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ORIGINAL PAPER

A 2-year aeropalynological survey of allergenic pollen in the atmosphere of Kastamonu, Turkey

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Abstract Knowledge of airborne pollen concentrations and the weather conditions influencing them is important for air quality forecasters, allergists and allergy sufferers. For this reason, a 7-day recording volumetric spore trap of the Hirst design was used for pollen monitoring between January 2006 and December 2007 in Kastamonu, Turkey. A total of 293,427 pollen grains belonging to 51 taxa were recorded during the study period. In the 2 years of study, the period March–August was identified as the main pollination season for Kastamonu. The highest monthly pollen counts were observed in May in both years. Six taxa made up 86.5% of the total amount of pollen recorded in the atmosphere of Kastamonu. These were as follows: Pinaceae (42.9%), Cupressaceae (20.6%), Poaceae (9.7%), *Quercus* (5.5%) *Betula* (5.3%) and *Carpinus* (2.6%). Four of these are considered to be highly allergenic (*Betula*, *Carpinus*, Cupressaceae and Poaceae). There were also a greater percentage of highly allergenic taxa found within the city, including *Betula pendula* that is not part of the local flora. This shows that through urban planting, the public and municipalities can unconsciously create a high risk for allergy sufferers. Daily average pollen counts from the six most frequently recorded pollen types were entered into Spearman's correlation analysis with meteorological data. Mean daily temperature, relative humidity, daily rainfall and wind speed were found to significantly ($p < 0.05$) affect atmospheric pollen concentrations, but the relationships between pollen concentrations and meteorological variables can vary and so there is a need for more local studies of this nature.

Keywords Aerobiology · Pollen calendar · Correlation analysis · Vegetation survey · Allergy

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1 Introduction

Pollen grains from wind-pollinated, anemophilous, plants are the most important source of allergens in the atmosphere. According to recent researches, the prevalence of pollen allergy in Europe is estimated to be about 40% (D'Amato et al. 2007). Atmospheric pollen grains trigger allergic attacks such as rhinitis and asthma in atopic individuals. Many studies have

therefore examined the relationship between airborne pollen concentrations and allergy (Altintas et al. 2004; Ozturk et al. 2004; Celik et al. 2005; Dursun et al. 2008; Ribeiro et al. 2009; Can et al. 2010).

Pollen grains are seasonal aeroallergens but can be found in the atmosphere almost all year round in certain biogeographical regions due to differences in the pollination periods of plants. The pollen content of the atmosphere varies according local flora, climate, meteorological factors and the season (Bush 1989; Jato et al. 2002; Gioulekas et al. 2004). After setting up a pollen-monitoring site, one of the first tasks undertaken by the operator is to produce a calendar that describes the seasonal variations in atmospheric pollen recorded at the location. Such pollen calendars have been prepared for many cities in Turkey (Ince 1994; Inceoğlu et al. 1994; Pehlivan and Butev 1994; Guvensen and Ozturk 2003; Ayvaz et al. 2008; Celenk et al. 2010; Erkan et al. 2010) and elsewhere (Nilsson et al. 1977; Goldberg et al. 1988; Dreissen and Derksen 1989; Subiza et al. 1995; Recio et al. 1998; Dvorin et al. 2001; Abreu et al. 2003; Boral et al. 2004; Weryszko-Chmielewska and Piotrowska 2004; Docampo et al. 2007; Piotrowska and Weryszko-Chmielewska 2006).

The uniqueness of this study is that it presents the first results of pollen monitoring undertaken at Kastamonu in Turkey, which is of interest to aerobiologists as well as professionals working in fields such as medicine and public health. A pollen calendar showing weekly average pollen counts (2006–2007 mean) has been prepared, with particular emphasis on those taxa considered to be important aeroallergens. The authors also examine the influence of meteorological factors on daily concentrations of airborne pollen recorded at the site.

2 Materials and methods

2.1 Site information

Kastamonu is situated in the Black Sea region in the North of Turkey (41°21′ N, 46°33′ E), altitude 775 m above sea level (Fig. 1). The city is situated in the valley of the Karaçomak River, lying in a north–south direction. The east and west slopes of the valley are predominantly covered by pine-juniper forest. The south of the city is dominated by riparian vegetation such as poplar and willow. The north side of the city is

Fig. 1 Location of the pollen-monitoring site at Kastamonu, Turkey

enclosed with cultivated lowland. Vegetation of the Ilgaz, Ballıdağ and Küre Mountains (15–30 km from the city) varies according to elevation and orientation of the slopes.

