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Analysis of airborne pollen grains in Denizli

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Abstract: Airborne pollen distribution in Denizli Province was measured volumetrically during 2 consecutive years, 2005 and 2006, on a weekly basis. A total of 11,981 pollen grains/m^3 belonging to 42 taxa were determined. In 2005 the total was 5368 pollen grains/m^3 and in 2006 it was 6613 pollen grains/m^3. Among the taxa recorded, 26 belonged to arboreal and 16 to nonarboreal taxa. At the end of the 2 years total pollen counts comprised 79.68% arboreal, 19.48% nonarboreal, and 0.84% unidentified taxa. The number of pollen grains/m^3 among arboreal plants was as follows: Pinaceae (24.19%), Cupressaceae/Taxodiaceae (15.99%), *Olea europaea* (11.35%), *Quercus* spp. (6.08%), *Platanus orientalis* (5.68%), *Acer* spp. (2.93%), *Morus* spp. (2.58%), *Salix* spp. (1.59%), and *Eucalyptus camaldulensis* (1.47%), and for nonarboreal representatives: Poaceae (6.63%), Asteraceae (3.08%), Chenopodiaceae/Amaranthaceae (2.27%), *Plantago* spp. (2.12%), Urticaceae (1.82%,) and *Xanthium strumarium* (1.52%). The distribution of pollen in the atmosphere of Denizli was highest in May, followed by June, April, and March.

Key words: Aeropalynology, pollen calendar, allergy, Denizli, Turkey

1. Introduction

The release of large amounts of pollen grains in the atmosphere by the male reproductive units of plants for the purpose of pollination is a natural phenomenon. However, during this release pollen grains come into contact with humans, resulting in allergic reactions symptomised by breathlessness and running and itching of the nose and eyes, which is called pollinosis (Wuthrich, 1989; D'Amato et al., 1991; Bousquet, 2001). These allergies are diagnosed as bronchial asthma, hay fever, naso-bronchial allergy, conjunctivitis, contact dermatitis, and others. The reason for these allergies is the presence of proteins, glycoproteins, or even a single peptide in the pollen wall and cytoplasm (Chanda, 1994). Therefore, information on the presence and frequency of particular pollen grains in our surroundings is of paramount importance for allergic patients in order to take preventive measures.

The pollen allergy incidence shows variation all over the world, depending on the countries and climates. The allergy incidence rates reported for some Mediterranean countries are as follows: Croatia 15%–20%, Italy 13%, Israel 15%, and Spain 15%–18% (Burney, 1993; Bousquet, 2001). In Turkey the incidence of allergies varies between 15% and 18%. Very few studies have been undertaken on the incidence of allergic rhinitis in Turkey. Study carried out in Denizli on 951 adults varying in age between 19 and 65 revealed that the incidence of allergic rhinitis in the population varies between 5% and 10%; it was higher among women than among men and higher among children as compared to adults (Topuz et al., 2006).

The dispersal of airborne pollen grains in countries (including Turkey) experiencing a Mediterranean climate has been evaluated volumetrically by many researchers (Abreu et al., 2003; Ballero & Maxia, 2005; Docampo et al., 2007; Stefanic et al., 2007). During the last decade, a lot of work has been done in Turkey as well (Aytuğ et al., 1995; Pinar et al., 1999; Bıçakçı et al., 2002; Güvensen & Öztürk, 2002; Kaplan, 2004; Celik et al., 2005; Bicakci, 2006; Celenk et al., 2010; Erkan et al., 2011; Kızılpınar et al., 2012). Aeropalynological studies undertaken in 49 regions of Turkey demonstrated that the most widespread and highest in number of pollen grains in the atmosphere are Cupressaceae, *Pinus* spp., and Poaceae, the other important taxa being *Artemisia* spp., Chenopodiaceae/Amaranthaceae, *Fraxinus* spp., *Olea europaea* L., *Platanus orientalis* L., *Quercus* spp., Urticaceae, and *Xanthium strumarium* L. (Bıçakçı et al., 2009).

Our aim in the present study was to investigate the airborne pollen distribution in the region of Denizli. A characterisation of anemophyllous taxa in the city

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was undertaken and variation and dynamics of pollen production recorded during 2 consecutive years, 2005 and 2006. The results obtained are expected to provide a pollen distribution calendar for the area in order to help in the prevention of allergic reactions in individuals with pollen hypersensitivity.

1.1. Study area and plant cover

Denizli Province is situated in the western Anatolian part of Turkey, covering approximately an area of 12,000 km^2, with a population of around 850,000. It is included in the Mediterranean phytogeographical division of Turkey and has a typical Mediterranean climate of the semiarid type (Akman, 1999). The area shows a rich plant diversity of both wild and cultivated forms. This diversity is exhibited in the pollen spectrum as well. The majority of the sources of airborne pollen are present in the local and regional flora. Some of them are used for ornamental purposes and do not represent the local flora, such as *Abies* Mill., *Alnus* Mill., *Cedrus* Link., *Cupressus* L., *Eucalyptus* L'Her., *Taxus* L., and *Tilia* L.

