Turkish Journal of Botany

http://journals.tubitak.gov.tr/botany/

Research Article

Turk J Bot
(2018) 42: 687-700
© TÜBİTAK
doi:10.3906/bot-1712-39

Analysis of airborne pollen of Gümüşhane Province in northeastern Turkey and its relationship with meteorological parameters

Yavuz TÜRKMEN[1], **Talip ÇETER**[2,*], **Nur Münevver PINAR**[1]
[1]Department of Biology, Faculty of Science, Ankara University, Ankara, Turkey
[2]Department of Biology, Faculty of Arts and Sciences, Kastamonu University, Kastamonu, TURKEY

Received: 20.12.2017 • **Accepted/Published Online:** 28.06.2018 • **Final Version:** 22.11.2018

Abstract: Knowledge of the types of atmospheric pollen and their concentrations in a particular area is critical for evaluating air quality and allergen exposure. This study was carried out to determine the pollen diversity and daily, monthly, and annual concentrations in Gümüşhane, whose relationships were then sought with the meteorological factors in the atmosphere of Gümüşhane. For this purpose, an aerobiological study was carried out with Hirst (Burkard) type pollen traps in the Gümüşhane city center between August 2010 and July 2012. Sampling and analysis of the pollens followed the method described by the Spanish Aerobiological Network. The duration of the main pollen season (MPS) was determined according to the 98% method, and daily pollen concentration in the MPS was statistically analyzed and compared with the meteorological parameters. A total of 41,544 pollen grains belonging to 70 taxa were recorded in Gümüşhane during the study period. In the first year (August 2010–July 2011) of the study, 36,020 pollen grains belonging to 63 taxa were detected, while a total of 5524 pollen grains belonging to 68 taxa were detected in the second year (August 2011 and July 2012). In both of the study periods, pollen grains from trees were the biggest contributors to the airborne pollen (85.6%), followed by grasses (Poaceae) (8.8%) and the other weeds (5.6%). Comparison of the meteorological parameters and pollen concentrations revealed that the meteorological parameters could have different effects on pollen concentrations of different taxa, where only the taxa that gave ≥1% airborne pollen for the study period were studied.

Key words: Gümüşhane, meteorological factors, correlation analysis, pollen calendar, pollen allergy

1. Introduction

Air quality has declined worldwide because of the excessive accumulation of pollutants in the atmosphere. Rapid industrialization and urbanization have led to a significant increase in respiratory disorders (Singh and Dahiya, 2008). More than 20%–30% of the world's population suffers from one or more allergic disease including bronchial asthma, allergic rhinitis, and atopy (Sin et al., 2007). Major causative agents are pollen grains, fungal spores, dust mites, and fragments from insects and plants (Çeter et al., 2008; Singh and Dahiya, 2008). Plants are the most important source of aeroallergens. Many studies have shown that there is a positive correlation between allergy symptoms and pollen concentrations (Burge, 1992). Therefore, detailed studies are among the emerging needs to analyze daily, seasonal, and annual variations of pollen concentrations in order to prevent possible new allergies and/or provide effective diagnosis and therapeutic management of allergic diseases (Singh and Dahiya, 2008).

Recently, there is a substantial improvement in the understanding of aeroparticulates, especially for pollen grains released by anemophilous pollination and then distributed by the wind. Meteorological factors such as temperature, precipitation, and humidity alter pollen concentrations in the atmosphere owing to their regulatory effects on flowering rate and pollination period. These parameters are also strong contributors to the transport of pollens (e.g., medium and long distance) and can wash off the airborne pollen, which creates alteration in pollen concentrations in confined areas (Esch et al., 2001). Therefore, many studies have examined the relationship between airborne pollen concentrations, meteorological factors, and allergies (Altıntaş et al., 2004; Öztürk et al., 2004; Çelik et al., 2005; Dursun et al., 2008; Singh and Dahliya, 2008).

Due to the fact that different plants undergo pollination periods in different seasons, the presence of airborne pollen is constant all through the year (Çeter et al., 2012). The pollen diversity in the atmosphere depends on the local flora, as well as the climate, season, and meteorological factors (Bush, 1989; Jato et al., 2002; Gioulekas et al., 2004). Many studies have focused on the determination of the

* Correspondence: talipceter@gmail.com

atmospheric pollen concentration of many cities in Turkey (İnce, 1994; İnceoğlu et al., 1994; Pehlivan and Butev, 1994; Güvensen and Öztürk, 2002, 2003; Ayvaz et al., 2008; Tosunoğlu et al., 2015a, 2015b; Bıçakçı et al., 2017; Uğuz et al., 2017, 2018) and also in other countries (Nilsson et al., 1977; Goldberg et al., 1988; Subiza et al., 1995; Abreu et al., 2003; Boral et al., 2004; Docampo et al., 2007).

Here we reporting, for the first time, the atmospheric pollen concentration of Gümüşhane, Turkey. The purpose of this study was to determine pollen diversity in the atmosphere of Gümüşhane; to determine daily, monthly, and annual changes of pollen concentrations; and to investigate the effects of meteorological parameters on pollen concentrations.

2. Materials and methods

2.1. Description of the area and site information

Gümüşhane is situated in the eastern Black Sea region in northeastern Turkey (39°45′N to 40°50′N, 38°45′E to 40°12′E), at an altitude of 1210 m above sea level, about 40 km southwest of Trabzon (Figure 1). The district covers an area of 1789 km^2. The water sources are the Kelkit River and Harşit River, as well as Lakes Karanlık, Artebel, and Kara. The city is located in the valley of the Harşit River. Gümüşhane is also surrounded by the high Zigana and Kop Mountains that constitute 56% of the area of Gümüşhane Province. The main trees in the forests are *Pinus sylvestris* and *Abies nordmanniana*. The Harşit River, which flows through the city center, is dominated by riparian taxa such as *Populus*, *Juglans*, *Tilia*, and *Salix*. Most Gümüşhane residents also have the following types of orchards in front of their houses: *Juglans regia*, *Morus alba* and *Morus nigra*, *Malus sylvestris*, and *Pyrus communis* trees. In addition to these, some other fruit trees and exotic taxa are planted.

Gümüşhane lies between the eastern Black Sea region and central Anatolia, so it has Mediterranean, Irano-Turan, and Euro-Siberian floristic characteristics. Mediterranean enclave taxa can be seen in this region. Another important floristic area is the Kürtün-Örümcek Forest, which is dominated by *Picea orientalis*. The city and its surroundings are dominated by plant communities including *Picea orientalis*, *Pinus sylvestris*, *Vaccinium myrtillus*, and *Fagus orientalis*. Other taxa such as *Rhododendron ponticum*, *Galium rotundifolium*, *Oxalis acetosella*, *Vaccinium arctostaphylos*, and *Isothecium myurum* are also found in these plant communities. Mixed deciduous forests containing different tree species (*Carpinus betulus*, *Corylus avellana*, *Fagus orientalis*, *Fraxinus angustifolia*, *Ostrya carpinifolia*, *Quercus* spp., and *Tilia rubra*) cover karstic limestone. In addition, *Platanus orientalis*, *Pinus nigra* subsp. *pallasiana*, *Acer pseudoplatanus*, *Acer negundo*, *Salix* sp., *Betula pendula*, *Juniperus* sp., *Fraxinus ornus*, *Cedrus libani*, and *Picea orientalis* are frequently seen in the parks and gardens of the city. The north and south slopes of the valley are frequently covered by *Quercus*, *Corylus*, and *Carpinus* taxa in addition to many other taxa such as annual and biennial species. In nearby agricultural areas *Triticum*, *Zea*, *Prunus*, *Malus*, *Pyrus*, *Vitis*, and some vegetables are cultivated (Davis et al., 1965–1985; Karaer and Kılınç, 2001).

