

Skin prick test reactivity in allergic rhinitis patients to airborne pollens

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Abstract The aim was to investigate the impact of atmospheric pollen in determining allergic rhinitis. It was conducted with 130 patients with allergic rhinitis in three different sites in Eskisehir, Turkey, in 2000–2001, using a gravimetric method with a Durham sampler. Skin prick test results, the symptoms of patients and their findings all confirmed the presence of allergic reactions to pollen allergens in the patients observed. During the period, a total of 47,082 pollen grains/cm² belonging to 45 taxa were recorded. Of the total pollen grains, 81.0% were arboreal and 18% non-arboreal. The majority of the investigated pollen grains were from Pinaceae, Salix spp., Chenopodiaceae/

Amaranthaceae, Cupressaceae and Poaceae. Pollen concentrations reached the highest level in May (54.36%). The pollen allergens provoking severe sensitization were grasscereal mixtures (58.5%), followed by arboreals (33.8%). All patients (100.0%) were sensitive to grass. This study emphasizes the significance of determining the types and concentrations of pollen with a view to comparing changes in highly concentrated allergens.

Keywords Pollen · Allergic rhinitis · Skin prick test

Introduction

Aerobiological investigations performed over the past 10 years have emphasized the following problems: the concentration of pollen in the air, pollen transport and the impact of pollen on mankind's health. Pollen grains that cause various allergic diseases have been the main emphasis of extensive aerobiological studies. The investigations confirmed the existence of a correlation between the number of allergic patients and the concentration of pollen in the atmosphere, as well as some idiosyncrasies in the allergic diseases prevalent in cities and towns (Levetin and Buck 1980; Ciprandi et al. 2005).

During the last decade clear evidence has emerged that there has been an increase in the incidence of pollen allergy in most European countries, and that this trend is particularly noticeable in urban areas (Cosentino et al. 1995). Pollinosis is a common

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allergenic disease affecting 15% of human population all over the world. Human beings are being exposed to more and more pollen occurring in relatively high concentrations in the air. This means that pollinosis is frequently caused by plants dependant upon the wind for cross-fertilization (Driessen et al. 1989; Latorre and Perez 1997). Knowledge of the abundance of allergenic pollen types and their pollen seasons is essential to allergologists, who can correlate hay fever symptoms with the presence of allergenic pollen in the atmosphere (Romano et al. 1988). Owing to their ubiquitous presence in nature, pollen grains represent an inevitable allergen source and are included in the most important agents responsible for provoking allergic manifestations (Hyde 1972; Al-Doory et al. 1980; Cosentino et al. 1995; Puc 2003). The sampling of pollen in the air is of particular interest to both clinicians and patients, in evaluating exposure to various allergen types in relation to allergy. Several reports have suggested that aerobiological and clinical data need to be combined to improve the diagnosis and proper treatment of allergic patients (Chapman and Williams 1984; Ricketti 1993). Numerous surveys have been carried out in different geographic areas and indoor environments (Singh and Babu 1982; Meiffren 1988; Chakraborty et al. 2001; Ciprandi et al. 2005).

Pollen allergy is an increasing problem, with the main pollen types causing rhinitis and asthma. The question that requires an answer is when the best time of the day is to be outdoors and when it is advisable to stay indoors (Spieksma 1990; Galan et al. 1995; D'Amato et al. 2002). Many people suffer from allergic diseases and much research has illustrated that pollen can play an important role in inducing such diseases. The fact that allergic symptoms are more prevalent in larger cities may be related to the increase in air pollution attributable to mineral or synthetic materials released into the atmosphere by cars and factories (Majd and Ghanati 1995; Nowak et al. 1996; Ekebom et al. 1997; Puc and Puc 2004). Although groves, farms and arboreals are more often found in villages and the suburbs, the intensity of pollen allergies is higher in urban centres, in industrial cities in particular. This fact suggests that there are some environmental factors which may increase pollen allergenicity beside the pollen allergens. These factors are more abundantly found in polluted atmospheres. Numerous studies on pollen allergy

confirm a positive correlation between the airborne pollen count and symptoms of allergy (Obtulowicz et al. 1991; Cosentino et al. 1995; Ciprandi et al. 2005). Patients suffering from pollen allergy manifest similar symptoms in the same period of the year, and have a positive skin reaction to a pollen allergen, which makes the diagnosis of allergic rhinitis easier (Obtulowicz et al. 1991).

Using airborne pollen grains as indicators of environmental contamination and pollution levels, various data reveal the periods when pollen grains are present in the atmosphere, as well as their peaks and the levels of concentration capable of causing allergies in Turkey (Kalyoncu et al. 1996, Yazicioglu et al. 2004).

This study was carried out to investigate the influence of atmospheric pollen in determining allergic rhinitis by comparing the frequency of skin reactions to air sampling data in three different places in a city of western Turkey over a 2-year period.

Subjects and methods

General climate of the city of Eskisehir

Eskisehir is situated at 39°06' and 40°09' N, 29°58' and 32°04' E in the West of Turkey, at an altitude of 788 m above sea level. Eskisehir has a Mediterranean, Irano-Turanian vegetation, and in the main a Mediterranean climate.

The meteorological data for Eskisehir were obtained from the Eskisehir Meteorological Service (Anonymous 2001).

There have been continuous meteorological observations for Eskisehir since 1940. The annual average rainfall for the period 1940–2001 was 294.1 mm. and the average temperature for the same period was 10.8°C. The warmest month during this period was July with an average temperature of 21.5°C. The annual average humidity was 67%. The predominant wind directions at the sampling site were west-northwesterly between March–October and east-southeasterly between November–February.