At higher altitudes, forests of *Pinus nigra* Arnold. subsp. *pallasiana* (Lamb.) Holmboe, *Pinus brutia* Ten., *Juniperus excelsa* M.Bieb., *Juniperus oxycedrus* L. subsp. *oxycedrus* L., *Quercus pubescens* Willd., and *Quercus infectoria* Olivier subsp. *boissieri* (Reuter) O.Schwarz dominate the area (approximately 40% of the total area). In addition to these, *Castanea sativa* Miller and *Corylus avellana* L. show a restricted distribution on mounts Babadağ and Çökelez situated within the borders of the province; but at lower altitudes scrubland and phrygana cover large areas and include such taxa as *Arbutus* spp., *Cistus* spp., *Olea europaea* L., *Phillyrea latifolia* L., *Pistacia* spp., *Quercus* spp., and *Sarcopoterium spinosum* (L.) Spach. The arboreal plant taxa commonly observed in the parks and some gardens of homes are *Abies* spp., *Acer negundo* L., *A. campestre* L., *Ailanthus altissima* (Miller) Swingle, *Alnus glutinosa* (L.) Gaerthner, *Cedrus* spp., *Cercis siliquastrum* L., *Cupressus sempervirens* L., *Eucalyptus camaldulensis*, *Fraxinus* spp., *Juglans regia* L., *Ligustrum vulgare* L., *Morus* spp., *Olea europaea*, *Pinus* spp., *Platanus orientalis* L., *Populus* spp., *Salix* spp., *Taxus baccata* L., *Thuja* spp., *Tilia argentea* Desf. ex DC, and *Ulmus minor* Miller, whereas nonarboreal taxa along the roads and in open spaces within the city limits are Poaceae and Asteraceae, together with *Amaranthus* spp., *Chenopodium* spp., *Mercurialis annua* L., *Parietaria judaica* L., *Plantago* spp., *Ranunculus* spp., *Rumex* spp., *Urtica* spp., and *Xanthium strumarium* L. Several taxa belonging to Cyperaceae, Juncaceae, and *Typha* spp. are found around the wetlands.

Olives, pomegranates, figs, apples, grapes, cherries, peaches, apricots, pears, quinces, plums, wheat, barley, oats, tobacco, cotton, tomatoes, peppers, radishes, onions, and garlic are cultivated widely in the province.

2. Materials and methods

In Denizli Province, for the period 2005–2006 atmospheric pollen distribution was recorded volumetrically (Hirst, 1952) on a weekly basis by placing a Lanzoni trap (a 7-day recorder, model VPPS 2000, by Lanzoni s.r.l.) at a height of 20 m from the ground on the roof top of Pamukkale University Hospital open to air circulation on all sides. Pollen was caught on 24-mm wide transparent tape coated by a thin film of silicon oil. The tape was mounted on a cylinder rotating at a speed of 2 mm/h. A complete rotation of the cylinder took 7 days. The strip was changed weekly. Weekly tape strips were cut into 7 pieces, each 48 mm in length. Each piece corresponded to 1 day sampling. These were examined microscopically using a ×40 objective (0.45 mm microscopic field) according to the methodology proposed by REA (Domínguez et al., 1991). Pollen grains were identified using the pollen collection in the Aerobiology Laboratory of the Botany Department, Ege University (İzmir, Turkey). Further comparisons were made using the illustrations published by different authors (Erdtman, 1966, 1969; Louveaux, 1970; Moore et al., 1991; Pehlivan, 1995; Sin et al., 2007). The allergenic potential of important types was presented according to Grant-Smith (Grant-Smith, 1990).

The pollen concentration is expressed as the daily average of pollen grains per cubic metre of air. The types of pollen recorded in the atmosphere of Denizli are presented as a pollen calendar in Figure 1, based on total weekly counts of pollen grains/m^3 in 2005 and 2006.

3. Results

The numbers recorded on a yearly basis were 5368 pollen grains/m^3 in 2005 and 6613 pollen grains/m^3 in 2006. Among the taxa recorded, 26 taxa were arboreal and 16 nonarboreal. The total percentage of pollen grains in the atmosphere during the 2 studied years was 79.68% arboreal (9547 pollen grains/m^3), 19.48% nonarboreal (2323 pollen grains/m^3), and 0.84% (101 pollen grains/m^3) unidentified plant taxa (Table 1).

Among woody taxa, maximum weekly pollen concentrations were as follows: Pinaceae 354 pollen grains/m^3, *Olea europaea* 315 pollen grains/m^3, Cupressaceae/Taxodiaceae 230 pollen grains/m^3, and *Platanus orientalis* 162 pollen grains/m^3. Among the herbaceous taxa the concentrations were found to be: Poaceae 81 pollen grains/m^3, Asteraceae 50 pollen grains/m^3, *Xanthium strumarium* 41 pollen grains/m^3, and *Plantago* spp. 29 pollen grains/m^3 (Table 1).

The woody taxa like Pinaceae (24.19%), Cupressaceae/Taxodiaceae (15.99%), *Olea europaea* (11.35%), *Quercus* spp. (6.08%), *Platanus orientalis* (5.68%), *Acer* spp.

