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Current glimpse of airborne allergenic pollen in Indian subcontinent

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Abstract

Respiratory allergic diseases such as bronchial asthma, rhinitis, urticaria, atopic dermatitis have been steadily increasing all over the world, including India. Owing to its alarming trend, several aerobiological surveys have been undertaken in different parts of India to delineate the variety of pollen and spore load. In this review, we have reported the current state of aerobiological knowladge in India with particular reference to allergenic airborn pollen occurence in 2001–2015. Pollen have been found to contribute a significant proportion in the air and caused allergy symptoms in the local inhabitants. Aerobiological records, a questionnaire survey and hospitalization records have been employed for the analysis. *Holoptelea integrifolia*, *Amaranthus spinosus* in northern region, *Sorghum vulgare*, *Pennisetum*, *Gynandropsis gynandra*, *Parthenium hysterophorus*, *Dolichandrone platycalyx* in southern regions, and *Parthenium hysterophorus* from the western region; *Cynodon dactylon*, *Cenchrus ciliaris* in the central area; *Acacia auriculiformis*, *Cleome gynandra*, *Catharanthus roseus*, *Phoenix sylvestris*, *Areca catechu*, and *Lantana camara* in the eastern regions as potential aeroallergens in India. The statistical approach confirmed the correlation between hospitalization rate associated with allergy-related health troubles and the prevalent allergenic pollen in the air. The Poaceae group has been found to be dominant throughout India. Immuno-biochemical studies identified various protein with allergenic potential found in the pollen recorded. Epitope identification and homology of the major allergenic protein Cat r1 of *Catharanthus* sp and Par j 1 of *Parietaria judaica* have been found. Identification of allergenic pollen grains and the modern approach concerning cross-reactivity and epitope revelation of dominant airborne pollen have important clinical implications for the prevention, diagnosis and treatments of allergic diseases in India.

Keywords: aeroallergen; pollen; SPT; ELISA; SDS-PAGE; IgE specific immuno-blot; hospitalization

Introduction

Respiratory allergy shows still an increasing trend all over the world. The airborne bio particles such as pollen grains, fungal spores, and dust mites act as vectors harboring specific proteins that react with the immune system to cause allergy. Amongst others, pollen grains play a significant role in allergenic manifestations and have been well studied across the world. Approximately 20% to 30% of the total population suffers from allergic diseases in India [1]. Since India comprises of varied climatic zones and geographical regions, the types and distribution of natural vegetation leads to a broad range of pollen grains being present in the air. The aeropalynological study in India was initiated as early as 1873 through the pioneering works of Cunningham. The allergenic airborn pollen has gained importance in the last few decades due to the alarming increase of atopic diseases in India.

Whatever the cause of illness is, allergy can severely affect the quality of social life, causing absenteeism of employees and can be fatal in some cases. Management of allergy is still a major challenge in medicine; a current possible treatments are antihistamines and immunotherapy. Avoidance of exposure to allergenic pollen grains could be one of the simplest strategies to reduce the effects of the malady. An efficient aerobiological monitoring and creation of pollen calendars allow local people to recognize the blooming periods and prevalence of different pollen grains in relation to local vegetation. Thus, sensitive people can avoid the areas with high concentration of allergenic pollen in the air. Pollen calendars have been constructed in different regions of the country and have shed light upon the richness of Indian flora. In furtherance to pollen monitoring, a few research groups have extended the study towards the identification of allergenic proteins employing biochemical methods. With the advent of modern technological platform such as proteomics, it has been easier to detect and characterize allergens from a wide variety of sources in very short time. Moreover, the purification and development of recombinant allergens was possible. Therefore, immunotherapy has been initiated and routinely practiced in India with purified as well as recombinant pollen allergens. In all, there has been a decently good amount of aeropalynological investigations and their implications for clinical significance. This review

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provides some insights into the aerobiological studies that have been conducted in different parts of India.

