

Aerobiological Researches on Pollen and Fungi in India During the Last Fifty Years: An Overview

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Abstract

More than 20-30% of the world population is known to suffer from one or other allergic ailments such as bronchial asthma, allergic rhinitis and atopic dermatitis etc. Major causative agents are pollen grains fungal spores, dust mites, insect debris and other plant fragments and foods etc. A detailed information on the daily, seasonal and annual variation of different bioparticulates in the atmosphere is prerequisite, for effective diagnosis and therapeutic management 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 made to review the researches on the important pollen/fungal allergens prevalent in different parts of India during the last 50 years. The major source of information has been the papers published in related journals in India and abroad. Studies carried out under an All India Coordinated Project on "Aeroallergens and Human Health" (1994-2000) has revealed the quantitative and qualitative prevalence of aerosols at different locations. Although pollen are present throughout the year but peak pollen season are March-May and August-October. Predominant airborne pollen identified are a members of Poaceae (grasses), *Holoptelea*, *Eucalyptus*, *Prosopis*, *Casuarina*, *Putranjiva*, *Cassia*, *Cocos*, *Pinus*, *Cedrus*, *Asteraceae*, *Cheno / Amaranth*, *Argemone*, *Xanthium*, *Artemisia*, *Cannabis* and *Parthenium* among weeds. Allergenicity important pollen are *Prosopis juliflora*, *Ricinus communis*, *Morus alba*, *Mallotus philippensis*, *Alnus nitida*, *Quercus incona*, *Cedrus deodara*, *Argemone mexicana*, *Amaranthus spinosus*, *Chenopodium album*, *Brassica campestris*, *Cocos nucifera*, *Parthenium hysterophorus*, *Cassia* and members of Poaceae. The fungal spores prevalent in both out door and indoor environments are *Aspergilli-Penicilli*, *Cladosporium*, *Ascospores*, *Alternaria*, *Dreschlera*, *Epicoccum*, *Nigrospora*, *Basidiospores* and others. Clinically important fungal allergens are different species of *Aspergillus fumigatus*, *Aspergillus flavus*, *Aspergillus nidulans*, *Alternaria alternata*, *Cladosporium cladosporoides*, *Ganoderma lucidum*, *Mucor mucedo*, *Fusarium solanii*, *Curvularia lunata*, *Neurospora sitophila*, *Scopulariopsis brevicaulis*, and others.

INTRODUCTION

Air carries large number of bioparticles (biopollutants) and chemicals, which poses burden for

the respiratory tract of humans. The bioparticles include pollen grains, fungal spores, insect debris, plant parts, animal danders and 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

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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 in air. 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 to be 20-30% across the globe¹⁻⁷. Of the various agents, pollen grains and fungal spores are the major sources of morbidity among sensitive individuals. A detailed information on their daily, seasonal and annual variations in the atmosphere is a prerequisite for proper diagnosis and treatment of allergic ailments. Preparation of National and Regional calendars are of immense help to the clinicians for effective diagnosis and therapeutic management of the disease.

India is blessed with multilingual, multicultural and multireligious population of more than 1.2 billion (1/5th of the world population). It comprises one of the richest flora on the earth. India is one of the countries where aerobiological studies were initiated as early as 19th century. Studies on various aspects of aerobiology have progressed rapidly, especially during the last 50 years.

Pollen grains caught attention of scientists in 18th century when Koelreuter reported dissemination of pollen by wind. After fifty years, pollen were suspected to be a causative agent of "Summer Catarrh" (hay fever) by John Bostock⁸. Later, Charles Blackley⁹ established that pollen grains play an important role in hay fever and allergy. Scheppegegrell from USA laid emphasis on field exploration and aerial surveys to record "aeroallergens" from the atmosphere¹⁰. Subsequent studies carried out by different workers throughout the world-established pollen grains to be responsible for respiratory allergic disorders¹¹⁻¹⁸.

Fungal spores were first reported to be an important cause of hypersensitivity in 1726¹⁹. Blackley⁹ 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^{4,20-24}.

