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ORIGINAL PAPER

Relationship between airborne pollen and skin prick test results in Elazığ, Turkey

M. Kilic · M. K. Altunoglu · S. Akpınar · G. E. Akdogan · E. Taskin

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Abstract This study investigated the relationship between the types of pollen in the air and sensitization to pollen in a skin prick test in allergic children. The pollen in the atmosphere of Elazığ city was measured between June 2013 and June 2014. The study included 520 children with allergic complaints. In the atmosphere of Elazığ city, pollen belonging to a total of 38 taxa was identified, including 20 woody plants and 18 herbaceous plants. The annual pollen integral of 108,313 pollen day/m^3 from the 38 taxa was identified. The most common pollen detected was woody plants (76.4%), weeds (14.1%), Poaceae (Gramineae) (9.1%), and unidentified plants (0.4%). The skin prick test in allergic children found that they were most commonly sensitized to mixture of grasses and cereals (43.8%), weed (14.1%), tree mixture I (10.1%), and tree mixture II (7.9%). There was no direct relationship between the frequency of pollen types in the atmosphere and the sensitization frequency to pollen, as identified by the skin prick test in allergic patients. We believe that the data from this study will provide new information to other researchers and clinicians in the evaluation of allergic diseases.

Keywords Airborne pollen · Volumetric method · Allergic children · Skin prick test

M. Kilic
Department of Pediatrics, Division of Allergy and Immunology, University of Firat, Elazig, Turkey

M. K. Altunoglu · S. Akpınar · G. E. Akdogan
Department of Biology, Faculty of Arts and Sciences, University of Kafkas, Kars, Turkey

E. Taskin
Department of Pediatrics, Division of Neonatology, University of Firat, Elazig, Turkey

M. Kilic (✉)
Cocuk Sagligi ve Hastalikları Anabilim Dalı, Fırat Universitesi Tip Fakultesi, 23119 Elazig, Turkey
e-mail: drmkilic@gmail.com

1 Introduction

Among airborne biological particles, pollen is one of the most important aeroallergens causing airway allergies (Singh and Hays 2016). Pollen is carried by the wind (anemogam pollination) and insects (entomogam pollination) and is generally divided into three groups: tree pollen, grass pollen, and weed pollen. Wind-pollinated plants produce pollen to ensure pollination and exist in high numbers in the air, remaining in the air for many hours or even days and sometimes being transported up to 200–300 km away (Singh and Hays 2016; Esch 2008; Andersson and Lidholm 2003).

Pollen allergy is a prominent health problem both in Turkey and around the world, and an increasing number of allergy-related diseases are being found to be caused by pollen. Pollen is the most common allergen, being found in the air in high concentrations across wide regions; moreover, it is difficult to take precautions against. For this reason, it is important to know the times of year when allergic reactions are more frequent and the types and amounts of pollen in the air. Aerobiological studies performed with the purpose of determining such factors are facilitating the diagnosis and treatment of pollen allergy (Mothes et al. 2004). The World Health Organization emphasizes the importance of predicting pollen seasons and recommends new studies on the effect of climate change on the number of aeroallergens and, accordingly, on human health. The pollination season in a region varies depending on the climate and vegetation. Annual changes in the pollen calendar are related to meteorological factors, of which environmental temperature plays a decisive role. In general, in damp and rainy weather, pollen precipitates on the ground, while pollen release is at its highest in dry, sunny, warm, and moderately windy weather (Weber 2003).

Situated at the intersection of Europe and Asia, Turkey encompasses various regions with different geographic and climatic features. In Turkey, the first studies on airborne allergenic pollen and the pollination period of taxa that produce pollen were conducted in 1960. These studies mostly used the gravimetric method. From the 2000s onwards, volumetric pollen traps were placed in many city centers and new studies were performed determining the diversity of pollen in different parts of the country. However, to date, no aeropalynological studies have been conducted in several regions, including eastern Anatolia, where Elazığ is situated (Altintaş et al. 2004; Bıçakçı et al. 2009a, 2011; Celenk et al. 2010).

This study investigated the relationship between the types of pollen in the air and the sensitization to pollen in a skin prick test in allergic children.