Studied area and gravimetric method

In this study, a gravimetric method with a Durham sampler was used. Using this method, Durham

conducted his studies in the USA. The instrument which bears his name is extremely simple and inexpensive. In 1946, Durham described a standard sampling device. The device is simple to use or construct, is portable and lacks power requirements. Durham sampler provides support for a 1×3 in. microslide which is mounted 1 in. above a 9-in. diameter disc. A second 9-in. disc serves as a rain shield and the two are attached by three 4-in. struts. The device is usually placed 150–180 cm above the ground level or at the roof level. Direct daily observation of collected catkins and male cones were made to determine the timing of pine pollen release. Durham gravity pollen collectors were employed in this study. This sampling device is approved by the National Pollen Survey Committee as standard for sampling atmospheric pollen by the gravity. These collectors were chosen instead of mechanical devices because of: (1) cost; (2) inaccessibility to power for mechanical samplers; (3) need for uninterrupted data collection; (4) likelihood of animal damage. The Durham pollen collector consists of two horizontal disks (23 cm in diameter, 15 cm apart), with the lower disk located 10 cm from ground level. A standard 268 cm glass slide covered with a thin film of glycerine jelly was placed on the lower disk to collect pollen (Durham 1946; Anderson 1985; Hansen and Wright 1987).

The Durham sampler, a gravimetric method device, was placed at a height of 1.75 m above ground level in the three stations (1. Osmangazi University Meselik Campus; 2. Anadolu University Yunus Emre Campus; 3. Anadolu University Iki Eylul Campus). The first station Latitude: 39° 48' N, Longitude: 30° 32' E, Altitude: 845 m. The second station Latitude: 39° 47' N, Longitude: 30°29' E, Altitude: 819 m. The third station Latitude: 39° 44' N, Longitude: 30°29' E, Altitude: 789 m. The first station is in the south of the city, but the second and third stations are in the north. Distances between the research stations and a meteorological station were measured by GARMIN GPS 12 CX device (Global Positioning System; Made in Taiwan, under USA patent). This device was also used to measure the altitude of the research stations.

Slides placed on the Durham sampler were changed daily. Before exposure, the slides were covered with glycerin jelly mixed with basic fuchsin (Charpin et al. 1974). The slides were examined daily under a light microscope. Pollen types were determined at

least up to family and genus levels by comparison with a reference pollen type. The grains that could not be identified were considered to be unidentified types. The number of pollen grains found on slides (22×22 mm) were counted.

Diagnostic criteria of allergic rhinitis

Predagnosis of allergic rhinitis was made by a physician from the researching team. If the patients had any symptoms such as sneezing, nasal congestion and itching symptoms, they were diagnosed as sensitive to pollen. After a family history for the allergic reactions of the patients was completed, the same physician performed clinical examinations of these patients. If any of such symptoms as turbinate colour, turbinate congestion, and nasal discharge occurred, the diagnosis of allergic rhinitis was confirmed. The same physician went on to perform skin prick tests on each of the patients (Ng et al. 2000).

Skin prick tests

Skin prick tests (SPT) were performed on all the patients. The antigens were applied with multi-test II applicators (multiple skin test applicator-Lincoln diagnostics). Gradation of the skin reaction is based on the relation of the size of the skin wheal and flare reaction compared to the positive control (histamine solution) and negative control (saline solution). The reaction is read after 15 minutes. Antigen induced wheals larger than the histamine control are read as 4+, at the same level with the control being 3+, reactions two thirds the control as 2+, and reactions one third the control as 1+ (Nelson 1983; Bernstein and Storms 1995). Grasses/cereals mixture, weeds mixture, arboreal mixture positive and negative controls were included in all tests. The allergens used were obtained from Allergopharma, Germany. Main groups of antigens were applied to all patients initially. Their subgroups were then applied in the same way according to the patient's positive reaction.

Statistical analysis

The statistical Package for Social Sciences (SPSS) software was used for calculations. Chi-square tests and percentages were used to compare and estimate prevalences between study populations. Spearman's Correla-

tion method was used to find the relationship between patient symptoms and pollen count, and pollen types.

The relationship between the patient age means were evaluated by *t* test, which assesses whether the means of two groups are statistically different from each other. A *p* value < 0.05 was deemed as significant.

Legal ethical consent

Ethical permission for the study was obtained prior to collection of data, by contacting and receiving approval from the appropriate management authority, Osmangazi University, the health directorship of the city involved. Participants were assured of the confidentiality of their responses and provided informed written consent.

Results

A total of 47,082 pollen grains/cm² from 45 taxa, 19,141 in 2000 and 27,941 in 2001, were identified in the atmosphere of Eskisehir from 1 January 2000 to 31 December 2001. Of 45 taxa, 26 were arboreal while 19 were non-arboreal plants. A total of 38,519 pollen grains/cm² were found to be arboreal (81.0%), 8,275 non-arboreal (18%) and 288 unidentified (1%; unshown data).

The mean ($\pm$ SD) age of the patients was 37.4 $\pm$ 11.7 years, ranging from 17 to 66. The proportion was lower in men than in women (32.6 $\pm$ 11.1 and 39.9 $\pm$ 11.2, respectively) [*t*=3.5, degrees of freedom (*df*) = 128, *p*=0.001]. Age ranged from 17 to 61 in men, and from 18 to 66 in women. More patients (65.4%) were female. Most patients were between the age group 31 and 45 (53.8), followed by the age group $\leq$ 30 (24.6%) and the age group $\geq$ 46 (21.5%; unshown data).

