

# Glimpse of Clinical Aerobiology in India: An Overview



**A B Singh\***

CSIR-Institute of Genomics and Integrative Biology, Delhi University Campus, India

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\*Corresponding author: A B Singh, Emeritus Scientist (EX), CSIR-Institute of Genomics and Integrative Biology, Delhi University Campus, India, Email: [singha49@hotmail.com](mailto:singha49@hotmail.com)

## Abstract

Today more than 30% of the world population is known to suffer from one or other allergic ailments such as bronchial asthma, allergic rhinitis and atopic dermatitis. Major causative agents are pollen grains fungal spores, dust mites, insect debris etc. Detailed information on the daily seasonal and annual variation of different agents in the atmosphere is prerequisite in proper diagnosis and treatment of allergic ailments. Aerobiological investigations have been carried out in different parts of country to ascertain aerial concentration and seasonality of pollen and fungal spores. An attempt has been to review the important pollen/fungal allergens prevalent in different parts of the country during the last twenty five years. The studies carried out under an All India Coordinated Project on "Aeroallergens and Human Health" have revealed the quantitative and qualitative prevalence of aerosols at are different centers.

Predominant airborne pollen identified are Poaceae, *Holoptelea*, Asteraceae, *Eucalyptus*, *Casuarina*, *Putranjiva*, *Cassia*, *Cocos*, *Pinus*, *Cedrus*, *Cheno/Amaranth*, *Argemone*, *Xanthium*, *Parthenium* and others. Allergenicity important pollen are *Prosopis juliflora*, *Ricinus communis*, *Morus*, *Mallotus*, *Alnus*, *Quercus*, *Cedrus*, *Argemone*, *Amaranthus*, *Chenopodium*, *Brassica*, *Cocos*, *Parthenium*, *Cassia* and grasses. The prevalent fungal spores in both outdoor and indoor environments are *Aspergilli* / *Penicilli*, *Cladosporium*, Ascospores, *Alternaria Dreschlera*, *Epicocum*, *Nigrospora*, *Candida ablicans* and others. Important fungal allergens are different species of *Aspergillus*, *Ganoderma*, *Mucor mucedo*, *Fusarium solani*, *Curvularia*, *Nigrospora*, *Scopulariopsis brevicaulis*, *Alternaria alternata* and others.

Air carries large number of bioparticles (biopollutants) and chemical pollutants and these poses burden for the respiratory tract of humans. The bioparticles include pollen grains, fungal spores, insect debris, plant parts, animal danders, mites, etc. These materials of biological origin are known to be causative agents of respiratory disorders like asthma, allergic rhinitis and atopic dermatitis. Rapid industrialization and urbanization though has resulted in booming the economy of the country but it has also contributed significantly in enhancing the problems of patients suffering from respiratory disorders as the quality of air deteriorated due to addition of large number of pollutants. The incidence of respiratory allergy is increasing all over the world. This is evident by the epidemiological data available from different parts of the world. The prevalence of respiratory allergy has been reported be 15-30% across the globe [1-5].

Of the various agents, pollen grains and fungal spores are the major source of morbidity among sensitive individuals. Detailed information on their daily, seasonal and annual variation in the Air carries large number of bioparticles (biopollutants) and chemical pollutants and these poses burden for the respiratory tract of humans. The bioparticles include pollen grains, fungal spores, insect debris, plant parts, animal dander, mites, etc. These materials of biological origin are known to be causative agents of respiratory disorders like asthma, allergic rhinitis and atopic dermatitis. Rapid industrialization and urbanization though has resulted in booming the economy of the country but it has also contributed significantly in enhancing the problems of patients suffering from respiratory disorders as the quality of air deteriorated due to addition of large number of pollutants. The incidence of respiratory allergy is increasing all over the world. This is evident by the epidemiological data available from different parts of the world. The prevalence of respiratory allergy has been reported be 15-30% across the globe [1-5].

Preparation of National and Regional pollen calendars is of immense help to the clinicians for effective diagnosis and efficient treatment of patients. India is blessed with multilingual, multicultural and multi religious population of more than 1.2 billion (1/5th of the world population). It comprises one of the richest flora on earth. India is one of the countries where aerobiological studies were initiated as early as 19th century. Studies on various aspects of aerobiology has progressed rapidly especially during the last twenty five years. An attempt has been made in this paper to review important air borne pollen and fungal allergens prevalent in different parts of the country.