The Küre and Ballıdağ Mountains have the Euxin flora of the Euro-Siberian phyto-geographical region, which is dominated by the following forest types: Sweet chestnut (*Castanea sativa*) 200–360 m, hornbeam-Sessile oak (*Carpinus betulus-Quercus petraea*) 200–1,000 m and oriental beech (*Fagus orientalis*) 130–720 m. Mixed deciduous forests of different tree species are developed on karstic limestones (*Carpinus betulus*, *Corylus avellana*, *C. colurna*, *Fagus orientalis*, *Fraxinus angsutifolia*, *Ostrya carpinifolia*, *Pistacia atlantica*, *Quercus* spp. and *Tilia rubra*) and subflora of these forests dominated by typical species include *Daphne pontica*, *Lilium martagon*, *Polygonatum multiflorum*, *Ruscus hypoglossum*, *Salvia forskahlei* and many more species. The flora of high elevations between 1,300–1,700 m of these mountains is dominated by fir or mixed fir forests (*Abies nordmanniana* spp. *Bornmuelleriana*).

The flora on the south facing slopes of these mountains is under the influence of a drier and cooler continental climate. Sessile oak (*Quercus petraea* spp. *Iberica*) and black pine (*Pinus nigra* spp. *pallasiana*) are dominant and are accompanied by *A. nordmanniana* spp. *bornmuelleriana* and *Pinus sylvestris* communities at higher elevations. Further inland the forest structure continues with pure black pine forest and mixtures of black pine and Sessile oak. Oaks comprise one of the most important deciduous trees. In addition, *Juglans regia*, *Platanus orientalis*, *Pinus nigra*, *Cupressus arizonica*, *Populus* sp., *Acer pseudoplatanus*, *Acer negundo*, *Salix* sp., *Morus alba*, *Morus nigra*, *Betula pendula*, *Thuja orientalis*, *Juniperus communis*, *Juniperus oxicedrus*, *Fraxinus ornus* *Fraxinus*

excelsior Cedrus libani, *Picea orientalis*, *Picea pungens* and *Malus sylvestris* are frequently seen in the parks and gardens of the city. Also in the agricultural land, wheat, maize, rice, vegetables, and in orchards and vineyards, apples, quinces, morellos, walnut and plums are cultivated (Vural 2003; Ceter et al. 2008).

2.2 Aeropalynological survey

Pollen data were collected using a 7-day recording volumetric spore trap of the Hirst design (Hirst 1952). The trap was placed on the roof of the Karadere Forest District Directorate building in the centre of Kastamonu at a height of 7 m above ground level (Fig. 1). Atmospheric sampling and analysis followed the method described by the Spanish Aerobiological Network (REA) (Galán et al. 2007). Pollen counts were converted into daily average concentrations (grains/m^3). The amount of pollen recorded weekly, monthly and annually is also presented.

Various methods for defining the start of the main pollen season (MPS) have been described in the literature (Jato et al. 2006). These techniques eliminate the long tails of low values at the start and the end of the seasons that may introduce bias to the results during statistical analysis (Sanchez-Mesa et al. 2003). The method chosen for defining the limits of the season often depends on the site, pollen type and amount of pollen in the air. In this study, it was decided to use the 98% method (Emberlin et al. 1993), whereby the start of the MPS is defined as the day when 1% of the season's catch had been recorded and the end occurs when 99% of the total catch had been reached.

2.3 Vegetation survey

In addition to this aeropalynological survey, field work was simultaneously carried out in the public parks and gardens in the city centre and natural or cultivated vegetation areas 40 km around the city. The vegetation survey was carried out during the main pollination period, and plant samples were identified. The degree of allergenicity of identified plant taxa (and pollen grains from these taxa recorded during the study) was classified according to information found in literature (Jelks 1987; Grant-Smith 1990; Mothes et al. 2004; Sulmont and Reseau National de Surveillance Aérobiologique (RNSA) CD 2005; D'Amato et al. 2007; Sin et al. 2007). The following categories were identified as follows: (1) highly allergenic taxa, (2) moderately allergenic taxa, (3) low allergenic taxa.

2.4 Meteorological data

Daily and monthly mean meteorological data (mean daily temperature, relative humidity, precipitation and wind speed) were obtained from the bulletin of the meteorological station located at the centre of Kastamonu.

2.5 Statistical analysis

Daily average pollen counts from the six most frequently recorded pollen types (Pinaceae, Cupressaceae, Poaceae, *Quercus*, *Betula* and *Carpinus*) were entered into Spearman's correlation analysis with meteorological data (mean daily temperature, relative humidity, precipitation and wind speed). Correlation analyses were only carried out on data recorded during the MPS (98% method). The statistical tests were performed using the statistical software package SPSS version 19.0 (SPSS—Chicago, Illinois, USA).

3 Results

The lowest temperatures recorded in Kastamonu during the study period were in December, January and February, whereas the warmest month in both years was August. There was also a summer maximum in precipitation, with the most rainfall recorded in June in both 2006 and 2007 even though relative humidity was generally lower in the summer months (Table 1).

The pollen calendar for Kastamonu showing average weekly pollen counts (2006–2007 mean) is presented (Fig. 2). Note that highly allergenic taxa are in black, moderately allergenic taxa are grey and low allergenic taxa are depicted using a pattern. In the 2 years of study, the period March–August was identified as the main pollination season for Kastamonu (Fig. 2).

