Pollen sensitization among Egyptian patients with respiratory allergic diseases

Manar F. Mohamed, Maged M. Refaat, Nermine A. Melek, Eman A. Ahmed, Nada M. Noor Aldin and Osama M. Abdel Latif

Department of Internal Medicine, Division of Allergy & Clinical Immunology, Faculty of Medicine, Ain Shams University, Cairo, Egypt.

Corresponding author: Manar F. Mohamed, Department of Internal Medicine, Division of Allergy & Clinical Immunology, Faculty of Medicine, Ain Shams University, Cairo, Egypt. Email: drmanarfarouk86@yahoo.com

Abstract

Pollen is responsible for seasonal allergies, such as allergic rhino-conjunctivitis (AR), and has become a growing public health concern. Climate change affects the range of allergenic species as well as the timing and length of the pollen season. In Egypt, data on pollinosis are scarce. This study aimed to identify the most prevalent pollen causing allergies among Egyptian patients with respiratory allergies. A total of 200 patients with respiratory allergic diseases, allergic rhinitis and/or bronchial asthma (BA), were included. Medical history taking and physical examinations were conducted on each patient. Complete blood count (CBC), total immunoglobulin E (IgE) determination, spirometry, specific IgE, and skin prick tests (SPTs) for common aeroallergens and food were performed. Of the 200 patients, 106 (53%) were females. The age of study subjects ranged 16-66 years (mean ± SD, 34.42 ± 13.0), and 65% were living in urban areas. Grass pollen, mainly from Timothy grass and maize, were the most prevalent allergens (28.5%). Timothy grass was the most common type of pollen in patients with AR (28.3 %). Elder pollen was more prevalent among asthmatic patients (P = 0.004). Bermuda grass was statistically more prevalent in rural than in urban areas (P = 0.008). Maize was linked to uncontrolled BA, whereas Timothy grass was the most prevalent among patients with moderate/severe AR. Forty-three patients had oral allergy syndrome; oranges and tomatoes were the most cross-reactive food allergies (12% and 11.5%, respectively). Exacerbation of allergic symptoms was noted during January, December, March, and June. In conclusion, pollen plays a substantial role in affecting patients with respiratory allergies in Egypt. Grass pollen is the most prevalent type of pollen, especially in urban areas.

Keywords: allergic rhinitis, bronchial asthma, grass pollen, pollinosis.

Date received: 25 March 2022; accepted: 29 April 2022

Introduction

Allergic airway diseases, such as bronchial asthma (BA) and allergic rhino-conjunctivitis (AR), are major health and economic burdens because of their impact on quality of life, including social life, school attendance, and work performance. Both genetic and environmental factors contribute to the development of allergic airway diseases, and one of the major environmental determinants causing respiratory allergy is pollen.
is characterized by a periodic repetition of symptoms during a specific pollen season that varies between countries. Patients sensitized to both seasonal (e.g., pollen) and perennial allergens (such as house dust mites (HDM), cockroaches, and molds) have year-round symptoms of respiratory allergy and experience exacerbation during the pollen season.\(^5\) Although the pollen season is related to the flowering season, air pollution and climate change are the main influencers of pollen allergenicity. Pollution, mainly in urban areas, leads to an increase in the pollen allergenic protein concentrations, with modifications of unexpressed proteins into more allergenic components that induce allergies in sensitized individuals.\(^4\) On the other hand, climate change affects the timing and length of the pollen season\(^5\) as well as their geographical extent and distribution.\(^6\)

