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Aeropalynological survey in Büyükorhan, Bursa

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Abstract: An aeropalynological survey of the atmosphere of Büyükorhan in Bursa Province was carried out from January 2012 to December 2013 using a Durham gravimetric sampler. The number of pollen grains per cm^2 was calculated on a weekly basis. Over 2 years a total of 13,274 pollen grains/cm^2 from 44 taxa, including 24 arboreal plants (APs) and 20 nonarboreal plants (NAPs), and unidentified pollen grains were recorded. In 2012 and 2013, respectively, 5159 and 8115 pollen grains were recorded. The pollen grains consisted of 87.46% APs, 12.20% NAPs, and 0.35% unidentified plants. *Pinus*, Cupressaceae/Taxaceae, *Quercus,* Poaceae, *Morus*, *Plantago*, *Olea europaea*, and *Cedrus* were responsible for the highest pollen amounts in the study area. The highest number of pollen grains (49.84%) was recorded during May.

Key words: Pollen calendar, pollen fall, airborne pollen, Büyükorhan, Bursa, Turkey

1. Introduction

Pollen allergy (hay fever, pollinosis) is a common disease caused by a hypersensitivity reaction of the respiratory tract and eye conjunctivae to pollen grains. During the last quarter of the 20th century an increase in the population of those who are hypersensitive was observed, especially in developed countries. Knowledge of the pollen content of the atmosphere is considered a very useful tool in the treatment and diagnosis of hay fever. Many different species of pollen grains disperse in the atmosphere, and they are correlated with the flora, agriculture, and climate of each region. Therefore, detecting pollen types and their concentrations is very important, particularly in the atmosphere of highly populated cities. Knowledge of the abundance of allergenic pollen types and their pollination seasons is useful to allergologists, who can correlate hay fever symptoms with the presence of allergenic pollen in the atmosphere (Romano and Castellano, 1992). For this reason, studies of airborne pollen variability and concentration in different areas have been carried out by researchers in many parts of the world (Giner et al., 2002; Peternel et al., 2003; Weryszko-Chmielewska and Piotrowska, 2004; Melgar et al., 2012; Ianovici et al., 2013). In Turkey, palynological studies began in the 1960s, and Durham samplers were frequently used for aeropalynological sampling in preliminary studies. In addition, many pollen calendars prepared in this manner in Turkey (Bicakci et al., 2002; Bicakci, 2006; Tosunoglu et al., 2009; Altunoglu et al., 2010; Ozturk et al., 2013) are important for studies that include phenology, ecology, and pollination biology (Rizzi Longo and Cristofolini, 1987).

The aims of this study were as follows: (1) to present the results from 2 years (2012–2013) of continuous sampling of airborne pollen in the atmosphere of Büyükorhan, Bursa Province; (2) to clarify what pollen types are present in the air, including the pollen percentage values and pollen season periods; and (3) to prepare a pollen calendar.

2. Materials and methods

2.1. Study area

Büyükorhan (Bursa Province) has a municipality area of nearly 5000 ha, and it is surrounded by Harmancık to the east, Mustafakemalpaşa to the west, Orhaneli to the north, and the town of Dursunbey in Balıkesir Province to the south. Büyükorhan is located on the southern slope of Uludağ (39°46.2′N, 28°54.0′E) at an altitude of 820 m.

According to meteorological data provided by the Turkish State Meteorological Service, the annual temperature (25-year average) is 14.6 °C. The minimum temperature is 0.6 °C, observed in February, and the maximum temperature is 31.7 °C, observed in July. The annual average rainfall is 585.8 mm, and the relative humidity is 64.0%. On average, 176 days of the year are sunny, 90 days are cloudy, and 109 days are rainy. The

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dominant wind direction in Büyükorhan is from the north.