2 Materials and methods

2.1 Study area, flora, climate, and meteorological data

The study was conducted in Elazığ in eastern Anatolia. The city lies between 40°21′ and 38°30′E longitude and 38°17′ and 39°11′N latitude (Fig. 1). Elazığ province has a surface area of 9.281 km^2 and an altitude of 1067 m. The total surface area of the province comprises 8.332 km^2 of land, 826 km^2 of dams and natural lakes, and 123 km^2 of forests. Elazığ is situated in the transition zone between the Mediterranean, Euro–Siberian, and Irano–Turanian phytogeographical regions. Elazığ has a continental climate, with cold, rainy winters and hot, dry summers. The temperature ranges between − 15 and + 42 °C, and the average annual rainfall is 433 mm, the maximum rainfall being observed during the spring. Recently, lakes that have been created as a result of the construction of new dams have caused deviations in the climate. The most marked change is that the winters, which were very cold and snowy in the past, are now relatively mild. Meteorological data from Elazığ city between June 2013 and June 2014 were obtained from the General Directorate of Meteorology.

2.2 Pollen sampling

In this study, pollen within the atmosphere of Elazığ city was measured between June 2013 and June 2014 by the volumetric method, using a Lanzoni VPPS 2000 device (VPPS 2000 Lanzoni, Bologna, Italy), which was placed on the roof of a building 15 m above ground level. The position of the sampler allowed air movement from all sides. Adhesive tape coated with silicone oil was placed in the sampler. The tape rolled on the drum in the pollen trap, which completed its full rotation in a week and was changed weekly. The adhesive tape from the device was sent for analysis to the Aerobiology Laboratory of the Department of Biology of Kafkas University's Faculty of Science and Literature.

2.3 Pollen identification

The adhesive tape was cut into seven equal pieces of 48 mm in length, representing 1 day. Reference preparations were prepared for daily microscopic examination using the "woodhouse" method (Wodehouse 1959). The tape fragments were mounted on slides covered with glycerin jelly mixed with basic fuchsine (Charpin et al. 1974). The slides were examined with Olympus light microscopy at × 400 magnification. The pollen counts of the identified taxa were converted into the concentration of airborne pollen grains per cubic meter. Pollen grains that could not be identified were considered to be unidentified types. Atmospheric sampling and analysis were

Fig. 1 Map is showing the location the city of Elazığ in Turkey

conducted according to the method of determining the intradiurnal variation patterns of airborne pollen by the Spanish Aerobiological Network (REA), which ascertains intradiurnal variation by transversally dividing slides into 12 intervals (Galán et al. 2007).

2.4 Skin prick test analyses

Five hundred and twenty children who were admitted to a pediatric allergy clinic with allergic complaints were enrolled in the study between January 2012 and December 2014. The skin prick tests of children were performed during the first outpatient visits between January 2012 and December 2014. All the enrolled children were allergic to at least one inhalant allergen, as detected by a skin prick test, had been born in the city of Elazığ, and had lived there continuously since birth. Standard skin prick tests were performed using antigens derived from the following mixtures: a grasses/cereals mixture, a weed mixture, tree mixtures I and II, *Dermatophagoides farinae*, *Dermatophagoides pteronyssinus*, mold mixtures I and II, *Blattella germanica*, cat epithelia, and dog epithelia. The grasses/cereals mixture contained *Holcus lanatus, Dactylis glomerata, Festuca pratensis, Lolium perenne, Poa pratensis, Phleum pratense, Secale cereale, Triticum sativum, Avenaa fatua,* and *Hordeum vulgare* antigens; the weed mixture contained *Artemisia vulgaris, Urtica dioica, Taraxacum vulgare, Plantago lanceolate,* and *Parietaria officinalis* antigens; tree mixture I contained *Alnus glutinosa, Corylus avellana, Populus alba, Salix caprea*, and *Ulmus scabra* antigens; tree mixture II contained *Betula alba, Quercus robur, Platanus orientalis,* and *Fagus sylvatica* antigens. For the skin prick test, standard allergen extracts from Allergopharma (Allergopharma GmbH & Co. KG, Reinbek, Germany) were used. Patients with positive skin prick test reactions to the tree pollen mixtures also underwent separate skin prick tests using each the following antigens: *A. glutinosa, P. alba, U. scabra, Pinus, S. caprea, P. orientalis, Q. robur, F. sylvatica, Cupressus, Fraxinus excelsior,* and *B. alba*. Similarly, patients with positive skin prick test reactions to the weed pollen mixture were subjected to skin prick tests using antigens of *Plantago lanceolata, Ambrosia artemisiifolia, A. vulgaris, Chenopodium album, P. officinalis, T. vulgare, Salsola kali,* and *U. dioica*. Histamine 10 mg/ml and diluent (0.9% sodium chloride) were used as positive and negative controls, respectively. Allergens and positive–negative controls were applied to the volar surface of the arm