The ongoing prevalence report of causal aeroallergens from various regions of India

The Indian subcontinent consists of 29 states located in discrete geographical regions and climatic zones ranging from the high-altitude northern and northeastern region with sub-tropical humid, with dry winters, and alpine climate; tropical semi-arid climate in the southern region; dry, arid desert with sub-tropical arid climate in the west to tropical wet (dry, humid) and temperate eastern Gangetic plain areas. Each region has distinct vegetation type and thus has diverse airborne pollen as well as the prevalence of allergenic pollen with divers impact on human health. Fig. 1a defines the location of aerobiological stations in India. The cities have been marked for the reports of the regional aero-palynological studies with respiratory allergy (Fig. 1b). Through several years, the arerbiological monitoring have identified a variety of pollen grains as aeroallergens. Below are the reports of some predominant allergens detected in different zones of India for last ten years.

In northern region

Continuous bio-monitoring by a Burkard 7-day volumetric sampler showed a pollen spectrum of 107 species for Allahabad, Uttarpradesh, in the years of 2002–2004. In these records, a tree plant, *Holoptelea integrifolia* was found to be a dominant [2]. *Holoptelea integrifolia*, an anemophilous species releases huge pollen loads (estimated 7650 pollen grains per anther) and due to its high pollen production, the dominance of *H. integrifolia* pollen in the air (50–56%) is common. This species was followed by Poaceae species, *Cryotaurens*, *Pinus roxburghii*, and *Ricinus communis*.

Holoptelea integrifolia is an important pollen allergen in India and sensitization of almost 10% of the atopic population in Delhi is reported [3]. Cross-reactivity between *H. integrifolia* and *Parietaria judaica*, native to the Mediterranean region has been revealed. In this study, 34% out of 44 patients sensitized to *H. integrifolia* had a positive skin test to *P. judaica* pollen extract in varying degrees. ELISA and ELISA inhibition studies suggested high cross-reactivity between *H. integrifolia* and *P. judaica* pollen. Immunoblot inhibition studies revealed that 14, 16, 28, 38, 42 and 46 kDa proteins common in *H. integrifolia* and *P. judaica* are probably cross-reactive proteins. These studies have also suggested that *H. integrifolia* and *P. judaica* pollen have IgE binding epitopes. However, Par j 1, the major allergen of *P. judaica*, was absent in *H. integrifolia* pollen.

Bio-monitoring during 2006–2007 in 2 sites within Allahabad city revealed 82 and 64 pollen types. The pollen of *H. integrifolia* was predominant contributing 50.55% and 61.99% in the air, respectively [4]. Among meteorological factors, the mean maximum temperature was positively correlated with the total pollen counts, whereas low temperature, high relative humidity, and rainfall was associated with low pollen counts during June–August.

A report from the Department of Pulmonary Medicine, King George's Medical University, Lucknow, was published in 2011. The report revealed 48 patients with nasobronchial allergy symptoms and being sensitive towards 32 types of local pollen grains [5]. The analyses revealed that 35.41% of people showed a marked positive response to *Amaranthus spinosus* pollen, followed by *Argemone mexicana* (22.91%), *Adhatoda vasica* (18.75%), *Ailanthus exelsa* (12.5%), *Holoptelea integrifolia* (10.41%). A majority (56%) of patients was less than 30 years of age and 80% patients had bronchial asthma associated with allergic rhinitis (AR).

An aerobiological survey from Delhi and the surroundings area reported the prevalence of pollen grains from 4 species of *Brassica* such as *B. campestris*, *B. juncea*, *B. nigra*, and *B. napus* in 2014 [6]. Among 159 atopic patients tested, 21.38% were positive to one or more than one species of *Brassica* pollen. The highest skin positive test (13.20%) was for *B. campestris* extract. Protein fractions 47, 56, 76, 87, and 90 kDa in all the four species were common and IgE

