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Pollen Diversity in the Atmosphere of Karacabey (Bursa), Turkey

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ABSTRACT

Pollen grains are known as important bio-allergens for sensitive individuals because of their presence in the air we breathe. Therefore, it is important to know the pollen load, major pollen types and sesonal variations of them for each populated region. The aim of this study was to determine the pollen types, densities and the pollen seasons of main pollen producers in Karacabey area. Pollen quantities and diversity studies were carried out by the gravimetric method in Karacabey (Bursa) atmosphere for two years, between 1 January 2015 and 31 December 2016. During sampling, the slides were changed weekly and examined by light microscopy. Annually 14226 pollen grains (15281 in 2015 and 13171 in 2016) belonging to 59 plant taxa (32 woody and 27 herbaceous taxa) were identified and pollen grains of woody taxa represented 72.63% (77.00% in 2015 and 68.27% in 2016) and herbaceous taxa represented 26.69% (22.30% in 2015 and 31.09% in 2016) of the annual pollen index (API) which was concordant and evaluated as a reflection of the dominant flora and maquis vegetation of the area. Types of pollen identified belonged to *Cupressaceae/Taxaceae, Pinus, Poaceae, Quercus, Platanus, Ambrosia, Olea, Plantago, Amaranthaceae, Salix,* and *Fraxinus* which were classified as dominant pollen types for the region and the the total amount for them was 88.21% of the annual pollen index. In this regard, April-May and August-September can be thought of as a risky period for sensitive individuals living in or visiting the region. One of the most exciting findings of this study was the high dominance of highly allergenic *Ambrosia* pollen in the atmosphere.

Keywords: Palynology, airborne pollen, allergenic pollen, NW Anatolia

INTRODUCTION

Pollen is known as a male gametophyte that plays an essential role in the pollination of flowering plants. The movement of pollens from one flower to the other can be in different ways. Wind and insects are the vectors with the highest share in pollination. Atmospheric pollens of wind-pollinated plants are also very important in terms of human health.

Pollen allergy is a common disorder and may result with diseases like allergic rhinitis, conjunctivitis and asthma in susceptible individuals. Towards the end of the 20th century, particularly in urbanized areas of developed countries, there had been an increase in the population of people who are hypersensitive to pollens. Also, pollen allergy is a global problem and is becoming more critical day by day with the increase of pollen sensitive individuals. The number of individuals complaining of pollinosis is about 40% in Europe (1). Therefore, many studies on atmospheric pollen monitoring have been designed and many researchers have focused on regional modelling and allergen pollen estimates in various regions around the world (2-13).

Atmospheric pollen studies are important to know the flowering periods of wind-pollinated plants because the pollination period for each plant varies. Therefore, the period and presence of the pollens of these plants in the atmosphere also vary. Varieties and densities of atmospheric pollens may vary according to geographical, ecological, meteorological factors as well as the floristic structure of the region. For this reason, the atmospheric pollens vary with different topographies and especially for the areas with climatic differences. The distribution of pollens during the year should be compared depending on meteorological factors and revealed with pollen calendars as a result of long-term studies.

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First palynological studies for Turkey began at the end of the 1960s and mostly Durham samplers were used. These studies have resulted with many pollen calendars of Turkey (14-18).

In this study, we aimed to determine the pollen types, densities and the pollen seasons of main pollen producers (especially those belonging to predominant pollen types). present in the atmosphere of Karacabey (Bursa).

MATERIAL and METHODS

Study Area

Karacabey is located on the south coast of the Marmara Sea in the North-West of Turkey (40° 12' 57.7368" N - 28° 21' 32.3964" E) (Figure 1). It is surrounded by Bursa province and Mudanya district in the east, the Marmara Sea in the north, Balıkesir province in the west, and Mustafakemalpaşa district and Uluabat Lake in the south and lies at an altitude of 125 m.

Flora and Climate

A typical Mediterranean climate exhibits in the study area and particularly Mediterranean maquis elements are dominant in the lower part of the region, including; *Pinus brutia* Ten., *Cercis siliquastrum* L., *Elaeagnus angustifolia* L., *Fraxinus angustifolia* Vahl., *Laurus nobilis* L., *Platanus orientalis* L., *Pistacia lentiscus* L., *Salix alba* L., *Celtis australis* L. and *Olea europaea* L. At higher altitudes and on the lower slopes overlooking the sea; *Fagus orientalis* Lipsky, *Quercus petraea* (Mattuschka) Liebl., *Carpinus betulus* L., *Castanea sativa* Miller, *Tilia tomentosa* Moench., *Robinia pseudoacacia* L., *Fraxinus ornus* L., *Alnus glutinosa* (L.) Gaertn., *Corylus avellana* L., *Acer campestre* L., *Clematis alba* L., *Smilax excelsa* L., *Hedera helix* L., *Fraxinus ornus* L., *Styrax officinalis* L., *Erica arborea* L., *Phillyrea latifolia* L., and *Ruscus aculeatus* L. are widely distributed (19-20). Also, trees such as *Cupressus sempervirens* L., *Cupressus arizonica* Greene, *Acer campestre* L., *Betula pendula* Roth, *Pinus pinaster* Ait., *Pinus pinea* L., *Thuja occidentalis* L., and *Juniperus oxycedrus* L. are highly planted plants for afforestation. On the other hand, *Juglans regia* L., *Malus domestica* Borkh., *Morus alba* L., *Populus alba* L., *Prunus domestica* L., *Acer negundo* L., and *Betula pendula* are the main trees that are planted mainly in parks and gardens.