A total of 293,427 pollen grains belonging to 51 taxa were recorded at Kastamonu during the study period. In 2006, 154,721 pollen grains belonging to 43 taxa were identified and counted. In 2007, the total number of pollen grains recorded was 138,706 from 46 taxa. Over the 2-year study period, pollen grains from woody perennials (trees) were the largest contributors

Table 1 Mean monthly meteorological data recorded at Kastamonu (2006–2007)

Year	Meteorological data	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
2006	Mean temperature (°C)	−1.9	−0.6	5.5	10.5	13.9	18.5	19.6	23.7	15.8	12.0	3.5	−0.2
	Total precipitation (mm)	23.9	41.8	32.0	11.3	45.0	57.3	7.0	3.3	45.8	32.6	35.2	13.8
	Mean relative humidity (%)	72.0	76.5	63.7	59.4	61.2	61.4	52.9	50.0	63.1	70.2	74.3	72.8
	Mean wind velocity (m/s)	0.8	0.5	1.0	0.9	0.9	0.7	0.8	0.8	0.6	0.4	0.5	0.8
2007	Mean temperature (°C)	0.4	0.3	4.8	6.3	17.0	18.9	21.9	22.2	17.2	13.2	3.2	0.3
	Total precipitation (mm)	36.6	12.8	18.1	40.3	22.7	79.8	11.6	13.2	8.4	21.7	30.6	35.8
	Mean relative humidity (%)	79.5	74	68	63	56	62	46	54	57	73	77	83
	Mean wind velocity (m/s)	1.6	2.93	3.35	3.6	3.5	3.4	3.9	3.6	3.3	1.32	1.62	1.5

to the airborne catch (85.4%), followed by grasses (Poaceae) (9.7%) and then weeds (4.9%) (Fig. 3; Table 2). In addition, just six taxa made up 86.5% of the total amount of pollen recorded in the atmosphere of Kastamonu. These were Pinaceae (42.9%), Cupressaceae (20.6%), Poaceae (9.7%), *Quercus* (5.5%) *Betula* (5.3%) and *Carpinus* (2.6%) (Table 2).

The highest total monthly pollen counts were recorded in May in both 2006 and 2007. Closer examination of the data showed that the highest peaks in pollen from trees occurred towards the end of May in both years (about week 20), which coincided with peak concentrations of Pinaceae and Cupressaceae pollen. Poaceae pollen concentrations also peaked at this time (weeks, 20–21) (Figs. 2, 4).

The taxa with pollen identified in the atmosphere of Kastamonu were divided into three groups: trees, weeds and grasses (Figs. 2, 5). The most common tree taxa are *Betula*, *Carpinus*, Cupressaceae/Taxaceae, *Fagus*, Pinaceae, *Quercus*, Rosaceae, *Salix*, *Populus* and Fabaceae. The most common weed taxa are Apiaceae, *Artemisia*, Asteraceae, *Carex*, Chenopodiaceae, Cruciferae, Plantago Urticaceae and *Rumex*. Grasses are those plants belonging to the Poaceae family.

Field work resulted in a total of 76 plant taxa being indentified in parks and gardens of the city centre and 251 taxa being identified in natural and cultivated areas surrounding the city. Of the plant taxa identified in the public parks and gardens in the city centre, 39 taxa were classified as highly allergenic (51%), 23 moderately allergenic (30%) and 14 taxa had low allergenic potential (19%). Of the plant taxa from natural and cultivated areas outside the city, 83 were classified highly allergenic (33%), 38 were moderately allergenic (15%) and 130 were low allergenic plants (52%).

There were a number of significant correlations ($p < 0.05$) between daily average pollen counts from the six most frequently recorded taxa and meteorological data (Table 3). There were significant positive correlations between daily average Cupressaceae, Poaceae and *Quercus* pollen counts and mean daily wind speed. There were also significant positive correlations between daily average Cupressaceae and *Quercus* pollen counts and mean daily temperatures. However, for Pinaceae and Poaceae, there was an opposite relationship with temperature (a significant negative correlation was noted between daily average Pinaceae and Poaceae pollen counts and mean daily temperature). Significant negative correlations were also witnessed between daily average *Betula* and *Quercus* pollen counts and rainfall. The influence of mean daily relative humidity also varied; there was a significant positive correlation with daily average Pinaceae and Poaceae pollen counts and a significant negative correlation with daily average *Quercus* pollen counts. There were no significant correlations between *Carpinus* pollen counts and any of the meteorological variables entered into the analysis.

4 Discussion

This paper presents the first detailed investigation of temporal variations in atmospheric pollen (pollen calendar) for Kastamonu (Fig. 2). Pollen counts can also vary spatially, which is shown by comparing the results presented here with similar studies conducted by other authors working in Turkey (Inceoğlu et al. 1994; Guvensen and Ozturk 2003; Ayvaz et al. 2008; Celenk et al. 2010; Erkan et al. 2010).