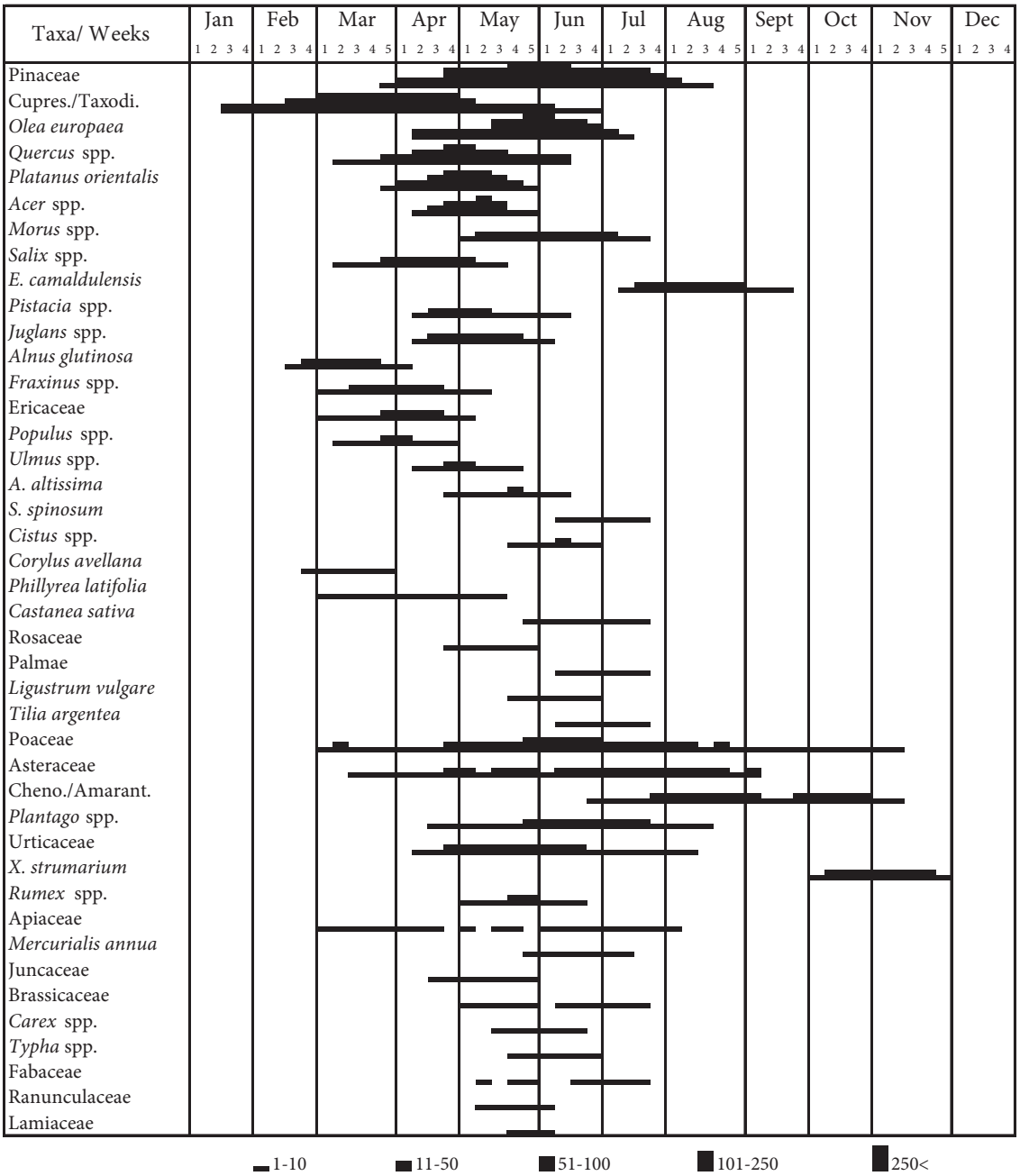

Figure 1. Pollen calendar of Denizli (2005–2006).

(2.93%), *Morus* spp. (2.58%), *Salix* spp. (1.59%), and *Eucalyptus camaldulensis* (1.47%) showed maximum pollen distribution in the atmosphere. These taxa represent 71.86% of the total pollen content in the atmosphere. On the other hand, among herbaceous taxa, Poaceae (6.63%), Asteraceae (3.08%) Chenopodiaceae/Amaranthaceae (2.27%), *Plantago* spp. (2.12%), Urticaceae (1.82%), and *Xanthium strumarium* (1.52%) pollen dominated the area. These taxa accounted for 17.44% of the total pollen content (Tables 1, 2).

The total pollen content in the atmosphere during May, June, April, March, and July was 32.53%, 23.21%, 16.44%, 9.51%, and 8.39% respectively (Table 2). These values amount to 90.08% of the total pollen content in the atmosphere. Monthly variations in the number of arboreal and nonarboreal airborne pollen in the atmosphere are presented in Figure 2. The frequency of pollen from both groups on a monthly basis shows that nonarboreal pollen dominate in August and September, whereas arboreal taxa are dominant in March, April, May, June, and July.

Table 1. Total pollen content (m^3) and their percentage on an annual basis (during 2005 and 2006).