## Earlier Studies

Pollen grains caught attention of scientists in 18th century when Koelreuter reported dissemination of pollen by wind. After fifty years, pollen was suspected to be a causative agent of "Sumer Catarrh" (hay fever) by John Botock [6]. Later on Charles Blackley [7] established that pollen grains play an important role in hay fever and allergy. Scheppegrell [8] from

USA laid emphasis on field exploration and aerial surveys to record "aeroallergens" from the atmosphere. Subsequent studies carried out by different workers throughout the world established pollen to be responsible for respiratory allergic disorders [9-15]. In India, Cunningham [16] from Calcutta was the pioneer to establish relationship between the airborne

organisms and the so called "Zymotic diseases". There was a conspiracy of silence on aerobiological studies for about half a century when two important centers started aerobiological investigations at Jaipur and Delhi [17-21]. Aerobiological studies in Kolkatta were initiated again at Bose Institute by Chanda and his students who also prepared pollination calendars for Calcutta, Falta and Kalyani [22-25].

Around same time extensive aerobiological investigations were initiated at Bangalore by S. N. Agashe [26,27]. Since then many centers have come up in different parts of the country which include Gwalior, Jabalpur, Santiniketan, Manipur, Gulbarga, Trivandrum, Lucknow, Mumbai and Bhopal [28-36]. Exhaustive studies have been carried out at different centers on airborne pollen types and their relationship with respiratory allergic disorders in atopic patients. Fungal spores were first reported to be an important cause of sensitivity in 1726 [37]. Blackley [7] suggested that *Chaetomium* and *Penicillium sp* are associated with "bronchial catarrh". Nearly half a century later in 1924, van Leumen reported *Aspergillus*, *Mucor* and *Penicillium* to be responsible for allergic reactions. Subsequently many scientists throughout the world carried out aerial surveys using different samplers to identify important fungal types and studied fungal sensitivity in hypersensitive individuals [3,38-42].

In India aero mycological studies were initiated in 1959 with the work of T Sreeramulu at Visakhapatnam. The studies spread further in other parts and many centers came into existence. The center at Aurangabad was initiated by S.T. Tilak in 1966 and the Mysore center was started by A. Ramalingam in 1965. Aerobiological studies at Madras were initiated by B.P.R. Vittal in 1976. Shivpuri and his students initiated work on fungal allergy in Delhi and the work is being carried out extensively by Singh and his students [43-47]. An All India coordinated project on aerobiology sponsored by CSIR, New Delhi was coordinated by Nair and Joshi (1980-83) and many new centers spread over 20 states carried out qualitative analysis of air borne pollen/fungal spores. The work carried out in different centers was compiled in the form a book entitled "Air borne pollen, spores and other plant material of India-A survey." Two decades later an All India coordinated project on "Aeroallergens and Human Health" was sponsored by The Ministry of Environment and Forest Govt. of India was under taken and successfully completed by AB Singh and his collaborators [3]. This provides upto date information seasonal and annual concentration of air borne pollen and spores of indoor and outdoor air of different eco geographical regions of India.

### Aeropalynological Studies

Studies on airborne pollen in India have been extensively studied during the last quarter century and have shown the existence of a rich and ever-changing air spora. From Delhi, aerial surveys have been carried out from time to time by Singh and his students. Singh and Babu [48-50] carried out aerobiological investigations to study variations in the pollen types of Delhi.

Malik et al. [51] studied air borne pollen grains from different zones of Delhi at human height. Two main pollen season were recognized (i) Feb.-April and Sept.-Nov. The dominant pollen grains reported were of Poaceae *Cheno/Amaranth*, *Ricinus communis*, *Morus cannabis*, *Parthenium* and *Artemisia*. Dirunal and seasonal variations of dominant pollen grains present in the atmosphere of Delhi has been studied by Singh et al [13]. A continuous air survey using Rotorod sampler for seven years was carried out by Singh et al. [14] from Delhi. The dominant pollen grains identified were *Morus*, *Cannabis*, Poaceae, *Cheno/Amaranth*, *Prosopis*, *Artemisia* and *Eucalyptus*. Significant variations in the annual pollen concentration during the seven year investigation period were recorded. Long term variations are important to study as they provide insight into the changing scenario in the vegetation due to biotic factors.