2.2. Aeropalynological survey

The present study was carried out from August 2010 to July 2012 using a 7-day recording Hirst type volumetric pollen and spores trap (Hirst, 1952). In the first year, the

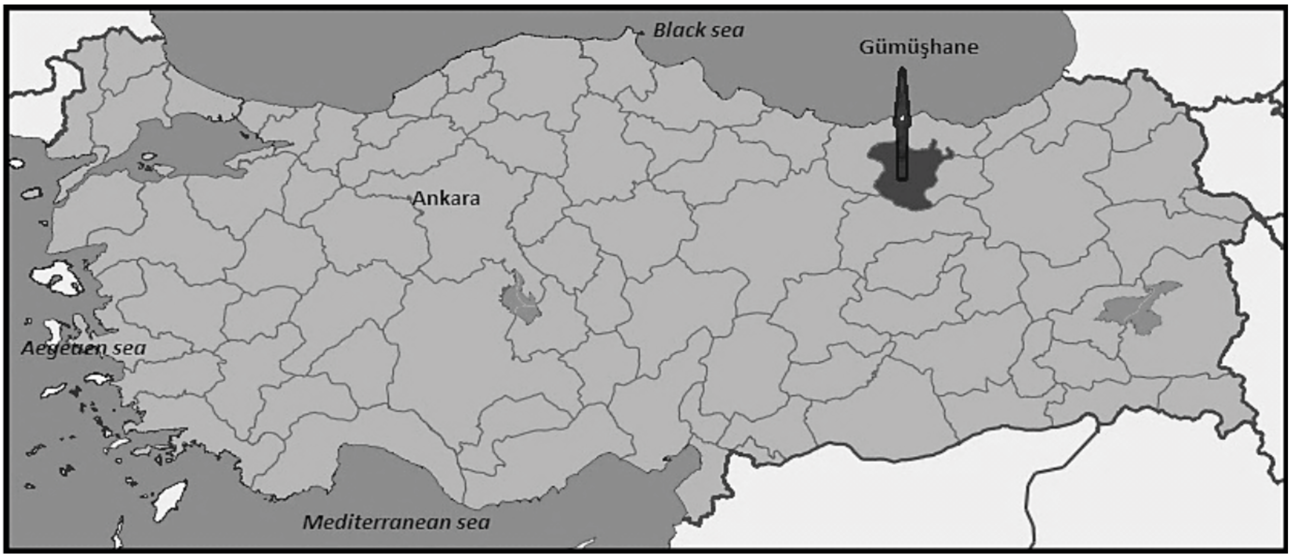

Figure 1. Location of the pollen monitoring site in Gümüşhane, Turkey.

study was conducted during August 2010–July 2011, while in the second year the period of August 2011–July 2012 was chosen to conduct the study. The trap was placed on a roof of a private property in the Karşıyaka neighborhood, next to the Harşit River, that was 15 m above from the ground. The protocols described by the Spanish Aerobiological Network (REA: Red Española de Aerobiología; Galán et al., 2007) to sample and analyze pollens were followed in the study. Pollen concentrations were recorded as daily average concentrations (pollen grains/m^3). The main pollen season (MPS) of any taxa that had pollen concentrations over 1% of the total pollen concentration detected in the atmosphere was determined with the 98% method (Emberlin et al., 1993; Jato et al., 2006). Pollen concentrations of 17 taxa were obtained at ≥1%, so the MPS was followed for only 17 taxa (considered as dominant taxa) among the species studied. The terminology used in the study was adopted from Galán et al. (2017).

2.3. Meteorological data

To determine the effect of meteorological parameters on pollen concentration, the meteorological data including mean daily temperature, relative humidity, precipitation, and wind speed for Gümüşhane in 2010, 2011, and 2012 were kindly provided by the Turkish Meteorological Data Archiving System.

2.4. Statistical analysis

Statistical analysis was performed for the following 17 dominant taxa: Pinaceae, Cupressaceae/Taxaceae, Poaceae, *Quercus*, *Betula*, *Alnus*, *Juglans*, Asteraceae, Amaranthaceae, *Carpinus*, *Corylus*, *Plantogo*, Fabaceae, *Rumex*, *Morus*, *Populus*, and *Rosaceae*. IBM SPSS 22.0 was used to perform Pearson correlation analysis (IBM Corp., Armonk, NY, USA). The meteorological data were correlated with the pollen data obtained during the MPS of each dominant species.

3. Results

The lowest temperatures recorded in Gümüşhane during the study were in December, January, and February while the warmest month was August in 2010 and July in 2011 and 2012. Furthermore, we noted that the monthly temperatures were higher in 2010. Relative humidity, in general, was lower in the months of summer. During the study period, there was no significant change in the mean wind speed, but we noted that the wind speed was relatively higher in June, July, and August (1.7–2.2 m/s). Comparison of the monthly mean temperatures showed that the coldest period terminated at the end of February in 2011 while the cold period ended in end of March of 2012 (Table 1; Figure 2). Precipitation during the first year of the study was considerably higher than the long-term average monthly precipitation over 1960–2012. The maximum precipitation was recorded as 93.5 mm in June 2010, 106.1 mm in April 2011, and 121.7 mm in May 2012 (Table 1).

A total of 41,544 pollen grains belonging to 70 taxa were recorded in Gümüşhane during the study period. In the first year (August 2010–July 2011) of the study a total of 36,020 pollen grains belonging to 63 taxa were detected while 5524 pollen grains belonging to 68 taxa were detected in the second year (August 2011 and July 2012) (Table 2). In both of the study periods, pollen grains from trees (woody perennials and shrubs) were the biggest contributors to the airborne pollen (85.6%), followed by grasses (Poaceae) (8.8%) and other weeds (5.6%). The most common tree taxa were *Alnus*, *Betula*, *Carpinus*, Cupressaceae/Taxaceae, Pinaceae, *Quercus*, *Morus*, *Populus* and Fabaceae. The most common weed taxa were *Artemisia*, Brassicaceae, Amaranthaceae, *Plantago*, *Rumex*, and Urticaceae. Grasses were evaluated as Poaceae (Figure 3; Table 2).

The highest concentrations of pollen were detected during March–July in both of the study years. Detailed examination of the data revealed that the highest monthly and daily pollen concentrations were detected in March and in May–June of the first year. The increase in March was related to Cupressaceae, *Betula*, and *Alnus* taxa while the dramatic increase in May–June resulted from Pinaceae, Poaceae, *Quercus*, and some species belonging to Cupressaceae (Figure 4).

Table 1. Mean monthly meteorological data recorded in Gümüşhane, obtained from the State Meteorological Service of Turkey.