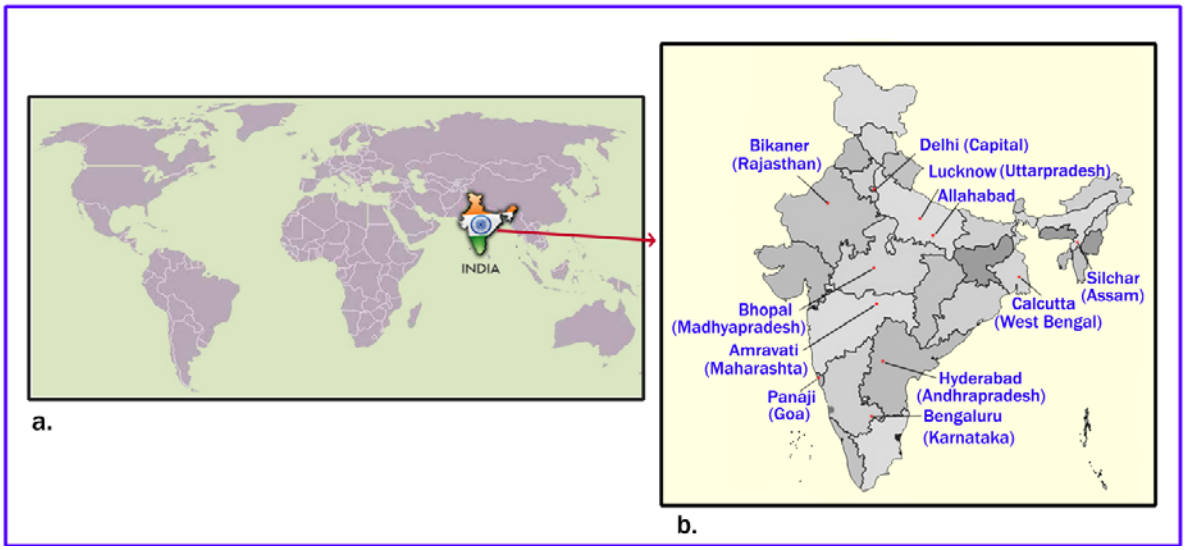

Fig. 1 Current aeropalynological research designed to identify allergenic pollen grains in India. **a** World map and position of the country of India. **b** The political map of India shows the states (within parenthesis) and cities where aeropalynological studies have been performed to identify several pollen grains as aero-allergens.

reactivity to these proteins was displayed; however, individual hypersensitivity exists.

In southern region

The immuno-biochemical study in association with hospital data, denoted the allergenic nature of *Gynandropsis gynandra* pollen tested in 105 atopic patients of the Allergy Clinic at the Bhagwan Mahavir Hospital and Research Center, Hyderabad, 2005 [7]. Fractions with molecular weights 46–37 kDa and 36–32 kDa of *Gynandropsis gynandra* pollen were demonstrated to be major allergens after SDS-PAGE, 1D blot studies, conducted at this center. Skin prick test (SPT) associated with a hospital survey, executed in the state of Andhra Pradesh in 2011, indicated the increased sensitivity to various antigens found in divers species of local vegetation. The highest sensitivity was found towards *Parthenium hysterophorus* (30.21%), *Prosopis juliflora* (25.67%), *Eucalyptus* spp. (20.54%), *Brassica nigra* (15.40%), followed by a lesser number of people sensitive towards *Chenopodium album*, *Cocos nucifera*, and *Acacia arabica* [8]. More than 80% out of 331 patients had naso-polips.

In Hyderabad, Andhra Pradesh, pollen allergies found in the patients with asthma, AR, and urticaria shed light upon grass pollen, the causal aeroallergen that is exerting a significant impact on local inhabitants [9]. The analysis was carried out on 500 patients attending the Allergy Clinic at Bhagwan Mahavir Hospital and Research Center, Hyderabad, and published in 2006. Skin test reactivity to 20 pollen allergens was studied by intradermal injections followed by ELISA test for further confirmation. The Chi-square test for the association of elevated IgE level and SPT positive pollen allergens presented 47% of patients to be positive to >5 pollens with an IgE value of >325 IU/ml and 69.2% of patients were positive to only one pollen with an IgE value of £325. Out of the top five pollen species, the three most predominant pollen allergens in allergic patients with asthma were: *Sorghum vulgare* (54.9%), *Pennisetum* sp. (53.1%) and *Artemisia* (48.1%).