During investigations carried out under AICP on Aeroallergens and human Health, 43 pollen types were recorded. *Holoptelea* was the major contributor (22.2%) followed by poaceae (1.8%) [3]. Aerobiological studies in Modi Nagar were carried out by Gaur and Kasana [52]. From, Gorakhpur, Poaceae was shown to be dominant [53]. Air borne pollen types of Dehradun were different from those observed in plains as pollen from pinaceae dominated at foothills of Himalayas. At Agra aeropalynological studies have been carried out by Shalini and Chauhan [54]. From Solan (Himachal Pradesh) 22 pollen types were recorded for high attitudes. The major pollen contributors to the atmosphere in Himalayan region were of Poaceae, Asteraceae, *Cassia*, *Quercus*, *Pinus* and *Cedrus* [3]. Aerial surveys at Bikaner (Rajasthan) showed 35 pollen types to be present in the atmosphere [55]. *Poaceae* (26.7%) ranks first followed by *Amaranth-Chenopod* (11.50%) and *cyperaceae* (10.30%). Maximum concentration of pollen was in March and minimum was in June.

From Bombay three pollen seasons are reported; (i) March-mid May (ii) Sept.-Nov. and (iii) Dec.-Feb. [56]. Grasses, *Parthenium*, *Chenopodium-Amaranthus* and *Cyperus* are the major source of air borne pollen in Kolhapur [57]. Atmospheric surveys revealed the important air borne pollen types representing the rural area around Gaya [58]. The studies conducted at Gwalior showed pollen of *Poaceae*, *Asteraceae*, *Apocynaceae*, *Rosaceae*, *Cicer*, *Malvaceae*, *Ricinus* and *Bougainvillea* to be dominant in the atmosphere. November was the month with maximum pollen catch [30]. Variability in grass pollen grains in India has been reviewed by Chaturvedi et al. [59]. Poaceae pollen has been reported to be dominant from the atmosphere of Nagpur [60]. The highest percentage was reported from Aurangabad (80.64%) followed by Bhavnagar (70.26%) and Raipur (66.73%) all in central India. Qualitative seasonal variations in the atmospheric pollen flora of Jabalpur have been studied by Oomachan et al [61]. Atmospheric surveys carried out at Pune revealed *Parthenium* pollen to be the highest contributor to the atmospheric pollen load with two peak seasons (i) Sept-Nov and (ii) Jan-April [3].

In Eastern India, Chanda and his students from Kolkatta and N.I. Singh from Imphal carried out extensive aerobiological surveys to assess the pollen types of West Bengal and Manipur. Grass pollen was reported to be dominant aeropollen in West Bengal [24]. In general three pollen seasons are recognized from West Bengal. These are (i) Aug (ii) March-July and (iii) [24]. The aeroflora of Eastern Himalayas has also been analysed and the dominant pollen types reported are *Acer*, *Alnus nepalensis*, *Betula*, *Pinus* [32,34]. Under AICP, 59 pollen types were identified from the atmosphere of West Bengal and May was the month with maximum pollen concentration. At Guhati, pollen of Poaceae, *Cheno/Amaranth*, Asteraceae, *Putranjiva*, *Mangifera* and *Eucalyptus* were found to be most prevalent [3]. *Poaceae*, *Cassia sp* and *Ageratum sp* are the dominant pollen types prevalent in the atmosphere of greater Silchar, Assam almost throughout the year [62].

From Southern India, Agashe and his students have made tremendous contribution in the study of aerobiology. The major pollen types identified from the atmosphere of Bangalore are *Parthenium hysterophorus*, *Casuarina equisetifolia*, *Cheno/Amaranth*, *Cocos nucifera*, *Ricinus communis* and grasses [26]. As a result of aerial surveys carried out for six years *Parthenium* (48%) was found to be most important weed followed by *Poaceae* and *Casuarina equisetifolia* [27]. Seasonal periodicity of predominant pollen in Bangalore atmosphere has been studied. *Casuarina equisetifolia*, *Parthenium hysterophorus* and *Holoptelea integrifolia* were the major types present. The concentration of *Parthenium* was found to be less as compared to earlier studies and this was attributed to rapid industrialization of Bangalore city and effectiveness of different eradication programmes [63]. Incidence of air borne pollen at two different locations was studied at Gulbarga.