Kocaçay Delta, which is the endpoint of the Susurluk river, consist of lagoons, small lakes, swamps, dunes and floodplain forests on the coast of Karacabey district. This place is one of the most Important Plant Areas (IPA)

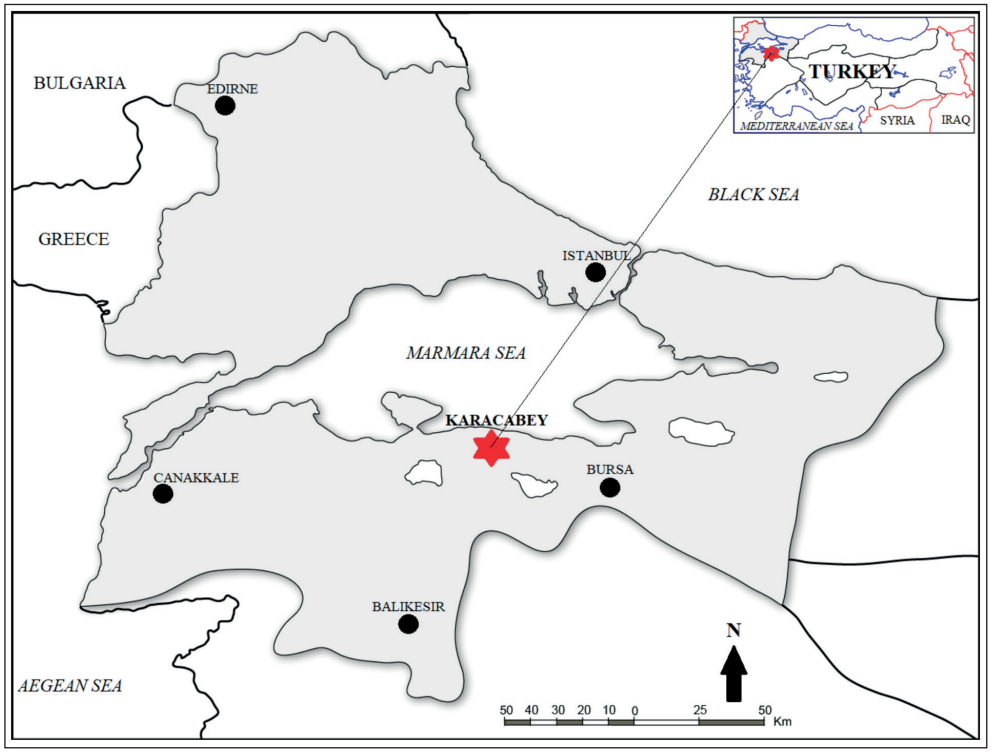

Figure 1. Location of study area (Karacabey).

with a mixture of open and flooded swamp communities containing lush and dense vegetation, flood plain forests, sandy pasture, and light saltwater and freshwater (21).

The climate of Karacabey is a form of transition of the Mediterranean climate to the Black Sea climate. Summers are not as dry and hot as the Mediterranean. Winter season is warm and rainy with a moderate structure and compared to Mediterranean winter tempratures are lower.

During the sampling period, meteorological parameters were provided by the Turkish State Meteorological Service in this study. According to the average values of the years 2015-2016 in Karacabey; January was the coldest month with 5.69°C, August was the hottest with 25.86°C, January had the most rain at 163.05 mm, July was the driest at 0.40 mm with the lowest relative humidity (66.25%), and January was the most humid (83.40%).

Aeropalynological Study

This study was conducted between January 2015 and December 2016. The Durham sampler, which is the device of the gravimetric method used in this research, was placed at the top of a building, 15 m above the ground level. Before being placed into the device, slides were covered with basic fuchsine added glycerin-jelly (22) and were changed weekly. Counting was conducted on a 24 x 24 mm area of the slide and was extrapolated to 1 cm^2 later. All pollen numbers are presented as per cm^2. In addition, when all the pollen types identified in the study were compared to atmospheric concentrations, those with more than 1% were considered to be dominant.

RESULTS

A total of 28452 pollen grains were biennially recorded per cm^2 according to gravimetric sampling in the Karacabey atmosphere. Annually 14226 pollen grains (15281 in 2015 and 13171 in 2016) belonging to 59 plant taxa (32 woody and 27 herbaceous taxa) were identified and pollen grains of woody taxa represented 72.63% (77.00% in 2015 and 68.27% in 2016) and herbaceous taxa represented 26.69% (22.30% in 2015 and 31.09% in 2016) of the annual pollen index (API) (Table I).

The amount of pollens in the Karacabey atmosphere has increased starting with January 2015, when sampling began. The gradual and regular increase in pollen amount doubled in April-May and reached its maximum level in May 2015 with many contributors including Cupressaceae/Taxaceae, *Pinus, Quercus, Platanus* and *Fraxinus* (Figure 2). Until May, the amount of pollens has increased in parallel to the temperature; but in the case of rainfall, contrary to the temperature, there was a gradual decline. With the decrease in heavy rainfall observed in April 2015, the pollen amount reached the highest level in May. However, after May, the amount of pollens in the atmosphere began to decrease due to the vegetation period of pollinating taxa and beginning summer heat

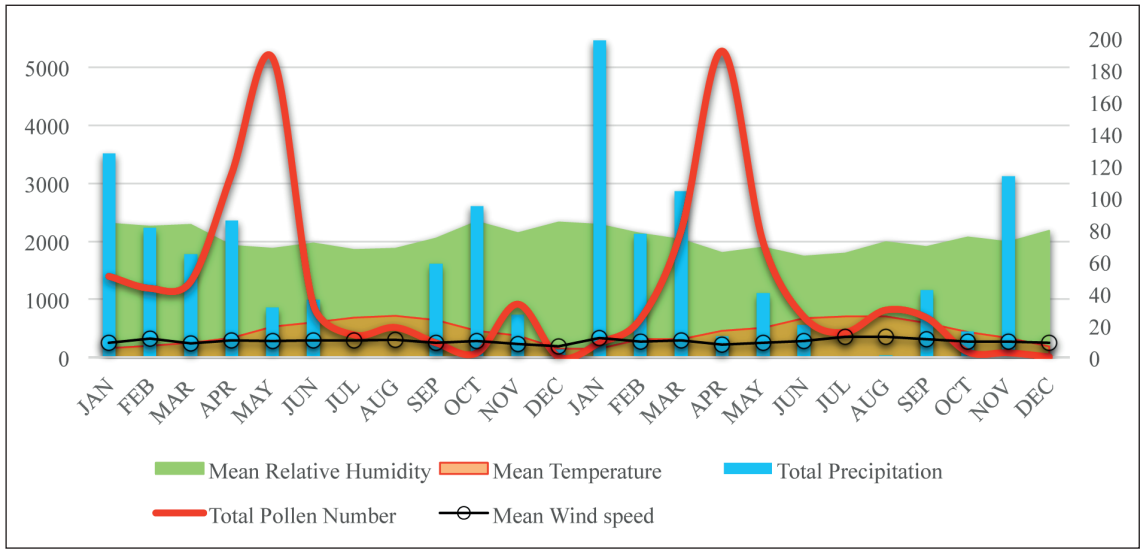

Figure 2. Monthly variation of airborne pollen (left axis) and meteorological parameters (right axis) in two consecutive years in Karacabey atmosphere.