Table 1 shows skin prick test results in patients sensitive to pollen. The pollen allergens causing severe sensitization were grasses–cereals (58.5%), followed by arboreals (33.8%) and grasses (21.5%). The pollen allergens causing moderate sensitization were grasses (53.8%), followed by grasses–cereals (21.5%) and arboreals (12.3%). The pollen allergens that caused mild sensitization were grasses (24.6%), followed by arboreals (1.5%). By and large, it was found that all the patients (100.0%) were sensitive to grasses, 80.0% patients to grasses–cereals, 47.7% patients to arboreals, 9.2% patients to weeds, and

6.2% patients to non-arboreals. Within grasses, grasses–cereals, arboreals, non-arboreals and weeds, the pollen allergens that caused the severest sensitization were from *Festuca pratensis* (42.3%), *Triticum sativum* (41.5%), *Betula verrucosa* (24.6%), *Chrysanthemum leucanth* (5.4%), and *Taraxacum vulgare* (4.6%), respectively.

The study was performed in 2000 and 2001, and the five most frequent arboreal pollen producers in the atmosphere of Eskisehir were found to be: Pinaceae (48.13%), *Salix* spp. (9.16%) and Cupressaceae (6.21%), followed by Rosaceae (3.53%) and *Quercus* spp. (3.03%). All arboreal pollen constituted 81.0% of the total pollen fall. The three most frequent herb plants were Chenopodiaceae/Amaranthaceae (7.82%), Fabaceae (1.97%), and Cruciferae (0.85%). Poaceae (4.22%) as a grasses–cereals, and Asteraceae (0.61%) as a non-arboreal were also identified in the atmosphere. The three most frequently identified Herb plants were Urticaceae (0.54%), *Artemisia* spp. (0.43%) and *Plantago* spp. (0.38%). Arboreal pollen counts were higher than herb pollen grains with respect to total pollen concentrations (81.0% and 16.8%, respectively). Detailed data have been presented in Table 2.

Monthly airborne arboreal pollen counts have been presented in Fig. 1. Arboreal pollen grains reached maximum counts in May in both years. Monthly average airborne herb pollen counts by months have been presented in Fig. 2. Herb pollen grains reached maximum levels in August in both years. Average airborne grasses–cereals pollen counts by months have been presented in Fig. 3. Grass pollen appeared during a maximum flowering period from February (the second week) and ceased in December (the first week). Grasses–cereals reached maximum levels in June in both years. The monthly distribution of atmospheric pollen in Eskisehir in 2000 and 2001 has been presented in Fig. 4. Pollen reached its maximum in May of both years.

The earliest pollen in the atmosphere of Eskisehir was noted in January 2001, with the predominant arboreal pollen grains were observed during this month. The number of pollen grains began to increase in February, March and April and reached a maximum in May (11,130 pollen grains in 2000 and 14,468 in 2001). *Pinus* spp., Poaceae, Cupressaceae, *Platanus* spp., Oleaceae, *Quercus* spp., Moraceae and Urticaceae released high amounts of pollen into the atmosphere throughout their

Table 1 Patient sensitization levels to pollen according to skin prick test results