Another study from Karnataka conducted in 2011 was designed to evaluate the allergenicity of *Dolichandrone platycalyx*. This species was found to be the one of the most common entomophilous avenue trees in the state of Karnataka along with its pollen load [10]. *Dolichandrone platycalyx* is commonly known as Nile trumpet tree, the variants of this tree are grown in Europe, Asia, and America (California and Florida). A number of 317 patients with respiratory allergy and 30 controls who attended a tertiary care center were incorporated in the study. A significant percentage of patients (16.1%) were sensitive to *Dolichandrone* pollen extract by skin-prick testing, whereas none of the control subjects seemed to be sensitized. *Dolichandrone platycalyx* was the fourth among the most common sensitizers after *Parthenium hysterophorus*, *Prosopis juliflora*, and *Artemesia vulgaris*. *Dolichandrone platycalyx* was categorized as a moderate pollen producer with 66 000 pollen grains per flower.

In western region

In 2001, 35 types of pollen grains were found from the Burkard 7-day volumetric sampler from the arid and semi-arid zone of Bikaner, Rajasthan. In the study, Poaceae ranked first with a concentration of 26.2%, followed by *Amaranthus*, *Chenopodium*, Cyperaceae, Asteraceae, and Papilionaceae. A maximum concentration of total pollen load was found in March (16.70%), and the minimum level was noted in June (2.5%) [11].

In 2004–2005, sampling was carried out by a Burkard 7-day volumetric sampler at Miramar beach in Panaji, the capital of Goa, a popular tourist site where 85% of total pollen catch were dominated by Poaceae species [12]. Significant contributors were *Cynodon*, *Peltophorum*, *Amaranthus*, *Tridax*, and *Cassia*. During the 2004–2006 period, Amravati in the state of Maharashtra displayed 41 species by the gravity slide method sampling at three sites at Amravati. There, *Parthenium hysterophorus* scored highest (41–46%) among all which appear in air seasonal and periodical rotation [13]. The Poaceae pollen was the second dominant group found. *Parthenium* is very well-known for the type-1 hypersensitivity reactions in sensitive individuals. Similar results were obtained during the study conducted in the years 2011–2012, when two different indoor sampling methods were applied: sampler method and gravity slide method at the same city in the Department of Botany (site 1) and University Guesthouse (site 2) of the SGB Amravati University campus. *Parthenium* was again dominated, followed by *Moringa oleifera*, and *Ricinus communis* in site 1, and *Caesalpinia pulcherima*, *Tridax procumbens*, and *Moringa oleifera* in site 2 [14].

In central region

A current report of 2014, from the state of Madhya Pradesh was based on the identification of common allergens at Bhopal and its surroundings. Allergens common in this area were claimed to be responsible for inducing united airway disease (UAD) in subjects, since no study has been done in this central geographical part of India in the recent past [15]. SPT was performed on 89 patients with clinical manifestations of UAD, from April 2013 to March 2014, with a broad spectrum of different allergen extracts. Among the extracts, 50 were from pollen antigens, 20 from fungi, 20 from insects, 12 from dust group, 6 types of dander, 6 types of fabrics and feathers, and 1 dust mite. The dominant pollen allergens identified were *Cynodon dactylon* (53.93%), *Cenchrus ciliaris* (47.19%), *Carica papaya* (40.44%), *Chenopodium murale* (37.07%), *Gynandropis gyandra* (37.07%), *Cyperus rotundus* (35.95%), *Cannabis sativa* (35.95%), *Amaranthus spinosus* (34.83%), *Cassia occidentalis* (34.83%), *C. siamea* (33.70%), *Ehretia laevis* (32.58%), *Ageratum conyzoides* (30.33%) and *Brassica campestris* (33.33%). Thus, the SPT results reflected the dominance of total pollen allergens' significant impact on human health.