Taxa	2005	2006	Total	Percentage (%)	Maximum weekly pollen concentration	Weeks with maximum concentration
Arboreal taxa						
Pinaceae	1012	1886	2898	24.19	354	5 May
Cupressaceae/Taxodiaceae	824	1091	1915	15.99	230	4 Mar
Olea europaea	534	825	1359	11.35	315	1 Jun
Quercus spp.	327	402	729	6.08	133	1 May
Platanus orientalis	323	358	681	5.68	162	2 May
Acer spp.	205	146	351	2.93	107	2 May
Morus spp.	141	168	309	2.58	47	4 May
Salix spp.	79	112	191	1.59	46	2 Apr
Eucalyptus camaldulensis	122	55	177	1.47	34	2 Aug
Pistacia spp.	60	71	131	1.09	41	1 May
Juglans regia	66	52	118	0.98	28	1 May
Alnus glutinosa	59	53	112	0.93	27	2 Mar
Fraxinus spp.	42	54	96	0.8	16	1 and 3 Apr
Ericaceae	47	28	75	0.63	15	4 Mar
Populus spp.	35	20	55	0.46	16	1 Apr
Ulmus spp.	23	31	54	0.45	14	1 May
Ailanthus altissima	26	21	47	0.39	12	4 May
Sarcopoterium spinosum	20	24	44	0.37	10	1 Jul
Cistus spp.	24	19	43	0.36	11	2 Jun
Corylus avellana	28	11	39	0.33	10	4 Feb; 1 Mar
Phillyrea latifolia	13	18	31	0.26	7	3 Apr
Castanea sativa	10	15	25	0.21	6	4 Jun
Rosaceae	17	7	24	0.2	6	3 May
Palmae	9	11	20	0.17	4	2 Jun; 1–2 Jul
Ligustrum vulgare	7	5	12	0.1	10	5 May
Tilia argentea	5	6	11	0.09	3	2 Jul
Total	4058	5489	9547	79.68		
Nonarboreal taxa						
Poaceae	423	371	794	6.63	81	3 Jun
Asteraceae	194	174	368	3.08	50	2–3 Jul
Chenopodia./Amarantha.	125	147	272	2.27	27	3 Oct
Plantago spp.	138	115	253	2.12	29	2 and 4 Jun
Urticaceae	118	100	218	1.82	27	2 Jun
Xanthium strumarium	97	85	182	1.52	41	4 Oct
Rumex spp.	40	15	55	0.46	16	4 May
Apiaceae	33	20	53	0.44	6	3 Mar; 3 May
Mercurialis annua	21	13	34	0.28	10	3 Jun
Juncaceae	14	11	25	0.21	7	2 May
Brassicaceae	9	15	24	0.2	5	4 May
Carex spp.	13	8	21	0.18	5	2 Jun
Typha spp.	9	5	14	0.11	3	1–2 Jun
Fabaceae	7	4	11	0.09	3	2 Jun
Ranunculaceae	3	3	6	0.05	2	5 May
Lamiaceae	2	1	3	0.02	1	4–5 May; 1 Jun
Total	1246	1087	2333	19.48		
Unidentified	64	37	101	0.84		
Total	5368	6613	11981	100.00		

Table 2. Monthly distribution and the total percentage of taxa with highest density in the atmosphere (2005 and 2006), and their allergenic potential.

Arboreal taxa	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (%)	Peak concentration in a week (grains/m^3)	Allergenic potential[a]
Pinaceae	-	-	0.06	1.52	9.70	9.35	3.73	0.26	-	-	-	-	24.19	May 5	*
Cupressaceae/Taxodiaceae	0.34	1.96	6.79	4.82	1.82	0.26	-	-	-	-	-	-	15.99	March 4	**
Olea europaea	-	-	-	0.29	4.73	6.15	0.18	-	-	-	-	-	11.35	June 1	***,**
Quercus spp.	-	-	0.26	2.50	3.11	0.21	-	-	-	-	-	-	6.08	May 1	**
Platanus orientalis	-	-	0.07	2.29	3.32	-	-	-	-	-	-	-	5.68	May 2	**
Acer spp.	-	-	-	0.64	2.29	-	-	-	-	-	-	-	2.93	May 2	*
Morus spp.	-	-	-	-	1.12	1.20	0.26	-	-	-	-	-	2.58	May 4	*
Salix spp.	-	-	0.29	1.12	0.18	-	-	-	-	-	-	-	1.59	April 2	*
Eucalyptus camaldulensis	-	-	-	-	-	-	0.25	1.00	0.22	-	-	-	1.47	August 2	*
Total (arboreal)	0.34	1.96	7.47	13.18	25.84	17.17	4.42	1.26	0.22	-	-	-	71.86		
Nonarboreal taxa															
Poaceae	-	-	0.21	0.26	1.54	2.37	1.29	0.48	0.18	0.22	0.08	-	6.63	June 3	***,**,*
Asteraceae	-	-	0.06	0.3	0.61	0.47	0.81	0.65	0.18	-	-	-	3,08	July 2-3	*
Chenopodia./Amarantha.	-	-	-	-	-	0.02	0.24	0.77	0.40	0.73	0.11	-	2.27	Oct. 3	**,*
Plantago spp.	-	-	-	0.07	0.31	0.89	0.75	0.10	-	-	-	-	2.12	June 2 and 4	***,*
Urticaceae				0.21	0.8	0.62	0.16	0.03					1.82	June 2	**,*
Xanthium strumarium	-	-	-	-	-	-	-	-	-	0.62	0.90	-	1.52	Oct. 4	**
Total (nonarboreal)			0.27	0.84	3.26	4.37	3.25	2.03	0.76	1.57	1.09		17.44		
Total	0.34	1.96	7.74	14.02	29.1	21.54	7.67	3.29	0.98	1.57	1.09	-	89.3		
Others	-	0.34	1.66	2.32	3.31	1.56	0.64	0.03	-	-	-	-	9.86		
Unidentified	0.02	0.03	0.11	0.10	0.12	0.11	0.08	0.09	0.07	0.06	0.05	-	0.84		
Total	0.36	2.33	9.51	16.44	32.53	23.21	8.39	3.41	1.05	1.63	1.14	-	100		

[a]According to Grant-Smith (1990); *** high; ** medium; * low.