Pollen allergens	Severe sensitization (3+) ^a n (%)	Moderate sensitization (2+) ^b n (%)	Mild sensitization (1+) ^c n (%)	Total (+) ^d n (%)	Total (−) ^e n (%)
Grasses	28 (21.5)	70 (53.8)	32 (24.6)	130 (100.0)	0
<i>Holcus lanatus</i>	33 (25.4)	20 (15.4)	12 (9.2)	65 (50.0)	65 (50.0)
<i>Dactylis glomerata</i>	44 (33.8)	13 (10.0)	16 (12.3)	73 (56.2)	57 (43.8)
<i>Lolium perenne</i>	35 (26.9)	17 (13.1)	16 (12.3)	68 (52.3)	62 (47.7)
<i>Phleum pratense</i>	30 (23.1)	14 (10.8)	5 (3.8)	49 (37.7)	81 (62.3)
<i>Poa pratensis</i>	41 (31.5)	15 (11.5)	13 (10.0)	69 (53.1)	61 (46.9)
<i>Festuca pratensis</i>	55 (42.3)	19 (14.6)	5 (3.8)	79 (60.8)	51 (39.2)
Non-arboreals	8 (6.2)	—	—	8 (6.2)	122 (93.8)
<i>Aster chinensis</i>	3 (2.3)	2 (1.5)	—	5 (3.8)	125 (96.2)
<i>Chrysanthemum koreanum</i>	2 (1.5)	5 (3.8)	—	7 (5.4)	123 (94.6)
<i>Dahlia cultorum</i>	2 (1.5)	4 (3.1)	1 (0.8)	7 (5.4)	123 (94.6)
<i>Solidago virgaurea</i>	2 (1.5)	2 (1.5)	3 (2.3)	7 (5.4)	123 (94.6)
<i>Chrysanthemum leucanth</i>	7 (5.4)	—	—	7 (5.4)	123 (94.6)
Weeds	10 (7.7)	2 (1.5)	—	12 (9.2)	118 (90.8)
<i>Artemisia vulgaris</i>	2 (1.5)	4 (3.1)	—	6 (4.6)	124 (95.4)
<i>Urtica dioica</i>	4 (3.1)	4 (3.1)	2 (1.5)	10 (7.7)	120 (92.3)
<i>Taraxacum vulgare</i>	6 (4.6)	2 (1.5)	2 (2.5)	10 (7.7)	120 (92.3)
<i>Plantago lanceolata</i>	4 (3.1)	4 (3.1)	—	8 (6.2)	122 (93.8)
Grasses–cereals	76 (58.5)	28 (21.5)	—	104 (80.0)	26 (20.0)
<i>Hordeum vulgare</i>	30 (23.1)	21 (16.2)	20 (15.4)	71 (54.6)	59 (45.4)
<i>Avena sativa</i>	40 (30.8)	17 (13.1)	4 (3.1)	61 (46.9)	69 (53.1)
<i>Secale cereale</i>	40 (30.8)	29 (22.3)	15 (11.5)	84 (64.6)	46 (35.4)
<i>Triticum sativum</i>	54 (41.5)	21 (16.2)	4 (3.1)	79 (60.8)	51 (39.2)
Arboreals	44 (33.8)	16 (12.3)	2 (1.5)	62 (47.7)	68 (52.3)
<i>Alnus glutinosa</i>	22 (16.9)	18 (13.8)	2 (1.5)	42 (32.3)	88 (67.7)
<i>Corylus avellana</i>	28 (21.5)	10 (7.7)	2 (1.5)	40 (30.8)	90 (69.2)
<i>Populus alba</i>	28 (21.5)	8 (6.2)	6 (4.6)	42 (32.3)	88 (67.7)
<i>Ulmus scabra</i>	24 (18.5)	16 (12.3)	2 (1.5)	42 (32.3)	88 (67.7)
<i>Salix caprea</i>	22 (16.9)	6 (4.6)	4 (3.1)	32 (24.6)	98 (75.4)
<i>Betula verrucosa</i>	32 (24.6)	10 (7.7)	2 (1.5)	44 (33.8)	86 (66.2)
<i>Fagus silvatica</i>	18 (13.8)	14 (10.8)	2 (1.5)	34 (26.2)	96 (73.8)
<i>Quercus robur</i>	22 (16.9)	28 (21.5)	4 (3.1)	54 (41.5)	76 (58.5)
<i>Platanus orientalis</i>	16 (12.3)	16 (12.3)	4 (3.1)	36 (27.7)	94 (72.3)

^a Strongly positive values

^b Moderately positive values

^c Lightly positive values

^d Total of all the positive values

^e Total of the all the negative values according to the Standardization Committee of the Northern Scandinavian Society of Allergology (1974)

pollination period, particularly in May. The amount of pollen was also high in June as can be seen in Table 2. From the beginning of July, the pollen of weeds became dominant, but the amount of pollen was lower than in spring. In July, the non-arboreal pollen of Poaceae, Urticaceae, Arteveaceae, *Rumex* spp., Umbelliferae, Fabaceae, Chenopodiaceae/Amaranthaceae and *Artemi-*

sia spp. and the arboreal pollen of *Ailanthus* spp., Cupressaceae, Pinaceae and *Cedrus* spp. were observed. High amounts of pollen grains from Chenopodiaceae/Amaranthaceae, *Cedrus* spp., *Artemisia* spp. were recorded in August–October and low amounts from pollen of *Cedrus* spp., Poaceae, Asteraceae, Chenopodiaceae/Amaranthaceae and *Artemisia* spp.

Table 2 The pollen proportions occurring in the atmosphere of Eskisehir in 2000 and 2001

Pollens in the atmosphere	n (%) 47,082 (100.0)
Arboreals	
Pinaceae	22,660 (48.13)
<i>Salix</i> spp.	4,313 (9.16)
Cupressaceae	2,924 (6.21)
Rosaceae	1,660 (3.53)
<i>Quercus</i> spp.	1,426 (3.03)
<i>Ailanthus</i> spp.	918 (1.95)
<i>Fagus</i> spp.	744 (1.58)
Oleaceae	1,177 (3.50)
<i>Populus</i> spp.	411 (0.87)
<i>Platanus</i> spp.	401 (0.85)
<i>Cedrus</i> spp.	361 (0.77)
Ulmaceae	243 (0.52)
Cistaceae	223 (0.47)
<i>Corylus</i> spp.	202 (0.43)
Moraceae	170 (0.36)
<i>Juglans</i> spp.	140 (0.3)
<i>Acer</i> spp.	118 (0.25)
<i>Carpinus</i> spp.	110 (0.23)
Ericaceae	81 (0.17)
Betulaceae	82 (0.17)
<i>Alnus</i> spp.	67 (0.14)
<i>Castanea</i>	65 (0.14)
Typhaceae	18 (0.04)
<i>Tilia</i> spp.	15 (0.03)
<i>Aesculus</i> spp.	7 (0.01)
Herbs	
Chenopod/Amaran	3,683 (7.82)
Fabaceae	926 (1.97)
Cruciferae	401 (0.85)
<i>Rumex</i> spp.	72 (0.15)
Umbelliferae	68 (0.14)
Caryophyllaceae	51 (0.11)
Cyperaceae	39 (0.08)
Rubiaceae	38 (0.08)
Solanaceae	6 (0.01)
Iridaceae	3 (0.01)
Linaceae	2 (0.0)
<i>Lonicera</i> spp.	1 (0.0)
Grasses–cereals	
Poaceae	1,986 (4.22)
Non-arboreals	
Asteraceae	289 (0.61)
Weeds	
Urticaceae	252 (0.54)
<i>Artemisia</i> spp.	204 (0.43)
<i>Plantago</i> spp.	178 (0.38)
<i>Bellis</i> spp.	42 (0.09)
<i>Taraxacum</i> spp.	17 (0.04)
Unidentified	288 (0.61)