Two pollen seasons, viz. Aug-Nov. dominated by weeds and grasses and Feb.-April dominated by trees and shrubs were recognized [36]. From the atmosphere of Trivandrum pollen of *Cocos nucifera* and *Peltophorum* were found to contribute 55% to the total pollen flora. From Trivandrum and Chennai 15 and 38 pollen types were identified and Poaceae was the most abundant type from both places [3]. Grass pollen (32%) has been reported to be dominant pollen type from Hyderabad followed by *Casuarina*, *Ricinus*, *Holoptelea*, *Ailanthus* and others [33]. Satheesh et al. [64] reported pollen of *poaceae* to be most predominant followed by *Casuarina equisetifolia* and *Prosopis juliflora* from Kodaikanal. From Visakhapatnam, site to site variations in air borne pollen were found to be related to the density of vegetation in different zones [35]. Aerobiological data is of immense help in the preparation of pollen calendar which are very useful for the clinicians in correlating the presence of pollen in the air with seasonal allergic symptoms. Pollen calendars have been prepared from different geographical regions of the world. From India also pollen/flowering calendars have been prepared for Sambalpur, Gulbarga, Imphal and Kodai Kanal [34,36,64,65]. Centre for Biotechnology (now known

as CSIR - Institute of Genomics and Integrative Biology) has published a book on pollen calendar of 12 different states of India [66]. The book also includes pollen seasons for grasses, weeds and trees prevalent in India.

### Clinically Important Pollen Allergens

Pollen is important cause of allergic disorders and they vary from place to place. It is therefore important for the clinician to select only those pollen antigens which are prevalent in the area where patient is residing. Based on clinico-immunological studies carried out at different regions in the world, important pollen allergens have been identified. From Northern India, *Prosopis juliflora*, *Xanthium*, *Ageratum*, *Amaranthus spinosus*, *Ricinus communis* and *Holoptelea integrifolia* are reported to be important allergens [43]. Studies carried out at Kanpur established *Amaranthus*, *Chenopodium*, *Holoptelea* and grasses to be important offending allergens [67]. Positive skin reactions in 16.9% of patient to *Pinus roxburghii* from the foot hills of Himalayas has been recorded by Singh et al [68]. At Chandigarh, out of 35 pollen antigens tested showed highest skin reactivity against *Rumex acetosa*, *Ailantus excelsa* (17.6%) followed by *Trewia nudiflora* (9.7%), *Argemone mexicana* (9.5%) and *Cedrus deodara* (9.3%). In Delhi 12.6% of the atopic patients had positive skin reactions to *Amaranthus spinosus*, 8.5% to *Populus deltoids* and 7.5% to *Dodonea viscosa* and *Bhauhinia variegata* [3].

From Central India, important pollen allergens identified are *Argemone*, *Brassica*, *Cannabis*, *Asphodelus*, *Parthenium*, *Cassia*, *Azadirachta*, *Poaceae*, *Alnus* and *Betula*. In a recent study *Morus* and *Trewia nudiflora* and *Parthenium* have been added to the list of allergens from central India. From Eastern India, allergenically significant pollen types based on clinical evaluation are *Lantana*, *Cucurbita maxima*, *Cassia fistula*, *Cocos nucifera* and *Calophyllum inophyllum*. High sensitivity to *Cocos nucifera* has been recorded by Karmakar et al. [69]. In Calcutta, 28.8% of the patients were found to be positive against *Solanum*, *sysimbrifolium*, 21.1% to *Crotolaria juncea* and 18.2% to *Ricinus communis* and *Ipomea fistula* [3]. From Southern India important pollen allergens reported are *Salvadora*, *Ricinus*, *Albizia lebeck* and *Artemisia scoparia* [70,71]. Allergenicity to *Parthenium* pollen is reported in 3.4% and 12% patients suffering from allergic rhinitis and bronchial asthma respectively from Bangalore [72]. At Trivandrum, maximum skin reactivity was recorded against *Mallatus philipensis* (12.1%) followed by *Prosopis juliflora* (6.3%).