In eastern region

Most of the aero-palynological work by a Burkard 7-day volumetric sampler investigated the aeroallergens the eastern zone of India. Bio-monitoring during 2004–2005 revealed a total of 32 pollen types in Calcutta metropolis [16]. The SPT was performed with a panel of most commonly occurring pollen types typically responsible for clinical features of pollinosis. The most abundant pollen grains found from the SPT were *Trema orientalis* (21.75%), followed by Poaceae (14.75%), *Casuarina equisitifolia* (7.5%), *Cocos nucifera*

(6.7%), *Azadirachta indica* (4.78%), *Carica papaya* (4.39%), Cyperaceae (3.39%), *Lantana camara* (2.63%), Amaranth-Chenopod group (2.63%) and *Peltophorum pterocarpum* (2.37%). Patients showed positive SPT responses to the pollen extract of *Saccharum officinarum* (54%), *Azadirachta indica* (54%), *Cocos nucifera* (53%), *Areca catechu* (42%), *Phoenix sylvestris* (39%), *Borassus flabellifer* (28%), and *Peltophorum pterocarpum* (23%). The highest pollen load in the air was found from March to July.

Another similar study conducted in Calcutta, 2008, reported a number of pollen types in the air [17]. The most predominant pollen found from the Burkard 7-day volumetric sampler was *Trema orientalis* (19%), followed by Poaceae (12.98%), *Casuarina equisitifolia* (5.76%), *Cocos nucifera* (5.7%), *Azadirachta indica* (4.65%), *Peltophorum pterocarpum* (3.71%), Cyperaceae (3.68%), *Delonix regia* (3.18%), and *Areca catechu* (2.56%). The total pollen concentration revealed a statistically significant positive correlation with temperature and wind speed and a negative correlation with air humidity. Patients most frequently showed a positive skin tests to the pollen of Poaceae (49%), *A. indica* (46%), *C. nucifera* (47%), Cyperaceae (35%), *P. pterocarpum* (33%), *A. catechu* (29%), *P. sylvestris* (26%), and *B. flabellifer* (23%). A positive correlation was found between visits to the clinic and monthly pollen count of *A. catechu*, *C. nucifera*, and Poaceae.

A recent aeropalynological work using a Burkard 7-day volumetric sampler in a suburban city of Konnagar, near to Calcutta, West Bengal, marked the prevalence of 36 types of pollen in the air [18]. A health survey report and hospitalization associated with the respiratory allergy symptoms and related troubles showed a statistically significant positive correlation with the total pollen count. The pollen calendar described the dominance of Poaceae followed by *Lantana camara*, *Carica papaya*, *Phoenix sylvestris*, Chenoamaranthus group, which were previously described to have allergenic properties. When hospital survey reports were analyzed, a significant positive correlation between the increase in hospitalization and occurrence of pollen of five most dominant species, i.e., the Poaceae, *Lantana camara* and *Phoenix sylvestris* was revealed. For example, the blooming period and prevalence of exotic *Lantana* species was clearly correlated with the patients' admission during 2010–2012.

In a recent study in Calcutta in 2014, a highly populated city, two rates of symptoms such as "blockers" (patients suffering from blocking nose) and "sneezers-runners" (patients suffering from sneezing and running nose) were considered to check the independence between AR and prevalence of pre-dominant disease symptoms of the attending patients with common allergens, type and severity of the disease [19]. Comparing "blockers" vs. "sneezers-runners" (64.1% vs. 35.9%), it was found that "blockers" had significantly more sensitization to polyvalent house dust, house dust mites and fungi ($P < 0.05$), while "sneezers-runners" had more sensitization to pollens ($P < 0.05$). Both bronchial asthma and sinusitis were significantly more common among the "blockers" ($P < 0.05$).