(Figure 2). With completion of the pollination periods of many pollen-producing taxa (e.g., spring pollinating trees), pollen grains of herbaceous plants (e.g., Poaceae, Amaranthaceae, *Plantago*, Urticaceae, *Ambrosia,* etc.) were recorded in the atmosphere more frequently than woody plants during the summer months (Table II). The gradual decrease in the amount of pollens continued until the end of the first sampling year; except the second peak of Cupressaceae/Taxaceae in November 2015. In the beginning of the second year, the amount of pollens began to increase again, but this amount reached the highest level in April instead of May, which had six times lower rainfall compared to the previous year (Figure 2).

Additionally, monthly mean temperatures in the second year were recorded as about 1.5°C higher compared to the ones in the first year. The amount of pollens in the Karacabey atmosphere gradually and rapidly decreased after April in the second year, and this decline continued throughout the summer. *Fraxinus* and Urticaceae pollens were the dominant types in the air in the second year because, the rainfall in the first year was considerably low in April 2015 (Figure 2, Table II).

Table I. Total amounts of airborne pollen grains for each taxa in Karacabey atmosphere in 2015-16. Mean and percentage values.

	2015		2016			
	n	%	n	%	Mean	%
Cupressaceae/Taxaceae	**4655**	**30.46**	**1910**	**14.50**	**3283**	**22.48**
Pinus	**3426**	**22.42**	**2759**	**20.95**	**3093**	**21.68**
Quercus	**1432**	**9.37**	**1421**	**10.79**	**1427**	**10.08**
Platanus	**581**	**3.80**	**991**	**7.52**	**786**	**5.66**
Olea	**388**	**2.54**	**543**	**4.12**	**466**	**3.33**
Salix	**308**	**2.02**	**231**	**1.75**	**270**	**1.88**
Fraxinus	**121**	**0.79**	**182**	**1.38**	**152**	**1.09**
Pistacia	116	0.76	116	0.88	116	0.82
Morus	93	0.61	107	0.81	100	0.70
Carpinus	44	0.29	131	0.99	88	0.62
Ericaceae	90	0.59	56	0.43	73	0.51
Betula	51	0.33	78	0.59	65	0.45
Populus	56	0.37	55	0.42	56	0.39
Castanea	41	0.27	49	0.37	45	0.32
Celtis	38	0.25	50	0.38	44	0.31
Acer	56	0.37	24	0.18	40	0.28
Alnus	46	0.30	25	0.19	36	0.25
Cedrus	25	0.16	40	0.30	33	0.23
Juglans	26	0.17	31	0.24	29	0.20
Rosaceae	15	0.10	38	0.29	27	0.19
Corylus	26	0.17	26	0.20	26	0.18
Fagus	12	0.08	30	0.23	21	0.15
Oleaceae	20	0.13	22	0.17	21	0.15
Vitis	27	0.18	10	0.08	19	0.13
Ostrya	20	0.13	16	0.12	18	0.13
Ulmus	9	0.06	18	0.14	14	0.09
Tilia	13	0.09	12	0.09	13	0.09
Abies	21	0.14	3	0.02	12	0.08

Table I continued

Ligustrum	4	0.03	12	0.09	8	0.06
Ailanthus	2	0.01	3	0.02	3	0.02
Robinia	2	0.01	2	0.02	2	0.01
Aesculus	2	0.01	1	0.01	2	0.01
Woody Plants	11766	77.00	8992	68.27	10379	72.63
Poaceae	**1690**	**11.06**	**1686**	**12.80**	**1688**	**11.93**
Ambrosia	**343**	**2.24**	**768**	**5.83**	**556**	**4.04**
Plantago	**325**	**2.13**	**386**	**2.93**	**356**	**2.53**
Amaranthaceae	**238**	**1.56**	**344**	**2.61**	**291**	**2.08**
Urticaceae	**147**	**0.96**	**251**	**1.91**	**199**	**1.43**
Rumex	145	0.95	129	0.98	137	0.96
Asteraceae	67	0.44	85	0.65	76	0.53
Xanthium	57	0.37	86	0.65	72	0.50
Artemisia	55	0.36	74	0.56	65	0.45
Fabaceae	73	0.48	48	0.36	61	0.43
Cyperaceae	47	0.31	45	0.34	46	0.32
Brassicaceae	41	0.27	41	0.31	41	0.29
Apiaceae	35	0.23	29	0.22	32	0.22
Mercurialis	34	0.22	21	0.16	28	0.19
Zea	23	0.15	20	0.15	22	0.15
Typha	13	0.09	27	0.20	20	0.14
Boraginaceae	22	0.14	9	0.07	16	0.11
Taraxacum	12	0.08	7	0.05	10	0.07
Ranunculaceae	10	0.07	5	0.04	8	0.05
Papaveraceae	10	0.07	4	0.03	7	0.05
Poterium	9	0.06	4	0.03	7	0.05
Rubiaceae	2	0.01	9	0.07	6	0.04
Helianthus	3	0.02	5	0.04	4	0.03
Juncaceae	3	0.02	5	0.04	4	0.03
Lamiaceae	0	0.00	5	0.04	3	0.02
Cannabaceae	3	0.02	0	0.00	2	0.01
Caryophyllaceae	0	0.00	2	0.02	1	0.01
Herbaceous plants	3407	22.30	4095	31.09	3751	26.69
Unidentified	108	0.71	84	0.64	96	0.67
Total	15281	100.00	13171	100.00	14226	100

The small pollen peak observed at the end of the summer and the beginning of the fall, especially in August-September, points to the *Ambrosia* pollination period. In the autumn and winter, the amount of pollens were recorded at the lowest levels, as in the previous year (Figure 2, Table II). In addition, Cupressaceae/Taxaceae pollens were lower compared to the ones in the second year the first year due to heavy rainfall pressure on the atmosphere pollen amount (Figure 2, Table II). Therefore, *Pinus* was recorded as the most dominant type in the atmosphere 2016.