In Büyükorhan, apart from miscellaneous private and public plants, field agriculture is common; therefore, the natural flora has been replaced by cultured plants in these areas. There are forests in the southern and southeastern parts of the settlement area. Major vegetation in these forest areas consists of *Pinus nigra* Arn. subsp. *pallasiana* (Lamb.) Holmboe, *Fagus orientalis* Lipsky., *Carpinus betulus* L., *Quercus pubescens* Willd., and *Juniperus oxycedrus* L. In addition to the natural vegetation of Büyükorhan, the following species are also frequently observed in the parks, gardens, and streets of the city: *Acacia* sp., *Acer* sp., *Alnus glutinosa* (L.) Gaertn., *Betula* sp., *Carpinus betulus* L., *Castanea sativa* Mill., *Cedrus libani* A. Rich., *Cercis siliquastrum* L., *Cornus mas* L., *Cupressus sempervirens* L., *Cupressus arizonica* Green, *Elaeagnus angustifolia* L., *Forsythia* sp., *Juglans regia* L., *Juniperus* sp., *Lonicera* sp., *Malus domestica* Borkh., *Morus* sp., *Olea europaea* L., *Platanus orientalis* L., *Populus* sp., *Prunus domestica* L., *Salix babylonica* L., *Thuja* sp., and *Tilia tomentosa* Moench. The field crops grown in the town are *Triticum* sp., *Zea mays* L., *Solanum tuberosum* L., and *Fragaria* sp.

2.2. Pollen sampling

From 1 January 2012 to 31 December 2013 a Durham gravimetric pollen trap was positioned at the top of a structure with a height of 3 m above ground level. On a weekly basis, slides were covered with glycerin jelly mixed with basic fuchsine (Charpin et al., 1974). A binocular light microscope was used for identification, and the number of pollen grains was expressed per cm^2 of the glass cover of the microscope. Pollen grains of identified taxa in Büyükorhan's atmosphere were shown on a calendar prepared using the average pollen count and constructed in 5 steps for weekly totals of pollen numbers.

3. Results and discussion

The total number of pollen grains collected over the 2-year sampling period was 13,274. A total of 44 taxa were identified; 24 belonged to arboreal plants (APs) and 20 to nonarboreal plants (NAPs). The total number of pollen grains consisted of 11,609 (87.46%) APs, 1619 (12.20%) NAPs, and 46 (0.35%) unidentified plants (Table 1).

Arboreal pollen grains were dominant in the atmosphere of Büyükorhan. The woody taxa, such as *Pinus* (36.93%), Cupressaceae/Taxaceae (20.69%), *Quercus* (18.86%), *Morus* (3.34%), *Olea europaea* (1.57%), and *Cedrus* (1.22%), showed maximum pollen distribution in the atmosphere, representing 82.61% of the total pollen content (Table 1). The frequency of arboreal pollen grains depends on the distribution and density of the local vegetation and on the rate of pollen production. According to other studies carried out in Europe, arboreal pollen grains are also dominant in Kütahya, Turkey (82.88%) (Biçakçı et al., 1999); Bursa, Turkey (78.61%) (Bicakci et al., 2003); İstanbul, Turkey (75.61%) (Celenk et al., 2010); Ostrowiec Swietokrzyski, Poland (73.00%) (Kasprzyk, 1996); Perugia (71.00%) and Ascoli-Piceno, Italy (55.00%) (Romano et al., 1988); and Balıkesir, Turkey (70.92%) (Bicakci and Akyalcin, 2000).

Among NAP taxa, Poaceae (7.00%) and *Plantago* (2.02%) pollen dominated the area. These taxa accounted for 9.02% of the total pollen content (Table 1). In Turkey, Poaceae is frequently found as nonarboreal pollen in the atmosphere (Bilişik et al., 2008; Altunoglu et al., 2008; Güvensen et al., 2013; Tosunoğlu et al., 2013).