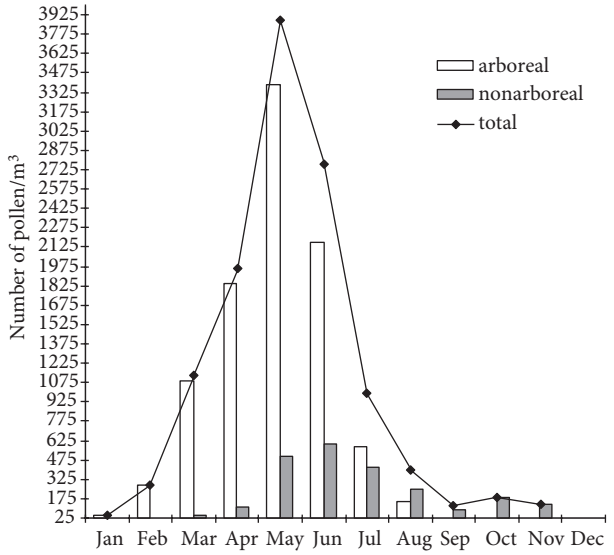

Figure 2. Total pollen content and variation in the number of arboreal and nonarboreal airborne pollen in Denizli (2005–2006).

The total pollen concentration among woody taxa was highest in May (19 taxa), followed by April (17 taxa), June (14 taxa), March (11 taxa), and July (8 taxa), but no pollen was recorded during October, November, or December. Out of herbaceous taxa, the highest number was recorded in June and May (14 taxa) and July (9 taxa), while in January, February, and December no herbaceous pollen was found. In June, equal numbers of arboreal/nonarboreal taxa were recorded, i.e. 14 woody and 14 herbaceous (Figure 3).

In January only Cupressaceae/Taxodiaceae and in February only Cupressaceae/Taxodiaceae, *Alnus glutinosa*, and *Corylus avellana* L. pollen was found in the atmosphere (Figure 1). In March, pollen of 14 taxa was recorded and among these Cupressaceae/Taxodiaceae (6.79%) were dominant. In April, 23 taxa were identified, the dominant ones being Cupressaceae/Taxodiaceae (4.82%), *Quercus* spp. (2.5%), and *Platanus orientalis* (2.29%). The highest

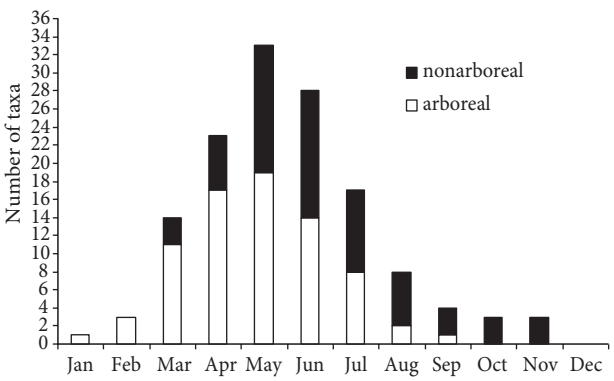

Figure 3. Monthly variation in the total number of arboreal and nonarboreal airborne pollen taxa in Denizli (2005–2006).

number of taxa (33) releasing pollen was recorded during May, the maximum being Pinaceae (9.7%) and *Olea europaea* (4.73%). In June 28 taxa were observed, dominated by Pinaceae (9.35%), *Olea europaea* (6.15%), and Poaceae (2.37%). Seventeen taxa were recorded in July, dominated by Pinaceae (3.73%) and Poaceae (1.29%). The number decreased to 8 taxa in August, including mainly *Eucalyptus camaldulensis* (1.00%), Cheopodiaceae/Amaranthaceae (0.77%), and Asteraceae (0.65%). Only 4 taxa were recorded in September, dominated by Chenopodiaceae/Amaranthaceae (0.4%). The number was very low (3 taxa) in October and November. No pollen taxa were recorded in December (Table 2).

Out of the total of 42 taxa recorded in the atmosphere, 89.3% belonged to only 15 taxa. The following taxa produced the greatest amounts of pollen in the atmosphere of Denizli (Figure 1; Table 2).

Pinaceae: This is the family with the highest number of pollen, found between the last week of March and the 3rd week of August. The values reached a peak in the 5th week of May.

Cupressaceae/Taxodiaceae: Cupressaceae/Taxodiaceae pollen was found in the atmosphere of Denizli from the 3rd week of January up to the end of June. The highest values were found in the 4th week of March.

***Olea europaea*:** *Olea* pollen in the Denizli atmosphere dominated from the 2nd week of April until the 2nd week of July. The highest values were recorded during the 1st week of June.

***Quercus* spp.:** *Quercus* species pollen was found in the atmosphere of Denizli from the 2nd week of March to the 2nd week of June. Maximum values (133 pollen grains/m^3) were obtained in the 1st week of May.

***Platanus orientalis*:** The pollen of *P. orientalis* dominated the atmosphere of Denizli from the last week of March until the last week of May. The highest values were recorded during the 2nd week of May.