Table II. Monthly variation of dominant pollen types in Karacabey atmosphere during 2015-2016. (%)

Taxa/Months		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Cupr. / Taxaceae	*2015*	8.91	7.42	7.36	0.44	0.52	0.01	0.01	0.00	0.01	0.05	5.70	0.03	30.46
	2016	1.70	4.03	5.57	1.87	0.05	0.05	0.03	0.04	0.62	0.18	0.30	0.06	14.50
	Mean	5.30	5.73	6.47	1.15	0.28	0.03	0.02	0.02	0.32	0.12	3.00	0.04	22.48
Pinus	*2015*	0.00	0.00	0.06	8.57	12.13	1.51	0.14	0.01	0.01	0.00	0.00	0.00	22.42
	2016	0.00	0.01	0.71	16.02	3.30	0.77	0.10	0.03	0.01	0.00	0.00	0.00	20.95
	Mean	0.00	0.00	0.39	12.29	7.71	1.14	0.12	0.02	0.01	0.00	0.00	0.00	21.68
Poaceae	*2015*	0.01	0.03	0.18	1.73	5.54	1.75	0.98	0.36	0.36	0.07	0.05	0.01	11.06
	2016	0.01	0.05	0.43	3.24	4.24	1.82	1.34	0.84	0.63	0.14	0.07	0.00	12.80
	Mean	0.01	0.04	0.30	2.48	4.89	1.79	1.16	0.60	0.50	0.10	0.06	0.00	11.93
Quercus	*2015*	0.00	0.00	0.01	1.75	7.60	0.01	0.00	0.00	0.00	0.00	0.00	0.00	9.37
	2016	0.00	0.00	1.12	9.16	0.45	0.05	0.02	0.00	0.00	0.00	0.00	0.00	10.79
	Mean	0.00	0.00	0.56	5.46	4.02	0.03	0.01	0.00	0.00	0.00	0.00	0.00	10.08
Platanus	*2015*	0.00	0.00	0.05	3.17	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.80
	2016	0.00	0.05	4.75	2.70	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.52
	Mean	0.00	0.02	2.40	2.93	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.66
Ambrosia	*2015*	0.00	0.00	0.00	0.00	0.00	0.01	0.07	1.77	0.32	0.07	0.02	0.00	2.24
	2016	0.00	0.00	0.00	0.00	0.00	0.00	0.03	3.25	2.49	0.03	0.03	0.00	5.83
	Mean	0.00	0.00	0.00	0.00	0.00	0.00	0.05	2.51	1.41	0.05	0.03	0.00	4.04
Olea	*2015*	0.00	0.00	0.00	0.00	2.07	0.46	0.01	0.00	0.00	0.00	0.00	0.00	2.54
	2016	0.00	0.00	0.00	0.33	3.64	0.13	0.03	0.00	0.00	0.00	0.00	0.00	4.12
	Mean	0.00	0.00	0.00	0.16	2.85	0.29	0.02	0.00	0.00	0.00	0.00	0.00	3.33
Plantago	*2015*	0.00	0.00	0.00	0.12	0.86	0.95	0.19	0.00	0.01	0.00	0.00	0.00	2.13
	2016	0.00	0.00	0.03	0.46	1.58	0.68	0.17	0.01	0.00	0.00	0.00	0.00	2.93
	Mean	0.00	0.00	0.02	0.29	1.22	0.82	0.18	0.00	0.00	0.00	0.00	0.00	2.53
Amaranthaceae	*2015*	0.01	0.00	0.01	0.00	0.01	0.07	0.16	0.63	0.54	0.11	0.01	0.00	1.56
	2016	0.02	0.01	0.01	0.00	0.08	0.19	0.33	1.12	0.74	0.09	0.03	0.00	2.61
	Mean	0.01	0.00	0.01	0.00	0.05	0.13	0.25	0.88	0.64	0.10	0.02	0.00	2.08
Salix	*2015*	0.00	0.00	0.03	1.93	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.02
	2016	0.00	0.02	1.48	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.75
	Mean	0.00	0.01	0.75	1.09	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.88
Urticaceae	*2015*	0.02	0.01	0.03	0.10	0.24	0.18	0.16	0.07	0.05	0.02	0.07	0.01	0.96
	2016	0.13	0.17	0.13	0.13	0.25	0.37	0.52	0.15	0.01	0.01	0.05	0.00	1.91
	Mean	0.07	0.09	0.08	0.12	0.25	0.28	0.34	0.11	0.03	0.01	0.06	0.01	1.43
Fraxinus	*2015*	0.10	0.03	0.07	0.18	0.28	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.79
	2016	0.02	0.42	0.90	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.38
	Mean	0.06	0.23	0.49	0.11	0.14	0.06	0.00	0.00	0.00	0.00	0.00	0.00	1.09
Woody Plants	*2015*	9.08	7.66	8.17	18.15	25.24	2.46	0.22	0.01	0.03	0.18	5.77	0.03	77.00
	2016	1.74	4.77	15.79	34.95	7.77	1.46	0.24	0.08	0.68	0.38	0.36	0.06	68.27
	Mean	5.41	6.22	11.98	26.55	16.51	1.96	0.23	0.05	0.35	0.28	3.06	0.04	72.63
Herb. Plants	*2015*	0.06	0.09	0.31	2.33	8.30	3.41	2.27	3.36	1.60	0.33	0.20	0.04	22.30
	2016	0.15	0.22	0.78	4.85	7.17	3.75	2.99	6.10	4.48	0.34	0.24	0.01	31.09
	Mean	0.11	0.15	0.54	3.59	7.74	3.58	2.63	4.73	3.04	0.33	0.22	0.02	26.69
Total	*2015*	9.17	7.79	8.56	20.69	33.77	5.92	2.53	3.38	1.64	0.50	5.99	0.07	100.00
	2016	1.89	5.03	16.65	40.05	15.05	5.28	3.28	6.19	5.18	0.73	0.61	0.07	100.00
	Mean	5.53	6.41	12.60	30.37	24.41	5.60	2.91	4.78	3.41	0.62	3.30	0.07	100.00

As an average of two sampling years, twelve plant taxa were recorded and taken as predominant pollen types, which comprised more than 1% of the total pollen content (Table I); Cupressaceae/Taxaceae (22.48%), *Pinus* (21.68%), Poaceae (11.93%), *Quercus* (10.08%), *Platanus* (5.66%), *Ambrosia* (4.04%), *Olea* (3.33%), *Plantago* (2.53%), Amaranthaceae (2.08%), *Salix* (1.88%), Urticaceae (1.43%) and *Fraxinus* (1.09%). These twelve dominant taxa represented 88.21% of the mean annual pollen index (Table I).