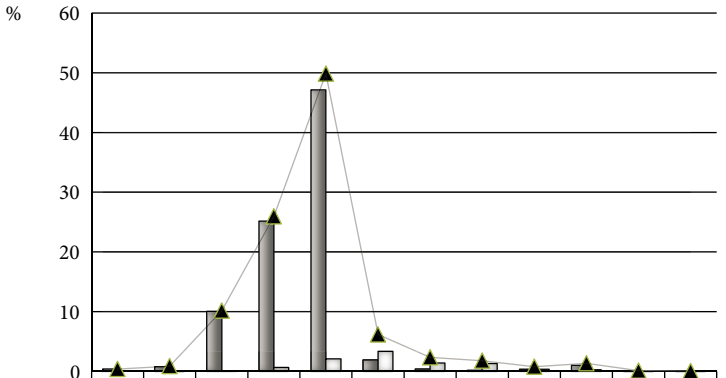
The monthly mean percentages of arboreal, nonarboreal, and total pollen grains recorded in the atmosphere of Büyükorhan are shown in Figure 1. In our study, there was an increase in the number of pollen grains from March to May (Figure 1). Over the sampling period the highest number of pollen grains was recorded in May with 49.84% of the total pollen grains, among which 47.11% originated from APs (Figure 1; Table 2). The second highest pollen count (25.95%) occurred in April and consisted mostly of *Pinus*, *Quercus*, Cupressaceae/Taxaceae, and *Morus* pollen grains (Table 2). During January, February, September, November, and December pollen grains were recorded in very low levels (<1.0%). In March, April, May, and October pollen grains of APs were dominant compared to June, July, and August which were dominated by nonarboreal pollen grains. The earliest airborne pollen grains recorded in January were from the following species: *Alnus glutinosa*, Cupressaceae/Taxaceae, *Betula*, and Poaceae (Figure 2). Pollen grains recorded in Büyükorhan's atmosphere in spring were mostly from APs such as Cupressaceae/Taxaceae, *Pinus*, *Fraxinus*, *Alnus glutinosa*, *Betula*, *Quercus*, *Platanus*, *Morus*, and *Olea europaea* (Figure 2).

A pollen calendar was prepared by using average values of pollen counts (Figure 2). The calendar shows pollination seasons, pollen intensities, and variations in pollen grains on a per-taxa basis. Eight plant taxa accounted for more than 1% of the total pollen content (Table 2).

Pinus pollen has been recorded at high levels in many Turkish cities (Bıçakçı et al., 2011b), such as Mudanya (11.48%) (Bıçakçı et al., 1995), Kütahya (35.82%) (B**ıçakçı** et al., 1999), Burdur (28.13%) (Bicakci et al., 2000a), Afyon (26.27%) (Bicakci et al., 2002), Fethiye (42.46%) (Bilisik et al., 2008b), Didim (45.58%) (Bilisik et al., 2008c), and İzmir (57%–57.3%) (Guvensen and Ozturk, 2003). In our study, pollen grains belonging to the genus *Pinus* comprised 36.93% of the total pollen in the atmosphere of Büyükorhan (Table 2). There was a relatively long season for pine pollen that started in the 2nd week of March, reached maximum levels in the 16th and 18th and between the 20th and 22nd weeks of the year, and ended in the 3rd week of October

Table 1. Annual pollen counts and percentage of pollen taxa recorded in Büyükorhan atmosphere (2012–2013).