Grasses, weeds, and trees are the main sources of pollen allergens. Grass pollen, with its abundant production and wide distribution, is responsible for 40% of pollen sensitization.\(^7\) A study in the United States showed that tree pollen was responsible for 25,000–50,000 hospital visits due to asthma during spring, whereas grass pollen was responsible mainly for summer visits.\(^8\) On the other hand, weeds are more prevalent during fall.\(^9\) *Parietaria*, ragweed, mugwort, sunflower, and Russian thistle are the main sources of weed pollen worldwide.\(^10\) Cross-reactions between plant-derived allergens and aeroallergens in previously sensitized patients lead to oral allergy syndrome (OAS). OAS is an immediate hypersensitivity reaction that occurs when raw fruits or vegetables come into contact with the oral mucosa, resulting in itching of the lips, tongue, and throat.\(^11\) OAS may be associated with more severe symptoms, such as angioedema or anaphylaxis, in 2%–10% of cases. The main allergenic components involved in OAS are profilins, pathogenesis-related protein 10 (PR 10), and lipid transfer proteins.\(^12\) As only few studies have reported the prevalence of pollen allergy in Egypt, our study aimed to determine the most prevalent types of allergenic pollen among Egyptian patients with respiratory allergies.

### Patients and Methods

#### Patient selection criteria

This cross-sectional study involved 200 patients (≥16 years old) who were newly diagnosed with respiratory allergic diseases, such as BA and/or AR, according to the Global Initiative for Asthma (GINA)\(^13\) and Allergic Rhinitis and its Impact on Asthma (ARIA) guidelines,\(^14\) respectively. They were recruited from the Allergy Clinic at Ain Shams University Hospitals from November 2017 to November 2019.

#### Exclusion criteria

Patients who were receiving allergen-specific immunotherapy or those who recently received antihistamines or any drug that might interfere with the skin prick test (SPT) results were excluded from the study. Patients with dermographism and pregnant females were also excluded.

#### Ethical statement

The study protocol was reviewed and approved by the Research Ethics Committee of the Faculty of Medicine, Ain Shams University (MS 292/2017).

#### Methods

All patients were subjected to detailed medical history taking, including the frequency, and timing of symptoms, history of pollen exposure, associated allergic conjunctivitis or OAS, assessments of asthma symptom control and AR severity using the GINA and ARIA guidelines, respectively. Spirometry for assessments of lung function and asthma control was performed. From peripheral blood samples, complete blood count (CBC) was performed using an autoanalyzer (Sysmex XT-1800i autoanalyzer, Sysmex, Japan) to determine the absolute eosinophilic count. Patients’ sera were tested for total IgE. SPTs and specific IgE for common environmental aeroallergens and food allergens were also performed.

#### Skin prick test (SPT)

Briefly, drops of standard allergen extract provided by Bencard (Allergy Therapeutic Ltd., England) were introduced on the volar aspect of the patient’s forearms while carefully pricking
The skin using a blood lancet, and the results were interpreted after 20 minutes. Wheals ≥3 mm were considered positive. Allergen extracts used in the SPT included different allergenic pollen (Bermuda grass, maize pollen, rye (cultivated), Timothy grass, wheat (cultivated), mugwort, ragweed, Russian thistle, alder, birch (silver), elder, olive), and other common allergens such as Alternaria alternata, Aspergillus fumigatus, cat fur, HDM (Dermatophagoides farinae and Dermatophagoides pteronyssinus), common food allergens (mixed nuts: almond, Brazil nuts, chestnut, hazelnut, walnut), orange, tomato, soya flour, wheat grain, whole egg, and cow’s milk.

**Serum total IgE**

For quantitative determination of the total IgE level in human serum, an enzyme-linked immunosorbent assay was performed using an automated system (ADVIA Centaur® XPT Immunoassay System, Siemens Healthineers, NY 10591, USA) according to the manufacturer’s instruction.16