Inceoğlu et al. (1994) observed pollen of 47 taxa in the atmosphere of Ankara that is located in Central

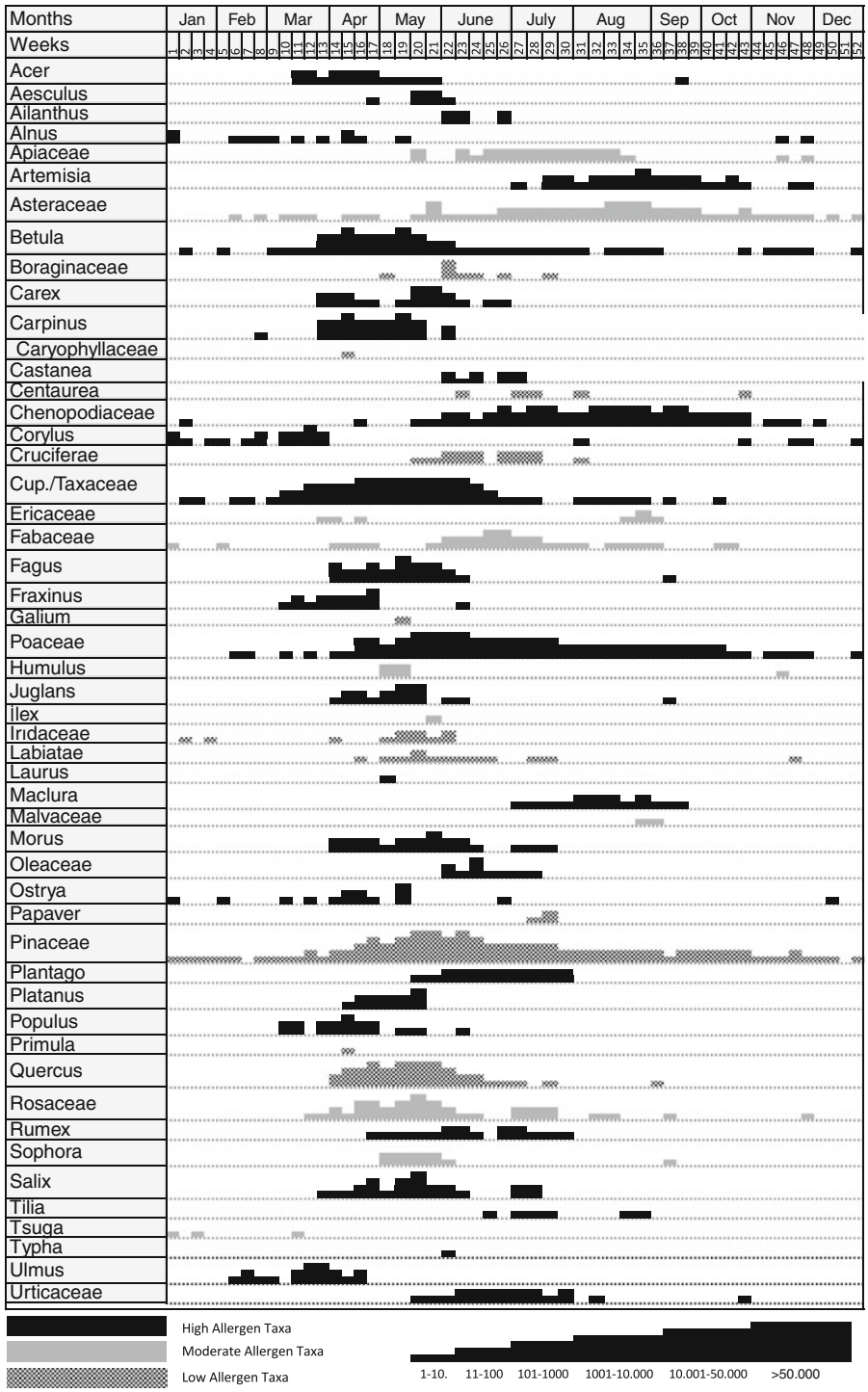

Fig. 2 Pollen calendar showing average weekly pollen counts recorded at Kastamonu (2006–2007 mean)

Anatolia. The most important pollen types identified were the trees Cupressaceae/Taxaceae, Pinaceae, *Betula*, Moraceae, *Platanus*, *Populus*, *Acer* and *Quercus* (76% of total), as well as Poaceae (14% of the total) and the weeds Chenopodiaceae/Amaranthaceae, *Plantago* and *Rurmex* (10% of total).