	2012		2013		2012–2013	
	TOTAL	%	TOTAL	%	TOTAL	%
Pinus	949	18.40	3953	48.71	4902	36.93
Cupressaceae/Taxaceae	1225	23.74	1522	18.76	2747	20.69
Quercus	1556	30.16	947	11.67	2503	18.86
Morus	95	1.84	348	4.29	443	3.34
Olea europaea	145	2.81	64	0.79	209	1.57
Cedrus	142	2.75	20	0.25	162	1.22
Alnus	51	0.99	46	0.57	97	0.73
Platanus	58	1.12	21	0.26	79	0.60
Fagus orientalis	48	0.93	8	0.10	56	0.42
Abies	10	0.19	42	0.52	52	0.39
Acer	35	0.68	17	0.21	52	0.39
Betula	34	0.66	14	0.17	48	0.36
Fraxinus	36	0.70	9	0.11	45	0.34
Juglans	26	0.50	16	0.20	42	0.32
Pistacia	35	0.68	7	0.09	42	0.32
Ulmus	6	0.12	21	0.26	27	0.20
Castanea sativa	18	0.35	6	0.07	24	0.18
Populus	10	0.19	8	0.10	18	0.14
Rosaceae	6	0.12	9	0.11	15	0.11
Tilia	5	0.10	8	0.10	13	0.10
Ericaceae	5	0.10	6	0.07	11	0.08
Salix	3	0.06	8	0.10	11	0.08
Carpinus	4	0.08	4	0.05	8	0.06
Ostrya carpinifolia	2	0.04	1	0.01	3	0.02
Arboreal pollen grains	4504	87.30	7105	87.55	11,609	87.46
Poaceae	336	6.51	593	7.31	929	7.00
Plantago	100	1.94	168	2.07	268	2.02
Chenopodiaceae/Amaranthaceae	46	0.89	52	0.64	98	0.74
Rumex	48	0.93	33	0.41	81	0.61
Ambrosia	9	0.17	48	0.59	57	0.43
Urticaceae	38	0.74	15	0.18	53	0.40
Asteraceae	13	0.25	16	0.20	29	0.22
Apiaceae	10	0.19	12	0.15	22	0.17
Artemisia	6	0.12	10	0.12	16	0.12
Brassicaceae	2	0.04	12	0.15	14	0.11
Fabaceae	7	0.14	6	0.07	13	0.10
Taraxacum	7	0.14	5	0.06	12	0.09
Cyperaceae	5	0.10	5	0.06	10	0.08
Xanthium	2	0.04	5	0.06	7	0.05
Mercurialis	4	0.08	1	0.01	5	0.04
Campanulaceae	-	-	1	0.01	1	0.01
Caryophyllaceae	-	-	1	0.01	1	0.01
Papaver	-	-	1	0.01	1	0.01
Rubiaceae	1	0.02	-	-	1	0.01
Typha	-	-	1	0.01	1	0.01
Nonarboreal pollen grains	634	12.29	985	12.14	1619	12.20
Unidentified	21	0.41	25	0.31	46	0.35
TOTAL	5159	100.00	8115	100.00	13,274	100.00



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Arboreal pollen grains	0.39	0.80	10.05	25.13	47.11	1.91	0.40	0.20	0.35	1.02	0.06	0.02
Nonarboreal pollen grains	0.00	0.05	0.08	0.66	2.09	3.37	1.40	1.31	0.35	0.29	0.05	0.03
TOTAL	0.41	0.90	10.18	25.95	49.84	6.19	2.36	1.81	0.80	1.37	0.14	0.06

Figure 1. Annual percentage of arboreal and nonarboreal pollen grains recorded in the atmosphere of Büyükorhan (mean values of 2012–2013).

Table 2. Plant taxa in Büyükorhan comprising more than 3% of the total pollen content and their yearly percentage of composition as a mean value.

Taxa/months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
Pinus	-	-	0.11	7.34	27.70	1.34	0.20	0.14	0.08	0.02	-	-	36.93
CupressaceaeTaxaceae	0.32	0.35	9.06	6.55	3.93	0.16	0.15	0.02	0.02	0.09	0.02	0.02	20.69
Quercus	-	-	-	7.50	11.32	0.03	-	-	-	-	-	-	18.86
Poaceae	0.02	0.03	0.08	0.32	1.79	2.49	1.08	0.89	0.17	0.08	0.04	0.02	7.00
Morus	-	-	0.01	1.33	2.00	-	-	-	-	-	-	-	3.34
Plantago	-	-	0.01	0.08	0.19	1.24	0.39	0.07	0.04	-	-	-	2.02
Olea europaea	-	-	-	-	1.44	0.13	0.01	-	-	-	-	-	1.57
Cedrus	-	-	-	-	-	-	-	0.03	0.24	0.91	0.04	-	1.22
Others	0.08	0.51	0.92	2.83	1.46	0.80	0.53	0.66	0.24	0.28	0.05	0.03	8.37
TOTAL	0.41	0.90	10.18	25.95	49.84	6.19	2.36	1.81	0.80	1.37	0.14	0.06	100.00

(Figure 2). In 2012 and 2013 the total pine pollen numbers were 949 and 3953 pollen/cm^2, respectively (Table 1), with the highest value (27.70% of the total number of pollen grains) recorded in May (Table 2).