***Acer* spp.:** The pollen of *Acer* species stayed in the atmosphere for a total period of 8 weeks. The highest values (107 pollen grains/m^3) were recorded during the 2nd week of May.

***Morus* spp.:** *Morus* species pollen stayed in the atmosphere for 12 weeks. It was found in the atmosphere of Denizli from May until the 3rd week of June. The highest values (47 pollen grains/m^3) were recorded during the 4th week of May.

***Salix* spp.:** *Salix* species pollen stayed in the atmosphere for 11 weeks. It was found in the atmosphere of Denizli from the 2nd week of March until the 3rd week of May. The highest values (46 pollen grains/m^3) were recorded during the 2nd week of April.

***Eucalyptus camaldulensis*:** The pollen of *E. camaldulensis* stayed in the atmosphere for 11 weeks. It

occurred in the atmosphere from the 2nd week of July until the 3rd week of September. The peak values (34 pollen grains/m^3) were recorded during the 2nd week of August.

Poaceae: This is the taxon with the highest number of pollen among herbaceous taxa. Pollen of different members of Poaceae was found in the atmosphere of Denizli from the 1st week of March until the 2nd week of November. The highest values were recorded during the 3rd week of June.

Asteraceae: The pollen was present all through 26 weeks from the 3rd week of March until the 1st week of September. The values reached a peak level during the 2nd and 3rd weeks of July.

Chenopodiaceae/Amaranthaceae: The pollen of Chenopodiaceae/Amaranthaceae was found in the atmosphere of Denizli from the last week of June until the 2nd week of November. However, the pollen values reached a maximum (27 pollen grains/m^3) in the 3rd week of October.

***Plantago* spp.:** *Plantago* species pollen dominated the atmosphere of Denizli from the 3rd week of April until the 3rd week of August. The highest number was found during the 2nd and 4th weeks of June.

Urticaceae: The pollen was recorded from the 2nd week of April until the 2nd week of August. The highest number (27 pollen grains/m^3) was found during the 2nd week of June.

***Xanthium strumarium*:** *X. strumarium* pollen was found in the atmosphere of Denizli mainly in October and November. Maximum values were obtained during the 4th week of October.

Other taxa with comparatively low percentages from the typical Mediterranean plant group distributed in the atmosphere of Denizli are *Pistacia* spp. (1.09%), Ericaceae (0.63%), *Populus* spp. (0.46%), *Cistus* spp. (0.36%), *Phillyrea latifolia* (0.26%), and Palmae (0.17%) (Table 1). Their pollination periods are presented in Figure 1. In accordance with these findings, pollen of these taxa was observed as follows: *P. latifolia* total 12 weeks (1 March to 3 May), *Pistacia* spp. (2 April to 2 June) together with Ericaceae total 10 weeks each (1 March to 1 May), *Populus* spp. total 8 weeks (2 March to 4 April), *Cistus* spp. (4 May to 4 June), and Palmae total 6 weeks each (2 June to 3 July).

4. Discussion

The aeropalynological studies undertaken by gravimetric (G) or volumetric (V) methods on the distribution of arboreal pollen in Ankara (Pinar et al., 1999); Rize, Afyon, and Bursa (Bıçakçı et al., 2002; Bicakci et al., 2002, 2003); İzmir (Guvensen & Ozturk, 2003); Zonguldak (Kaplan, 2004); Bartın (Kaya & Aras, 2004); Manisa (Ay et al., 2005); Denizli (Celik et al., 2005); Bitlis (Celenk & Bicakci, 2005); Çanakkale (Guvensen et al., 2005); Sakarya (Bicakci, 2006); and İstanbul (Celenk et al., 2010) show that although percentage values differ from the present data, in general, the values of arboreal (39.39%–94%) taxa are higher than those of nonarboreal (6.00%–59.28%) ones (Table 3). An evaluation of the data obtained both qualitatively as well as quantitatively revealed that the reason for the dominance of arboreal atmospheric pollen types in the region is the presence of many shrubs and tree taxa producing large quantities of pollen (Table 3). Only in Bitlis Province in the eastern part of Turkey is the percentage of woody taxa (39.39%) lower than that of herbaceous taxa (59.28%), but pollen from herbaceous taxa like Poaceae (25.19%) and Urticaceae (12.31%) is greater in number (Celenk & Bicakci, 2005). The dominance of nonarboreal pollen in the atmosphere in Bitlis Province is due to a high number of taxa from steppe vegetation cover, in particular members of Poaceae.

A comparison of the present findings with gravimetric studies undertaken by us earlier in Denizli Province shows that there is not much difference in the percentage distribution of woody taxa in the atmosphere (Celik et al., 2005). Specifically, the highest number of pollen of the arboreal plants followed the trend Pinaceae (2805 pollen grains/cm^2), Cupressaceae/Taxaceae (971 pollen grains/cm^2), *Quercus* spp. (672 pollen grains/cm^2), *O. europaea* (482 pollen grains/cm^2), and *Platanus orientalis* (390 pollen grains/cm^2), and for nonarboreals Poaceae (428 pollen grains/cm^2) were followed by Chenopodiaceae/Amaranthaceae (183 pollen grains/cm^2). No difference is seen in the seasonal behaviour of pollen. However, the volumetric study undertaken here showed that instead of *Quercus* spp. (672 pollen grains/cm^2) *O. europaea* (1359 pollen grains/m^3) ranks third (Table 3).