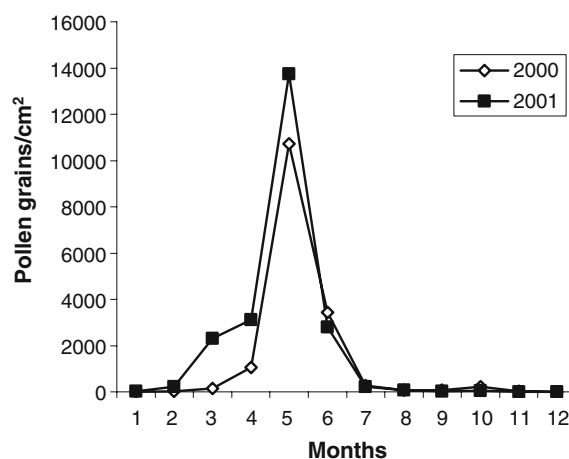


Fig. 1 Monthly average airborne arboreal pollen counts

were recorded in November. The lowest quantity of Poaceae, Chenopodiaceae/Amaranthaceae and *Cedrus* spp. pollen was recorded in December. During a 2 year study, pollen in the atmosphere of Eskisehir was observed continuously from January to December.

A comparison of skin prick test results in patients with allergic rhinitis and the pollen count in the atmosphere has been given in Table 3. There was a significant relationship between the number of pollen allergens in patients with allergic rhinitis and pollen count, with regards to the frequency of non-arboreals, Weeds, Grasses–Cereals and Arboreals ($p < 0.001$, each one). Pollen allergens occurred more frequently in patients with allergic rhinitis than in the atmosphere.

Table 4 shows the correlation coefficients between patient symptom levels and sensitization levels to pollen allergens by a Spearman's correlation test. There were significant correlations between sensitiza-

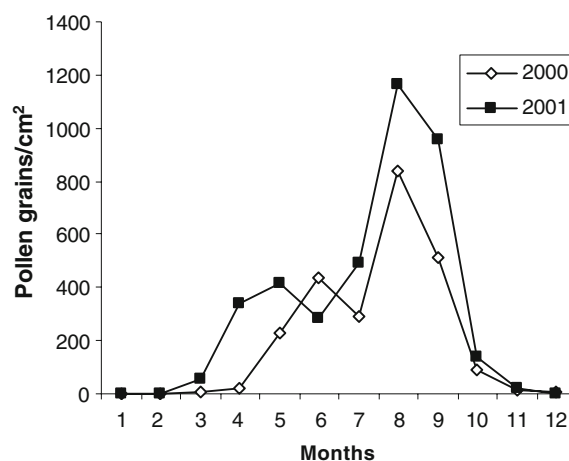


Fig. 2 Monthly average airborne herb pollen counts

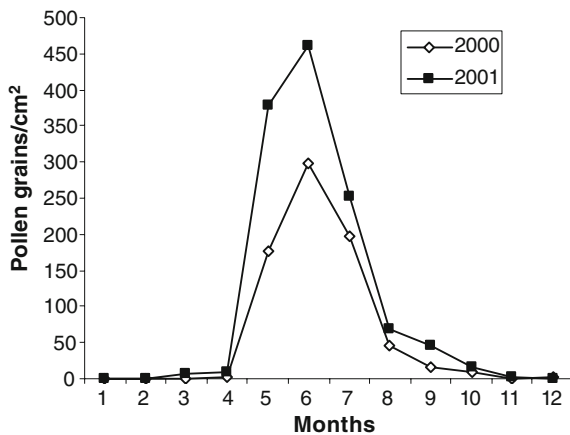


Fig. 3 Average airborne grasses-cereals pollen counts by months

tion levels of grasses and symptoms/findings, with the exception of those for nasal congestion and nasal itching. Significant correlations between sensitization levels to grasses-cereals and symptoms/findings were noted, with the exception of those for nasal congestion, nasal itching and turbinate color. It was found that there were significant correlations between sensitization levels to weeds and all the findings. There were significant correlations between sensitization levels to arboreals and sneezing, turbinate color and turbinate congestion.

Discussion

The present study contributes to our knowledge of the relationship between airborne pollen and its effects on allergic patients in Eskisehir.

In our study, a total of 38,519 pollen grains/cm² were found to be arboreal (81.0%), 8,275 as non-arboreal (18%) and 288 as unidentified (1%). The reason for this difference could be the character of vegetation and the geographical location of the city. Dominant arboreal pollen originated from Pinaceae (48.13%), *Salix* (9.16%) and Cupressaceae (6.21%), followed by Rosaceae (3.53%) and *Quercus* (3.03%).

Seasonal monthly concentrations for grass pollen were higher in 2001 than in 2000. This was probably caused by the higher wind speed in July 2001 (4.4 m/s) than in July 2000 (3.4 m/s). McDonald (Mc Donald 1980) has also showed that wind velocity has the greatest influence on the numbers of grass pollen in the atmosphere. In addition, in 2001, the effect of

sunny and rainy weather in the city was greater than in 2000, and a corresponding rise in the number of pollen grains was recorded coincidentally with a rise in both temperature and humidity in all the three campuses in the aftermath of rain. This effect may also have caused the higher grass pollen concentrations. This finding is in line with Mc Donald (1980) showing that sunny and rainy weather has been reported to have a positive effect upon the increase in the total number of pollen grains, as humidity increases in unison with a rise in temperature. In our study, in 2000, the concentration of grass pollen was lower. This result may be relevant to the fact that heavy rain is known to hamper pollination, which results in a far slower increase in pollen in the affected area (Mc Donald 1980; Inceoglu et al. 1994). Furthermore, periods with zero pollen concentrations in the air are associated with the fact that heavy rain washes pollen out of the air (Aytug 1974).