Cupressaceae/Taxaceae pollen grains are found throughout the year, with some exceptions. In Turkey, Cupressaceae/Taxaceae (or *Cupressus* type) pollen grains have been recorded as dominant in many locations (Bicakci and Akyalcin, 2000; Bicakci et al., 2000b; Bıçakçı et al., 2010). There are similar reports from Italy (Ballero and Maxia, 2003) and Greece (Gioulekas et al., 2004). Pollen grains of the families Cupressaceae and Taxaceae were identified together because of their similarities. These 2 families accounted for 20.69% of the total pollen grains in the atmosphere (Table 2). The Cupressaceae/Taxaceae pollen season reached a maximum in the 12th, 13th, and 18th– 19th weeks (Figure 2). The total pollen count was 1225 and 1522 pollen/cm^2 in 2012 and 2013, respectively (Table 1). The highest value occurred in March, with 9.06% of the total number of pollen grains (Table 2).

Pollen grains of *Quercus* comprised 18.86% of the total pollen content (Table 1). These types of pollen grains are also dominant in Nerja (8.91%) (Docampo et al., 2007), Cordoba Hornachuelos National Park (59.81%) (Garcia-Mozo et al., 2007), and Yalova (3.07%) (Altunoglu et al., 2008). The pollen season started in the 1st week of April,