**Serum Specific IgE**

The involved allergen specific IgE were [Bermuda grass, maize pollen, rye, Timothy grass, wheat, mugwort, ragweed, Russian thistle, alder, birch, elder, olive, Alternaria alternata, Aspergillus fumigatus, cat fur, Dermatophagoides farinae and Dermatophagoides pteronyssinus]. The test was performed using cellulose disc-based enzyme allergosorbent test kits (RIDASCREEN Spec. IgE supplied R-Biopharm AG, An der neuen Bergstraße 17, D-64297 Darmstadt, Germany), according to the manufacturer’s instructions. Briefly, allergens were attached to cellulose discs placed in the wells of a microwell plate then patient’s sera containing allergen specific IgE and an anti-human IgE antibody conjugated with alkaline phosphatase were added. Many washing steps were done to remove the unattached conjugate. Lastly, we added a substrate with interactions that yielded a yellow color. A photometric measurement was then carried out at 405 nm using a reference wavelength of 620 nm. For each test, we run the standards (in duplicate) as well as the positive and negative control on the same plate. We calibrated the standard curve for RIDASCREEN Spec. IgE against the International reference preparation “2nd WHO IRP 75/502 for human IgE”, where specific IgE was considered positive if ≥ 0.35 IU/ ml.17

**Spirometry**

After the determination of patients’ sex, age, height, and weight, patients were asked to fully inhale before beginning forced exhalation.18 The flow-volume curves and the volume–time curves were then displayed using a spirometry (VIASYS, made in German 2007).19 Numerical values were given only for the forced expiratory volume in 1 second (FEV1), forced vital capacity (FVC), and FEV1/FVC ratio. Grades of severity of obstructive airway diseases were interpreted according to the American Thoracic Society guidelines.20

**Statistical analyses**

The data collected were revised, coded, tabulated, and introduced into a computer using the Statistical Package for Social Sciences (SPSS v20). Data were analyzed and presented according to the type of data obtained for each parameter. Parametric numerical data are presented as the mean ± standard deviation and range, whereas nonparametric numerical data are presented as the median and interquartile range (IQR). The chi-squared test was used to examine the relationship between two qualitative variables. A P ≤ 0.05 was considered statistically significant.

**Results**

This study included 200 subjects, newly diagnosed AR and/or BA. Their demographic data showed that 106 (53%) were females. The mean age of the patients was 34.42 ± 13.0 years (range, 16–66 years). The majority of patients were living in urban areas (65%), and 60.5% had family history of atopy. AR was the most frequent respiratory allergy (117 patients), whereas 56 patients had both AR and BA.

Regarding the severity of AR, 51.4% patients had moderate to severe intermittent AR, 41%
moderate to severe persistent AR, 5.2% mild intermittent AR, and 2.3% mild persistent AR. Regarding BA control symptoms, 72.3% of patients had partially controlled asthma, 18.1% controlled asthma, and 9.6% uncontrolled asthma. In our study, 43 patients (21.5%) had OAS. The median absolute eosinophil count was 130 (IQR, 75–280) cells/mm³, whereas the median total IgE level was 90 (IQR, 35–225) IU/mL.

The results showed that 93% of the study population had a positive SPT, and 171 (85.5%) patients were sensitized to a pollen. *D. pteronyssinus* was the most prevalent allergen (32%) causing atopy, followed by Timothy grass (28.5%), maize pollen (28.5%) and *D. farinae* (28%) (Table 1).

**Table 1.** Skin prick test results of 200 patients with common aeroallergens.

| Pollen              | SPT positive |
|---------------------|--------------|
| Timothy grass       | 57 (28.5%)   |
| Maize               | 57 (28.5%)   |
| Russian thistle     | 48 (24.0%)   |
| Cultivated rye      | 46 (23.0%)   |
| Mugwort             | 36 (18.0%)   |
| Alder               | 32 (16.0%)   |
| Bermuda grass       | 28 (14.0%)   |
| Ragweed             | 26 (13.0%)   |
| Cultivated wheat    | 25 (12.5%)   |
| Olive               | 15 (7.5%)    |
| Elder               | 14 (7.0%)    |
| Birch               | 12 (6.0%)    |

Animal dander

| Pollen             | SPT positive |
|--------------------|--------------|
| Cat fur            | 26 (13.0%)   |
| Molds              | 14 (7.0%)    |
| Alternaria         | 22 (11.0%)   |

Dust mites

| Pollen                           | SPT positive |
|----------------------------------|--------------|
| *Dermatophagoides farinae*       | 56 (28.0%)   |
| *Dermatophagoides pteronyssinus* | 64 (32.0%)   |

The majority of patients were sensitized to grass pollen, which included Timothy grass, maize, and Russian thistle, whereas tree pollen caused the least sensitization among the pollen (Figure 1).