The main pollen seasons for the dominant pollen types and durations based on weekly data are presented in Table I. Out of all dominant taxa; Cupressaceae/Taxaceae, Poaceae, and Urticaceae families have the longest main pollen seasons; and the shortest pollen seasons were recorded for *Salix*, *Platanus* and *Olea* pollens. In addition, the most common pollen types were Cupressaceae/Taxaceae pollens (except for August 2015), which were also the pollens that have risen earliest in the spring (Table II). *Fraxinus Platanus, Salix* pollens (from woody plants) were also earlier pollen types in early spring. Of the herbaceous plants, pollen grains of the early flowering Poaceae and Urticaceae members, were recorded in the atmosphere beginning with January (Table II). *Ambrosia* and Amaranthaceae pollen grains were recorded as the latest pollen types reaching maximum density in the atmosphere in early fall (Table II). One of the most remarkable findings in this survey was that the pollen of invasive species, *Ambrosia*, which is extensively distributed in Europe, was recorded among the dominant pollen types in Karacabey atmosphere (Table II).

When the weekly data were evaluated, it was noteworthy that the highest number of pollen grains in the atmosphere in 2015 was recorded in the 16th week. During this week, after the precipitation, the temperature increased and the humidity decreased, and the pollen amount reached the highest level. In the second sampling year, it is noteworthy that the atmospheric pollens were recorded at the highest level in the 15th week, six weeks earlier than the previous year. The reason for the highest level of pollens in this week is the same as in the first year, which is the increase in humidity and temperature after rainfall. The lowest amount of pollen in the atmosphere of Karacabey was recorded in the 39th (2015) and 52nd (2016) weeks (Figure 3).

When the changes in the weekly pollen amount of the plant taxa, which mostly contributed to the atmosphere of Karacabey, are examined;

Cupressaceae/Taxaceae: Pollens belonging to pollen grains of these families were recorded in all months of two years (except August 2015). In the 4th week, the amount of pollens started to increase and reached the highest value in the 9th week and decreased in the 13th week. Also, winter pollination of some species belonging to the Cupressaceae/Taxaceae family were also observed in the first year (47th week). In the second year; the amount of pollens was increased from the 3rd week, reached the highest value in the 10th week and began to decrease in the 17th week (Figure 3).

Pinus: The amount of pollens started to increase in the 13th week, and reached the highest value in the 16th and decreased in the 23rd week. In the second year; the amount of pine pollens started to increase from the 12th week, reached the highest value in the 15th and began to decrease on the 22nd week (Figure3).

Poaceae: Pollens of Poaceae family members were present in the Karacabey atmosphere in almost every week of both years. The amount of Poaceae pollens started to increase from the 13th week in the first year, reaching the highest level in the 20th week and a decrease was observed after the 24th week. In the second year; the amount of pollens increased starting by the 13th week, reaching the highest value in the 20th week and began to decrease in the 27th week (Figure 3).

Quercus: The pollen of *Quercus* taxa increased in the atmosphere starting from the 14th week and reached the highest level in the 18th week. A decrease was observed after the 21st week in the first sampling year. In the second year; pollination started from the 12th week, peaked on the 15th week, and began to decrease on the 18th week. However, there was a significant decline after the 20th week (Figure 3).

Platanus: The plane tree pollens were among the dominant pollen types with the shortest pollination period in both years. Pollen grains of *Platanus* appeared in the atmosphere in the 13th week and the highest levels were recorded in the 16th week in 2015. In the second year, they started to be encountered from the 9th week, and they reached their maximum in the 13th week (Figure 3).

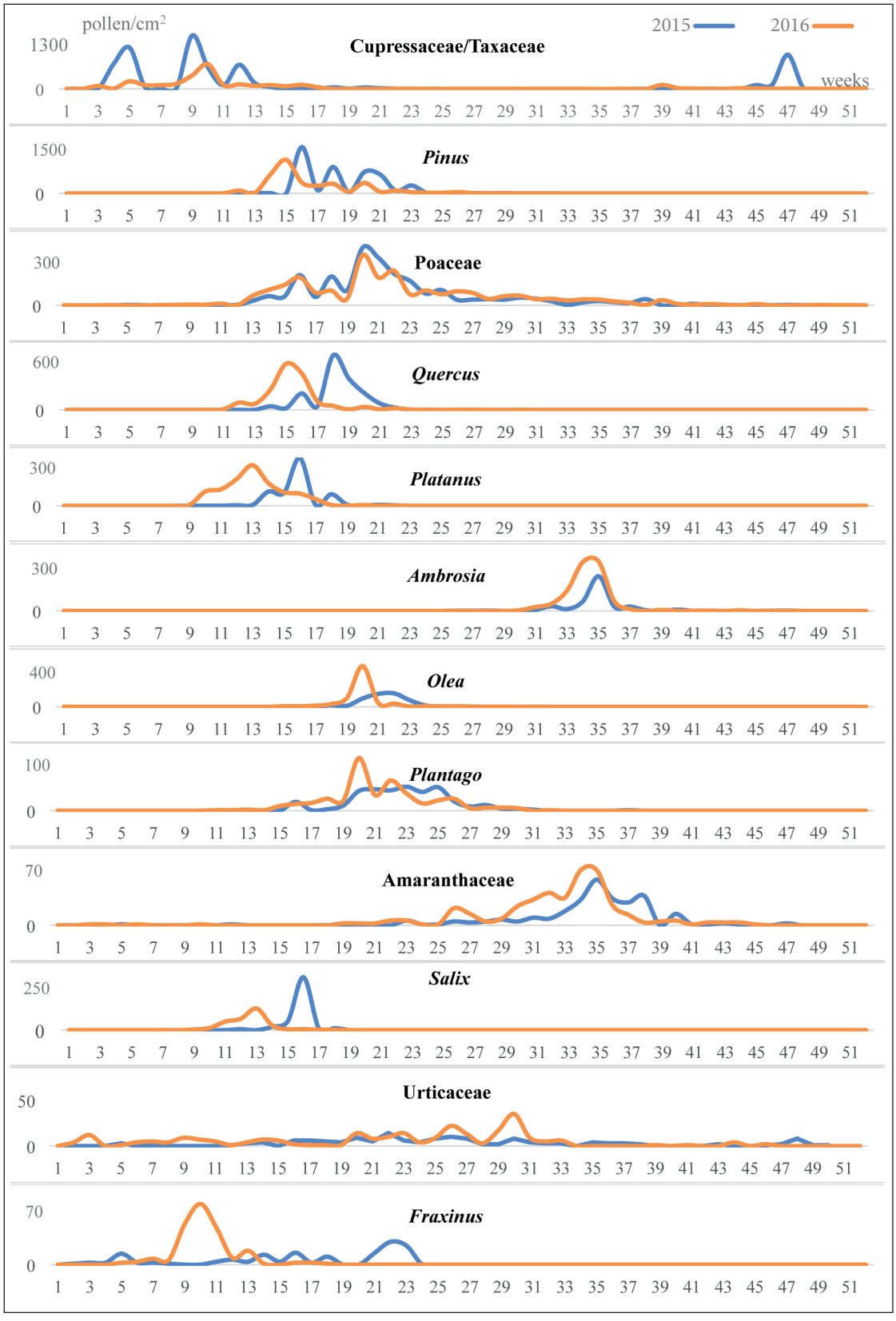

Figure 3. Weekly variation of dominant pollen types in the atmosphere of Karacabey.