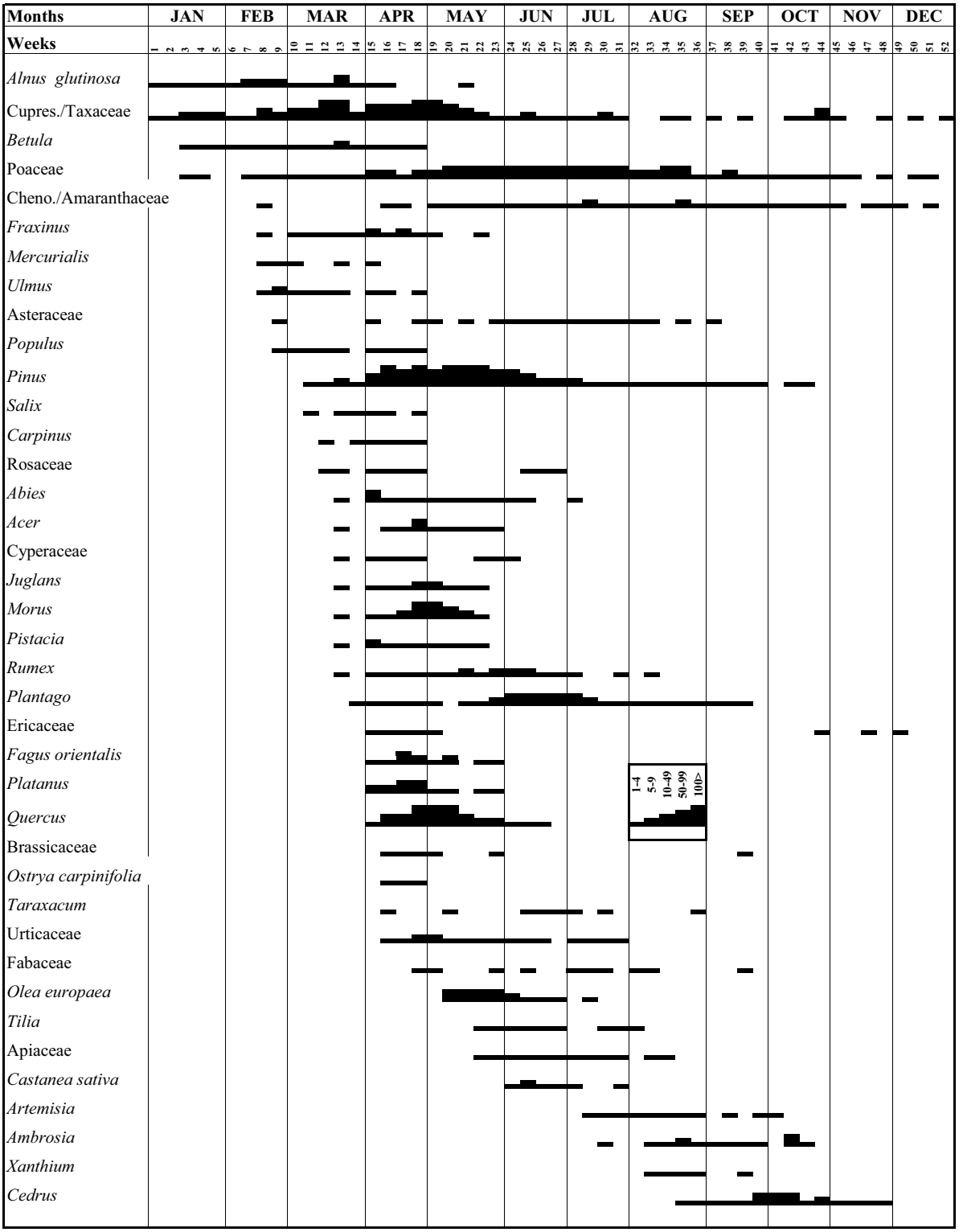


Figure 2. Pollen calendar of Büyükorhan, Bursa.

reached a maximum level between the 18th and 20th weeks, and lasted until the 3rd week of June (Figure 2). The total number of *Quercus* pollen grains in 2012 was 1556, compared to 947 pollen/cm^2 in 2013 (Table 1). This type of pollen reached its maximum level in May, accounting for 11.32% (Table 2).

Poaceae was the most abundant nonarboreal pollen type in the atmosphere of Büyükorhan, and this family represented 7.00% of the annual pollen index (Table 1). Poaceae pollen grains were recorded throughout the year but mainly in low concentrations (Table 2). This long pollination period was most likely due to limited identification; Poaceae pollen may be identified at the family level, and this type of pollen originates from many wild grass species with different flowering times over several months. Poaceae pollen grains were initially recorded in the atmosphere of Büyükorhan in the 3rd week of January, reached maximum levels between the 20th and 31st weeks, and lasted until the 3rd week of June (23rd week) (Figure 2). The total pollen numbers per cm^2 were 336 and 593 in 2012 and 2013, respectively (Table 1). The highest value was reported in June, which accounted for 2.49% of the total number of pollen grains (Table 2). Poaceae pollen grains were reported as the most common among NAPs in studies conducted in İzmir (7.7%–6%) (Guvensen and Ozturk, 2003), Sakarya (18.95%) (Bicakci, 2006), and Didim (6.33%) (Bilisik et al., 2008c).

The other dominant contributors to pollen grains in the atmosphere of Büyükorhan belonged to the genus *Morus*, which constituted 3.34% of the total pollen count (Table 2). Mulberry was one of the dominant types of tree pollen in the atmosphere of the study area because it is widely cultivated in orchards. The pollen season of mulberry was relatively short; it started in the 4th week of March, reached a maximum during the 18th–19th weeks, and ended in the 4th week of May (Figure 2). The total pollen counts were 95 and 348 pollen/cm^2 in 2012 and 2013, respectively (Table 1). *Morus* pollen grains were mostly identified within the family Moraceae in the other studies, except Bursa (Bicakci et al., 2003) and İzmir (Guvensen et al., 2003), which had lower levels, and Fethiye, which had higher levels (9.29%) (Bilisik et al., 2008b).

Plantago pollen grains accounted for 2.02% of the total pollen grains in the atmosphere (Table 2). *Plantago* pollen was found to be dominant in Porto (Abreu et al., 2003) and Lublin (Weryszko-Chimielewska and Piotrowska, 2004). The *Plantago* pollen season started in the last week of March (14th week), reached a maximum between the 24th and 28th weeks, and ended in the 3rd week of September (39th week) (Figure 2). The total number of pollen grains per cm^2 was 100 in 2012 and 168 in 2013 (Table 1). The highest value was recorded in June, which accounted for 1.24% of the total number of pollen grains (Table 2).