Year/months	Meteorological data	8	9	10	11	12	1	2	3	4	5	6	7
First year (August 2010– July 2011)	Mean temperature (°C)	23.5	19.6	11.9	7.9	5.3	0.4	–0.2	3.6	8.3	12.8	16.7	21.9
	Total precipitation (mm)	0	8.2	87.1	1.2	14.2	27.7	41.2	36.6	106.1	59.9	67.5	11.9
	Mean relative humidity (%)	59.5	65.2	74.6	65.2	64.5	62.6	67.7	58.3	64.2	62.3	60.0	52.7
	Mean wind speed (m/s)	2.1	1.6	1.1	0.7	1.2	1.6	1.5	1.5	1.7	1.5	1.9	1.9
Second year (August 2011– July 2012)	Mean temperature (°C)	20.0	16.4	10.6	0.7	1.1	–1.5	–3.8	–0.1	11.2	14.5	19.0	21.2
	Total precipitation (mm)	21.5	11.6	32.6	17.0	5.3	53.3	53.0	32.4	67.3	121.7	50.6	30.2
	Mean relative humidity (%)	55.0	56.0	57.7	65.3	56.9	67.3	63.8	60.2	52.2	63.7	54.0	49.9
	Mean wind speed (m/s)	2.3	1.7	1.4	1,2	1.1	1.3	1.4	1.7	1.3	1.4	1.9	2.0

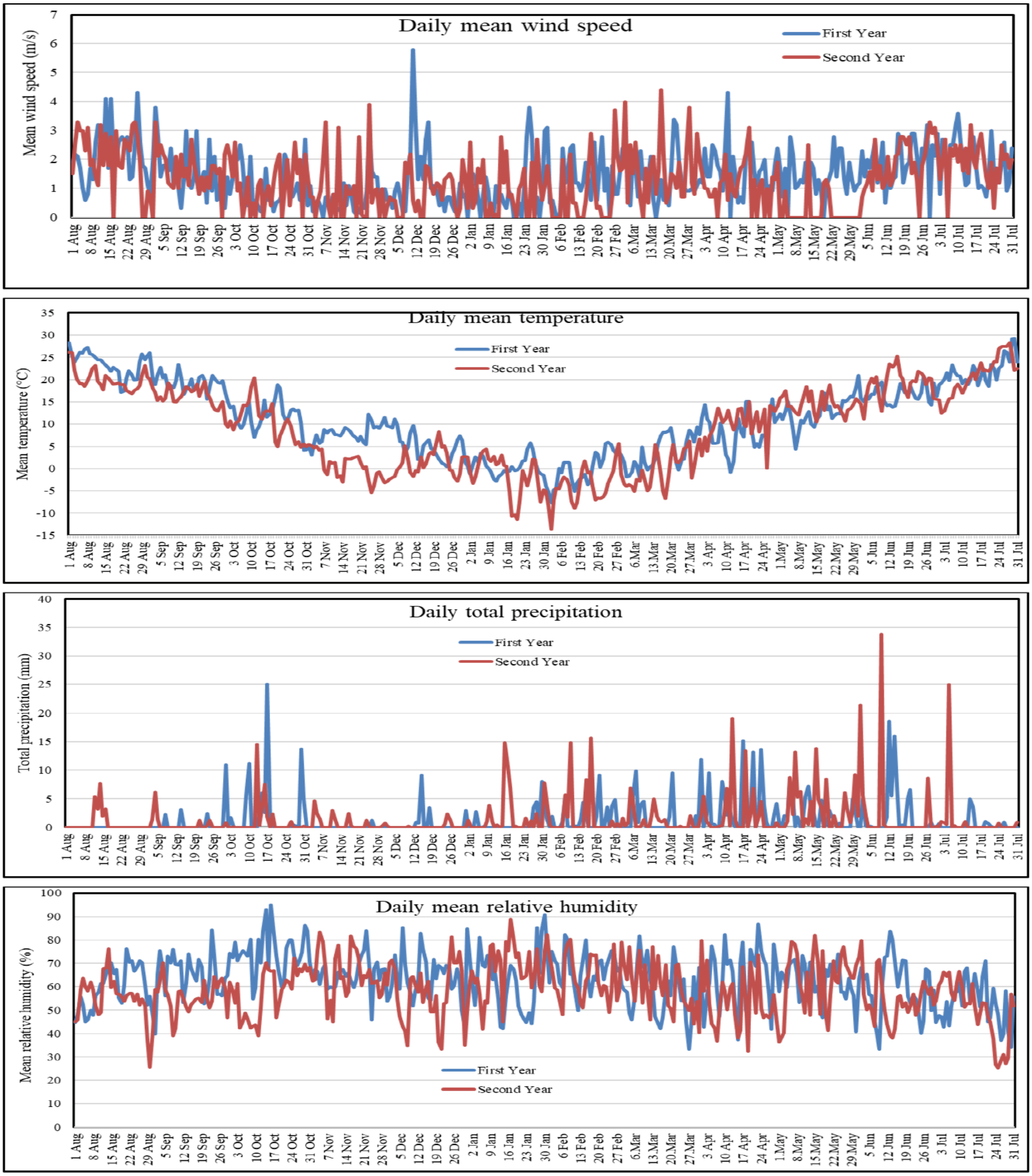

Figure 2. Graph of daily meteorological factors.

In addition, 17 dominant taxa made up 87% of the total amount of pollen recorded in the atmosphere at Gümüşhane. These were Pinaceae (30.9%), Cupressaceae/Taxaceae (17.7%), Poaceae (8.8%), *Quercus* (7.5%), *Betula* (4.7%), *Alnus* (2.5%), *Juglans* (2.2%), Asteraceae (except *Artemisia* and *Taraxacum*, 1.5%), Fabaceae (1.5%), Amaranthaceae (1.5%), *Carpinus* (1.37%), *Rumex* (1.27%), Corylus (1.27%), Rosaceae (1.2%), *Morus* (1.1%), *Plantago* (1.04%), and *Populus* (1.01%). Detailed graphs (Figure 5) are provided for the daily pollen concentrations of seven of these taxa whose pollen concentrations were above 2%.

Table 2. Annual pollen concentrations and percentages of pollen taxa recorded in Gümüşhane (August 2010–July 2012).

	First year (August 2010– July 2011)		Second year (August 2011– July 2012)		otal	
Taxa	Pollen count	%	Pollen count	%	Pollen count	%
Trees	31,249	86.7	4306	77.9	35,555	85.6
Acer	117	0.3	53	0.96	170	0.63
Aesculus	60	0.1	21	0.38	81	0.24
Ailanthus	30	0.08	20	0.36	50	0.22
Alnus	777	2.1	161	2.91	938	2.505
Apiaceae	91	0.2	64	1.16	155	0.68
Berberidaceae	4	0.0	6	0.09	10	0.09
Betula	1652	4.5	268	4.85	1920	4.675
Carpinus	642	1.7	58	1.05	700	1.375
Castanea	18	0.0	30	0.54	48	0.54
Casuarina	93	0.2	0	0.0	93	0.2
Corylus	250	0.6	107	1.94	357	1.27
Cup/Taxa	8069	22.4	721	13.05	8790	17.725
Elaeagnaceae	19	0.0	15	0.27	34	0.27
Eucalyptus	0	0.0	2	0.04	2	0.04
Ericaceae	15	0.0	6	0.11	21	0.11
Fabaceae	285	0.6	132	2.39	417	1.5
Fagus	99	0.2	56	1.01	155	0.605
Fraxinus	193	0.4	39	0.71	232	0.555
Hedera	21	0.06	7	0.13	28	0.095
Juglans	307	0.7	204	3.69	511	2.195
Lonicera	0	0.0	2	0.05	2	0.05
Maclura	60	0.1	19	0.34	79	0.22
Morus	370	1.0	61	1.1	431	1.1
Myrtaceae	4	0.0	5	0.09	9	0.09
Oleaeceae	32	0.0	25	0.45	57	0.45
Ostyra	79	0.2	24	0.43	103	0.315
Pinaceae	14,227	39.5	1234	22.34	15461	30.92
Platanus	45	0.1	24	0.43	69	0.265
Populus	329	0.9	62	1.12	391	1.01
Pterocarya	9	0.0	9	0.17	18	0.17
Quercus	2493	6.9	444	8.04	2937	7.5
Rhamnaceae	11	0.0	6	0.11	17	0.11
Robinia	143	0.4	35	0.63	178	0.515
Rosaceae	160	0.4	109	1.97	269	1.185
Salix	192	0.5	72	1.3	264	0.9
Sambucus	0	0.0	5	0.09	5	0.09
Sophora	184	0.5	35	0.63	219	0.565
Tamarix	11	0	14	0.25	25	0.125

Table 2. (Continued).