MATERIAL AND METHODS

An attempt has been made in this review to analyse important aerobiological surveys with reference to pollen and fungi carried out in different parts of India during the last fifty years. The publications pertaining to qualitative and quantitative prevalence of air borne pollen and fungal spores in indoor and outdoor environment have been analysed. The papers appearing in related journals in India and in other international publications have been reviewed. There is no denying the fact that bulk of the papers reviewed appeared in Indian journal of Aerobiology an official publication of Indian Aerobiological Society.

The review has been compiled in several sub headings as aeropalynological surveys of pollen grains, clinical important pollens as allergens, fungal surveys in outdoor and indoor work environments and allergenically important fungi prevalent in different parts of the country. Some of the fungal surveys conducted over crop fields in rural India are also discussed

An All India coordinated project on aerobiology of India sponsored by CSIR, New Delhi, was coordinated by Nair and Joshi 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"²⁵. Two decades later an All India coordinated project on "Aeroallergens and Human Health (AICP)" sponsored by the Ministry of Environment and Forest", Govt. of India was completed by Singh and his collaborators^{4,7}. This provides up to date information on seasonal and annual concentrations of air borne pollen and spores of indoor and outdoor air of different ecogeographical regions of India. Altogether 18 aerobiological units and 5 clinical centres were established to screen allergenicity of local pollen and spore allergens under this project.

RESULTS AND DISCUSSION

The results have been discussed in the following sub headings:

Aeropalynological surveys

In India, Cunningham²⁶ from Calcutta (now known as Kolkata) was the pioneer to establish relationship between the airborne organisms and the so-called "Zymotic diseases". There was a complete absence on Indian aerobiological research for about half a century when two important centers started aerobiological investigations at Jaipur and Delhi²⁷⁻³¹. Aerobiological studies in Kolkata were initiated again at Bose Institute by Chanda and his students, who prepared pollination calendars for Kolkata, Falta and Kalyani³²⁻³⁵.

Around same time, extensive aerobiological investigations were initiated at Bangalore by Agashe and coworkers^{36,37}. Since then many centers have come up in different parts of the country which include Gwalior, Jabalpur, Santiniketan, Manipur, Gulbarga, Thiruvananthapuram, Visakhapatnam, Lucknow, Mumbai and Bhopal³⁸⁻⁴⁶. Exhaustive studies have since been carried out at different centers on airborne pollen types and their relationship with respiratory allergic disorders in atopic patients.

Airborne pollen in India have been extensively studied during the last quarter century and have demonstrated the existence of a rich and ever-changing air spora in the country. In Delhi, aerial surveys for pollen and fungi have been carried out from time to time by Singh and his students. Singh and Babu⁴⁷⁻⁴⁹ carried out aerobiological investigations to study variations in the pollen types of Delhi. Malik et al⁵⁰ studied air borne pollen grains from different zones of Delhi at human height. Two main pollen seasons were recognized (i) Feb.-April and Sept.-Nov. The dominant pollen grains reported were of Poaceae Cheno/ Amaranth, *Prosopis*, *Ricinus communis*, *Morus*, *Cannabis*, *Parthenium* and *Artemisia*. Singh et al reported Diurnal and seasonal variations of dominant pollen grains present in the atmosphere of Delhi⁵¹. A continuous air sampling at Delhi using Rotorod sampler for seven years was carried out by Singh et al¹⁷. The dominant pollen grains identified were *Morus*, *Cannabis*, Poaceae, Cheno/Amaranath, *Prosopis*, *Artemisia* and *Eucalyptus*. Significant variations in the annual pollen concentration during the seven-year investigation period are recorded. The concentration declined gradually over a period of seven years but

there was sharp decline in first two years attributed to industrialization and urbanization of Delhi and its suburbs. Long term variations are important to study as they provide insight into the changing aerobiological scenario due to changing vegetation and biotic factors.