Ambrosia: Pollen grains were recorded in the atmosphere of Karacabey in late summer. In 2015, the number of pollen grains began to increase in the 31st week reaching the maximum level in the 35th week and the decrease started after the 37th week. In 2016; the pollination season of *Ambrosia* started during the 30th week, peaked in the 35th week and decreased after the 36th week (Figure 3).

The weeks with the highest pollen amounts for other dominant pollen types in 2015 and 2016 respectively, were; 22nd - 20th week for *Olea,* 23rd - 20th week for *Plantago,* 35th - 35th week for Amaranthaceae, 16th - 13th week for *Salix,* 22nd - 30th week for Urticaceae, and 22nd - 10th week for *Fraxinus* (Figure 3).

DISCUSSION

During the sampling period; 59 types of pollens were detected in Karacabey atmosphere, and pollen grains of woody plants were dominant in the atmospheric spectrum with a two-year average of 72.96%, and also herbaceous plants were found at a rate of 26.37% (Table I). The high dominance of pollen grains of woody plants in the atmosphere is very common in Western and North-Western Turkey (15, 23-28).

The data from the two-year atmospheric sampling were considered inadequate to generate a pollen calendar, and Table II was prepared to show monthly distributions of pollens recorded intensively in the atmosphere over the years. It is noted that pollen types of woody plants were seen at maximum levels in the atmosphere between February and May, while pollen types of herbaceous plants were recorded at maximum levels in May-August and September (Table II). This was an expected result for anemophilous trees that began their vegetation period earlier. On the other hand, the annual herbs release their pollens during the mid or late summer period related to the life cycle and seed development time. It has been identified that woody plants such as Cupressaceae/Taxaceae, *Pinus, Quercus, Platanus, Olea, Salix, Fraxinus* and herbaceous plants such as Poaceae, *Plantago* Amaranthaceae, and Urticaceae are the characteristic airborne pollen types in many parts of the Mediterranean periphery (6,16,29-32).

Family members of Cupressaceae/Taxaceae and Poaceae deserve exclusive emphasis due to their very long pollen season, likely because of including many taxa and as a result of limited identification as well as Amaranthaceae and Urticaceae. Cupressaceae/Taxaceae pollens make a high contribution to the annual pollen index in the Karacabey atmosphere. Also, cypress family members have been shown to be the main cause of winter pollinosis in the Mediterranean basin (33) since they produce a large amount of pollens both in spring and autumn. Therefore, they have been shown as the main cause of pollinosis (34,35). Another type of pollen that needs to be emphasized is *Ambrosia* pollen. There are three species of the genus *Ambrosia* in Turkey. *A. maritima* L. and *A. tenuifolia* Spreng are naturally distributed species, but *A. artemisiifolia* L. is a species which is invasive and naturalized in North Anatolia. *Ambrosia* pollen is one of the most important aeroallergens (36). Atmospheric *Ambrosia* has been previously reported at small amounts in many regions of Turkey; some of these might have originated from indigenous species, and the possible transport by wind from Europe has also been reported (13). The presence of the plant in the region has not been reported before, but the fact that *Ambrosia* has been recorded and among the dominant pollens probably indicates that *Ambrosia artemisiifolia* turns the invasion direction into North-West and western Anatolia. Intercalarily, it is thought that the pollen of this taxon is found in the Karacabey atmosphere and the plant may be present in the agricultural areas in and around Karacabey, or that the pollen can be transported remotely by wind from provinces such as Istanbul and Duzce, where the plant distribution has been shown before. When the amount of pollen was compared, an increase of 1.5 times was observed in the atmosphere of Karacabey in the second year compared to first year. The reason for this might be the less rain during the pollination period in the second year and increased temprature (Figure 2, Table I-II).

The pollens from the atmospheric pollen spectrum and the floristic characteristics of woody plants in Karacabey match the pollen grains of Karacabey atmosphere (*Pinus, Quercus, Platanus, Olea, Salix,* and *Fraxinus*). In this regard, the widespread *Pinus brutia*, which goes down to the sea and spreads up to nearly 850 m in height, might be effective. *Pinus pinea* and *Pinus pinaster*, cultivated mostly near the coast, maybe the other major reason for the dominance of the pine pollen grains. *Pinus* pollen grains were recorded as work in this dominantly in the Turkey and Europe (15,37,38). On the other hand, *Quercus*, and *Fraxinus* species, which were recorded as dominant pollen types in the Karacabey atmosphere, were also the frequently encountered plants in maquis and floodplain forests of the

region. The amounts of *Quercus* and *Fraxinus* pollens in terms of this study showed similar results with the previous studies carried out in Turkey and Europe (35,39). Another dominant pollen type belongs to the plane tree (*Platanus*) and is naturally distributed in the valleys or where the groundwater is high in North-West Anatolia. *Platanus acerifolia* and *Platanus orientalis* are used intensely in the roadside afforestation in the city. *Platanus* was the fifth most frequent pollen type in the Karacabey atmosphere in both of the sampling years. According to the other studies carried out in Europe and Turkey, *Platanus* pollen grains were also recorded as a dominant type (23,40).

In accordance with the abundance of willow trees in the creek and lower beds of the study area, *Salix* was another dominant pollen type. It is also possible to come across the species of this genus in parks and gardens in the city center. Many studies carried out in Turkey and Europe showed similar results (41,42). *Olea europaea* is a very intensely cultivated plant in western and southern Anatolia, and olive pollen has taken place among the dominant atmospheric pollens in previous aerobiological studies in the region (23,28,43). It is also konown that the pollen of the olive tree creates a great risk for pollinosis (44). The dominance of Poaceae pollen from herbaceous plants in the atmosphere of Karacabey is not surprising because it is a usual for Turkey in general. Even in the eastern regions of Anatolia, Poaceae pollens have been recorded more intensely than the pollens of woody plants (11,45). The reason for the excess amount of pollens belonging to the Poaceae family in Karacabey atmosphere may be because of the agricultural potential of the family members having economic importance. Besides, the Poaceae family contains a large number of genera and species, and pollen identifications are not possible at the genus or species level so that the pollination is reflected as very long. Poaceae pollens have been reported as a dominant type in Turkey and also in Europe previously (6,11,26,46).