**Figure 1.** Prevalence (%) of different pollen among patients with respiratory allergies.

In this study, the months when patients reported the peak of their symptoms were January (26.5%), December (21.5%), March (18%), and June (16%) (Figure 2).

**Figure 2.** Peaks of exacerbation of respiratory allergies as presented by month.

The most prevalent pollen causing respiratory allergy in rural and urban areas was Timothy grass (34.3%) and maize pollen (29.2%), respectively. Regarding Bermuda grass, its prevalence in rural areas was significantly higher than in urban areas (*P* < 0.008) (Table 2).
Table 2. Comparison between the prevalence of different types of pollen in rural and urban areas.

| Types of pollen       | Rural (n = 70) | Urban (n = 130) | *P value |
|-----------------------|---------------|----------------|----------|
|                       | N  | %   | N  | %   |          |
| Timothy grass         | 24 | 34.3% | 33 | 25.4% | NS       |
| Bermuda grass         | 16 | 22.9% | 12 | 9.2%  | 0.008    |
| Maize                 | 19 | 27.1% | 38 | 29.2% | NS       |
| Cultivated rye        | 13 | 18.6% | 33 | 25.4% | NS       |
| Cultivated wheat      | 11 | 15.7% | 14 | 10.8% | NS       |
| Mugwort               | 11 | 15.7% | 25 | 19.2% | NS       |
| Russian thistle       | 20 | 28.6% | 28 | 21.5% | NS       |
| Ragweed               | 8  | 11.4% | 18 | 13.8% | NS       |
| Elder                 | 7  | 10.0% | 7  | 5.4%  | NS       |
| Birch                 | 6  | 8.6%  | 6  | 4.6%  | NS       |
| Alder                 | 12 | 17.1% | 20 | 15.4% | NS       |
| Olive                 | 7  | 10.0% | 8  | 6.2%  | NS       |

*P value >0.05 is not significant (NS).

It was found that 145 (66.8%) patients with AR had pollen allergy, whereas 72 (33.2%) patients with BA were sensitized for pollen allergens. Elder pollens were the most prevalent pollen among asthmatics (p < 0.004), whereas Timothy grass was the most prevalent pollen among patients with AR (28.3%). Patients who had mild intermittent AR (n=9) showed the greatest number of positive results to alder and maize (33.3%), whereas patients with mild persistent AR (n=4) showed the greatest number of positive SPT results to Bermuda grass, Russian thistle, cultivated rye, and wheat pollen. In addition, patients who had moderate/severe intermittent AR (89) showed the greatest number of positive SPT results to maize pollen (29.2%). Moreover, patients who had moderate/severe persistent AR (n=71) showed the greatest number of positive SPT results to Timothy grass pollen (32.4%) (Table 3).

Table 3. Relation between severity of allergic rhinitis and types of pollen.