On the other hand, in the provinces listed above, the maximum number of pollen belongs to Cupressaceae/Taxaceae (306–10,093 grains), Pinaceae (1872–18,202 grains), *Pinus* (1523–3374 grains), Poaceae (350–3698 grains), and *Quercus* (380–1134 grains). In our study too, the maximum number of pollen belonged to Pinaceae, Cupressaceae/Taxodiaceae (1915 pollen grains/m^3), *O. europaea* (1359 pollen grains/m^3), Poaceae (794 pollen grains/m^3), and *Quercus* spp. (729 pollen grains/m^3) (Table 1). A perusal of the months with maximum distribution of pollen in these provinces shows there is a resemblance with the data published for Rize except for February. The reason for these differences is the distinct type and duration of the pollination season of the different pollen sources, which varies from city to city, depending on the climate and vegetation.

In many other Mediterranean countries several aeropalynological studies have been conducted for many years using different types of samplers (Burkard or

Table 3. A comparison of the distribution of arboreal and nonarboreal pollen in different provinces of Turkey.

City	Arboreal taxa			Nonarboreal taxa			Pollen season	Dominant taxa and pollen numbers	Methods
	Number of taxa	Number of pollen grains	%	Number of taxa	Number of pollen grains	%			
Afyon	21	10,010	69.67	19	3828	26.64	May, Apr, Jun	*Pinus* (3374) Poaceae (1580) Cupressaceae (1480)	G
Ankara	22	4618	76	22	1156	24	Jun, May, Mar, Apr	Pinaceae (1872) Cupres./Taxa.(1101) *Platanus* (505)	V
Bartın	18	13,758	72.81	13	4726	24.32	May, Apr, Jun, Jul	*Populus* (3900) Poaceae (3698) Pinaceae (3150)	G
Bitlis	21	1309	39.39	25	1970	59.28	Jun, May, Apr	Poaceae (837) Urticaceae (409) *Juglans* (318)	G
Bursa	36	10,998	78.61	23	2850	20.37	Apr, May, Jun, Mar	*Pinus* (2920) *Olea europaea* (1992) *Platanus* (1961)	V
Çanakkale	24	3548	86.65	15	483	11.78	Apr, Mar, May	Pinaceae (2295) *Quercus* (380) Cupres./Taxa.(306)	G
Denizli	20	5752	83.9	14	1104	16.10	May, Jun, Apr, Mar, Jul	Pinaceae (2805) Cupres./Taxa.(971) *Quercus* (672)	G
***Denizli**	**26**	**9547**	**79.68**	**21**	**2333**	**19.48**	**May, Jun, Apr, Mar, Jul**	**Pinaceae (2898) Cupres./Taxo.(1915) *Olea europaea* (1359)**	**V**
İstanbul (Asian part)	36	20,894	75.61	29	6361	23.02	Apr, Mar, May	Cupres./Taxa.(10093) Urticaceae (2356) *Pistacia* (2121)	V
İzmir	26	3820	84.05	24	685	15.29	May, Apr, Mar	*Pinus* (2598) *Quercus* (530) Poaceae (350)	G
Manisa	34	6962	78.6	21	1784	20.17	May, Apr, Mar	*Pinus* (2945) Poaceae (1268) Cupres./Taxa.(1158)	G
Rize	20	3951	83.69	10	679	14.38	Feb, Mar, Apr	*Alnus* (1661) Cupressaceae (640) *Castanea sativa* (448)	G
Sakarya	22	7504	69.45	18	3037	28.11	Apr, Mar, May	Poaceae (2048) *Pinus* (1523) *Quercus* (1134)	G
Zonguldak	26	57,544	94	17	3760	6	Mar, Apr, May	Pinaceae (18202) *Populus* (13039) *Carpinus* (5192)	G

* Present study G: gravimetric (cm^2) V: volumetric (m^3)

Lanzoni types samplers); and in some of these countries the dominant airborne taxa determined are Cupressaceae, Poaceae, Hamamelidaceae, Pinaceae, Urticaceae, *Quercus* spp., *Acer* spp., Myrtaceae, Caryophyllaceae, Oleaceae, Betulaceae, and *Plantago* spp.

In Porto (Portugal) the total pollen content was 88% and all the pollen producing taxa belonged to woody taxa (Abreu et al., 2003). In Cagliari (Italy) the pollen distribution was as follows: Cupressaceae (51.13%), Pinaceae (20.39%), Urticaceae (5.13%), Anacardiaceae (3.97%), Oleaceae (3.58%), and Polygonaceae (2.76%) (Ballero and Maxia, 2003), whereas in Thessaloniki (Greece) the spectrum is reported as Cupressaceae (24.9%), *Quercus* spp. (20.8%), Urticaceae (13.6%), Oleaceae (9.1%), Pinaceae (8.9%), Poaceae (6.3%), Platanaceae (5.4%), *Corylus* spp. (3%), and Chenopodiaceae (2.5%) (Gioulekas et al., 2004). The pollen spectrum in Nerja (southern Spain) has been reported as *Pinus* (25.04%), *Olea* (19.93%), Urticaceae (14.03%), Cupressaceae (13.89%), *Quercus* (8.91%), and Poaceae (7.21%) (Docampo et al., 2007). In Cordoba (southern Spain) the trend is as follows: *Quercus* (59.81%), Poaceae (13.2%), *Olea europaea* (10.99%), and *Plantago* (4.71%) (Garcia-Mozo et al., 2007).