During investigations carried out under AICP at Delhi 43 pollen types were recorded. *Holoptelea* was the major contributor (22.2%) followed by Poaceae (1.8%)⁴. Aerobiological studies at Modi Nagar were carried out by Gaur and Kasana⁵². From, Gorakhpur, Poaceae was recorded to be dominant pollen⁵³. Air borne pollen types of Dehradun were different from those observed in plains as pollen from Pinaceae dominated at foothills of Himalayas⁵⁴. At Agra aeropalynological studies have been carried out by Shalini and Chauhan⁵⁵. From Solan (Himachal Pradesh) 22 pollen types were recorded from high attitudes of Himalayas. The major pollen contributors to the atmosphere in Himalayan region are of Poaceae, Asteraceae, *Cassia*, *Quercus*, *Pinus* and *Cedrus*⁴. Aerial surveys at Bikaner (Rajasthan) showed 35 pollen types to be present in the atmosphere⁵⁶. Poaceae (26.7%) ranks first followed by Amaranth-Chenopod (11.50%) and Cyperaceae (10.30%). Maximum concentration of pollen was recorded in March and minimum in June.

From Bombay, three pollen seasons were reported; (i) March-mid May (ii) Sept.-Nov. and (iii) Dec.-Feb.⁵⁷. Grasses, *Parthenium*, Cheno-Amaranth and *Cyperus* are the major source of air borne pollen in Kolhapur⁵⁸.

Atmospheric surveys revealed the important air borne pollen types representing the rural area around Gaya⁵⁹. The studies conducted at Gwalior showed pollen of Poaceae, Asteraceae, Apocynaceae, Rosaceae, *Cicer*, Malvaceae and *Ricinus*, to be dominant in the atmosphere. November was the month with maximum pollen catch⁴⁰. Variability in aerial grass pollen grains in India has been reviewed by Chaturvedi et al⁶⁰. Poaceae pollen has been reported to be dominant from the atmosphere of Nagpur⁶¹.

Qualitative seasonal variations in the atmospheric pollen flora of Jabalpur have been studied by Oomachan et al⁶². 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-April⁴.

In Eastern India, Chanda and his students from Kolkatta and Singh from Imphal carried out extensive aerobiological surveys to assess the pollen types of West Bengal and Manipur, respectively. Grass pollen is reported to be dominant aeropollen in West Bengal³⁴. In general three pollen seasons are recognized from West Bengal. These are (i) Aug-Nov. (ii) March-July and (iii) Dec.-Feb. The aeroflora of Eastern Himalayas has also been analyzed and the dominant pollen types reported are *Acer*, *Alnus nepalensis*, *Betula*, *Pinus*^{42,44}. Under AICP, 59 pollen types were identified from the atmosphere of West Bengal and May was the month with maximum pollen concentration. At Gauhati, pollen of Poaceae, Chenop/ Amaranth, Asteraceae, *Putranjiva*, *Mangifera* and *Eucalyptus* were found to be most prevalent⁴. Poaceae, *Cassia sp* and *Ageratum sp* are the dominant pollen types prevalent in the atmosphere of Greater Silchar, Assam almost throughout the year⁶³.

From Southern India, Agashe and his students have made significant contribution on the aerobiology of Karnataka. The major pollen types identified from the atmosphere of Bangalore are *Parthenium hysterophorus*, *Casuarina equisetifolia*, Chenop/ Amaranth, *Cocos nucifera*, *Ricinus communis* and grasses³⁶. Aerial surveys carried out for six years reported *Parthenium* (48%) to be most important weed pollen followed by Poaceae and *Casuarina equisetifolia*³⁷. Seasonal periodicity of predominant pollen in Bangalore atmosphere has been studied and *Casuarina equisetifolia*, *Parthenium hysterophorus* and *Holoptelea integrifolia* are 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 programs⁶⁴. 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 recognized⁴⁶. From the atmosphere of Trivandrum, pollen of *Cocos nucifera* and *Peltophorum* were found to contribute 55% to the total pollen flora⁴¹. From Trivandrum and Chennai 15 and 38 pollen types respectively were identified and Poaceae was the most abundant type from both places⁴. Grass pollen (32%) has been

reported to be dominant pollen type from Hyderabad followed by *Casuarina*, *Ricinus*, *Holoptelea*, *Ailanthus* and others⁴³, Satheesh et al⁶⁵ reported pollen of Poaceae to be most predominant followed by *Casuarina equisetifolia* and *Prosopis juliflora* from KodaiKanal. Site to site variations in air borne pollen were found to be related to the density of vegetation in different zones of Visakhapatnam⁴⁵.