In another study conducted in 2009, identified 65 pollen types in the atmosphere of Greater South Assam. *Acacia auriculiformis*, *Amaranthus spinosus*, *Cocos nucifera*, and *Ricinus communis* were found to be dominant [20]. Within the members of Poaceae group, *Imperata cylindrica* was found to be the predominant species in the study area. Although pollen grains of *Cleome* and *Trewia* were less frequently observed in the air, the *C. gynandra* and *T. nudiflora* plants were found to be quite frequent in the vicinity of South Assam. Therefore, all those species were selected for biochemical and immunological studies. Immunoblot analysis identified 8 IgE reactive bands in *Cassia alata* in the molecular weight range of 90–27 kDa. The pollen of *Acacia auriculiformis*, *Cleome gynandra*, and *Cocos nucifera* were identified to contain 5 Immuno reactive fractions, each in the molecular weight range of 97–29 kDa, 90–18 kDa and 66–32 kDa, respectively. *Trewia nudiflora* showed a single immunogenic band at 41 kDa. It can be estimated that maximum IgE binding fractions were found at the high molecular range between 40–97 kDa. Immuno-reactive fractions in the weight range of 50, 55, 60, 67 and 90 were common in several pollen samples.

Environmental factors and correlation due to their prevalence

Meteorological parameters are crucial in suspension, transportation and spread of bioaerosols, including pollen grains. In accordance with different studies, meteorological factors impact considerably on the pollen counts in an air. The negative relationship between minimum relative humidity, maximum relative humidity, maximum precipitation and the prevalence of pollen in air has been reported, which means that when those three elements rise, the pollen counts decrease. The average minimum temperature is as a variable that helps to suspend pollen and accelerate high pollen counts in the air when low temperature increases [18,20].

Clinically relevant pollen allergens and their relevance to hospital admission

There are many clinically important pollen allergens that have a significant impact on human health and elevating up to type 1 hypersensitivity reaction and thus impact hospitalization trend of local inhabitants.

An aerobiological survey conducted in an agricultural farm located in the suburban zone of Calcutta recorded the *Catharanthus roseus* (CR) pollen with 3.6–5.4% contribution to the aeropollen load [21]. SPT on 282 respiratory allergic individuals, residing within a 15 km radius of the study area, revealed 29.8% sufferers who were positive to CR pollen. Among them, 80.9% were directly involved in gardening. After the gel filtration of the whole pollen extract on a Sephacryl S-200 column, it showed 5 eluted fractions. Among them, fraction I showed optimum IgE-reactivity in ELISA-inhibition. The fraction I showed four protein components in SDS-PAGE, within which 3 (40–66 kDa) were detected to be IgE-reactive in the western blot immunoblotting applying patient sera.

Further detailed work on allergens from CR pollen unearthed Cat r 1, a member of cyclophilin proteins shortly known as Cyps. Cat r1 was obtained by initial IgE specific

western blot, N terminal sequencing followed by cDNA cloning in *Escherichia coli* to recombinantly express the protein [22]. The gene sequence was found to be identical to cytosolic Cyp sequence of periwinkle deposited in the Plant Gene Register (GenBankTM X85185) following SDS-PAGE and IgE-specific immunoblot of recombinant Cat r 1. Cat r 1 expressed in *E. coli* was subjected to 12% SDS-PAGE. The experiment again was confirmed by cross-reactivity between Cyps.

In a clinico-immunological study, airborne *Areca catechu* pollen was found to be immuno-reactive skin tests to 38.6% of allergic respiratory patients in Calcutta [23]. There are 6 IgE-reactive protein components in the whole pollen extract, among which 48, 18 and 116 kDa were most common IgE reactive protein factions. The 48 kDa component was reported to be cross-reactive with other palm pollen types. In IgE ELISA inhibition of *A. catechu* pollen extract with the *Areca* nut extract, the nut extract displayed 50% inhibition with a concentration of 110 ng/ml.