An evaluation of these results reveals that the pollen taxa reported from these countries resemble ours. The main reason for this is that all these countries experience a Mediterranean climate and have plant taxa typical of the Mediterranean region. Moreover, in all these studies woody taxa are best represented in numbers. For Denizli, the pollen concentration of woody taxa is higher than that of herbaceous taxa. The reason for this is the high amount of pollen production by various woody taxa. However, in Vinkovci (Croatia), again a country with a Mediterranean climate, similar studies have shown that there is a predominance of herbaceous pollen like Urticaceae (46.58%), *Ambrosia* sp. (19.66%), Poaceae (11.01%), and *Quercus* sp. (4.89%) (Stefanic et al., 2007). The data published clearly show that there are differences in both natural plant cover and composition and this is very important, particularly in different urban locations. In some provinces the predominance of aerial pollen sources can be attributed to many ornamental plants in parks and gardens bordering the aerobiological stations.

The taxa with reported allergic effects were recorded by us in Denizli Province as well. The types of pollen present in the atmosphere of Denizli are shown in the form of a pollen calendar in Figure 1, based on total weekly counts of pollen grains/m^3 during 2005–2006. A list of the 15 taxa with the maximum number of atmospheric pollen and their allergenic potential in Denizli according to Grant-Smith (1990) is given in Table 2.

Among the woody taxa, pollen with maximum concentration belongs to Pinaceae, in particular *Pinus* spp., because these are present as natural forests and in the city centre. Moreover, taxa like *Pinus*, *Abies*, and *Cedrus* species are grown for ornamental purposes but their allergenic potential is low. These are followed by Cupressaceae/Taxodiaceae such as *Juniperus* spp., which are widely distributed in the natural landscape. The members of *C. sempervirens*, *Thuja* spp., and *T. baccata* are planted in the city centre for different purposes and these too contribute to the spectrum, but all these are medium allergenic. Olive, as a typical member of the Mediterranean climate, is cultivated on a large scale for commercial purposes in Denizli Province. *Olea europaea* is considered now to be a major allergen and a new source of rural and urban air pollution in the Mediterranean countries, resulting in pollinosis (Waisel et al., 1991). Pollen of this taxon in general shows a medium to high degree of allergenic potential.

On the basis of pollen concentration (6.08%), *Quercus* spp. rank fifth; these are widely distributed in the surrounding forests and maquis. *Platanus orientalis* is generally planted in large numbers in the city centre as well as in parks and gardens; some of these are even regarded as monumental trees. Pollen of *Quercus* spp. and *Platanus orientalis* is known to be medium allergenic.

Moreover, in parks and gardens and alongside the roads *Acer* spp., *Morus* spp., *Salix* spp., and *Eucalyptus camaldulensis* are planted for landscape architectural purposes; their pollen may cause allergenic effects in susceptible individuals in Turkey and in other areas of the East Mediterranean region (Guneser et al., 1996).

An evaluation of the allergenic potential of nonarboreal taxa shows that Poaceae tops the list among herbaceous taxa but ranks fourth among the total pollen spectrum, because members of the Poaceae are widely distributed in the natural landscapes, and are also cultivated in agricultural fields. Some species are sown as lawn grass in city centres as important green areas. The pollen of Poaceae is responsible for pollinosis and has a very high allergenic effect.

Among other herbaceous taxa, Chenopodiaceae/Amaranthaceae are widely distributed in different habitats in many parts of the city. Their pollen causes low and medium levels of allergy. *Plantago* spp. pollen has either low or high allergenic potential depending on the species, while pollen of many members of Asteraceae in general shows low allergenic potential. The members of Urticaceae, *Parietaria* spp., and *Urtica* spp. are mostly found as ruderals in the city centres, on walls, and occupying abandoned areas. These show low to medium allergenic potential. *Xanthium strumarium* has medium allergenic effects. It has been postulated that there is an extensive cross-reactivity among different individual species of the genus, as well as to a certain degree among members of the family Asteraceae.

In the light of these evaluations during 2005–2006 the atmosphere of Denizli was dominated by 15 taxa, but 9 taxa showed allergenic potential varying between high and medium levels. These taxa are Cupressaceae/Taxodiaceae, *Olea europaea*, *Quercus* spp., *P. orientalis*, Poaceae, Chenopodiaceae/Amaranthaceae, *Plantago* spp., Urticaceae, and *Xanthium strumarium*, and represent 53.46% of the total pollen content. In particular, evaluating the maximum weekly occurrences of pollen of these taxa is of great significance in order to control allergenic diseases in Denizli.

5. Conclusions

In Turkey incidence of allergies varies between 15% and 18%. In Denizli this incidence is about 5%–10%, on the basis of the population data of this province collected during 2005–2006 (Topuz et al., 2006). As preventive care for persons sensitive to pollen allergy in the municipality of Denizli, health practitioners should carefully note the allergenic potential, period of presence, and frequency of different pollen types in the atmosphere. The results of the present study and the pollen calendar designed for the pollen season for the city of Denizli and its surroundings provide useful data for allergologists, and timely information on airborne pollen types and concentrations to individuals with pollen hypersensitivity, thus allowing them to adjust their daily activities so as to minimise their contact with allergens and improve their quality of life both at home and at work.

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