Tilia	36	0.1	65	1.18	101	0.64
Tsuga	9	0	2	0.04	11	0.02
Verbascum	0	0.0	1	0.02	1	0.02
Ulmus	113	0.3	81	1.47	194	0.885
Viburnum	0	0.0	2	0.08	2	0.08
Grass (Poaceae)	3316	9.2	329	5.96	3645	8.8
Weeds	1455	4	889	16	2344	5.6
Artemisia	62	0.1	72	1.3	134	0.7
Asteraceae	142	0.3	151	2.73	293	1.5
Boraginaceae	32	0.0	20	0.36	52	0.36
Brassicaceae	39	0.1	47	0.85	86	0.475
Campanulaceae	7	0.0	2	0.04	9	0.04
Cannabis	9	0.0	9	0.16	18	0.16
Carex	32	0.0	34	0.62	66	0.62
Caryophyllaceae	37	0.1	38	0.69	75	0.395
Centaurea	10	0.0	0	0.0	10	0.0
Cistaceae	13	0.0	1	0.02	14	0.02
Amaranthaceae	144	0.4	138	2.5	282	1.5
Galium	69	0.1	31	0.56	100	0.33
Humulus	18	0.0	30	0.54	48	0.54
Lamiaceae	53	0.1	29	0.59	82	0.345
Liliaceae	20	0.0	10	0.18	30	0.18
Malvaceae	0	0.0	2	0.05	2	0.05
Papaveraceae	26	0.07	16	0.29	42	0.18
Plantago	278	0.7	76	1.38	3.4	1.04
Primula	0	0.0	3	0.08	3	0.08
Poterium	36	0.0	15	0.29	51	0.29
Reseda	1	0.0	5	0.09	5	0.09
Ranunculaceae	12	0.0	7	0.15	19	0.15
Rumex	323	0.9	90	1.63	413	1.265
Taraxacum	16	0.04	9	0.16	25	0.1
Typha	5	0.0	1	0.03	6	0.03
Urticaceae	72	0.2	41	0.74	113	0.47
Total	36,020	100.0	5524	100.0	41,544	100

The pollen calendar of Gümüşhane shown in Figure 6 was constructed based on the average weekly pollen detection during August 2010–July 2012. It indicates that some pollen types (i.e. Poaceae and Pinaceae) were observed in the atmosphere every month during the study period.

In this study, the MPS of the taxa was determined in accordance with the 98% method. According to this method, the date on which 1% of the total pollen amount of a taxa is detected is accepted as the beginning of its MPS, and the date on which 99% is determined is accepted as the end of MPS. When pollen concentrations of all the taxa are taken into account in the 2-year study period, it is generally seen that the pollination period in Gümüşhane Province was from late February to mid-July. In Table 3, periods of MPS (as starting and end day, and duration) and highest pollen concentration days for each dominant taxa are detailed.

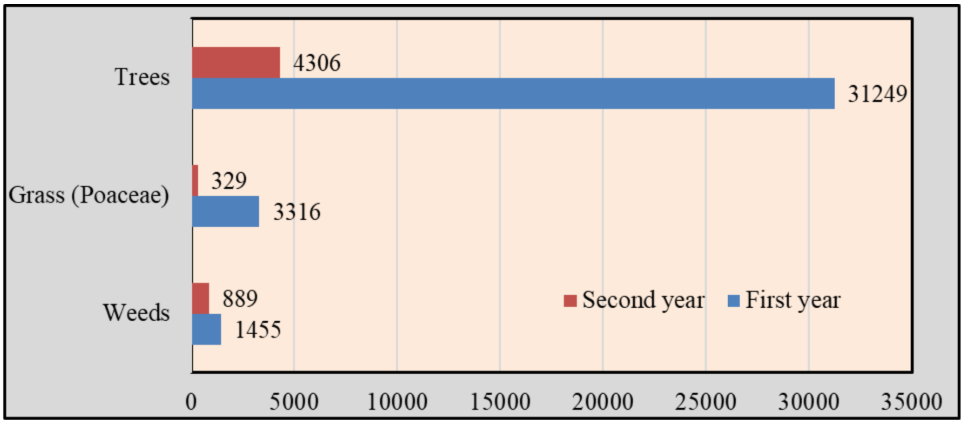

Figure 3. Annual pollen integral graph for the three main plant groups during the study period (first year: August 2010–July 2011, second year: August 2011–July 2012).

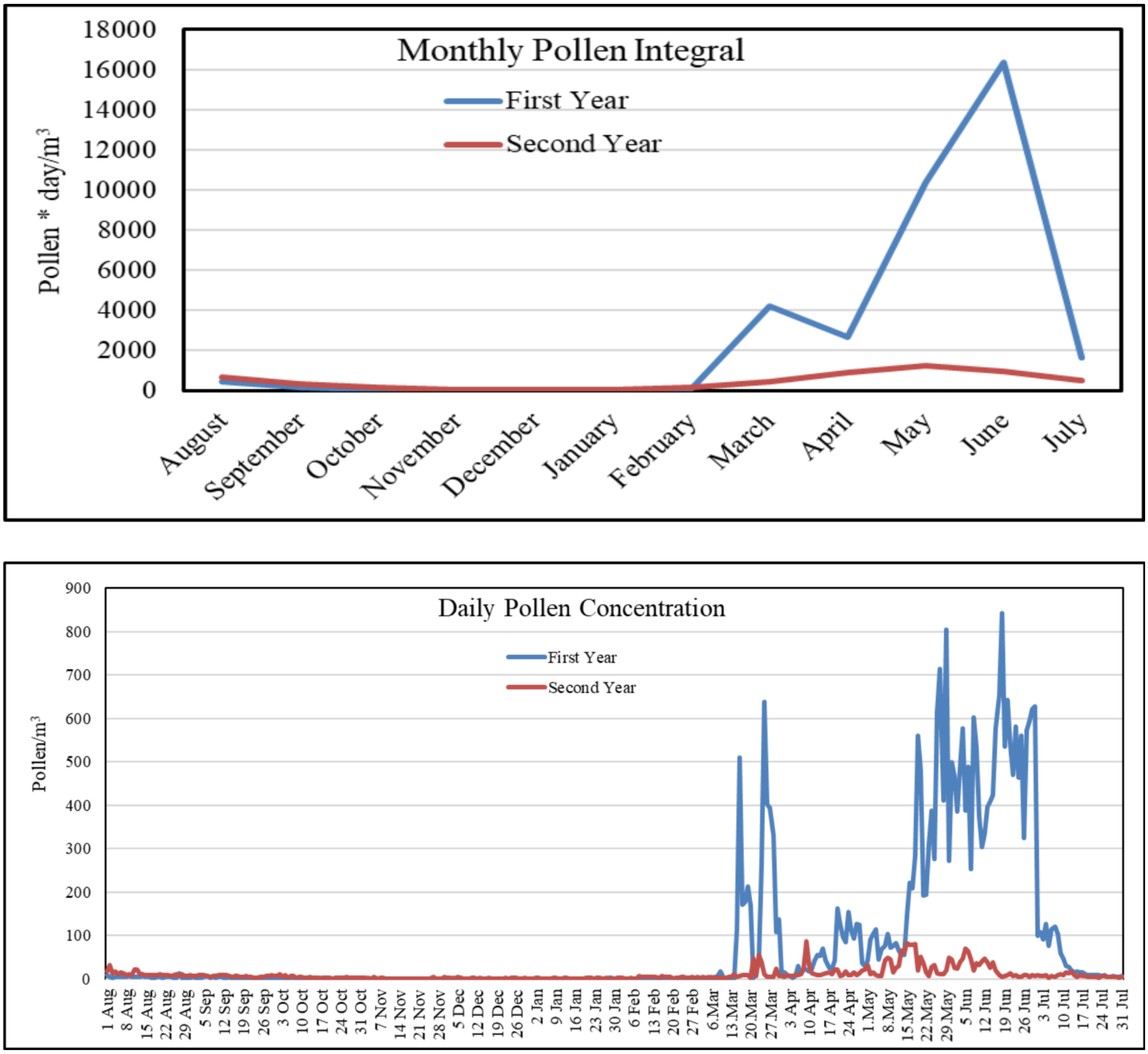

Figure 4. Monthly pollen integral and daily pollen concentration graph for Gümüşhane (first year: August 2010–July 2011, second year: August 2011–July 2012).