The higher numbers of pollen grains in 2001 was attributed to greater wind speed, lower rainfall and higher temperature in spring than in 2000. The mean wind speed in spring 2001 was 4.1 m/s, while it was 3.7 m/s in spring 2000. The mean temperature in spring 2001 was 14.1°C, while it was 14.2°C in spring 2000. The mean humidity in spring 2001 was 62.3%, while it was 57.2% in spring 2000. Another reason for the greater amount of pollen in 2001 is the higher precipitation between April 2000 and 2001 (125.1–66.8 mm; Anonymous 2001). Storage of water in the soil during the winter caused plant

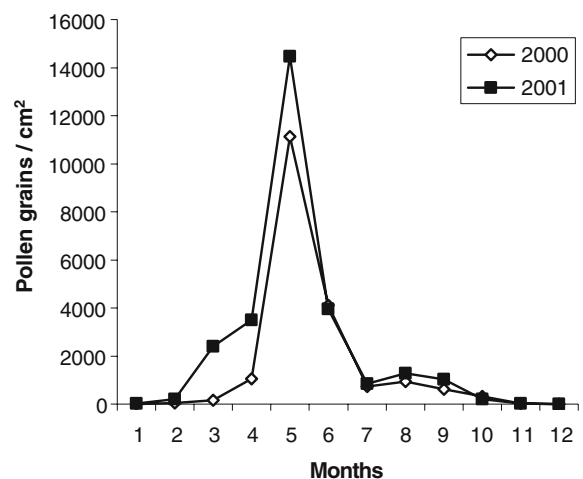


Fig. 4 Monthly totals of atmospheric pollen in Eskisehir, 2000–2001

Table 3 Number of positive skin-prick tests allergens in patients with allergic rhinitis

Pollen allergens	Number of positive skin prick tests allergens in patients with allergic rhinitis <i>n</i> (%)	130 (100.0)	Pollen count in the atmosphere <i>n</i> (%)	47,082 (100.0)	χ^2 ; <i>df</i> ; <i>p</i>
Grasses	130 (100.0)		Unidentified		
<i>Holcus lanatus</i>	65 (50.0)		Unidentified		
<i>Dactylis glomerata</i>	73 (56.2)		Unidentified		
<i>Lolium perenne</i>	68 (52.3)		Unidentified		
<i>Phleum pretense</i>	49 (37.7)		Unidentified		
<i>Poa pratensis</i>	69 (53.1)		Unidentified		
<i>Festuca pratensis</i>	79 (60.8)		Unidentified		
Non-arboreals	8 (6.2)		289 (0.61)		63.65; 1; 0.000
<i>Aster chinensis</i>	5 (3.8)		Unidentified		
<i>Chrysanthemum koreanum</i>	7 (5.4)		Unidentified		
<i>Dahlia cultorum</i>	7 (5.4)		Unidentified		
<i>Solidago virgaurea</i>	7 (5.4)		Unidentified		
<i>Chrysanthemum leucanth.</i>	7 (5.4)		Unidentified		
Weeds	12 (9.2)		Unidentified		
<i>Artemisia vulgaris</i>	6 (4.6)		204 (0.43)		51.07; 1; 0.000
<i>Urtica dioica</i>	10 (7.7)		252 (0.54)		120.33; 1; 0.000
<i>Taraxacum vulgare</i>	10 (7.7)		17 (0.04)		1329.56; 1; 0.000
<i>Plantago lanceolata</i>	8 (6.2)		178 (0.38)		110.21; 1; 0.000
Grasses–Cereals	104 (80.0)		1986 (4.22)		1799.54; 1; 0.000
<i>Hordeum vulgare</i>	71 (54.6)		Unidentified		
<i>Avena sativa</i>	61 (46.9)		Unidentified		
<i>Secale cereale</i>	84 (64.6)		Unidentified		
<i>Triticum sativum</i>	79 (60.8)		Unidentified		
Arboreals	62 (47.7)		Unidentified		
<i>Alnus glutinosa</i>	42 (32.3)		67 (0.14)		5823.08; 1; 0.000
<i>Corylus avellana</i>	40 (30.8)		202 (0.43)		2340.19; 1; 0.000
<i>Populus alba</i>	42 (32.3)		411 (0.87)		1348.05; 1; 0.000
<i>Ulmus scabra</i>	42 (32.3)		243 (0.52)		2183.77; 1; 0.000
<i>Salix caprea</i>	32 (24.6)		4313 (9.16)		37.06; 1; 0.000
<i>Betula verrucosa</i>	44 (33.8)		82 (0.17)		5522.38; 1; 0.000
<i>Fagus silvatica</i>	34 (26.2)		744 (1.58)		483.03; 1; 0.000
<i>Quercus robur</i>	54 (41.5)		1426 (3.03)		633.15; 1; 0.000
<i>Platanus orientalis</i>	36 (27.7)		401 (0.85)		1018.4; 1; 0.000

growth and increased flowering intensity in spring (Mc Donald 1980).