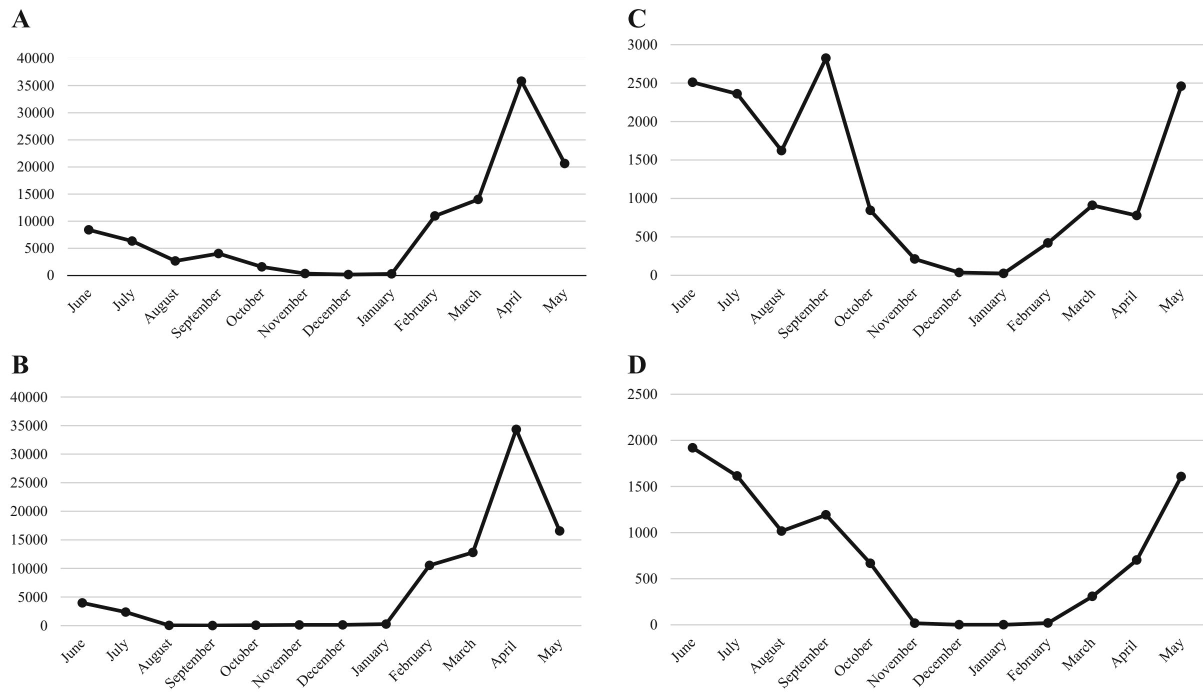

Fig. 2 **a** Monthly variation of total pollen (pollen/m^3), **b** monthly variation of total tree pollen (pollen/m^3), **c** monthly variation of total weed pollen (pollen/m^3), and **d** monthly variation in total number of Poaceae pollen grains (pollen/m^3) in the atmosphere of Elazıg, 2013–2014 years

epidermally. The skin prick tests were evaluated 15 min after application. A positive test was defined as a reaction with a mean weal diameter $\geq$ 3 mm greater than the negative control (Bousquet et al. 2012).

Firat University clinical research ethics committee approved this study, and written informed consent was obtained from all the subjects and/or their parents.

2.5 Statistical analyses

All the statistical analyses were performed using IBM SPSS Statistics for Windows version 21.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were expressed as the mean $\pm$ standard deviation, median, and range. A p value < 0.05 was considered to be statistically significant.

3 Results

In the pollen analysis, pollen belonging to 38 taxa, including 20 woody and 18 herbaceous plants, was detected in the atmosphere of Elazığ city. The herbaceous plant pollen was divided into three groups: Poaceae pollen, weed pollen, and unidentified pollen. The pollens of the woody plants were determined to genus levels. The annual pollen integral of 108,313 pollen day/m^3 from 38 taxa was identified.