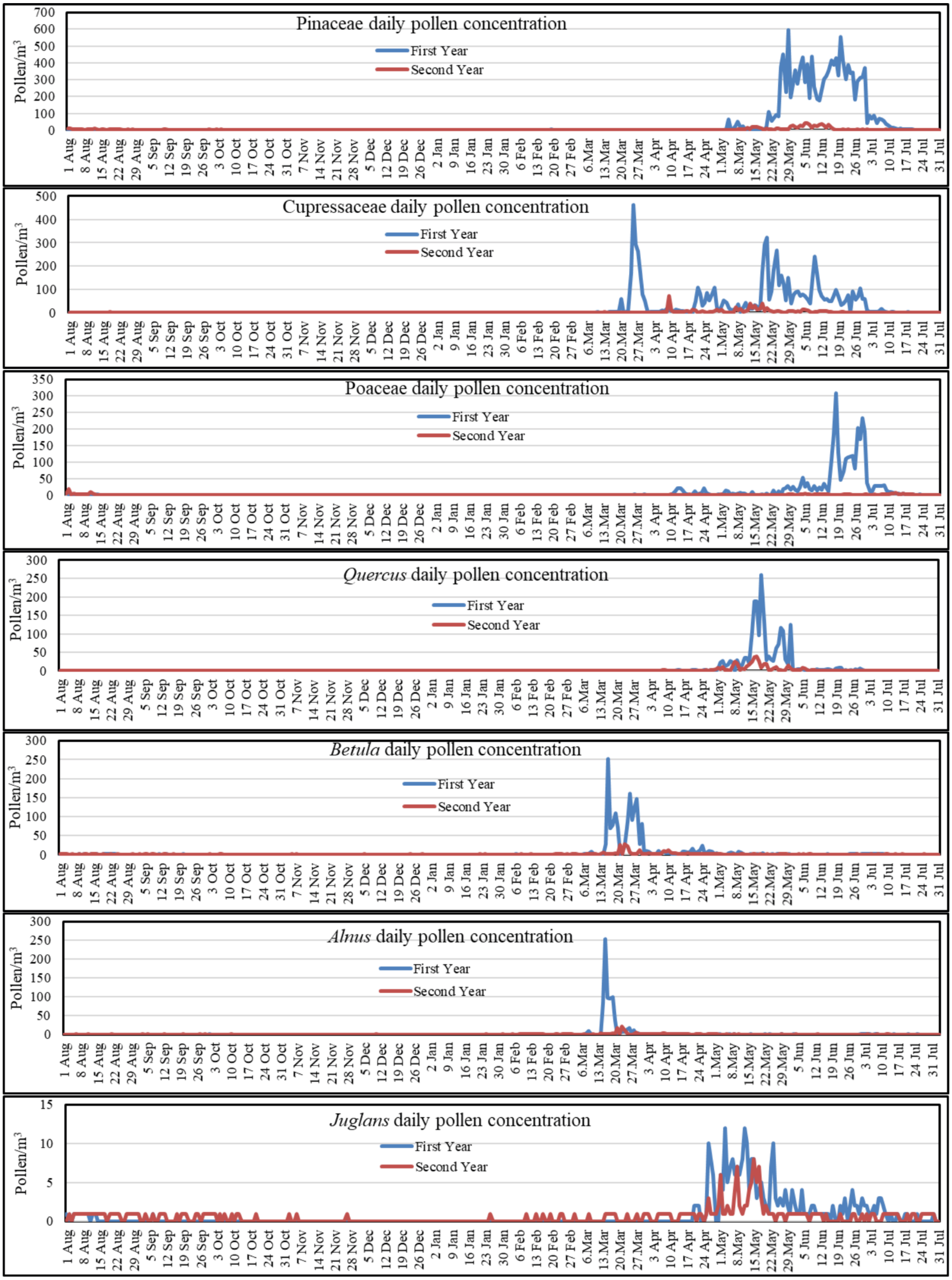

Figure 5. Daily pollen concentration of 7 most dominant taxa (>2%) for the atmosphere of Gümüşhane during the study period (first year: August 2010–July 2011, second year: August 2011–July 2012).