Plantago and Amaranthaceae pollens are frequently represented pollen types in atmosphere of Turkey (11,47,48,49), but a high proportion of ragweed pollen was an unexpected result for the study area. The ruderal plant *Plantago* has a wide distribution in urbanized areas. Pollen grains of the Amaranthaceae family were seen as a dominant type in the atmosphere, probably because of crowded family members and different pollination periods. Amaranthaceae and *Plantago* pollens were also found as a predominant type in many studies (15,26,50). The pollen grains of Urticaceae family members were the last dominant type in Karacabey atmosphere during the studied years. Pollination season lasted throughout the year. Urticaceae family member pollen grains were also recorded as a dominant type in other aeropalynological studies (51-53).

In general, dominant pollen types recorded in the Karacabey atmosphere have also been reported as important aeroallergens in previous studies (1,6,7,54-57).

In conclusion, 14226 pollen grains belonging to 59 taxa were identified in the atmosphere of Karacabey for an average of two sampling years. Among these, 32 pollen types belonged to woody, and 27 to herbaceous plants. In this study, as in many studies, woody taxa were more common than herbaceous taxa in terms of the number of types and pollen amounts. Dominant pollen types in the air of Karacabey were previously reported to be a cause of highly allergic reactions in susceptible individuals by various authors. In this respect, April-May and August-September can be accepted as risky periods for sensitive individuals living in or visiting the region. The high levels of *Ambrosia* pollen and its dominance are remarkable and can represent a hot-spot for North-West Anatolia.

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REFERENCES

1. D'Amato G, Cecchi L, Bonini S. Allergenic pollen and pollen allergy in Europe. Allergy 2007;62:976-90.
2. Badya KK, Pahsa MK. A pollen calendar for Chittagong University Campus, Chittagong (Bangladesh). Aerobiol 1991;7:62-8.
3. Majas F, Noetinger M, Romero E. Airborne pollen and spores monitoring in Buenos Aires city: A preliminary report Part I Trees and shrubs. (AP). Aerobiology 1992;8:285-96.
4. Kobzar VN. Aeropalynological Monitoring in Bishkek, Kyrgyzstan. Aerobiol 1999;15:149-53.
5. Ballero M, Maxia A. Pollen spectrum variations in the atmosphere of Cagliari, İtaly. Aerobiol 2003;19:251-9.
6. Gioulekas D, Papakosta D, Damialis A, Spieksma F, Giouleka P, Patakas D. Allergenic pollen records (15 years) and sensitization in patients with respiratory allergy in Thessaloniki, Greece. Allergy 2004;59:174-84.