| Types of pollen       | Total (n = 173) | Mild intermittent (n = 9) | Mild persistent (n = 4) | Mod/severe intermittent (n = 89) | Mod/severe persistent (n = 71) |
|-----------------------|----------------|--------------------------|-------------------------|---------------------------------|-------------------------------|
|                       | No. | %   | No. | %   | No. | %   | No. | %   | No. | %   |
| Timothy grass         | 48  | 28.3% | 2   | 22.2% | 1   | 25.0% | 23  | 25.8% | 23  | 32.4% |
| Bermuda grass         | 25  | 14.5% | 1   | 11.1% | 2   | 50.0% | 11  | 12.4% | 11  | 15.5% |
| Mugwort               | 29  | 16.8% | 1   | 11.1% | 0   | 0.0%  | 17  | 19.1% | 11  | 15.5% |
| Russian thistle       | 43  | 24.9% | 1   | 11.1% | 2   | 50.0% | 22  | 24.7% | 18  | 25.4% |
| Ragweed               | 24  | 13.9% | 1   | 11.1% | 0   | 0.0%  | 13  | 14.6% | 10  | 14.1% |
| Elder                 | 10  | 5.8%  | 2   | 22.2% | 0   | 0.0%  | 7   | 7.9%  | 1   | 1.4%  |
| Birch                 | 12  | 6.9%  | 1   | 11.1% | 0   | 0.0%  | 5   | 5.6%  | 6   | 8.5%  |
| Alder                 | 25  | 14.5% | 3   | 33.3% | 0   | 0.0%  | 15  | 16.9% | 7   | 9.9%  |
| Maize                 | 48  | 27.7% | 3   | 33.3% | 0   | 0.0%  | 26  | 29.2% | 19  | 26.8% |
| Cultivated rye        | 39  | 22.5% | 1   | 11.1% | 2   | 50.0% | 18  | 20.2% | 18  | 25.4% |
| Cultivated wheat      | 22  | 12.7% | 0   | 0.0%  | 2   | 50.0% | 8   | 9.0%  | 12  | 16.9% |
| Olive                 | 14  | 8.1%  | 1   | 11.1% | 0   | 0.0%  | 6   | 6.7%  | 7   | 9.9%  |

Patients with controlled asthma (n=15) showed the greatest number of positive results to alder pollen (26.7%). Patients with partially controlled asthma (n=60) showed the greatest number of...
positive results to maize pollen (30%). Patients with uncontrolled asthma (n=8) showed the greatest number of positive results to maize pollen (37.5%) (Table 4).

**Table 4.** Relation between types of pollen and severity of bronchial asthma.

| Types of pollen    | Total (n = 83) | Controlled (n = 15) | Partially controlled (n = 60) | Uncontrolled (n = 8) |
|--------------------|---------------|---------------------|------------------------------|---------------------|
|                    | No. | %   | No. | %   | No. | %   | No. | %   |
| Timothy grass      | 19  | 22.9| 3   | 20.0| 16  | 26.7| 0   | 0.0 |
| Bermuda grass      | 10  | 12.0| 0   | 0.0 | 10  | 16.7| 0   | 0.0 |
| Mugwort            | 16  | 19.3| 1   | 6.7 | 13  | 21.7| 2   | 25.0|
| Russian thistle    | 15  | 18.1| 3   | 20.0| 12  | 20.0| 0   | 0.0 |
| Ragweed            | 9   | 10.8| 1   | 6.7 | 6   | 10.0| 2   | 25.0|
| Elder              | 11  | 13.3| 3   | 20.0| 6   | 10.0| 2   | 25.0|
| Birch              | 2   | 2.4 | 0   | 0.0 | 1   | 1.7 | 1   | 12.5|
| Alder              | 17  | 20.5| 4   | 26.7| 12  | 20.0| 1   | 12.5|
| Maize              | 22  | 26.5| 1   | 6.7 | 18  | 30.0| 3   | 37.5|
| Cultivated rye     | 18  | 21.7| 1   | 6.7 | 15  | 25.0| 2   | 25.0|
| Cultivated wheat   | 10  | 12.0| 1   | 6.7 | 8   | 13.3| 1   | 12.5|
| Olive              | 6   | 7.2 | 1   | 6.7 | 3   | 5.0 | 2   | 25.0|

Moreover, the most prevalent cross-reactive food allergens in this study were oranges (12%), tomatoes (11.5%), and soya (11%). Tomatoes were highly cross-reactive with Timothy grass (43.5%) and maize pollen (39.1%). Oranges were highly cross-reactive with cultivated rye and Russian thistle (33.3%). Soya was highly cross-reactive with cultivated rye (36.4%), Timothy grass (27.3%), and Russian thistle (27.3%) (Table 5).