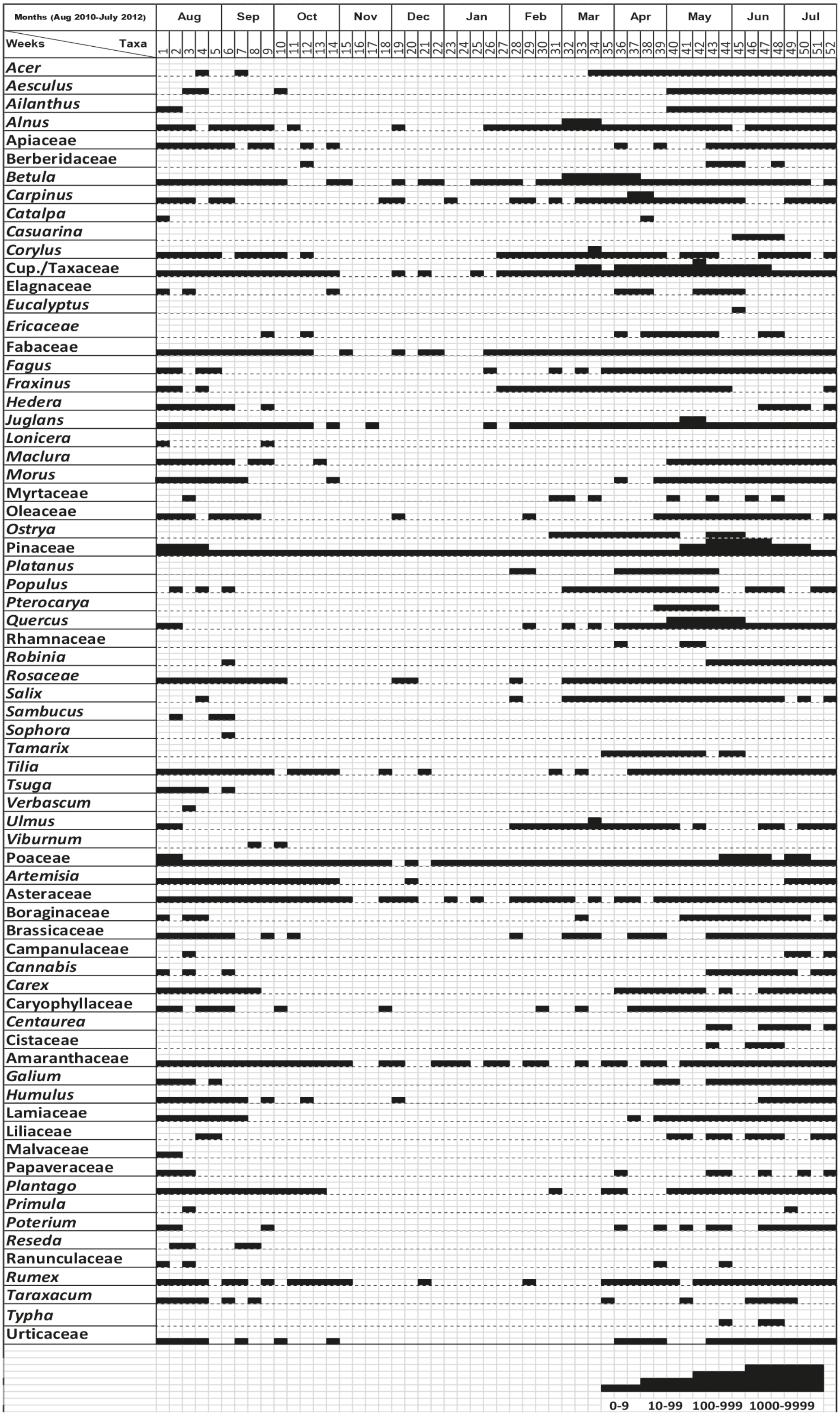

Figure 6. Pollen calendar showing average weekly pollen concentrations recorded in Gümüşhane. Precipitation

Table 3. Pearson's correlation analysis between daily total pollen concentration and meteorological data (*r* value).

Correlations	Daily mean wind speed	Daily mean temperature	Daily total precipitation	Daily mean relative humidity
Pinaceae	0.168*	–0.012	–0.014	–0.003
Cupressaceae	0.054	–0.102	–0.092	0.012
Poaceae	0.169*	0.032	–0.082	0.054
Quercus	–0.354**	–0.017	–0.171	–0.191
Betula	–0.271*	–0.145	–0.235	–0.423**
Alnus	–0.117	0.433*	–0.100	–0.164
Juglans	0.003	–0.251**	0.009	0.090
Asteraceae	0.331**	0.363**	–0.191*	–0.158
Amaranthaceae	0.157	0.142	0.107	0.082
Carpinus	0.063	0.052	0.190	0.296**
Corylus	–0.265	0.445**	–0.128	–0.375*
Plantago	–0.008	–0.134	–0.113	–0.071
Fabaceae	–0.004	–0.015	–0.149	–0.084
Rumex	0.047	–0.401**	–0.106	–0.012
Morus	0.124	–0.371**	–0.083	0.022
Populus	0.023	0.072	0.132	0.001
Rosaceae	0.006	–0.308**	–0.043	0.029

*: Correlation is significant at the 0.05 level (P-value). **: Correlation is significant at the 0.01 level (P-value).

A Pearson correlation test was performed to determine the statistical relationships of the daily pollen concentrations in the MPS of the taxa with the meteorological parameters in the same period (Table 4). According to the results, a positive correlation was found between daily mean wind speed and Pinaceae, Asteraceae, and Poaceae pollen concentrations, whereas *Quercus* and *Betula* pollen concentrations were negatively correlated. A positive correlation was found between daily mean temperature and *Alnus*, Asteraceae, and *Corylus* pollen concentrations, whereas *Juglans*, *Rumex*, *Morus*, and Rosaceae pollen concentrations were negatively correlated. Statistical analysis results showed a positive correlation between relative humidity and *Carpinus* pollen concentration and a negative correlation between *Betula* and *Corylus* pollen concentration. Daily total precipitation showed only a negative correlation with Asteraceae pollen concentration.

Discussion

In this study, we presented for the first time the volumetric and meteorological investigation of airborne pollen for the province of Gümüşhane, Turkey. It is not possible to compare the present study directly with any previous survey done in Gümüşhane. Most previous studies were carried out using the gravimetric method, and our results do not completely coincide with the data from those investigations. Nevertheless, we recognize that our pollen concentrations are comparable to those of other studies conducted in Turkey. The characterized pollen diversity of Gümüşhane was consistent with the local flora and vegetation. Local variations in the flora, vegetation, and topographic features affected regional pollen concentrations, as was previously shown for Turkey (İnceoğlu et al., 1994; Güvensen and Öztürk, 2003; Ayvaz et al., 2008; Çeter et al., 2012) as well as for other countries in the Mediterranean region such as Greece (Gioulekas et al., 2004) and Spain (Docampo et al., 2007).

Our results matched with the literature finding that arboreal plants (such as Pinaceae, Cupressaceae/Taxaceae, and *Quercus*) are the biggest contributors to airborne pollen. However, the pollen concentrations for these arboreal taxa were very variable when compared to the studies conducted with the Durham method (Güvensen and Öztürk, 2003; Ayvaz et al., 2008). The main reason for the quantitative differences is that the volumetric method allows capturing the airborne pollens more efficiently than the Durham method.

The time period (e.g., month) in which highest pollen detection was obtained and some of the dominant taxa recorded in Gümüşhane (Pinaceae, Cupressaceae/Taxaceae, *Quercus*, *Betula*, and Poaceae) were similar to

Table 4. Main pollen season (MPS) for the dominant taxa (>1%) in Gümüşhane's atmosphere.

Dominant taxa	Main pollen season		MPS length (days)	Max. daily concentration (pollen/m^3) / date
	Start	End		
Pinaceae	3 May	24 July	84	594 / 29.05.2011
Cupressaceae	15 March	9 July	117	463 / 25.03.2011
Poaceae	9 April	13 August	127	309 / 17.06.2011
Quercus	28 April	21 June	55	260 /19.05.2011
Betula	14 March	11 May	59	252 / 16.03.2011
Alnus	8 March	30 April	54	253 / 16.03.2011
Juglans	20 April	9 July	81	12 / 12.05.2011
Asteraceae	9 May	26 November	202	13 / 27.08.2011
Amaranthaceae	2 June	10 October	163	7 / 07.07.2011
Carpinus	13 March	4 May	51	77 / 20.04.2011
Corylus	6 February	23 March	46	40 / 16.03.2011
Plantago	4 May	18 August	97	25 / 29. 06.2011
Fabaceae	26 March	13 August	141	14 / 25.05.2011
Rumex	1 June	17 August	78	25 / 23.06.2011
Morus	1 May	21 June	52	36 / 04.05.2011
Populus	25 March	7 May	44	22 / 18.04.2011
Rosaceae	11 April	14 August	128	8 / 13.04.2011

those obtained for such studies done in Turkey (İnceoğlu et al., 1994; Güvensen and Öztürk, 2003; Ayvaz et al., 2008; Çeter et al., 2012; Uğuz et al., 2017, 2018). In particular, the month of highest concentration and the most dominant taxa were similar to those found in a study conducted in Kastamonu (Çeter et al., 2012). We assume that this similarity is a result of the location (Irano-Turan) and climate of both cities. The differences between the dominant taxa and the detection of pollen types and grains were caused by differences in the flora, vegetation, and topographical features. The weeds taxa identified in Gümüşhane (i.e. Amaranthaceae, *Plantago*, and *Rumex*) were also similar to those identified in other previous studies (İnceoğlu et al., 1994; Pınar et al., 1999, 2004; Çeter et al., 2012). The abundance of weed taxa pollen in our study was the consequence of the prevalence of such weeds along the Harşit and Kelkit rivers. Çeter et al. (2012) observed that the highest pollen detection was in May for Kastamonu. In the current study, however, May 2011 and June 2012 were found to have the highest pollen concentrations recorded in Gümüşhane Province. The difference can be attributed to the location of Gümüşhane between the Northeast Anatolia region and the Black Sea region, which distinguishes the climate of Gümüşhane, so the pollination season tends to start later. This is because the regional meteorological parameters are the most important stimulants for flowering, which affects both the term of the MPS and the month with the highest pollen record.