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 KodaiKanal^{44,46,65,66}. Centre for Biochemical Technology renamed as Institute of Genomics and Integrative Biology, Delhi has published a book, which include 12 pollen calendars for different states of India⁶⁷. The book also includes pollen seasons for grasses, weeds and trees prevalent in hill region and southern states of India.

Clinically important pollen allergens

Pollen are important cause of allergic disorders and they vary from place to place. It is therefore, important for the clinicians to select only those pollen antigens which are prevalent in the area where patient is residing. Based on clinico-immunological studies carried out in different regions of the country, important pollen allergens have been identified.

From Northern India, *Prosopis juliflora*, *Xanthium strumarium*, *Ageratum conyzoides*, *Amaranthus spinosus*, *Ricinus communis* and *Holoptelea integrifolia* are reported to be important allergens⁶⁸.

Studies carried out at Kanpur established *Amaranthus*, *Chenopodim*, *Holoptelea* and grasses to be important offending allergens⁶⁹. Positive skin reactions in 16.9% of patient to *Pinus roxburghii* from the foot hills of Himalayas has been recorded by Singh et al⁵⁴. At Chandigarh, out of 35 pollen antigens tested *Rumex acetosa*, *Ailanthus excelsa* showed highest skin reactivity (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 *Bauhinia variegata*⁴.

From Central India, important pollen allergens identified are *Argemone*, *Brassica*, *Cannabis*, *Asphodelus*, *Parthenium*, *Cassia*, *Azadirachta*, Poaceae, *Alnus* and *Betula*. In a recent study *Morus*, *Trewia nudiflora* and *Parthenium* have been added to the list of allergens from this region⁴. 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 al⁷⁰. In Calcutta, 28.8% of the patients were found to be sensitive against *Solanum sysimbrifolium*, 21.1% to *Crotolaria juncea*, and 18.2% to *Ricinus communis* and *Ipomea fistula*⁴.

From Southern India important pollen allergens reported are *Salvadora*, *Ricinus*, *Albizia lebbek* and *Artemisia scoparia*^{71,72}. Allergenicity to *Parthenium* pollen is reported in 3.4% and 12% patients suffering from allergic rhinitis and bronchial asthma respectively from Bangalore⁷³. At Trivandrum, *Mallotus philippensis* showed maximum skin reactions (12.1%) followed by *Prosopis juliflora* (6.3%)⁴.

Airborne fungal survey

In India aeromycological studies were initiated in 1959 by Sreeramulu at Visakhapatnam. The studies spread further in other parts and many centers came into existence. The center at Mysore was started by Ramalingam in 1965 while at Aurangabad it was initiated by Tilak in 1966. Aerobiological studies at Madras (now Chennai) were initiated by Vittal in 1976. Shivpuri and his students initiated the work on fungal allergy in Delhi and the work was further extended by Agarwal, Singh and their students^{54,68,74-76}.

Fungi are ubiquitous in nature and cosmopolitan in distribution. There are more than 80,000 spp of fungi and these have evolved with elaborate mechanisms for their dispersal. The spores produced, form a normal component of outdoor air and also of indoor environment such as store houses, hospitals, libraries, residential building etc. Due to 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

Outdoor aeromycoflora

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 used to monitor the airborne fungi. *Cladosporium* has been reported as the most dominant fungi followed by basidiospores and ascospores at various places.

From Northern India, *Aspergilli-Penicilli*, *Cladosporium*, *Helminthosporium*, *Epicoccum* and *Dreschlera* are reported to be important fungi in ambient air. Singh et al⁵⁴ carried out aerial surveys at Dehradun for two consecutive years and reported *Cladosporium*, *Alternaria*, smut spores, *Curvularia*, Ascospores, *Nigrospora*, *Aspergilli-Penicilli* and *Epicoccum* as dominant forms. July to October was the period of high spore catch. Gupta et al⁷⁷ reported 98 fungal types from the atmosphere of Delhi as a result of two year of aerobiological survey at five different locations in Delhi metropolis. *Cladosporium* contributed maximum (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 identified⁷⁸. From Solan, Himachal Pradesh 17 fungal types and from Lucknow, 40 fungal types were isolated and identified. The dominant types were *Aspergilli-Penicilli*, *Cladosporium*, *Helminthosporium*, *Epicoccum* and *Drechslera*⁴.