7. Mandal J, Chakraborty P, Roy I, Chatterjee S, Gupta-Bhattacharya S. Prevalence of allergenic pollen grains in the aerosol of the City of Calcutta, India: A two year study. Aerobiol 2008;24:151-64.
8. Ribeiro, H, Abreu I. A 10-year survey of allergenic airborne pollen in the city of Porto (Portugal). Aerobiol 2014;30:333-44.
9. Puljak T, Mamić M, Mitić B, Hrga I Hruševar D. First aerobiological study in Mediterranean part of Croatia (Dalmatia): Pollen spectrum and seasonal dynamics in the air of Split. Aerobiol 2016;32:709-23.
10. Potoglu Erkara I, Osoydan K, Karatas M. Relationship between meteorological factors and airborne pollen grains of Kızıltepe (Mardin), Turkey. Journal of Applied Biological Sciences 2016;10(1):33-40.
11. Bicakci A, Tosunoglu A, Altunglu MK, Saatçıoglu G, Kese, AM, Ozgokce F. An aeropalynological survey in the City of Van, A High Altitudinal Region, East Anatolia-Turkey. Aerobiol 2017;33:93-108.
12. Werchan B, Werchan M, Mücke HG, Simoleit UGA, Zuberbie, T, Bergman KC. Spatied distribution of allergenic pollen through a large metropolitan area, Enverion Monit. Assess 2017;189:1969.
13. Bicakci A, Tosunoglu A. Allergenic pollen in Turkey, Asthma Allergy Immunol 2019; 17:7-24.
14. Bicakci A, Ergun S, Tatlıdil S, Malyer H, Ozyurt S, Akaya A, Sapan N. Airborne pollen grains of Afyon, Turkey. Acta Bot Sin 2002;44(11): 1371-5.
15. Bicakci A. Analysis of airborne pollen fall in Sakarya, Turkey. Biologia 2006;61(4):457-61.
16. Tosunoglu A, Bicakci A, Malyer H, Sapan N. Airborne pollen fall in Köyceğiz specially protected area (SW Turkey). Fresen Environ Bull 2009;18(10): 1860-5.
17. Altunoglu MK, Toraman, E, Temel M, Bicakci A, Kargioglu M. Analysis of airborne pollen grains in Konya, Turkey, 2005. Pak J Bot 2010;42(2):765-74.
18. Guvensen A, Celik A, Topuz B, Ozturk M. Analysis of airborne pollen grains in Denizli. Turk J Bot 2013;37:74-84.
19. Atalay İ. Nemli-yarı nemli soğuk iğne yapraklı (ladin, göknar, karaçam ve sarıçam) ormanlar. In: Atalay İ (ed). Türkiye Vejetasyon Coğrafyasına Giriş. 1983:359.
20. Övünç A. Karadağ' ın Florası (Karacabey- Bursa) (Thesis). İzmir: Ege Üniversitesi Fen Fakültesi;1997.
21. Byfield AJ, Ozhatay N. Türkiye'nin Kuzey Kumullarının Korunmasına Yönelik Rapor. Doğal Hayatı Koruma Derneği İstanbul. 1995.
22. Charpin J, Surinyach R, Frankland AW. Atlas of European Allergenic Pollens. Sandoz Editions, Paris. 1995; 229.
23. Altunoglu MK, Bicakci A, Celenk S, Canıtez Y, Malyer H, Sapan N. Airborne pollen grains in Yalova, Turkey, 2004. Biologia 2008;63(5): 658-63.
24. Bilişik A, Akyalcin H, Bicakci A. Airborne pollen grains in Savaştepe (Balıkesir). Ekoloji 2008;17(67):8-14.
25. Guvensen A, Ozturk M. Airborne pollen calendar of Izmir Turkey. Ann Agric Environ Med 2003;10:37-44.
26. Bicakci A, Akyalcin H. Analysis of airborne pollen fall in Balıkesir, Turkey, 1996-1997. Ann Agric Environ Med. 2000;7:1-6.
27. Erkan P, Bicakci, A, Aybeke M, Malyer H. Analysis of airborne pollen grains in Kırklareli. Turk J Bot 2011;35:57-65.
28. Saatçıoğlu G, Tosunoğlu A, Malyer H, Bıçakçı A. Airborne pollen grains of Gemlik (Bursa). Asthma Allergy Immunol 2011;9:29-36.
29. Bıçakçı A, Iphar S, Malyer H, Sapan, N. Mudanya ilçesinin (Bursa) Polen takvimi. Uludag Univ Tıp Fak Derg 1995;1-3:17-21.
30. Ceter T, Pınar NM, Güney K. A-2 year aeropalynological survey of allergenic pollen in the atmosphere of Kastamonu, Turkey. Aerobiol 2012;28:355-66.
31. Tosunoglu A, Altunoglu MK, Bicakci A, Kılıc O, Gonca T, Yılmazer I, et al. Atmospheric pollen concentrations in Antalya, South Turkey. Aerobiologia 2015; 31(1): 99-109.
32. Tosunoglu A, Bicakci A. Seasonal and intradiurnal variation of airborne pollen concentrations in Bodrum, SW Turkey. Environ Monit Assess 2015;187(4):4384.
33. Hidalgo PJ, Galán C, Domínguez E. Male phenology of three species of Cupressus: Correlation with airborne pollen. Trees 2003;17:336-44.
34. Papa G, Romano A, Difonso M, Viola M, Artesani M, Di Gioacchino M, et al. Prevalence of sensitization to Cupressus sempervirens: A 4-years retrospective study. Sci Tot Environ 2001;270:83-7.
35. Docampo S, Recio M, Trigo MM, Melgar M, Cabezudo B. Risk of pollen allergy in Nerja (Southern Spain): A pollen calender. Aerobiol 2007;23:189-99.
36. Thibaudon M, Kamel E, Besancenot JP. Ambroisie et allergie - Le cas de la France. Environnement, Risque & Sante 2004;3(6):353-67.
37. Damialis A, Gioulekas D, Lazopoulou C, Balafoutis C, Vokou D. Transport of airborne pollen into the city of Thessaloniki: The effects of wind direction, speed and persistence. Int J Biometeorol 2005;49:139-45.
38. Bilisik A, Yenigün A, Bicakci A, Eliacik K, Canıtez Y, Malyer H, Sapan N. A obsevation study of airborne pollen fall in Didim, Turkey, 2004-2005. Aerobiol 2008;24:61-6.
39. Kaplan A, Ozdogan, Y. Seasonal variations of airborne pollen grains in Karabük, Turkey. Karabük İli hava polenlerinin mevsimsel değişimleri. Karaelmas Fen ve Müh Derg 2015;5(2):89-100.
40. Giner MM, Garcīa JSC, Camacho CN. Seasonal fluctuations of the airborne pollen spectrum in Murcia (SE Spain). Aerobiol 2002;18:141-51.
41. Nilsson S, Gothard JP. Pollen calendar for Huddinge (Sweeden), 1977-1981. Grana 1982;21:183-5.

42. Ince A, Kart L, Demir R, Ozyurt MS. Allergenic pollen in the atmosphere of Kayseri, Turkey. APJAI 2004;22:123-32.
43. Bicakci A, Tatlıdil S, Sapan N, Malyer H, Canıtez Y. Airborne polen grains in Bursa, Turkey, 1999- 2000. Ann Agric Environ Med 2003;10(1):31-6.
44. Liccardi G, D'Amato M, D'Amato G. Oleaceae pollinosis: A review. Int Arch Allergy Immuno 1996;111:210-7.
45. Celenk S, Bicakci A. Aerobiological investigation in Bitlis, Turkey. Ann Agric Environ Med 2005;12: 87-93.
46. Clot B. Trends in airborne pollen: An overview of 21 years of data in Neuchâtel (Switzerland). Aerobiol 2003;19:227-34
47. Guvensen A, Uysal I, Celik A, Ozturk M. Analysis of airborne pollen fall in Canakkale, Turkey. Pak J Bot 2005; 37(3):507-18.
48. Bilisik A, Bicakci A, Malyer H, Sapan N. Analysis of airborne pollen spectrum in Fethiye-Muğla, Turkey. Fresen Environ Bull 2008;17(6):640-6.
49. Kızılpınar I, Dogan C, Artac H, Reisli I, Pekcan S. Pollen grains in the atmosphere of Konya (Turkey) and their relationship with meteorological factors, in 2008. Turk J Bot 2012;36:344-57.
50. Riberio H, Abreu I, Cunha, M. An aerobiological study of the Porto Region (Portugal). Aerobiol 2003;19:235-41.
51. Bicakci A, Koc RD, Tatlıdil S, Benlioglu ON. Analysis of airborne pollen fall in Uşak, Turkey. Pak J Bot 2004;36(4):711-7.
52. Ture C, Bocuk H. Analysis of airborne pollen grains in Bilecik, Turkey. Environ Monit Assess 2009;151:27-35.
53. Peternel R, Čulig J, Mitić B, Vukušić I, Šostar Z. Analysis of airborne pollen concentrations in Zagreb, Croatia, 2002. Ann Agric Environ Med 2003;10:107-12.
54. D'Amato G, Lobefalo G. Allergenic pollen in the Southern Mediterranean Area. J Allergy Clin Immunol 1989;83:116-22.
55. D'Amato G, Spieksma FThM, Bonini S. Allergenic pollen and pollinosis in Europe. Oxford; Blackwell Scientific Publications, 1991:226.
56. Varela S, Subiza J, Subiza JL, Rodríguez R, García B, Jerez M, et al. Platanus pollen as an important cause of pollinosis. J Allergy Clin Immunol 1997;100:748-54.
57. Fang R, Xie S, Wei F. Pollen survey and clinical research in Yunnan, China. Aerobiol 2001;17:165-9.