Pollen grains from Pinaceae and Poaceae were observed almost every month in the atmosphere of Gümüşhane. The reason was that the Kürtün-Örümcek Forest had Pinaceae communities and many Pinaceae trees were also present in the city center of Gümüşhane. In addition, our samples reflected considerable pollen detection from *Quercus*, which was the third most concentrated pollen in the atmosphere. This abundance was due to the widespread presence of *Quercus* plants on the hill slopes around the city of Gümüşhane. This shows that the topography, along with other factors, has a prominent influence on the types and distribution of pollen. Similarly, Pinaceae pollen was detected as a dominant taxon in the atmosphere of Kastamonu while *Quercus* pollen was detected among the most common taxa in the atmospheres of Kastamonu and Artvin (Çeter et al., 2012).

A significant percentage of the pollen in the atmosphere of Gümüşhane belongs to arboreal taxa, since they have the capability to produce more pollen than nonarboreal plants. Pinaceae, Cupressaceae/Taxaceae, *Quercus*, *Betula*, *Alnus*, and *Carpinus* are anemophilous trees. The abundance of tree pollen in the atmospheres of other cities was also given in previous studies (Güvensen and Öztürk, 2003;

Kaplan et al., 2003; Çeter et al., 2012). The wide diversity of pollen found in our study was due to the vegetation of Gümüşhane and its geographical location.

Similar to other municipalities, Gümüşhane has a typical urban system of government. Since the city workers were apparently unaware that *Betula pendula* is a highly allergenic plant, it was extensively used in Gümüşhane for ornamental plantings, which became an allergy cause for the residents.

In the first year of our study, the total pollen concentrations were observed to be higher than those obtained in the second year. A possible reason for this was the weather conditions related to the warm phase of the El Niño–Southern Oscillation phenomenon, which occurred in the first year of the study (Calderón-Ezquerro et al., 2016). Table 1 shows that the mean temperatures were higher in the first year than the second year of the study, which was recorded especially during the pollination period. Comparing the two study years, we found a significant decrease in the pollen detection for the second year. May and June are generally the period of pollen release for some nonherbaceous plants (e.g., Pinaceae, *Quercus*, and some Cupressaceae). However, pollen concentrations from these taxa were lower than the expected values, which could have resulted from the excessive precipitation (121.7 mm) and the extended rainy days that occurred in May 2012, which possibly washed away the pollen from the atmosphere. Thus, meteorological factors, as well as variations in the flora, vegetation, and topography, greatly affected the pollen concentrations in the MPS.

Another explanation for the considerable decrease in the pollen concentrations may be related to the stage of growth of the vegetation, because spring weather particularly started later because of low temperatures. Similar results were reported in previous studies (Hart, 1994; Kızılpınar et al., 2012). In the second year of the study, the growth of vegetation might have started later because the temperature did not exceed −0.1 °C until the end of March 2012 (Table 1). This explains why lower pollen detection was observed for *Betula* and *Alnus* in the second year.

Our statistical analyses revealed significant correlations between the effects of several meteorological parameters and pollen concentrations (Table 3). Some aerobiological studies showed that increases in wind speed and mean daily temperatures may have positive effects on pollen detection, especially in the MPS, whereas increases in the amount of rainfall, number of rainy days, and relative humidity may have negative effects on daily pollen concentrations (Schappi et al., 1998; Sanchez-Mesa et al., 2003; Smith and Emberlin, 2005; Noah et al., 2013). The effects of the meteorological factors on pollen detection showed dependence on the type of the taxa. For example, wind speed had a positive effect on Pinaceae, Poaceae, and Asteraceae pollen, whereas it had a negative effect on the pollen of *Quercus*, *Betula*, and *Alnus* (Table 3). Temperature had a positive effect on the *Alnus*, *Corylus*, and Asteraceae pollen, whereas it had a negative effect on the pollen of *Juglans*, *Rumex*, *Morus*, and Rosaceae. Relative humidity showed a positive correlation with *Carpinus* while it had a negative correlation with *Betula* and *Corylus*. A similar result was noted by Çeter et al. (2012). This emphasizes the fact that relationships found in one place cannot be applied directly to another and highlights the need to develop site-specific forecast models (Galán et al., 1995).

As a result of this study, it has been determined that the 70 pollen taxa detected in Gümüşhane's atmosphere were generally caused by the flora of the area and/or cultivated plants, among which a small number originated from exotic plants used in landscaping. Pollen detected in Gümüşhane's atmosphere was found to be predominantly from the wind-pollinated woody taxa. The main pollination season of the detected taxa differed from March to July, where the highest pollen concentration was observed in May and June. The results of the study showed that meteorological parameters could have different effects on pollen concentrations depending on the taxa.

Acknowledgments
This work was funded by a grant from the Scientific and Technological Research Council of Turkey (TÜBİTAK, SBAG, Project No: 109S265) and the Ankara University Office of Scientific Research Projects (14H0430001 HPD), as well as by COST Action ES0603 (EUPOL). The results presented here address one of the main scientific challenges described in COST Action ES0603, specifically Work Package 1 (pollen production and release).

References

Abreu I, Ribeiro H, Cunha M (2003). An aeropalynological study of the Porto region (Portugal). Aerobiologia 19: 235-241.

Altıntaş DU, Karakoc B, Yılmaz GB, Pınar NM, Kendirli SG, Cakan H (2004). Relationship between pollen counts and weather variables in east-Mediterranean coast of Turkey. Does it affect allergic symptoms in pollen allergic children? Clin Dev Immunol 11: 87-96.

Ayvaz A, Baki A, Doğan C (2008). Seasonal distributions of aeroallergens in the atmosphere of Trabzon, Turkey. Asthma Allergy Immunology 6: 11-16.

Bıçakçı A, Tosunoğulu A, Altunoğlu MK, Saatcioğlu G, Keser AM, Özgökce F (2017). An aeropalynological survey in the city of Van, a high altitudinal region, East Anatolia-Turkey. Aerobiologia 33: 93-108.

Boral D, Chatterjee S, Bhattacharya K (2004). The occurrence and allergising potential of airborne pollen in West Bengal, India. Ann Agr Env Med 11: 45-52.

Burge HA (1992). Monitoring for airborne allergens. Ann Allergy 69: 9-21.

Bush R (1989). Aerobiology of pollen and fungal allergens. J Allergy Clin Immunol 64: 1120-1124.

Calderón-Ezquerro MC, Guerrero-Guerra C, Martinez-López B, Fuentes-Rojas F, Téllez-Unzuenta F, López-Espinoza ED, Calderón-Segura ME, Martinez-Arroyo A, Trigo-Pérez MM (2016). First airborne pollen calendar for Mexico City and its relationship with bioclimatic factors. Aerobiologia 32: 225-244.

Çelik G, Mungan D, Pınar NM, Mısırlıgil Z (2005). Poplar pollen-related allergy in Ankara, Turkey: How important for patients living in a city with high pollen load? Allergy Asthma Proc 26: 113-119.

Çeter T, Pınar NM, Alan Ş, Yıldırım Ö (2008). Polen ve sporların haricinde atmosferde bulunan alerjen biyolojik partiküller. Asthma Allergy Immunology 6: 5-10 (in Turkish).

Çeter T, Pınar NM, Güney K, Yıldız A, Aşcı B, Smith M (2012). A 2-year aeropalynological survey of allergenic pollen in the atmosphere of Kastamonu, Turkey. Aerobiologia 28: 355-366.