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 types⁴. Sinha et al⁷⁹ carried out aerial survey for fungi at Jimeshedpur and reported 23 fungal genera with 40 species. Members of Deuteromycetes (14 genera) were dominant followed by Phycomycetes⁵ and Ascomycetes⁴. The important fungal types present in the atmosphere of Imphal, Manipur has been identified by Singh and Singh⁷⁵. Aeromycoflora at the foothills of Eastern Himalayas has been studied by Majumdar and Bhattacharya⁸⁰. A total of 18 fungal spore types were identified and the predominant types were *Alternaria*, *Aspergilli*, *Cercospora*, *Cladosporium*, *Curvularia*, *Dreschlera*, *Epicoccum*, *Fusarium* etc. *A. flavus*, *A. fumigatus*, *A. Niger*, *P. citrinum* and *M. hiemalis* in the atmosphere of greater silichar area in Assam⁶³.

From Western India Tilak⁸¹ 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*, *Dreschlera*, *Periconia*, *Pithomyces*, *Stachybotrys*, *Memnoniella*, *Torula* etc. Tilak⁸² reported spore type belonging to 37 ascomycetes genera to be common in air. A close relationship was observed 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 encountered⁴.

From Bangalore, the seasonal periodicity of fungal spores was recorded by Agashe and Sudha⁸³. Maximum concentration of dry spores was reported during North East Monsoon season whereas ascospores and basidiospores were predominant during South West Monsoon. *Nigrospora* has been reported as a dominant fungi from Madras (Chennai)⁸⁴. Of the 34 fungal types identified from Visakhapatnam, *Aspergilli*-*Penicilli*, *Cladosporium*, *Curvularia*, Basidiospores and Uredospores were the dominant types from Chennai. Of the 50 fungal types identified, *Periconia*, *Curvularia* and *Ganoderma* were the dominant types. *Tetraploa* was reported to be dominant along with other fungal types from Trivandrum⁴. Adhikari et al⁸⁵ carried out a study of airborne fungal spores 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/m³) in the second sampling year.

Indoor occupational aeromycoflora

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 out doors. 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 is briefly described here.

Bakery

Different sections of a bakery in Delhi were surveyed and 74 fungal types belonging to 33 genera were isolated⁸⁶. *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^{15,86}. Allergenicity significant fungal aerosols prevalent in a rural bakery of West Bengal were also reported⁸⁷.

Granary

Aspergillus sp are the predominant fungi followed by *Cladosporium*. *A. flavus* had two distinct seasons from Sept.-Nov. and May-June. Where as *Cladosporium* was prevalent during winter months. Other important contributors are *Rhizopus*, *Curvularia*, *A. versicolor*, *A. fumigatus*, *Epicoccum nigrum* and *Alternaria*⁸⁸. Fungal diversity present in the dust of grain storage godowns has been studied by Pugalmaran and Vittal⁸⁹ at Madras.

Poultry

Different sections of poultry were surveyed and 130 fungal types were identified⁹⁰. 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* were predominant fungi. An analysis of the aeromycospores of a poultry farm in Kerala has been done and the important fungal types identified⁹¹.

Sugar industry

Cladosporium is reported to be present in high concentration (60%) from Nov.-March in both baggage 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 to the airspora⁹².

Library

Several studies have been done on the aeromycoflora of libraries. *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 increased several fold⁸⁶. low concentration of airborne fungi was reported in airconditioned libraries compared with conventionally ventilated libraries Nadimuthu and Vittal⁹³. Mycoflora of library dust in Jalgaon (Maharashtra) was studied with reference to deterioration of books. Deuteromycotina members were found to be very common and showed luxuriant growth in the dust of stored books⁹⁴.