Pollen grains of *Olea europaea* composed 1.57% of the total pollen amount (Table 2). These pollen grains had a relatively short season, which started in the second week of May (20th week), reached a maximum in the 20th–23rd weeks, and ended in the second week of July (Figure 2). The total number of *Olea europaea* pollen grains was 145 and 64 in 2012 and 2013, respectively (Table 1). The highest value was recorded in May, which accounted for 1.44% of the total number of pollen grains (Table 2). *Olea europaea* pollen grains were found in high levels in the atmosphere of Murcia (9.36%) (Giner et al., 2002), Çanakkale (5.13%) (Guvensen et al., 2005), Toledo (7.5%) (García-Mozo et al., 2006), and Kuşadası (34.46%) (Tosunoğlu et al., 2013).

Pollen grains of *Cedrus* comprised 1.22% of the total pollen count in the atmosphere of Büyükorhan (Table 2). The *Cedrus* pollen season started in the 4th week of August (35th week), reached a maximum between the 20th and 22nd weeks, and ended in the last week of November (48th week) (Figure 2). The total number in 2012 was 142, compared to 20 in 2013 (Table 1). The highest value was in October, which accounted for 0.91% of the total number of pollen grains (Table 2).

According to other studies carried out in Europe, Gramineae, Urticaceae, Oleaceae, and *Artemisia* were found in Ascoli Piceno, Italy (Nardi et al., 1986). The dominant airborne taxa were Gramineae, *Alnus*, *Artemisia*, *Urtica*, *Betula*, and *Quercus* in Leiden, the Netherlands (Spieksma et al., 1991); *Pinus*, *Olea*, *Platanus*, Gramineae, Cupressaceae, Taxaceae, *Quercus*, *Acer*, *Morus*, *Xhanthium*, *Castanea*, Chenopodiaceae, Amaranthacea, *Corylus, Artemisia, Urtica*, and *Fraxinus* in Bursa (Bicakci et al., 2003); *Pinus*, Cupressaceae/Taxaceae, Gramineae, *Platanus*, *Quercus*, *Olea*, *Salix*, Urticaceae, Moraceae, *Plantago*, Chenopodiaceae/Amaranthaceae, *Ailanthus*, *Juglans*, *Carpinus*, and Rosaceae in Balıkesir (Bicakci and Akyalcin, 2000); *Pinus*, *Quercus*, Cupressaceae/Taxaceae, *Salix*, *Platanus*, *Populus*, *Carpinus*, *Fagus*, Moraceae, *Corylus*, *Fraxinus*, Gramineae, Chenopodiaceae/Amaranthaceae, *Xanthium*, and Urticaceae in Sakarya (Bicakci, 2006); and *Olea europaea*, Cupressaceae/Taxaceae, *Pinus*, *Platanus*, Poaceae, and *Morus* in Kuşadası (Tosunoğlu et al., 2013).

In addition, all of the dominant pollen types that were recorded in Büyükorhan were reported to be important allergens in other studies conducted throughout the world. The high levels of important allergic pollen grains recorded in this study were consistent with results reported for *Pinus*/Pinaceae (Bousquet et al., 1984; Harris and German, 1985; Fang et al., 2001; Bıçakçı et al., 2011b), Cupressaceae/Taxaceae (D'Amato and Licardi, 1994; Bıçakçı et al., 2010), *Quercus* (Levétin and Buck, 1980; Spieksma, 1990; D'Amato et al., 1991), Poaceae (Bousquet et al., 1984; D'Amato and Spieksma, 1992; Mandal et al., 2008; Bıçakçı et al., 2009b), *Morus* (Chapman et al., 1984; Benito Rica et al., 2001), *Plantago* (Gioulekas et al., 2004; Bıçakçı et al., 2011a), and *Olea europaea* (D'Amato and Lobefalo, 1989; Macchia et al., 1991; D'Amato and Liccardi, 1994; Liccardi et al., 1996; Gioulekas et al., 2004; Bıçakçı et al., 2009a).

In conclusion, pollen grains from 44 taxa were identified during the pollen season in the atmosphere of Büyükorhan, and among these taxa 8 constituted 91.63% of the total spectrum (Table 2). In the investigated region, pollen grains were recorded year round and reached their maximum levels from March to May (Figure 1). The pollen calendar for the region presented in this study may be useful for allergologists to establish an exact diagnosis.

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