**A. Airborne Fungi:** Fungi are ubiquitous in nature and cosmopolitan in distribution. There are more than 80,000 spp of fungi and these have evolved elaborate mechanisms for their dispersal. The spores produced forms a normal component of outdoor air and also of indoor environment such as store houses, hospitals, libraries, residential building etc. Due to their small size, spores remain suspended in the atmosphere for a long time. When inhaled by susceptible individuals they cause respiratory disorders. Aerobiological

studies in India have progressed along three different lines. These include (i) study of airborne fungal spores in the atmosphere of different places, (ii) study of fungal spores present in indoor environments and (iii) study of mycoflora over crop fields.

**B. Outdoor Fungal Flora:** Aerobiological studies have been carried out in different cities and towns to monitor air borne fungal spores. Various techniques like gravity settling method (settle plates, gravity slides), impaction techniques (Rotorod sampler and aeroscope) and volumetric devices (Burkard trap, Anderson samplers) have been popularly used. *Cladosporium* has been reported as the most predominant fungi by most of the investigators. Basidiospores and ascospores are the second dominant group. From Northern India, *Aspergilli-Penicilli*, *Cladosporium*, *Helminthosporium*, *Epicoccum* and *Drechslera* are reported to be important fungi in ambient air. Singh et al. [68] carried out aerial surveys at Dehradun for two consecutive years. *Cladosporium*, *Alternaria*, smut spores, *Curvularia*, Ascospores, *Nigrospora*, *Asp-Penicilli*, *Epicoccum* were the dominant forms reported. July to October was the period of high spore catch. Gupta et al. [47] reported 98 fungal types from the atmosphere of Delhi as a result of two years of aerobiological survey at five different locations in Delhi metropolis. *Cladosporium* contributed 25-40% to the total air borne fungal load followed by *Ustilago* (24%), *A. flavus* (10-13%) *Alternaria* (11%) and *A. niger* (8%). Aeromycological studies at Jabalpur have been carried out and important fungi prevalent in the atmosphere have been identified [73]. From Solan, 17 fungal types and from Lucknow 40 fungal types were recorded. The dominant types were *Aspergilli-Penicilli*, *Cladosporium*, *Helminthosporium*, *Epicoccum* and *Drechslera* [3].

Aerobiological surveys carried out in Eastern India revealed *Aspergilli Penicilli*, *Cladosporium*. Ascospores, rust and smut spores, *Nigrospora*, *Periconia*, *Ganoderma* and *Rhizopus* to be major fungal types. Sinha et al. [74] carried out aerial survey for aerofungi at Jameshedpur and reported 23 fungal genera with 40 species. Members of Deuteromycetes (14 genera) were dominant followed by Phycmycetes (5) and Ascomycetes (4). The important fungal types present in the atmosphere of Imphal, Manipur has been identified by Singh & Singh [75]. Aeromycoflora at the foot hills of Eastern Himalayas has been studied by Majumdar and Bhattacharya [76]. A total of 18 fungal spore types were identified and the predominant types were *Alternaria*, *Aspergilli*, *Cercospora*, *Cladosporium*, *Curvularia*, *Drechslera*, *Epicoccum*, *Fusarium* etc. *A. flavus*, *A. fumigatus*, *A. niger*, *P. citrinum* and *M. haemilis* are dominant fungi recorded from the atmosphere of greater silichar area in Assam [62].

From Western India Tilak et al. [77] reported Deuteromycetes to contribute 70% to the total fungal aerospora in the atmosphere of Aurangabad. The other common types recorded are *Alternaria*, *Curvularia*, *Nigrospora*, *Aspergilli-*

*Penicilli*, *Drechslera*, *Periconia*, *Pithomyces*, *Stachybotrys*, *Memnoniella*, *Torula* etc. Tilak [78] reported spore type belonging to 37 ascomycetes genera to be common in air. He classified them into four types based on their diurnal periodicity. He also suggested that there exist a close relationship between rainfall and release of ascospores. Recent survey reported 18 fungal types and 22 fungal types from the atmosphere of Aurangabad and Pune respectively *Cladosporium*, *Aspergilli-Penicilli*, *Curvularia*, *Rhizopus* and *Helminthosporium* were the common fungal types encountered.