The pollen of the Poaceae family accounted for 9.1% of the total pollen in the atmosphere. During the year-long measurement, we observed that the pollination period of Poaceae pollen extended from March to November, and the pollen concentration particularly increased between May and August (Fig. 2d). We determined that pollen of the weed family constituted 14.1% of the pollen in the atmosphere (Fig. 2c). The most frequent weed pollen belonged to Urticaceae (4.9%), *Mercurialis* (2.1%), *Ambrosia* (1.9%), *Plantago* (1.2%), Chenopodiaceae/Amaranthaceae (1.1%), and *Artemisia* (1%) (Table 1). In addition, woody plant pollen accounted for 76.4% of the total pollen in the atmosphere. The most frequent tree pollens in the air were those of Pinaceae (20.1%), Cupressaceae/Taxaceae (19.2%), *Fraxinus* (14.4%), *Quercus* (10.2%), *Alnus* (4.1%), *Platanus* (1.6%), and *Morus* (1.5%) (Table 2). Finally, unidentified plant

Table 1 Monthly distribution of Poaceae and weed pollen grains in the atmosphere of Elazıg, 2013–2014 years (pollen/m^3)

Taxa	June	July	August	September	October	November	December	January	February	March	April	May	Annual total (pollen/m^3)
Poaceae	**2722**[a]	1614	1015	1192	665	17	1	–	19	308	701	1607	9861
Urticaceae	1478	**1833**	458	111	6	–	–	–	30	165	99	1146	5326
Mercurialis sp.	77	36	8	11	11	51	16	14	382	619	333	**706**	2264
Ambrosia sp.	–	1	230	**1594**	310	25	–	–	–	–	–	–	2160
Plantago sp.	**493**	367	76	14	–	–	–	–	–	56	86	213	1305
Chenopodiaceae	71	134	299	**596**	74	11	–	–	–	9	7	43	1244
Artemisia sp.	–	47	293	**413**	355	6	–	–	–	–	–	–	1094
Rumex sp.	126	65	–	–	–	–	–	–	–	4	41	**180**	418
Humulus sp.	72	58	**110**	40	–	–	–	–	–	–	–	–	280
Cruciferae	22	9	–	–	–	–	–	–	–	15	**125**	104	275
Umbelliferae	**89**	65	52	11	–	2	–	–	–	3	4	24	250
Compositae	45	**63**	48	12	9	–	–	–	–	13	18	26	234
Xanthium sp.	–	–	18	47	**51**	16	–	–	–	–	–	–	126
Cyperaceae	**37**	14	4	–	–	–	–	–	–	2	16	10	83
Labiatae	**26**	18	4	–	–	–	–	–	–	–	9	5	62
Leguminosae	8	10	–	–	–	–	–	–	–	–	**35**	8	61
Boraginaceae	**27**	1	–	–	–	–	–	–	–	–	–	14	42
Centaurea sp.	**23**	–	–	–	–	–	–	–	–	–	–	–	23
Herbaceous total pollen	5316	4335	2615	4041	1481	128	17	14	431	1194	1474	4086	25,108
Unidentified	61	55	27	11	49	132	20	10	8	24	20	50	467
Total	5377	4390	2642	4052	1530	260	37	24	439	1218	1494	4136	25,575

[a]The bold-typed values show the highest level for taxon pollen during a year

Table 2 Monthly distribution of tree pollen grains in the atmosphere of Elazıg, 2013–2014 years (pollen/m^3)

Taxa	June	July	August	September	October	November	December	January	February	March	April	May	Annual total (Pollen/m^3)
Pinaceae	3476	1980	45	15	42	111	25	8	–	188	**8623**[a]	7306	21,833
Cupress/Taxa.	87	172	3	–	3	7	25	30	**8830**	4843	4814	2049	20,863
Fraxinus sp.	7	2	–	–	–	–	–	4	269	4339	**10,196**	877	15,694
Quercus sp.	3	79	–	–	–	–	–	–	–	219	**5671**	5136	11,108
Alnus sp.	–	–	–	–	–	–	74	228	1234	**2218**	777	–	4531
Platanus sp.	–	–	–	–	–	–	–	–	–	98	722	**964**	1784
Morus sp.	3	–	–	–	–	–	–	–	–	8	**1662**	–	1673
Ericaceae	14	10	–	3	26	5	5	–	5	**402**	349	218	1037
Populus sp.	–	–	–	–	–	–	–	–	27	226	**516**	–	769
Acer sp.	2	–	–	–	–	–	–	–	–	65	**420**	226	713
Oleaceae	**404**	100	–	–	–	–	–	–	–	–	–	170	674
Juglans sp.	–	1	–	–	–	–	–	–	–	3	**589**	61	654
Salix sp.	2	1	–	–	–	–	–	–	–	15	**358**	71	447
Fagus sp.	3	2	–	–	–	–	–	–	–	–	**120**	96	221
Ulmus sp.	–	–	–	–	–	–	–	–	**136**	24	8	–	168
Betula sp.	2	–	–	–	–	–	–	–	–	21	**115**	6	144
Ligustrum sp.	–	–	–	–	–	–	–	–	39	**96**	12	–	147
Rosaceae	18	5	–	–	–	–	–	–	–	20	**75**	14	132
Tilia sp.	**79**	15	–	–	–	–	–	–	–	–	–	–	94
Carpinus sp.	–	–	–	–	–	–	–	–	–	31	21	–	52
Total	4100	2367	48	18	71	123	129	270	10,540	12,816	35,048	17,194	82,738