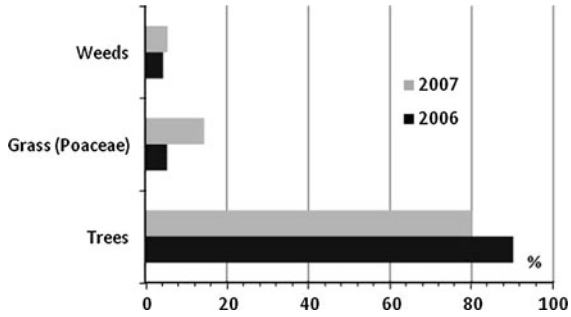

Fig. 3 Pollen from three groups presented as a percentage of the total amount of pollen recorded during 2006–2007 at Kastamonu. The three groups being: (*1*) trees; (*2*) grasses; (*3*) weeds

In Trabzon, located in the Black Sea region of Turkey, Ayvaz et al. (2008) showed that of the total amount of pollen recorded in a Durham trap, 59.2% belonged to trees and 40.8% were from herbaceous taxa. The most common taxa recorded in Trabzon were *Corylus* (17.9%), Poaceae (13.6%), *Pinus* (7.9%) and Alnus (5.3%).

Guvensen and Ozturk (2003) also used a gravimetric method to study atmospheric pollen in İzmir, which is located in the western part of Turkey. The authors found that the most dominant woody species were *Pinus*, *Quercus*, Oleaceae and Cupressaceae/Taxaceae and that the most dominant herbaceous species were Poaceae, Chenopodiaceae/Amaranthaceae, Cruciferae and *Plantago*. It was also observed that fewer taxa were recorded at high level (20 m) compared to low level (1.60 m), 59 taxa and 50 taxa, respectively.

Erkan et al. (2010) studied atmospheric pollen concentrations in Tekirdağ, Northwest Turkey. The authors observed pollen grains of 45 taxa, of which 25 taxa belonged to arboreal plants ($\sim$64% of total pollen grains) and 20 taxa to non-arboreal plants ($\sim$36% of total pollen grains). In Tekirdağ, the most pollen was recorded from April to June and the largest amounts of pollen were from Cupressaceae/Taxaceae, Pinus, Poaceae, Chenopodiaceae/Amaranthaceae *Quercus* and *Platanus*.

Celenk et al. (2010) also examined atmospheric pollen concentrations in north-western Turkey, in samplers situated in the Asian and European parts of İstanbul. According to their study, the highest amounts of pollen grains were recorded in April, and the main pollen types contributed more than 80% of the total pollen sum recorded at the two pollen-monitoring sites: Cupressaceae/Taxaceae, Urticaceae, *Pistacia*, *Quercus*, *Platanus*, *Fraxinus* and *Xanthium*.

In this study, six dominant taxa (Pinaceae, Cupressaceae, Poaceae, *Quercus, Betula* and *Carpinus*) comprised the majority (86.5%) of the total amount of pollen recorded at Kastamonu. However, the dominance of particular taxa can vary spatially. For example, in previous studies carried out in Turkey, i.e. Ankara (Inceoğlu et al. 1994), Tekirdağ (Erkan et al. 2010) and Izmir (Guvensen and Ozturk 2003), the dominant taxa were also recorded as being Pinaceae, Cupressaceae, Poaceae and *Quercus*. *Carpinus* is also a common element of the flora around Kastamonu, which is reflected in the pollen counts at the site. In addition, high atmospheric pollen concentrations of *Betula* result from planting trees in parks and gardens in the city centre (particularly *B. pendula*).

The pollen spectrum recorded at Kastamonu relates well to the local flora and vegetation of the area. The District of Kastamonu is quite heavily wooded (74% of the area contains trees or shrubs). In this aeropalynological survey, 85.4% (90% in 2006 and 80% in 2007) of the pollen grains identified in the atmosphere belonged to non-herbaceous taxa (Table 2). Pollen grains from these plants were found to make comparable contributions in other studies conducted in Turkey (Inceoğlu et al. 1994; Guvensen and Ozturk 2003; Ayvaz et al. 2008; Celenk et al. 2010; Erkan et al. 2010) as well as other countries in the Mediterranean region such as Greece (Gioulekas et al. 2004) and Spain (Docampo et al. 2007). This is related to the vegetation of Kastamonu (both natural and cultivated) and the high pollen production rates of trees and shrubs.

Four of the six dominant taxa recorded at Kastamonu are considered to be highly allergenic (*Betula*, *Carpinus*, Cupressaceae and Poaceae) (Fig. 2). Previous studies have shown that that there is a positive relationship between allergic symptoms and atmospheric pollen concentrations (Burge 1992). For a plant to be considered an important source of aeroallergens in a given area, its pollen must trigger allergic reactions but it must also release sufficient amounts of pollen into the air. Source strength is related to the amount of pollen a plant releases into the air (anemophilous plants generally produce the most pollen), as well as the number of plants present (Emberlin 1997; Frenz 2001; Mothes et al. 2004; Skjøth et al. 2010). The results of field work showed that the majority of plants (51%) collected from public parks and gardens within the city were from highly allergenic

Table 2 Annual pollen counts and percentage of pollen taxa recorded at Kastamonu (2006–2007)