The Poaceae family is probably the most common on the earth, and grass pollen allergy is common in many parts of the world (Puc 2003; Puc and Puc 2004). In our study, we also found that grasses–cereals allergens were the most common aeroallergens (58.5%) in pollen allergic patients for both severe and moderate sensitization.

We found that all the patients (100.0%) were sensitive to grasses. Allergens of grass pollen are the

most common cause of allergic inflammation of nasal mucosa and rhinitis. The concentration of grass pollen grains reaches the very high values of 4,000–5,000 grains in 1 m³. Almost 80% of pollinosis sufferers are allergic to antigens of grass pollen in Holland and France (Weeke and Spieksma 1991). Within grasses, grasses–cereals, arboreals, non-arboreals and weeds, the pollen allergens that caused severe sensitization were *Festuca pratensis* (42.3%) and *Triticum sativum* from the grasses (42.3%). Since the discussed pollen is constituted of pollen grains of grasses from the

Table 4 Correlation coefficients (*r*) between the patient symptom levels and pollen allergens^a

	Grasses (<i>n</i> =130)	Grasses–cereals (<i>n</i> =104)	Weeds (<i>n</i> =12)	Arboreals (<i>n</i> =62)	Non-arboreals (<i>n</i> =8)
Nasal congestion (<i>n</i> =115)	0.932	0.303	0.760	0.336	0.619
Sneezing (<i>n</i> =119)	0.021*	0.018*	0.118	0.044*	0.403
Nasal itching (<i>n</i> =83)	0.521	0.461	0.171	0.366	0.976
Turbinate color (<i>n</i> =70)	0.047*	0.060	0.004**	0.026*	0.332
Turbinate congestion (<i>n</i> =94)	0.006**	0.035*	0.016*	0.013*	0.305
Nasal discharge (<i>n</i> =106)	0.012*	0.001**	0.027*	0.275	0.172

^a Patients (*n*=130)*(*r*) Correlation is significant at $p<0.05$ **(r) Correlation is significant at $p<0.01$

family Poaceae, they are the most frequent cause of pollen allergy in some parts of Poland (Obtulowicz et al. 1991). In our study, *Betula verrucosa* of the arboreals was the 3rd most common pollen allergen. It has been found to be one of the major airborne allergens in Alaska, Northern Europe, Gotland, Sweden and Estonia. A large number of people have been found to be exposed to these allergens (Anderson 1985; van Hage-Hamsten et al. 1987; Hjelmroos and van Hage-Hamsten 1993). In the present study, *Chrysanthemum leucanth* (5.4%) and *Taraxacum vulgare* (4.6%) of the Asteraceae family (the fourth and fifth in our population) were among the most frequent causes of pollinosis in spite of their low atmospheric concentration. Cosentino et al. (1995) also found that in Southern Sardinia those were the most frequent causes of pollinosis owing to the similar Mediterranean climate.

In the present study, the most frequent arboreal pollen producer in the atmosphere of Eskisehir was Pinaceae (48.13%). In a similar study of the symptoms of allergic rhinitis, the concentration of pine pollen in air was found to be rather concentrated (8,000 grains in 1 m³; Fornaciari et al. 1996). An explanation for this finding could be that the allergenic activity of Pinaceae pollen is low (Hosen 1990; Freeman 1993); however, its allergens can cause allergic reactions (Southworth 1988; Pettyjohn and Levetin 1997). Pollen may be important as an adjuvant, enhancing the symptoms triggered by grass pollen allergens (Southworth 1988; Pettyjohn and Levetin 1997). In our study, the 2nd and 3rd most frequent arboreals pollen producers were found to be *Salix* spp. (9.16%) and Cupressaceae (6.21%). In some studies, it was found that these families

represented one of the most important pollinosis provoking plants (D'Amato et al. 1983; Nardi et al. 1986; Cosentino et al. 1995).

In addition, the following evidence based discussions indicate the clinical impact from the clinical allergological point of view: Both the frequency and severity of respiratory allergic diseases such as allergic rhinitis have an increased importance in recent years (D'Amato et al. 2002). In atopic individuals, exposure to air pollution increases airway responsiveness to aeroallergens (Ciprandi et al. 2005). Pollen is a good model with which to study the interrelationship between pollinosis and respiratory allergic diseases (D'Amato and Spieksma 1990). Biological aerosols carrying antigenic proteins, such as pollen grains or plant-derived paucimicronic components, can produce allergic complaints. Several factors influence these, i.e., type of air pollutant, plant species, nutrient balance, climatic factors, and degree of airway sensitisation and the hyperresponsiveness of exposed subjects (Koivikko et al. 1986). Furthermore, the airway mucosal damage and the impaired mucociliary clearance induced by air pollution may facilitate the penetration and the access of inhaled allergens to the cells of the immune system, and so promote airway sensitisation (Nowak et al. 1996). As a consequence, an enhanced immunoglobulin E-mediated response to aeroallergens and enhanced airway inflammation favoured by air pollution could account for the increasing prevalence of allergic respiratory diseases in our region and all over the world (Ricketti 1993, Yazicioglu et al. 2004, Potoglu Erkara et al. 2007).

In our study, herb plants, and weeds, especially Chenopodiaceae/Amaranthaceae, Urticaceae, *Artemisia*

spp. and *Plantago* spp. and also Poaceae were found to be rather frequent. Cosentino et al. (1995) and Ekeboom et al. (1997) found similar results indicating that pollen is rather allergenic.

Arboreal pollen grains were higher in number than herb pollen grains with respect to total pollen concentrations (81.0% and 16.8%, respectively). The reason for this situation could be the characteristics of vegetation and the geographical location of the city.