[a]The bold-typed values show the highest level for taxon pollens during a year

Table 3 Meteorological data of the city of Elazığ between 2013 and 2014 years

Months	Average monthly temperature (°C)	Monthly average maximum temperature (°C)	Monthly average minimum temperature (°C)	Average monthly relative humidity (%)	Average monthly wind speed (m/s)	Average monthly strong wind speed (m/s)	Total monthly precipitation (mm)
June (2013)	24.1	31.6	14.5	30.2	2.6	12.8	4.9
July (2013)	27.6	34.8	18.6	23.8	3.4	13.2	0.0
August (2013)	27.2	34.9	18.3	23.5	2.3	11.6	0.0
September (2013)	20.7	29.1	13.2	33.6	2.3	12.7	8
October (2013)	13.1	21.7	6.4	41.1	2.4	13.7	18.2
November (2013)	9.0	14.8	4.8	67.9	2.0	11.3	32.1
December (2013)	− 1.3	2.2	− 4.4	72.3	2.0	15.7	12.8
January (2014)	2.6	7.5	− 1.4	73.6	2.0	13.7	40.9
February (2014)	4.2	11.0	− 1.4	57.6	2.3	12.9	24.5
March (2014)	9.2	15.5	4.1	58.3	2.7	12.6	33.9
April (2014)	14.2	20.8	7.7	52.5	2.6	12.6	64.2
May (2014)	19.1	26.2	11.4	44.3	2.2	13.0	31.9

pollen accounted for 0.4% of the total pollen in the atmosphere. When the monthly distribution of pollen was analyzed, we found that the highest pollen concentration in Elazığ city occurred in April 2014, although airborne pollen was detected during every month analyzed. The number of pollen grains detected during the month of April 2014 was 36,542 pollen grains day/m^3, constituting 33.7% of the total number of pollen grains detected (Fig. 2a). The data related to the meteorological parameters of Elazığ during the study period are given in Table 3.

Of the 520 children included in the study, 58.2% (*n* = 303) were male and 41.8% (*n* = 217) were female, and their ages ranged from two to 18 years. Asthma was diagnosed in 32.6% of the patients (*n* = 170), rhinitis in 41% (*n* = 213), and both rhinitis and asthma in 26.4% (*n* = 137). The patients were recorded as being either allergic to a single allergen (47.1%; *n* = 258) or to multiple allergens (52.9%; *n* = 292). Most frequently, sensitization was induced to allergens derived from a grasses/cereals mixture (43.8%; i = 308). Following this, the sensitization to *D. farinae* was detected in 19.1% of cases (*n* = 134), *D. pteronyssinus* in 18.2% (*n* = 128), weed mixture in 14.1% (*n* = 99), mold mixture I in 9.2% (*n* = 65), tree mixture I in 8.8% (*n* = 62), and tree mixture II in 6.3% (*n* = 44) (Table 4). There was no direct relationship between pollen concentration in the atmosphere and pollen sensitization in the skin prick test of allergic patients in our study.

4 Discussion

Few studies have hitherto been performed to determine the types and concentrations of pollen in the atmosphere in the eastern Anatolia region of Turkey. These studies showed that the most frequent

Table 4 The distribution and frequencies of sensitization for each allergen in 520 children with allergic complaints