Year	2006		2007		Total	
Taxa	Pollen count	%	Pollen count	%	Pollen count	%
Trees	**139,568**	**90.2**	**111,016**	**80.035**	**250,584**	**85.4**
Acer	104	0.1	186	0.1	290	0.1
Aesculus	97	0.1	129	0.1	226	0.1
Ailanthus	86	0.1	104	0.1	190	0.1
Alnus	47	0.0	62	0.0	109	0.0
Betula	9,831	6.4	5,756	4.2	15,587	5.3
Carpinus	5,839	3.8	1,880	1.4	7,719	2.6
Castanea	313	0.2	45	0.0	358	0.1
Corylus	497	0.3	100	0.1	597	0.2
Cupressaceae/Taxaceae	34,099	22.0	26,379	19.0	60,478	20.6
Ericaceae	31	0.0	38	0.0	69	0.0
Fabaceae	368	0.2	1,023	0.7	1,391	0.5
Fagus	1,854	1.2	3,376	2.4	5,230	1.8
Fraxinus	215	0.1	393	0.3	608	0.2
Ilex		0.0	2	0.0	2	0.0
Juglans	252	0.2	1,339	1.0	1,591	0.5
Laurus	2	0.0		0.0	2	0.0
Maclura	201	0.1	101	0.1	302	0.1
Morus	401	0.3	1,099	0.8	1,500	0.5
Oleaceae	272	0.2	80	0.1	352	0.1
Ostrya	98	0.1	207	0.1	305	0.1
Pinaceae	75,346	48.7	50,400	36.3	125,746	42.9
Platanus	219	0.1	387	0.3	606	0.2
Populus	1,105	0.7	29	0.0	1,134	0.4
Quercus	6,143	4.0	10,033	7.2	16,176	5.5
Rosaceae	767	0.5	4,364	3.1	5,131	1.7
Salix	720	0.5	3,311	2.4	4,031	1.4
Sophora		0.0	2	0.0	2	0.0
Tilia		0.0	54	0.0	54	0.0
Tsuga	17	0.0		0.0	17	0.0
Ulmus	644	0.4	137	0.1	781	0.3
Grass (Poaceae)	**8,335**	**5.4**	**20,096**	**14.5**	**28,431**	**9.7**
Weeds	**6,818**	**4.4**	**7,594**	**5.5**	**14,412**	**4.9**
Apiaceae	453	0.3	138	0.1	591	0.2
Artemisia	191	0.1	829	0.6	1,020	0.3
Asteraceae	1,397	0.9	2,959	2.1	4,356	1.5
Boraginaceae	6	0.0	430	0.3	436	0.1
Carex	116	0.1	802	0.6	918	0.3
Caryophylaceae	2	0.0		0.0	2	0.0
Centaurea	4	0.0	25	0.0	29	0.0
Chenopodiaceae	3,378	2.2	1,545	1.1	4,923	1.7
Crucifera	315	0.2	112	0.1	427	0.1
Galium		0.0	2	0.0	2	0.0

Table 2 continued

Year	2006		2007		Total	
Taxa	Pollen count	%	Pollen count	%	Pollen count	%
Iridaceae		0.0	11	0.0	11	0.0
Humulus	77	0.1		0.0	77	0.0
Lamiaceae	46	0.0	19	0.0	65	0.0
Malvaceae		0.0	11	0.0	11	0.0
Papaver	58	0.0		0.0	58	0.0
Plantago	314	0.2	325	0.2	639	0.2
Primula		0.0	2	0.0	2	0.0
Rumex	190	0.1	117	0.1	307	0.1
Typha		0.0	3	0.0	3	0.0
Urticaceae	271	0.2	264	0.2	535	0.2
Total	**154,721**	**100.0**	**138,706**	**100.0**	**293,427**	**100.0**

Bold values indicate sum of tree pollen, grass pollen, weed pollen and total pollen