In another study conducted in Calcutta, SPT results of the patients with respiratory allergies presented 31.1% positive response to *Delonix regia* pollen [24]. Nine IgE-reactive protein bands were found in the crude extract, within which the 66 kDa allergen was found to be a glycoprotein. IgE-binding components of 66, 56, 32, 28, 25, and 23 kDa were observed to be cross reactive with *D. regia* and *Peltophorum pterocarpum* pollen extracts through ELISA inhibition and dot blot studies. In those experiments, the 96- and 43 kDa components were specific to *D. regia*.

Peltophorum pterocarpum, an avenue tree, also contributes 8% of total pollen load in southern Calcutta. Its protein extract was found to cause sensitization in 14–23% of respiratory allergic subjects [25]. ELISA, histamine release assay, along with SDS-PAGE and IgE specific immunoblot marked the 8 IgE binding protein components as 76, 56, 66, 49, 28, 26, 23, 22 kDa. Among them, 28 kDa protein was found to be major as it showed binding in 75% of patients' sera for IgE specific immunoblotting after periodate modification.

A two-year biomonitoring survey in Calcutta detected an increase in the concentration of an exotic species of *Lantana camara*, contributing 10.5% to the total pollen load [26]. Among 1500 respiratory allergic patients, 21% showed positive skin reaction, out of which 7.93% showed +2/+3 level of response. SDS-PAGE followed by IgE specific immunoblot identified many reactive protein bands from the 20–97 kDa range.

The tree pollen of *Prosopis juliflora*, known as Mesquit, was identified as IgE reactive protein and its cross reactivity with *Phaseolus lunatus*, known as Lima bean, was discovered from Delhi [27]. SDS-PAGE resolved the pollen of Mesquite and seed extracts of Lima bean into 33 and 22 distinct protein bands, respectively, the molecular weight ranging from 14 to >100 kDa. Western blot analysis of *P. juliflora* pollen extract with pooled sera from hypersensitive patients (n = 10) exhibited 16 allergenic proteins. *Prosopis lunatus* extract with the same pooled sera detected nine IgE reactive components. Immunoblot inhibition showed the inhibition of IgE binding components of 20, 26, 35, 66 and 72 kDa of *P. juliflora* by *P. lunatus* extract, demonstrating the presence of cross-reactive allergens.

Discussion

In India, regional disparities in vegetation type are noted, leading to diverse seasonal and annual composition of airborne pollen and the patterns of their distribution. The pollen calendars created according to the seasonal prevalence and concentration of allergenic pollen show differences in dominant pollen grains in the air. According to the published reports, *Holoptelea integrifolia* (during 2002–2005), *Amaranthus spinosus* (in 2011), *Brassica* pollen (during 2004–2006) exhibited high concentration. In the southern region, pollen of *Gynandropsis gynandra* (2005), *Sorghum vulgare*, *Pennisetum* sp. (2006) and Parthenium hysterophorus, *Dolichandrone platycalyx* (2011) was found to be predominant. Pollen of Poaceae, Amarathus-Chenopod group (2001–2005), and *Parthenium hysterophorus* (2004–2006) was significant in the western region. The allergenic pollen of *Cynodon dactylon* and *Cenchrus ciliaris* (2013–2014) was characteristic for aerosol of the central regions. Since ten years, there seemed to be many important allergenic pollen types prevailing in the eastern region, such as pollen of *Trema orientalis* and *Acacia auriculiformis* which dominated in the 2004–2006 sampling period. Pollen of Poaceae, *Lantana camara*, *Carica papaya*, *Phoenix sylvestris* was predominant during the period of 2010–2012.

These pollen grains seemed to cause hypersensitivity in sensitive people either by their seasonal increase in the air or by their annual or perennial pattern of dispersion. Meteorological parameters play a significant role in dissemination and retention of pollen in the air. Hospital data from each region of India, along with immuno-biochemical tests and statistical interpretation, supported the idea that local people suffer from allergies associated with the occurrence of respective dominant local allergenic pollen.