Davis PH, Tan K, Mill RR (1965–1985). Flora of Turkey and the East Aegean Islands. Vols. 1–9. Edinburgh, UK: Edinburgh University Press.

Docampo S, Recio M, Trigo MM, Melgar M, Cabezudo B (2007). Risk of pollen allergy in Nerja (southern Spain): a pollen calendar. Aerobiologia 23: 189-199.

Dursun AB, Celik GE, Alan S, Pınar NM, Mungan D, Mısırlıgil Z (2008). Regional pollen load: effect on sensitisation and clinical presentation of seasonal allergic rhinitis in patients living in Ankara, Turkey. Allergol Immunopath 36: 371-378.

Emberlin J, Savage M, Jones S (1993). Annual variations in grass pollen seasons in London 1961–1990: trends and forecast models. Clin Exp Allergy 23: 911-918.

Esch RE, Hartsell CJ, Crenshaw R, Jacobson RS (2001). Common allergenic pollens, fungi, animals, and arthropods. Clin Rev Allerg 21: 261-292.

Galán C, Ariatti A, Bonini M, Clot B, Crouzy B, Dahl A, Fernandez-Gonzalez D, Frenguelli G, Gehrig R, Isard S et al. (2017). Recommended terminology for aerobiological studies. Aerobiologia 33: 293-295.

Galán C, Cariñanos P, Alcázar P, Dominguez-Vilches E (2007). Spanish Aerobiology Network (REA) Management and Quality Manual. Cordoba, Spain: Servicio de Publicaciones Universidad de Córdoba.

Galán C, Emberlin J, Dominguez E, Bryant R, Villamandos F (1995). A comparative analysis of daily variations in the Gramineae pollen counts at Cordoba, Spain and London, UK. Grana 34: 189-198.

Gioulekas D, Balafoutis C, Damialis A, Papakosta D, Gioulekas G, Patakas D (2004). Fifteen years' record of airborne allergenic pollen and meteorological parameters in Thessaloniki, Greece. Int J Biometeorol 48: 128-136.

Goldberg C, Buch H, Moseholm L, Weeke ER (1988). Airborne pollen records in Denmark 1977-1986. Grana 27: 209-217.

Güvensen A, Öztürk M (2002). Airborne pollen calendar of Buca İzmir, Turkey. Aerobiologia 18: 229-237.

Güvensen A, Öztürk M (2003). Airborne pollen calendar of Izmir, Turkey. Ann Agr Env Med 10: 37-44.

Hart ML, Wentworth JE, Bailey JP (1994). The effects of trap height and weather variables on recorded pollen concentration at Leicester. Grana 33: 100-103.

Hirst JM (1952). An automatic volumetric spore trap. Ann Appl Biol 39: 257-265.

İnce A (1994). Kırıkkale atmoserindeki allerjik polenlerin incelenmesi. Turk J Bot 18: 43-56 (in Turkish).

İnceoğlu O, Pınar NM, Şakiyan N, Sorkun K (1994) Airborne pollen concentration in Ankara, Turkey. Grana 33: 158-161.

Jato V, Dopazo A, Aira MJ (2002). Influence of precipitation and temperature on airborne pollen concentration in Santiago de Compostela (Spain). Grana 41: 232-241.

Jato V, Rodríguez-Rajo FJ, Alcázar P, De Nuntiis P, Galán C, Mandrioli P (2006). May the definition of pollen season influence aerobiological results? Aerobiologia 22: 13-25.

Kaplan A, Şakıyan N, Pınar NM (2003). Daily *Ambrosia* pollen concentration in the air of Ankara, Turkey (1990-1999). Acta Bot Sin 45: 1408-1412.

Karaer F, Kılınç M (2001). The flora of Kelkit Valley. Turk J Bot 25: 195-238.

Kızılpınar I, Doğan C, Artaç H, Reisli I, Pekcan S (2012). Pollen grains in the atmosphere of Konya (Turkey) and their relationship with meteorological factors, in 2008. Turk J Bot 36: 344-357.

Nilsson S, Proglowski J, Nilsson I (1977). Atlas of Airborne Pollen Grains and Spores in Northern Europe. Stockholm, Sweden: Verlag.

Noh YM, Lee H, Muller D, Lee K, Shin D, Shin S, Choi TJ, Kim KR (2013). Investigation of the diurnal pattern of the vertical distribution of pollen in the lower troposphere using LIDAR. Atmos Chem Phys 13: 7619-7629.

Öztürk F, Türktas I, Asal K, İleri F, Pınar NM (2004). Effect of intranasal triamcinolone acetonide on bronchial hyper-responsiveness in children with seasonal allergic rhinitis and comparison of perceptional nasal obstruction with acoustic rhinometric assessment. Int J Pediatr Otorhi 68: 1007-1015.

Pehlivan S, Butev F (1994). Aksaray ili atmosferindeki polenlerin araştırılması. Gazi Üniversitesi Fen Bilimleri Enstitüsü Dergisi 7: 143-151 (in Turkish).

Pınar NM, Geven F, Tuğ GN, Ketenoğlu O (2004). Ankara atmosferinde Gramineae polen sayılarının meteorolojik faktörlerle ilişkisi (1999-2002). Asthma Allergy Immunology 2: 65-70 (in Turkish).

Pınar NM, Şakıyan N, İnceoğlu O, Kaplan A (1999). A one-year aeropalynological study at Ankara, Turkey. Aerobiologia 15: 307-310.

Sanchez-Mesa JA, Smith M, Emberlin J, Allitt U, Caulton E (2003). Characteristics of grass pollen seasons in areas of southern Spain and the United Kingdom. Aerobiologia 19: 243-250.

Schappi GF, Taylor PE, Kenrick J, Staff IA, Suphioglu C (1998). Predicting the grass pollen count from meteorological data with regard to estimating the severity of hayfever symptoms in Melbourne (Australia). Aerobiologia 14: 29-37.

Sin AB, Pınar NM, Mısırlıgil Z, Çeter T, Yıldız A, Alan Ş (2007). Polen Alerjisi: Türkiye Alerjik Bitkilerine Genel Bir Bakış. Ankara, Turkey: Engin Yayınevi (in Turkish).

Singh AB, Dahiya P (2008). Aerobiological researches on pollen and fungi in India during the last fifty years: an overview. Indian Journal of Allergy, Asthma and Immunology 22: 27-38.

Smith M, Emberlin J (2005). Constructing a 7-day ahead forecast model for grass pollen at north London, United Kingdom, Clin Exp Allergy 35: 1400-1406.

Subiza J, Jerez M, Jimenez JA, Narganes MJ, Cabrera M, Varela S, Subiza E (1995). Clinical aspects of allergic disease: allergenic pollen and pollinosis in Madrid. J Allergy Clin Immun 96: 15-23.

Tosunoğlu A, Altunoglu MK, Bıçakçı A, Kilic O, Gonca T, Yilmazer I, Saatcioglu G, Akkaya A, Celenk S, Canitez Y et al. (2015a). Atmospheric pollen concentrations in Antalya, South Turkey. Aerobiologia 31: 99-109.

Tosunoğlu A, Babayiğit S, Bıçakçı A (2015b). Aeropalynological survey in Büyükorhan, Bursa. Turk J Bot 39: 40-47.

Uğuz U, Güvensen A, Şengonca Tort N (2017). Annual and intradiurnal variation of dominant airborne pollen and the effects of meteorological factors in Çeşme (Izmir, Turkey). Environ Monit Assess 189: 530.

Uğuz U, Güvensen A, Şengonca Tort N, Eşiz Dereboylu A, Baran P (2018). Volumetric analysis of airborne pollen grains in the city of Uşak, Turkey. Turk J Bot 42: 57-72.