From Southern India studies on seasonal periodicity of fungal spores in Bangalore, the Garden city of India was conducted. Maximum concentration of dry spores were reported in North east Monsoon where as ascospores and basidiospores were dominant during South West Monsoon [79]. *Nigrospora* has been reported to be dominant fungi from Madras renamed as Chennai now [80,81]. Of the 34 fungal types identified from Visakhapatnam, *Aspergilli-Penicilli*, *Cladosporium*, *Curvularia*, Basidiospores, Uredospores were the dominant types from Chennai. Of the 50 fungal types were identified, *Periconia*, *Curvularia* and *Ganoderma* were the dominant types. *Tetraploa* was reported to be dominant along with other fungal types from Trivandrum [3]. Adhikari et al [82] carried out study of airborne fungal spore in rural agricultural areas of India for two consecutive years. The concentration of viable fungi varied from 72-1796 colonies forming unit per cubic meter of air in the first year and 155-1256 (CFU/m<sup>3</sup>) in the second sampling year.

**C. Indoor Fungal Flora:** Human beings are exposed to both outdoor and indoor environment. Environment of the work place plays crucial role in the hypersensitive individuals with the symptoms increasing during working hours and reducing afterwards. However, in some cases symptoms prevail throughout the day. Children employed in various industries are also exposed to occupational allergens. Studies on mycoflora of indoor environment are relatively few in India when compared with outdoors. The occupational areas surveyed include hospitals, poultry farms, libraries, bakeries farm houses, domestic houses, grain stocks, leather store houses etc. *Aspergillus*, *Penicillium*, *Cladosporium* and some moniliaceous fungi are predominant in the air of most of the indoor environment surveyed. The fungal flora observed in various working and occupational environments in India are briefly described here.

**D. Bakery:** Different sections of a bakery in Delhi were surveyed and 74 fungal types belonging to 33 genera were isolated [51]. *Aspergilli/Penicilli* (69.2%) were the dominant spore type in the packing section with a peak in October followed by smut spores (28.5%) with peak in Feb-April. *Aspergillus flavus* was the dominant fungal type in both packaging and storage section. Allergenicity significant fungal aerosols have been shown to be prevalent in a rural

bakery of West Bengal [82].

**E. Granary:** *Aspergillus* sp are the predominant fungi followed by *Cladosporium*. *A. flavus* had two distinct seasons from Sept.-Nov. and May-June. *Cladosporium* was prevalent during winter months. Other important contributors are *Rhizopus*, *Curvularia*, *A. versicolor*, *A. fumigatus*, *Epicoccum nigrum* and *Alternaria* [83]. Fungal diversity present in the dust of grain storage godowns has been studied by Pugalmaran and Vittal [84].

**F. Poultry:** Different sections of poultry were surveyed and 130 fungal types were identified [85]. In hatchery section, *Aspergilli-penicilli* spores were dominant. In poultry shed area, *Cladosporium*, *Candida albicans*, *A. flavus*, *A. niger*, *Scopulariopsis brevicaulis*, *P. nigricans*, *Alternaria* sp are reported to be predominant fungi. An analysis of the aeromycospores of a poultry farm in Kerala has been done and important fungal types identified by Jothish & Nair [86].

**G. Sugar Industry:** *Cladosporium* is reported to be present in high concentration (60%) from Nov.-March in both baggase storage and cane cutting sections of the industry. The high concentration of *Cladosporium* coincided with the crushing season in Sugar industry. *A. fumigatus*, *Epicoccum*, *Saccharomyces* and smut spores are other major contributors [87].

**H. Library:** Lot of work has been done on the aeromycoflora of libraries. High concentration of *Cladosporium*, *Penicillium*, *Paecilomyces* and *Aspergillus* sp were reported to be dominant in Library environment. After agitation of books, concentration of *A. niger*, *Penicillium* sp. and *Cladosporium* was found to increase several fold [51,88]. Nadimuthu and Vittal [89] reported air borne fungi to be present in low concentration in air conditioned libraries when compared with conventionally ventilated libraries. Mycoflora of library dust in Jaglaon (Maharashtra) was studied with reference to deterioration of books. Deuteromycotina members were found to be very common and showed luxuriant growth in the dust from stored books [90].

**I. Cattle Shed:** Two sections of a large rural indoor cattle shed were surveyed. Altogether 35 fungal types were identified. *A. niger*, *A. flavus*, and *Cladosporium cladosporioides* were found to be dominant fungal types recorded [91].