**Table 5.** Comparison between cross-reactive food and different types of pollen in 83 subjects with bronchial asthma.

| Type of pollen          | Food          |
|-------------------------|---------------|
|                         | Milk (n = 15) | Tomato (n = 23) | Egg whole (n = 21) | Wheat (n = 16) | Orange (n = 24) | Soya (n = 22) | M. nuts (n = 16) |
|                         | N  | %   | N  | %   | N  | %   | N  | %   | N  | %   | N  | %   | N  | %   |
| Timothy grass          | 8  | 53.3| 10 | 43.5| 11 | 52.4| 5  | 31.3| 6  | 25.0| 6  | 27.3| 4  | 25.0|
| Bermuda grass          | 2  | 13.3| 6  | 26.1| 2  | 9.5 | 5  | 31.3| 4  | 16.7| 2  | 9.1 | 3  | 18.8|
| Mugwort                | 5  | 33.3| 6  | 26.1| 5  | 23.8| 4  | 25.0| 4  | 16.7| 2  | 9.1 | 5  | 31.3|
| Russian thistle        | 4  | 26.7| 6  | 26.1| 3  | 14.3| 5  | 31.3| 8  | 33.3| 6  | 27.3| 3  | 18.8|
| Ragweed                | 3  | 20.0| 2  | 8.7 | 2  | 9.5 | 1  | 6.3 | 4  | 16.7| 3  | 13.6| 2  | 12.5|
| Elder                  | 1  | 6.7 | 2  | 8.7 | 3  | 14.3| 0  | 0.0 | 2  | 8.3 | 1  | 4.5 | 1  | 2.5 |
| Birch                  | 0  | 0.0 | 3  | 13.0| 1  | 4.8 | 1  | 6.3 | 1  | 4.2 | 2  | 9.1 | 1  | 6.3 |
| Alder                  | 5  | 33.3| 4  | 17.4| 2  | 9.5 | 1  | 6.3 | 7  | 29.2| 3  | 13.6| 0  | 0.0 |
| Maize                  | 8  | 53.3| 9  | 39.1| 7  | 33.3| 5  | 31.3| 6  | 25.0| 4  | 18.2| 5  | 31.3|
| Cultivated rye         | 2  | 13.3| 6  | 26.1| 6  | 28.6| 3  | 18.8| 8  | 33.3| 8  | 36.4| 5  | 31.3|
| Cultivated wheat       | 2  | 13.3| 6  | 26.1| 2  | 9.5 | 1  | 6.3 | 4  | 16.7| 4  | 18.2| 2  | 12.5|
| Olive                  | 3  | 20.0| 3  | 13.0| 3  | 14.3| 3  | 18.8| 2  | 8.3 | 4  | 18.2| 3  | 18.8|

Data presented as number (No.) and percentage (%), M. nuts= mixed nuts.
Discussion

Pollen is divided into three main groups: grasses, weeds, and trees. Our study aimed to determine the most prevalent allergenic pollen among Egyptian patients with respiratory allergies (AR and/or BA). The study included 200 patients, newly diagnosed with respiratory allergies.

Most of our patients with respiratory allergies were living in urban areas (65%), which agreed with a previous study that demonstrated that patients living in urban areas had a higher prevalence of pollen-induced AR than patients living in rural areas (23.1% versus 14.0%, P < 0.001). This observation was previously explained by Strachan, 1989, who noticed a reduced prevalence of asthma among children living in farms as increased exposure to pathogens during childhood resulted in tolerance to different allergens. He concluded that living in urbanized areas leads to reduced pathogen exposure, with a subsequent high risk of allergy.

In a study included 25,393 women, residents of rural areas in Iowa, USA, had a lower odds ratio of developing allergies than residents of urban areas. This is because the former group lived in areas with low levels of pollution as they avoided traffic-related air pollution, which is the main environmental cause of the high prevalence of allergies in urban areas. Another finding in support to our results was that carbon dioxide (released in urban areas) acts as an important nutrient to plants, which allows the growth of a greater number of plants producing different allergenic pollen in urban areas, resulting in an increased allergy prevalence.