Allergens	*n* (%)
Grasses-cereals mixture[a]	308 (43.8)
House dust mite	
Dermatophagoides farinae	134 (19.1)
Dermatophagoides pteronyssinus	128 (18.2)
Weed mixture[b]	99 (14.1)
Plantago lanceolata	63 (9)
Ambrosia artemisiifolia (Ragweed)	51 (7.3)
Artemisia vulgaris	43 (6.1)
Chenopodium album	37 (5.3)
Parietaria officinalis	32 (4.6)
Taraxacum vulgare	30 (4.3)
Salsola kali	25 (3.6)
Urtica dioica	17 (2.4)
Trees mixture I[c]	62 (8.8)
Trees mixture II[d]	44 (6.3)
Cupressus	59 (8.4)
Populus alba	46 (6.5)
Platanus orientalis	43 (6.1)
Fraxinus excelsior	37 (5.3)
Salix caprea	36 (5.1)
Alnus glutinosa	34 (4.8)
Betula alba	17 (2.4)
Quercus robur	15 (2.1)
Ulmus scabra	14 (2)
Fagus sylvatica	12 (1.7)
Pinus	10 (1.4)
Mold mixture I[e]	65 (9.2)
Mold mixture II[f]	18 (2.6)
Animal dander	
Cat	50 (7.1)
Dog	31 (4.4)
Cockroach (*Blattella germanica*)	19 (2.7)

[a]Grasses-cereals mixture: *Holcus lanatus, Dactylis glomerata, Festuca pratensis, Lolium perenne, Poa pratensis, Phleum pratense, Secale cereale, Triticum sativum, Avenaa fatua* ve *Hordeum vulgare*

[b]Weed mixture: *Artemisia vulgaris, Urtica dioica, Taraxacum vulgare, Plantago lanceolata* ve *Parietaria officinalis*

[c]Tree mixture I: *Alnus glutinosa, Corylus avellana Populus alba, Salix caprea, Ulmus scabra*

[d]Tree mixture II: *Betula alba, Quercus robur, Platanus orientalis, Fagus sylvatica*

[e]Molds mixture I: *Alternaria alternata, Cladosporium herbarum, Botrytis cinerea, Curvularia lunato, Fusarium moniliforme, Helminthosporium halodes*

[f]Molds mixture I: *Aspergillus fumigatus, Mucor mucedo, Penicillium notatum, Oullularia pullulan, Rhizopus nigricans, Sepula lacrymans*

concentrated pollen types in the atmosphere were *Fraxinus*, Cupressaceae, *Quercus*, *Salix*, *Juglans*, Poaceae, and Urticaceae in the spring, and Poaceae and Chenopodiaceae/Amaranthaceae in the autumn (Bıçakçı et al. 2009b).

Aerobiological studies done in Turkey have detected that Poaceae pollen has been found most frequently in April and August. These studies reported that Poaceae pollen constituted 1.3–35% of the total amount of pollen in the atmosphere and was the second most common pollen in the air after tree pollen. Poaceae pollen was detected in the highest concentration in the eastern central and eastern Anatolia (Bıçakçı et al. 2009b). In Europe, Poaceae pollen exists in the atmosphere throughout the year but was found to be at its highest concentration between May and August (D'Amato et al. 2007); throughout different regions of Spain, concentrations of Poaceae pollen ranged between 7 and 11% (Jato et al. 2009). In comparison, we determined that the concentration of Poaceae pollen was 9.1% of the total pollen in the air. In additional, our results demonstrated that Poaceae pollen is found most frequently in the atmosphere between May and September. These results seem to be compatible with the characteristics of the climate, geographic conditions, and vegetation of the region. Because agriculture is an important source of income for the people of Elazığ city, certain agricultural products (wheat, barley, oats, rye) belonging to the Poaceae genus are grown for food and animal feed in the area. Similarly, aerobiological studies have reported that the quantity of pollen grains in the atmosphere is related to the vegetation of a region (García-Mozo et al. 2016; Jato et al. 2002).

Pollination of weeds generally occurs between August and October. The most common types of weed pollen encountered in the atmosphere of Turkey are *U. dioica, P. lanceolata,* and *A. vulgaris*. In eastern Anatolia, where Elazığ city is situated, the most abundant types of pollen during the summer and the autumn are Urticaceae and Chenopodiaceae/Amaranthaceae, respectively (Bıçakçı et al. 2009b). In our study, the most frequent weed pollens in the atmosphere were Urticaceae, *Mercurialis*, *Ambrosia* (i.e., ragweed), *Plantago*, and Chenopodiaceae. The Urticaceae pollen is reportedly the most frequently encountered type of weed pollen in the atmosphere in central and southern Europe (Čamprag et al. 2015). We found that *Mercurialis* pollen ranked second among the most frequently encountered types of weed pollen. This may be because *Mercurialis annua* is native to the Middle East (Iran, Qatar, Turkey), North Africa, and Europe (Singh and Shahi 2008). In Turkey, there are three *Ambrosia* species: *Ambrosia maritima*, *Ambrosia tenuifolia*, and *A. artemisiifolia*. In studies conducted in Turkey, *Ambrosia* pollen was observed in 16 of 67 regions (Bıçakçı and Tosunoğlu 2015; Behçet 2004). In the present study, *Ambrosia* pollen was the third most frequently found type of weed pollen in the atmosphere, being at higher concentrations in August and October. Annual total ragweed pollen levels were measured at 2160 pollen grains - day/m^3. In Europe, *Ambrosia* pollen is found in the air in higher concentrations; for example, in Hungary and Serbia, the concentration of ragweed pollen in the air can amount to 1000–2000 pollen grains/m^3 per day during certain periods, and about 20,000 pollen grains/ m^3 annually (Makra et al. 2004).