Conclusions

A regional pollen calendar could be more efficient in constructing a concept of a remedy to the allergy sufferers by giving the support for diagnosis and therapy for the future healthier society. Geographical diversities lead to discrete pollen compositions in the respective regional areas in the air. Therefore, there is a need to carry more aerobiological studies in different regions at regular intervals to identity the occurrence time and changes in the trend of incidence of allergens and respiratory allergy. Detailed information on indigenous pollen is of paramount importance for the clinical practitioners in diagnosis and management of allergic patients.

When all these relevant facts are taken into consideration, it is clear that allergen avoidance is an important issue for the treatment of allergies and asthma. In particular, all possible allergens are required to be characterized biochemically as well as at the molecular level. The study of interrelationships of allergenic pollen grains and their cross-reactivity could lead to understanding their similarities at the molecular level, sharing similar epitopes. Future studies up to epitope level identification of the already recognized dominant antigenic pollen grains could be advantageous for the understanding

of IgE-mediated binding and histamine release. Thus, the future construction of recombinant vaccines generation for the sufferers and also for the general public could make it possible to provide protection against hypersensitivity in future India.

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Authors' contributions
The following declarations about authors' contributions to the research have been made: study idea and layout: SGB; aerobiological and clinical data procurement and clarification: KG; wrote the first draft of the manuscript: KG; revised the article critically for important intellectual content: SGB.

Competing interests
No competing interests have been declared.

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Badania zawartości alergenów pyłkowych w powietrzu na subkontynencie indyjskim

Streszczenie
W ostatnich latach na całym świecie drastycznie wzrasta liczba chorób alergicznych układu oddechowego (astma oskrzelowa, nieżyt nosa) oraz pokrzywka czy atopowe zapalenie skóry. Trend wzrostowy występuje również w Indiach, dlatego podjęto badania aerobiologiczne w celu określenia regionalnych różnic zawartości pyłku i zarodników w powietrzu.

W artykule przedstawiono obecny stan badań aerobiologicznych prowadzonych w latach 2001–2015 w Indiach, ze szczególnym uwzględnieniem zawartości alergenów pyłkowych. Badania te potwierdzają znaczny udział alergenów pyłkowych w aeroplanktonie. Analizowano również korelację pomiędzy zawartością alergenów pyłkowych w powietrzu a danymi dotyczącymi hospitalizacji pacjentów, u których wystąpiły symptomy alergii. W regionach Indii północnych do alergenów pyłkowych należą *Holoptelea integrifolia*, *Amaranthus spinosus*, w regionach południowych *Sorghum vulgare*, *Pennisetum*, *Gynandropsis gynandra*, *Parthenium hysterophorus*, *Dolichandrone platycalyx*, w regionach zachodnich *Parthenium hysterophorus*, na obszarach centralnych *Cynodon dactylon*, *Cenchrus ciliaris*, a w regionach wschodnich *Acacia auriculiformis*, *Cleome gynandra*, *Catharanthus roseus*, *Phoenix sylvestris*, *Areca catechu* i *Lantana camara*. W okresie kwitnienia roślin produkujących pyłek alergiczny oraz tuż po tym okresie, wystąpiła znaczna korelacja pomiędzy wskaźnikiem hospitalizacji z powodu problemów zdrowotnych związanych z alergiami oraz zawartością alergenów pyłkowych w powietrzu. Stwierdzono, że pyłek gatunków z rodziny Poaceae jest dominujący na całym obszarze Indii. W badaniach immunobiochemicznych określono alergenny białkowe występujące w pyłku dominujących gatunków. Wykazano istnienie podobnych epitopów oraz homologię głównych białek alergennych, białka Cat r1 pochodzącego z *Catharanthus* sp. oraz białka Par j 1 pochodzącego z *Parietaria judaica*. Identyfikacja alergenów pyłkowych, określanie epitopów dominujących ziaren oraz wiedza o możliwej reaktywności krzyżowej alergenów ma istotne znaczenie kliniczne w zakresie zapobiegania, diagnozowania i leczenia chorób alergicznych w Indiach.