Of our study patients, 21.5% complained of OAS symptoms. Two large Korean studies conducted on patients with respiratory allergy had results similar to our findings, with the prevalence of OAS ranging from 20.0% to 41.7%. Regarding the SPT results, 186 patients had positive SPTs for different allergens. We detected a higher prevalence of people allergic to HDM (D. pteronyssinus, 32%), followed by Timothy grass (28.5%), maize grass pollen (28.5%) and D. farinae (28%). A previous study reported that 45%–85% of patients with respiratory allergies were SPT-positive to HDM. Frankland and El-Hefny, 1971, were the first to point out to the high prevalence of people allergic to HDM in Egypt, especially D. farinae, attributing Egypt’s dry climate as a major reason behind the high prevalence. Since then, many studies have confirmed the widespread presence of HDM and other mites in domestic settings across Egypt and in the Middle East.

The prevalence of pollen allergy differs globally by region, depending on the climatic conditions. For example, Middle Eastern countries are known to have a dry, desert-like climate. Moreover, countries such as Egypt also have coastal regions with a Mediterranean climate. Besides the effects of climate on the high diversity of pollen worldwide, introducing invasive allergenic pollen increases pollen prevalence, with new pollen sensitization.

In this study, grass pollen was the most frequent pollen allergen that patients were sensitized to, with 28.5% of patients reacting to Timothy grass and maize grass pollen. This was followed by Russian thistle (24%) and cultivated rye (23%), which contrast with tree pollen that has less frequent sensitization (elder, 7%; birch, 6%). Our results agree with the notion that grass pollen is one of the most frequent reasons for plant-related allergic reactions worldwide. It is thought that at least 40% of patients with respiratory allergies worldwide are sensitized to grass pollen allergens, which comprise 9,000 different grass species (Poaceae). Hugg et al., 2017 demonstrated that grass was the most frequent cause of pollen allergy in Europe and the USA. This is because grasses grow on every continent and in almost all types of environments. Grasslands were estimated to constitute 20%–30% of the vegetation covering the Earth, which explains the large percentage of grass pollen allergy globally. Comparative studies from Middle Eastern countries, which include Egypt, Jordan, Kuwait, and the Kingdom of Saudi Arabia (KSA), showed that grass pollen was the most frequent allergen responsible for respiratory allergies among patients, with Bermuda grass being the most frequent in Kuwait and KSA.
On the other hand, a Chinese study that included 6,043 patients with AR revealed that most of these patients were sensitized to weed pollen. Another study by Sung et al., 2017 in Korea found that the sensitization rate to trees (25.2%) was the highest among pollen types, with birch pollen being the highest among tree pollen (10.3%), followed by weeds (19.9%) (mugwort and ragweed).

In the present study, we found that 66.8% of patients with AR had pollen allergy, whereas 33.2% of patients with BA were positive to pollen allergens. The most prevalent pollen in patients with BA was maize pollen (26.5%), whereas Timothy grass pollen was the most frequent (28.3%) in patients with AR. Furthermore, tree pollen (elder) was significantly more prevalent in patients with asthma than in patients with AR. This could be explained by the notion that grass pollen, because of its large size, has a low probability of entering the lower airways and triggering asthma. In contrast, tree pollen allergens have been recorded in sizes that are small enough to enter the lower airways, which may cause asthmatic responses in susceptible people.

To the best of our knowledge, we are the first to report the relationship between the severity of AR and BA and the types of pollen allergens in Egyptian population. Regarding AR, patients with moderate/severe intermittent AR showed the highest SPT positivity to maize pollen (29.2%). Meanwhile, patients with moderate/severe persistent AR showed the highest SPT positivity to Timothy grass pollen (32.4%). Patients with partially controlled asthma showed the highest positivity to maize pollen (30%), which was also true for patients with uncontrolled asthma (37.5%).