Although there are regional differences, in Turkey, the most common types of tree pollen in the atmosphere are reportedly those of *Pinus* spp., *Q. robur*, *Plantanus orientalis*, *Cupressus sempervirens*, *Olea europea*, *Salix* spp., and *F. sylvatica*. In addition, the most frequently detected tree pollens in the eastern Anatolia region are reportedly those of *Fraxinus* spp., Cupressaceae, *Quercus* spp., *Salix* spp., and *Juglans* spp. (Bıçakçı 2011). In our study, the most common types of tree pollen found in the atmosphere were those of *Pinus* spp., Cupressaceae/Taxaceae, *Fraxinus* spp., *Quercus* spp., *Alnus* spp., and *Platanus* spp. In all 59 regions of Turkey where pollen studies have been carried out, *Pinus* pollen has been encountered, ranking as the most common type of pollen in the atmosphere in 42 of the 59 regions. In these studies, the concentration of *Pinus* pollen in the atmosphere was found to range from 2.74 to 69.31% and the pollen was most prevalent between April and June (Bıçakçı et al. 2011). In the present study, *Pinus* pollen was the most frequently detected pollen in the atmosphere (20.1%). Approximately 95% of the forests in the city of Elazığ contain oak trees. However, our study found *Pinus* pollen levels were the highest according to the total amount of pollen, possibly because of the features of *Pinus* pollen. *Pinus* pollen grains have two air sacs, which causes them to stay in the air longer and allows them to be carried very long distances (Szczepanek et al. 2017). We detected a higher rate of the total annual amount of *Fraxinus* pollen (14.4%) than that reported in the relevant data published on atmospheric pollen studies in Turkey, in which *Fraxinus* pollen was observed in 39 of the 55 regions studied (Bıçakçı et al. 2009c). In Elazığ, *Fraxinus* spp. is omnipresent in parks, gardens, and bordering streets, thanks to its resistance to air pollution and diseases. The other most common tree pollen found in the atmosphere in the present study belonged to the *Quercus* (oak), *Alnus* (alder), and *Platanus* (plane) taxa.

Along with genetic predisposition, environmental factors play an important role in the development of allergic diseases. One of the most important environmental factors is the presence of aeroallergens (Esch 2008; Andersson and Lidholm 2003). We detected tree pollen (76.4%), weed pollen (14.1%), and Poaceae pollen (9.1%) in the atmosphere of Elazığ city. In contrast, the allergens detected in the skin test on children with allergic complaints in Elazığ were Poaceae pollen (43.8%), weed pollen (14.1%), tree mixture I (10.1%), and tree mixture II (7.9%). Some papers have shown positive correlations between airborne pollen concentration and allergic symptomatology. However, it has not been reported that there was exactly a relationship between pollen concentration in the atmosphere and the pollen sensitization in the skin prick test of allergic patients (Bousquet et al. 1984; D'Amato and Lobefalo 1989; Subiza et al. 1995). In our study, we found no direct relationship between the frequency of pollen types in the atmosphere and the sensitization frequency to pollen in the skin prick test in allergic patients. This lack of correlation has been attributed to different biological characteristics of the pollen and the role of complex physiopathological mechanisms in the development of allergic diseases. Although wind-pollinated trees shed more pollen into the atmosphere, this type of pollen has fewer allergenic properties than Poaceae or weed pollen. This is most likely because certain properties determine the allergenic potency of the pollens. The allergenic property of a pollen is affected by factors such as size, weight, the structure of the pollen, and the number of epitopes contained in the pollen (Negrini 1992). In general, the diameter of the inhalant pollens is between 20 and 110 μm. An intact pollen is too large to reach the alveoli (Esch and Bush 2009). These large particles are removed by the nasal mucosa and upper tracheobronchial passages. Particles < 5 μm generally reach the alveoli of the lungs. However, a hypotonic medium (such as rain water) allows rapid hydration of the pollen grain, which expels allergen-containing inhalable materials, which, being smaller, reach the lower airways and induce asthma. The dissolved allergenic content of Poaceae pollen is released in the form of small granules (0.6–2.5 μm) (Suphioglu et al. 1992; Driessen and Quanjer 1991). In addition, there is a high cross-reaction between the members of the Poaceae family, owing to similarities in the sequence of amino acids. In a person with a sensitivity to any one Poaceae species, skin prick test positivity can be detected for all types of Poaceae pollen because of cross-reaction (D'Amato et al. 2007; Jaeger 2008; Esch and Klapper 1989).