**J. Residential Houses:** *Cladosporium* and *Aspergillus* were found to be predominant in the houses of allergy patients in Bangalore [92]. A total of 17 fungal antigens were tested on patients with respiratory allergy in Agra. *Rizopus nigricans* showed maximum (20-95%) allergenicity followed by *Fusarium solani* (14.80%) [93].

**K. Fungal Allergens:** Fungal allergy is a worldwide problem. Many fungal species are known to cause severe respiratory and cutaneous allergic diseases. Several

investigators from different parts of India have identified potential fungal allergens of their area. Shivpuri and his colleagues initiated clinical studies in Delhi in 1970's and found nineteen fungal extracts to be of allergenic significance. He reported *C. cerbarum*, *A. niger*, *A. fumigatus*, also to be important fungal allergens [43]. Important fungal allergens causing sensitization in patients of nasobronchial allergy of hilly regions has been identified. *Ganoderma lucidium* has been reported to induce sensitization in hypersensitive patients. Skin test results with spore and whole body extracts of *Ganoderma* showed 28.48% and 17.44% of patients to be positive to respective extracts [94]. Gupta et al [47] observed through ELISA that high level of specific IgE against *Fomes pectinatis* in the sera of exposed population. Common environmental allergens responsible for respiratory allergy have been reviewed by Singh & Kumar [95]. From Bangalore, *Mucor mucedo*, *Fusarium solani*, *Curvularia*, *Nigrospora* were found to be allergenically significant [71]. *A. flavus*, *Heminthosporium*, *Neurospora*, *Candida* and *Cladosporium* have been reported to be important allergenic fungi in A.P. (Acharya, 1980).

**L. Occupational Fungal Allergens:** Epidemiological surveys for respiratory diseases were carried out among agricultural industrial workers such as bakeries, poultry farms, granaries and sugar industry. About 40-59% of workers in different work environments suffered from one or more respiratory ailments. *Aspergillus* was found to be the major contributor. The sensitization pattern of workers in a bakery environment revealed high level of IgE and IgG antibodies to six species of *Aspergillus Scopulariopsis brevicaulis* spores could sensitize poultry workers and this was evident by significantly high levels of IgE antibodies in the workers [75]. The work done by various investigators with respect to fungal allergens in both outdoor and indoor environment, has been reviewed recently by Singh and Deval [96]. Clinical studies were carried out at different places under AICP on "Aeroallergens and Human Health". The study provided important information on potential fungal allergens of different places. The important fungal allergens identified were *A. ochraceous*, *A. japonicus*, *Cladosporium*, *Alternaria alternata*, *A. versicolor*, *Uromyces* and *Ustilago*, *A. ochraceous*, *A. Japonicus*, *Urmoyces*, *Ustilago*, *Neurospora sitophils*, *Sporotrichum* has been reported to be allergenic for the first time [3].

**M. Fungi of Crop Fields:** Aerobiological studies with respect to plant diseases of different crops have been carried out by various investigators. Tilak & Babu [97] investigated certain diseases of bajra crop. Aerial dissemination of uredinospore of ground nut rust was studied by Mallarah & Rao [98]. Aerobiological and epidemiological studies with respect to ground nut rust have also been carried out by Murdhankar & Pandey [99]. Aeromycoflora of crop fields like cereals, pulses, vegetables oil, seeds and cash crops have

been conducted in Imphal. A close relationship between meteorological factors, growth stage of crop and spore load in the air over the field was observed. In the maize crop, spores of pathogenic fungi were reported to be abundant in the air 4-5 weeks prior to the appearance of disease [100]. *Alternaria alternata* was reported to be causal organism of leaf and stem spot disease of sunflower. The conidia were trapped from the air when the crop was in flowering stage [101].

Day to day variations in the concentration of *Alternaria* over onion field infected with purple blotch was studied by Chawla & Rajasaab [102]. The conidia were present in high concentration in the air when the crop was at 7-8 leaf stage state. Studies over a carrot field revealed that the concentration of conidia of *Alternaria davuhi*, the causative agent of leaf blight, increased with the progress of the disease [103]. The uredospores of *Periodospora mori* causing mulberry rust appeared in the air from August onwards and spore concentration gradually increased up to December corresponding with the disease severity [104].