We compared the residency of the patients with the types of pollen and noticed that the most prevalent pollen types in rural and urban areas were Timothy grass (34.3%) and maize (29.2%), respectively, which indicates that grass pollen is prevalent throughout urban and rural areas. The high prevalence of grass pollen allergy in urban areas can be explained by the elevated levels of CO₂ that have been shown to increase grass pollen production by 50% per flower. Consistent with our results, a study conducted in Finland demonstrated that grass pollen exposure increased with the decreasing level of urbanization. This might be illustrated from the allergology point of view that the most urban environments, with small frequently managed patches of vegetation, have little potential to produce considerable amounts of pollen grains and to expose people to pollen. Thus, staying in urban environments would reduce the overall exposure to grass pollen, although occasionally higher levels of exposure may be encountered.

In addition, our study revealed that the prevalence of Bermuda grass pollen was significantly higher in rural areas than in urban areas (p=0.008). However, findings of a study by Sánchez et al., 2018 conducted in Colombia, USA disagreed with our observation. Their study aimed to explore whether the growth conditions of the Bermuda grass pollen modify the allergic response of patients with AR in rural versus urban areas. They concluded that Bermuda grass pollen was more prevalent in urban areas, and its growth conditions modify its allergenicity.

There were monthly variations in the frequency of exacerbations during the study period. Peaks of allergic respiratory diseases recorded in January, December, March, and June were 26.5%, 21.5%, 18%, and 16%, respectively. This could be explained by the higher rate of viral infections and allergen exposure during winter (December and January), pollination of the majority of pollen during spring (March), and when the grass pollen is at its peak (late spring) (June), with a lower level of exacerbation in summer when the climate becomes drier. Our results agree with data of a research performed on the onset and duration of several allergenic pollen types in the USA. Such studies showed that the start dates for the appearance of significant allergens was prevalent earlier in the year (January). Another observation indicated that grass pollen was present in the air during late spring and early summer (March and June).

In this study, the most prevalent cross-reactive food with pollen, as evidenced by the SPTs, were oranges (12%), followed by tomatoes (11.5%) and soya (11%).
demonstrated that tomatoes were highly cross-reactive with Timothy grass (43.5%) and maize pollen (39.1%). Oranges were cross-reactive with cultivated rye and Russian thistle (33.3%). Soya was cross-reactive with cultivated rye (36.4%), Timothy grass (27.3%), and Russian thistle (27.3%). In line with our study, a paper published by the European Academy of Allergy and Clinical Immunology (EAACI) demonstrated that 60% of food allergies in adults were linked to an inhalant allergy. Another study in Bosnia revealed that 50% of the study population was allergic to Timothy grass, which was correlated with tomatoes, melons, and peanuts. Vieths et al., 2002 performed a study on the cross-reactivity between allergens and pollen, revealed that there was a significant cross-reaction between grass pollen and tomatoes and oranges. This may be attributed to the notion that profilins and cross-reactive carbohydrate determinants, which are present in grass pollen, are also present in different fruits and vegetables, such as oranges and tomatoes.

Our study has several strengths, as discussed above, however it has certain limitations. The limitations of this work include that it was conducted in a single center with a relatively small sample size. In conclusion, pollen plays a substantial role in patients with respiratory allergies in Egypt. In addition, grass pollen is the most prevalent type of pollen, especially in urban areas.

Author Contributions
MR designed the study, NN, MM were responsible for data collection. MM prepared the manuscript. OA, NA and EA shared in data analysis and critical revision of the manuscript. All authors read and approved the final manuscript.

Declaration of Conflicting Interests
The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding
The author(s) denies receipt of any financial support for the research, authorship, and/or publication of this article.

Ethical approval
The study protocol was reviewed and approved by the Research Ethics Committee of the Faculty of Medicine, Ain Shams University (MS 292/2017).

Informed consent
A signed consent form was obtained from each study participant.

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