman, R. (1993). Annual variations in the concentrations of Betula pollen in the London area, 1961–1990. *Grana*, *32*, 359–363.

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*, 196–200.

Gehrig, R., & Peeters, A. G. (2000). Pollen distribution at elevations above 1000 m in Switzerland. *Aerobiologia*, *16*, 69–74. doi:10.1023/A:1007607121614.

Jato, V., Dopazo, A., & Aira, M. J. (2002). Influence of precipitation and temperature on airborne pollen concentration in Santiago de Compostela (Spain). *Grana*, *41*, 232–241. doi:10.1080/001731302321012022.

Jones, A. M., & Harrison, R. M. (2004). The effects of meteorological factors on atmospheric bioaerosol concentrations—a review. *The Science of the Total Environment*, *326*(1–3), 151–180. doi:10.1016/j.scitotenv.2003.11.021.

Kasprzyk, I. (1996). Palynological analyses of airborne pollen fall in Ostrowiec Swietokrzyski in 1995. *Annals of Agricultural and Environmental Medicine*, *3*, 83–86.

Koivikko, A., Kupias, R., Makinen, Y., & Pohjola, A. (1986). Pollen seasons: Forecasts of the most important allergenic plants in Finland. *Allergy*, *41*, 233–242. doi:10.1111/j.1398-9995.1986.tb02023.x.

Latalowa, M., Mietus, M., & Uruksa, A. (2002). Seasonal variations in the atmosphere Betula pollen count in Gdańsk (southern Baltic coast) in relation to meteorological parameters. *Aerobiologia*, *18*, 33–43. doi:10.1023/A:1014905611834.

Lejoly-Gabriel, M., & Leuschner, R. M. (1983). Comparison of airborne pollen at Louvain-la-Neuve (Belgium) and Basel (Switzerland) during 1979 and 1980. *Grana*, *22*, 59–64.

Leuschner, R. M., Christen, H., Jordan, P., & Vonthein, R. (2000). 30 years of studies of grass pollen in Basel (Switzerland). *Aerobiologia*, *16*, 381–391. doi:10.1023/A:1026528223020.

Longo, L. R., Sauli, M. P., & Ganis, P. (2004). Aerobiology of Urticaceae pollen in Trieste (NE Italy). *Aerobiologia*, *20*, 53–61. doi:10.1023/B:AERO.0000022982.22908.27.

Makra, L., Juhász, M., Borsos, E., & Béczi, R. (2004). Meteorological variables connected with airborne ragweed pollen in Southern Hungary. *International Journal of Biometeorology*, *49*(1), 37–47. doi:10.1007/s00484-004-0208-4.

Makra, L., Juhász, M., Mika, J., Bartzokas, A., Béczi, R., & Sümeghy, Z. (2006). An objective classification system of air mass types for Szeged, Hungary with special attention to plant pollen levels. *International Journal of Biometeorology*, *50*(6), 403–421. doi:10.1007/s00484-006-0026-y.

Makra, L., Juhász, M., Mika, J., Bartzokas, A., Béczi, R., & Sumeghy, Z. (2007). Relationship between the Péczely's large-scale weather types and airborne pollen grain concentrations for Szeged, Hungary. *Grana*, *46*(1), 43–56. doi:10.1080/00173130601080704.

Rodriguez-Rajo, F. J., Jato, V., & Aira, M. J. (2003). Pollen content in the atmosphere of Lugo (NW Spain) with reference to meteorological factors (1999–2001). *Aerobiologia*, *19*, 213–225. doi:10.1023/B:AERO.0000006527.12928.26.

Romano, B., Mincigrucci, G., Frenguelli, G., & Bricchi, E. (1988). Airborne pollen content in the atmosphere of Central Italy (1982–1986). *Experientia*, *44*, 625–629. doi:10.1007/BF01953320.

Spieksma, F. Th. M., Frenguelli, G., Nikkels, A. H., Mincigrucci, G., Smithvis, L. O. M. J., Bricchi, E., et al. (1989a). Comparative study of airborne pollen concentrations in central Italy and The Netherlands, 1982–1985. *Grana*, *28*, 25–36.

Spieksma, F. Th. M., D'Amato, G., Mullins, J., Nolard, N., Wachter, R., & Weeke, E. R. (1989b). City spore concentrations in the European Economic Community (ECC). VI. Poaceae (grasses) 1982–1986. *Aerobiologia*, *5*, 38–43. doi:10.1007/BF02446486.

Spieksma, F. Th. M., Nolard, N., & Jager, S. (1991). Fluctuations and trends in airborne concentrations of some abundant pollen types, monitored at Vienna, Leiden and Brussels. *Grana*, *30*, 309–312.

SPSS (2006). S*tatistical package for social sciences, version 15.0*. Chicago: SPSS.

Stennett, P. J., & Beggs, P. J. (2004). Pollen in the atmosphere of Sydney, Australia, and relationships with meteorological parameters. *Grana*, *43*(4), 209–216. doi:10.1080/00173130410000758.

Weber, R. W. (1998). Pollen identification. *Annals of Allergy, Asthma & Immunology*, *80*, 235–240.

Weiss, S. T. (2002). Eat dirt—the hygiene hypothesis and allergic diseases. *The New England Journal of Medicine*, *347*, 930–931. Editorial. doi:10.1056/NEJMe020092.