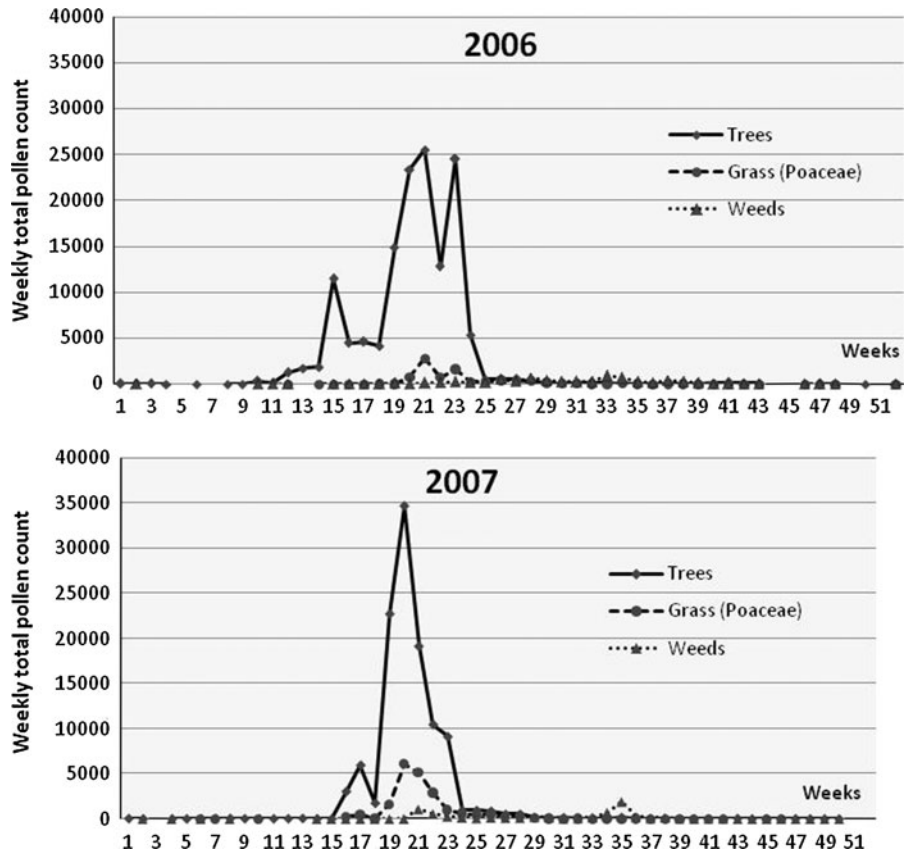

Fig. 4 Total weekly pollen count data recorded at Kastamonu (2006–2007). Data are divided into three groups: (*1*) trees; (*2*) grasses; (*3*) weeds

taxa. In comparison, only 33% of plants collected from natural or cultivated areas surrounding the city were considered to be highly allergenic. It can be argued that plants growing within the city can be important sources of allergenic pollen recorded at the trap (Bricchi et al. 2000; Skjøth et al. 2008) and shows that the public and central municipalities could unconsciously create a high risk for allergy sufferers.

However, the results of this study ought to be approached with some caution. Although the urban