In this study, arboreal pollen peaked in May 2000 and 2001. Pollination starts to increase in April, the reason for which could be wind speed and precipitation occurring more frequently in this month (Anderson 1980; Guvensen and Ozturk 2003; Potoglu Erkara et al. 2007). Arboreal pollen decreased in June and July, completing their pollination; whereas, herb pollen showed a relatively higher concentration in August in 2000 and 2001. The reason for the change could be that pollen distribution shows a good correlation with relative humidity and a rise in temperature during this period (Guvensen and Ozturk 2003).

Grasses–Cereals pollen reached a maximum in June. In June and July, temperature and speed velocity showed an increase, thus producing a positive effect on pollination. Similar findings have been reported by other researchers (Mc Donald 1980).

Atmospheric pollen hit the highest point in May and decreased in June. The reason for the increase is that a high amount of pollen is produced and released, whereas the reason for the decrease after May could be due to cessation of the pollination periods of many arboreal plants (Bicakci et al. 2003; Potoglu Erkara et al. 2007). Even though they represented only a small proportion of the airborne particles present in the atmosphere, pollen grains could be the cause of allergic responses in susceptible humans.

The correlation between the monthly airborne pollen counts and the monthly meteorological factors from January 2000 to December 2001 clearly indicated that the pollen concentration was affected by all meteorological parameters (wind speed, temperature, rainfall and humidity).

The lower pollen concentration could be attributed to high rainfall and humidity and the low temperature in April. Heavy and continuous rainfall stopped pollen dispersal. In addition, the lower wind speed slowed down pollen dispersal in the atmosphere (Aytug 1974; Mc Donald 1980; Inceoglu et al. 1994; Norris-Hill 1999; Ribeiro et al. 2003).

In our study, all the pollen allergens were more often identified in those patients with allergic rhinitis than in the atmosphere. These allergens may cause allergic sensitization symptoms in patients, agreeing with earlier studies (Obtulowicz et al. 1991; Cosentino et al 1995).

There were significant correlations between the sensitization levels of all the pollen allergens and symptoms/findings. With regard to symptoms, pollen allergens caused a higher sneezing symptom score and the 100.0% of grasses and weeds presented important findings. It seems that grass and weed pollen is the most important allergenic pollen in the region under examination. There were significant correlations between the sensitization levels of weeds and all the findings. It was found that there were significant correlations between sensitization levels of arboreals and sneezing, turbinate color and turbinate congestion.

Alnus spp., Cupressaceae, *Quercus*, spp. *Platanus* spp., *Juglans* spp., Moraceae, Pinaceae, Oleaceae, *Fraxinus* spp., *Acer* spp., Poaceae, Chenopodiaceae/ Amaranthaceae, Asteraceae, Urticaceae, *Plantago* spp., *Artemisia* spp., *Rumex* spp., *Salix* spp. and *Populus* spp. Pollen identified in the atmosphere of Eskisehir, may cause asthma and allergic rhinitis in susceptible people (Levetin and Buck 1980; Eriksson et al. 1984; Bousquet et al. 1986; D'Amato and Spiekma 1990). The pollen grains of Rosaceae, Cyperaceae, Fabaceae, Cruciferae, *Cedrus* spp., *Ailanthus* spp., Caryophyllaceae, Typhaceae taxa have also been shown to produce milder allergic pollen grains in Eskisehir (Levetin and Buck 1980; Eriksson et al. 1984; Bousquet et al. 1985; Koivikko et al. 1986).

Since we have not yet been able to find any study conducted on this subject in our region, we recommend that further comprehensive research is needed in order to expose the relationship between patients with allergic rhinitis and airborne pollen.

Several important limitations should be considered in interpreting the results of our study. One of the limitations of this study was our study period not being adequate for the purpose of analysis of meteorological parameters due to social and economic problems in the study team, which prevented the evaluation and comparison of the relationship between pollen and illness according to long term meteorological parameters and the changing conditions of atmosphere.

Since the numbers of some pollen grains was lower when compared to the others, in order to enhance the

power of the study, the current study was comprised of a period of 2 years. Moreover, it was in a consecutive 2 year period, which limited generalization and comprehensive comparisons of the results by years. Thus, in order to definitively answer this question a large sample containing different years and regions is needed.

Since airborne natural and cultural pollen grains are presented together in the atmosphere, they are included into not only a group of grasses, but also into a group of grasses–cereals.

Although this shows that patients have a 100.0% sensitivity, it also meant that these pollen grains were unidentifiable in the atmosphere.

Conclusion

A comparison of the amount of airborne pollen with the symptom of disease, with skin reactions to a pollen allergen, makes the recognition of pollen allergy much easier, and enables a better understanding of the pathomechanism of the disease.

Our study seems to emphasize the significance of establishing the types and concentrations of regional outdoor pollen with a view to comparing the changes for highly concentrated allergens in different areas. This could prove useful for allergic testing as well as in preventing development of severe symptoms in affected patients.

We suggest that similar studies should be conducted routinely to review changes in meteorological conditions, vegetation and cultivation areas. Some of the most important allergenic pollen grains, such as Pinaceae, *Salix* spp., Chenopodiaceae/Amaranthaceae, Cupressaceae and Poaceae, were also found in high concentrations in the studied area. These pollen types are responsible for many cases of pollinosis in the Mediterranean region and other parts of the world.

This study may be of use to allergologists in establishing a precise diagnosis and thus help people suffering from allergic diseases.

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