Allergic diseases associated with Poaceae pollen are common in Europe. Sensitivity rates to Poaceae among patients allergic to pollen were reportedly 20% in Denmark and 80% in Holland and France (D'Amato et al. 2007; Heinzerling et al. 2009). In Turkey, Şahiner et al. (2012) reported sensitivity to grass in 70.4% of allergic patients and Canitez et al. (2007) in 11.9% of allergic patients. In our previous published study, we identified a Poaceae sensitization rate of 60.1% in a skin prick test in allergic children in Elazığ city (Kilic and Taskin 2016). The following types of weed pollen have been reported as the most allergenic throughout the world: *A. vulgaris, U. dioica, P. lanceolata, P. officinalis, Ambrosia* spp., *C. album*, and *T. vulgare*. Sensitivity to weed pollen is most commonly observed in the United States (Gadermaier et al. 2004, 2014; Mohapatra et al. 2008). In central and northern Europe, sensitivity to weed pollen is less common. However, weed pollen is a prominent cause of allergic diseases in Mediterranean countries. In our study, the weed antigens with the highest sensitization rates included *P. lanceolata* (9%), *A. artemisiifolia* (7.3%), *A. vulgaris* (6.1%), and *C. album* (5.3%). In Turkey, sensitization to weed pollen in the skin prick test of allergic children has been determined to range between 7 and 23.1% of cases (Şahiner et al. 2012; Tezcan et al. 2003). Şahiner et al. (2012) performed a skin prick test in children with respiratory tract allergies and detected sensitization to weed pollen in 23.1% of their study participants. In addition, they evaluated children with weed pollen allergy and detected sensitivities to the *Chenopodium* mixture (3.6%), *P. lanceolata* (3.5%), *A. vulgaris* (2.8%), *S. kali* (1.8%), and *Parietaria judaica* (0.6%). The types of tree pollen that have reportedly caused the most prevalent allergic reactions throughout the world are *Betula* spp., *Cupressus* spp., *Olea* spp., *Alnus* spp., and *Corylus* spp. (Swoboda et al. 2008). In northern Europe, and especially in Scandinavian countries, *Betula* spp. is the tree pollen that most often causes allergic respiratory diseases; in the Mediterranean region, *Olea* spp. and *Cupressus* spp. are the most common causes (Asam et al. 2015). In the skin prick test conducted in the present study, we found sensitization rates of 10.1% for tree mixture I (which contained *A. glutinosa*, *C. avellana*, *P. alba*, *S. caprea*, and *U. scabra*) and 7.9% for tree mixture II (which contained *B. alba, Q. robur*, *P. orientalis*, and *F. sylvatica*). The allergens containing single tree antigens that induced sensitization in the skin prick test are as follows, in order of frequency, from most common to least common: *Cupressus* spp., *P. alba*, *P. orientalis*, *F. excelsior*, and *S. caprea*. *Pinus* pollen was found to be the most frequent among the tree pollens in the atmosphere. However, we found sensitization to the *Pinus* allergen to be 1.4% in the skin prick test.

5 Conclusions

This is the first study in which pollen was measured in the atmosphere in Elazığ and the eastern Anatolia region using the volumetric method and a Lanzoni VPPS 2000 device. The pollen concentrations of 38 taxa, amounting to an annual pollen integral of 108,313 pollen day/m^3, were determined in the atmosphere of Elazığ during 1 year of pollen measurement. We found that airborne pollen reached its maximum concentration in April 2014. There was no precise correlation between the frequency of pollen types in the atmosphere and the sensitization frequency to pollen in the skin prick test in allergic patients. We believe that the data from this study will provide new information to other researchers and clinicians, contributing to the further evaluation of allergic diseases.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the clinic.

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