Aerophyllo-mycoflora of some solanaceous crop plants in Bhilai Nagar (M.P.) showed fungal population to exhibit wide variation at different stages of crop development. Maximum number of micro-organisms were recorded during nascent stage and minimum number was observed during seedling stage [105] Aerial surveys over cotton field at Ahmedpur showed *Ramularia areola*, *Cercospora sp.* *Helminthosporium sp.*, *Alternaria sp.* to be pathogenic to the cotton crop [106]. Hedge et al. [107] carried out studies at Ugarkhura and Dharwad (Karnataka) and reported load of uredospores of *Phakopsora pachyryhizi* to be maximum in Aug-Sept. which also coincided with the critical stage of infection at flowering and pollination stages. They also developed prediction model for the disease based on severity of disease and environment factors. Ugarkhurd has been shown to be source of infection and hot spot for soyabean rust outbreak in Karnataka [108]. Many more investigators have made significant contributions to the knowledge towards aerobiology of fungal plant pathogens and have been reviewed recently by Vittal [109].

### Conclusion

To conclude, the progress in the field of aerobiology has been very impressive in the last twenty five years. It was not possible to cover each and every paper published in this article but an attempt has been made to review selected publication from different geographical locations of India. However, with the understanding of molecular mechanism of allergy, both diagnosis and therapy have gained prominent position now.

### Future Priorities

Allergy has been known for more than a century but the subject has suffered due to lack of knowledge on basic allergic mechanism and poor diagnostic procedures. In the last two decades a fast growth has been observed in the field of aerobiology. A large number of pollen/fungal allergens have been identified from different geographical locations. However

due to urbanization and industrialization the flora of a region is continuously changing with respect to the number of weeds and introduction of exotic trees. Regular atmospheric surveys are therefore recommended in order to study the seasonal and annual variations of different allergens. Till date most of the surveys conducted are mainly in urban areas. Rural area should be included in the study as a major fraction of our population live in these areas. This is also important as maximum information on indigenous allergens is essential for the diagnosis and treatment of allergic disorders.

Aerobiological investigations should be correlated with clinical studies in order to establish a relationship between the concentration of allergens and the patient's syndrome. The increase in the prevalence of allergic diseases should be studied in detail. Efforts should be made to standardize the antigenic extracts prepared from various allergens. Another important aspect that is to be studied in detail is the cross reactivity among different allergens. This will be helpful in minimizing the suffering of patients to a great extent. The rapid development in the field of aerobiology has resulted in the understanding of prevalence of different allergens. This information should be linked with immunological and clinical studies so that it is of direct significance to both the patients and allergy practitioners.

### Fungal Prevention

- a. Identification of source and environmental conditions that help the fungi in getting airborne in significant concentrations should be known.
- b. The substrate on which these microorganisms grow and flourish should be removed.
- c. The kitchen should be kept clean and dry as it contains plenty of substrate for the growth of fungi.
- d. Bathrooms should also be kept clean and dry.
- e. As fungi are occupational hazards, the working environmental conditions should be improved.
- f. Work places should be well ventilated and hygienic.
- g. Reduction of moisture inside the work places is recommended.
- h. The quality of air should also be improved by periodic maintenance of air treatment plant, fumigation and application of antifungal agents.
- i. Personal filter masks of the pore size sufficient to stop the entry of respirable size microbes should be used.
- j. Regular health check up of patients is recommended.

### Pollen Allergen Avoidance

- i. Allergen avoidance is the main strategy to control pollinosis.
- ii. The common saying "prevention is better than cure" should be strictly observed in the case of allergy prevention.

- iii. The existing allergenically significant trees should be replaced by non-allergic trees in phased manner.
- iv. Patients should avoid going outdoors on days of high pollen concentration in air.
- v. Windows should be closed in the evening when pollen generally settles down to minimize their concentration in indoor environment.
- vi. Use of air conditioners is recommended as it decreases indoor pollen count.
- vii. Eliminate weed and grasses in and around your house.
- viii. Don't plant too many trees or shrubs around your house.
- ix. After coming home, take bath and wear fresh clothes.
- x. A general awareness among people through media will also be helpful in controlling the problem of increasing respiratory allergy.

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