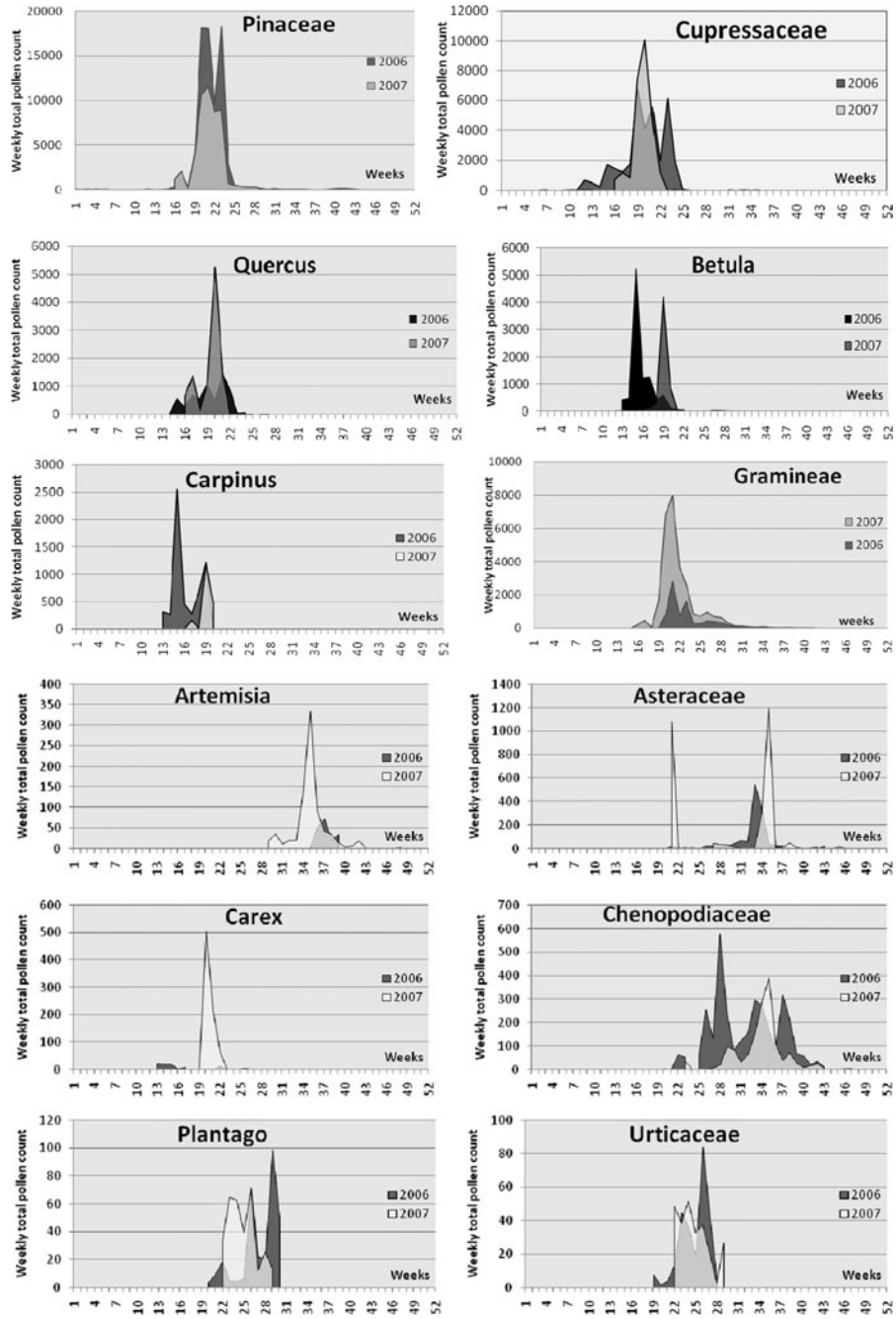

Fig. 5 Weekly pollen concentrations of most important taxa belong to trees, grasses and weeds groups in Kastamonu atmosphere (2006–2007)

areas of Kastamonu contained a higher percentage of highly allergenic plants compared to the surrounding countryside (51% compared to 33%), it should be noted that the number of highly allergenic taxa recorded in the city (39 taxa) was actually lower than in rural areas (83 taxa). Of course the number of plants identified does not directly relate to the source of allergenic pollen. For instance, the amount of pollen produced by different species can vary (Prieto-Baena et al. 2003). In addition, the number of species counted does not necessarily relate to the amount of plants present, it could be one plant or one hundred.

Daily average pollen concentrations of the six most frequently recorded taxa were entered into

Table 3 The results of Spearman's correlation analysis between daily average pollen counts of selected taxa and meteorological data

Correlations	Mean daily wind speed	Mean daily temperature	Daily rainfall	Mean daily relative humidity
Betula	−0.019	0.217	− 0.243*	−0.144
	0.876	0.065	0.039	0.223
Carpinus	0.137	0.225	−0.056	0.010
	0.320	0.079	0.717	0.877
Cupressaceae	0.261**	0.376**	−0.047	−0.087
	0.005	0.000	0.607	0.348
Pinaceae	0.055	−0.262**	0.110	0.153*
	0.000	0.000	0.000	0.161
Poaceae	0.160*	−0.367**	0.127	0.207**
	0.000	0.021	0.400	0.136
Quercus	0.453**	0.263*	−0.346**	−0.459**
	0.000	0.021	0.004	0.000

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

Spearman's correlation analysis with corresponding meteorological data (Table 3). In general, it was shown that increases in mean daily temperatures were related to increases in daily average pollen concentrations, whereas increases in rainfall and relative humidity had an opposite effect on daily average pollen concentrations and caused them to decrease. Similar results can be found throughout aerobiological literature (Schappi et al. 1998; Sanchez-Mesa et al. 2003; Smith and Emberlin 2005; Stach et al. 2008). However, there were some exceptions to this, as it was found that increases in mean daily temperatures caused Pinaceae and Poaceae pollen counts to decrease whereas increases in relative humidity resulted in atmospheric concentrations of pollen from these two taxa to increase. This could be related to the climate of the region, with high temperatures causing plants to stop flowering and precipitation and relative humidity reaching a maximum during late spring and early summer when Pinaceae and Poaceae plants typically flower (Table 1; Fig. 2). It should also be noticed that there were only a few significant relationships with rainfall. A similar phenomenon was also noted by Stach et al. (2008) during a study of grass pollen counts at Poznań in Poland, where precipitation also reaches a maximum during summer.

Daily average Poaceae pollen counts were positively correlated with wind speed, but several authors have found an opposite relationship (i.e. significant negative correlations between grass pollen counts and wind speed) (Emberlin and Norris-Hill 1996; Stach et al. 2008). This emphasises the fact that relationships found in one place cannot always be applied to another and highlights the need to develop site-specific forecast models (Galán et al. 1995).

5 Conclusion

Four of the six most dominant taxa in the atmosphere of Kastamonu are considered to be highly allergenic (*Betula*, *Carpinus*, Cupressaceae and Poaceae). The presence of *Betula pendula* in the city, which is not part of the local flora, shows that the general public and municipalities can unconsciously create a high risk for allergy sufferers through urban planting. Knowledge of airborne pollen concentrations and the weather conditions influencing them is important for air quality forecasters, allergists and allergy sufferers. The pollen calendar showing mean weekly pollen counts (2006–2007) will help health care professionals and allergy sufferers to plan treatment and medication. Mean daily temperature, relative humidity and wind speed were found to significantly affect atmospheric pollen concentrations from selected taxa, but the relationships between pollen concentrations and meteorological variables can vary from between different pollen types and from site to site, and so there is a need for more local studies of this nature.

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presented here address one of the main scientific challenges described in COST Action ES0603, specifically Work Package 1 (pollen production and release).

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