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 dominant fungal types recorded⁸⁵.

Residential houses

Cladosporium and Aspergilli were predominant in the houses of allergy patients at Bangalore⁹⁵.

A total of 17 fungal antigens were skin tested on patients with respiratory allergy in Agra. *Rizopus nigricans* showed maximum (20-95%) allergenicity followed by *Fusarium solani* (14.80%)⁹⁶.

Fungi of allergenic significance

Many fungal species are known to cause severe respiratory and cutaneous allergic diseases world over. Several investigators have identified potential fungal allergens in different geographical region of the country. Shivpuri and his colleagues initiated clinical studies in Delhi in 1970's and identified nineteen fungal extracts to be of allergenic significance. *C. herbarum*, *A. niger*, *A. fumigatus*, and *A. alternata* were reported as important fungal allergens⁶⁸.

Important fungal allergens causing sensitization in patients of nasobronchial allergy of hilly regions of India have been identified by Singh et al⁵⁴. *Ganoderma lucidum*, a new fungal type has been reported to induce sensitization in hypersensitive patients in Delhi⁹⁷. Skin test results with spore and whole body extracts of *Ganoderma* showed marked positive reaction in 28.48% and 17.44% of patients, respectively high level of specific IgE were observed by ELISA against *Fomes pectinatis* in the sera of exposed population. Common environmental allergens responsible for respiratory allergy has been reviewed by Singh and Kumar¹⁶. From Bangalore, *Mucor mucedo*, *Fusarium solani*, *Curvularia* and *Nigrospora* were reported to be allergenically significant⁷². *A. flavus* *Heminthosporium*, *Neurospora*, *Candida albicans* and *Cladosporium* have been reported to be important allergenic fungi in Andhra Pradesh⁷².

Effect of Occupational fungal allergens

Epidemiological surveys for respiratory diseases were carried out among agricultural industry workers from bakeries, poultry farms, granaries and sugar industry. About 40-59% of workers in different work environments were reported to suffer from one or more respiratory ailments⁷⁵. The sensitization pattern of workers in a bakery environment revealed high level of IgE and IgG antibodies to six species of

Aspergillus. Sensitization with *Scopulariopsis brevicaulis* was evident by significantly high levels of IgE in the poultry workers²³. The work done by various investigators with respect to fungal allergens in both outdoor and indoor environments has been reviewed recently by Singh and Deval⁹⁸.

Clinical studies carried out under coordinated programme by Singh and collaborators provided information on potential fungal allergens of different places in India⁴. The important fungal allergens identified were *A. ochraceous*, *A. japonicus*, *Cladosporium*, *Alternaria alternata*, *A. versicolor*, *Uromyces* and *Ustilago*, *A. ochraceous*, *A. japonicus*, *Uromyces*, *Ustilago*, *Neurospora sitophila* and *Sporotrichum* have been reported as new allergens.

Aeromycoflora of crop fields

Aerobiological studies with respect to plant diseases of different crops have been carried out by various investigators. Tilak and Babu⁹⁹ investigated air spora over bajra crop (*Pennisetum typhoides*) with respect to certain diseases. Aerial dissemination of uredinospores of ground nut rust was studied by Mallaiah and Rao¹⁰⁰. Aerobiological and epidemiological studies with respect to ground nut rust have also been carried out by Murdhankar and Pandey¹⁰¹ in Maharashtra. Aeromycoflora of crop fields like cereals, pulses, vegetable oils, seeds and cash crops have been studied in Manipur and North East India. 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 disease¹⁰². *A. 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 stage¹⁰³.

Day to day variations in the concentration of *Alternaria porri* conidia over onion field infected with purple blotch was studied by Chawda and Rajasaab¹⁰⁴. 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

disease¹⁰⁵. The uredospores of *Periodispora mori* causing mulberry rust appeared in the air from August onwards and spore concentration gradually increased upto December corresponding with the disease severity¹⁰⁶.

Aerophyllo-mycoflora of some Solanaceous crop plants in Madhya Pradesh showed fungal population to exhibit wide variation at different stages of crop development. Maximum number of microorganisms were recorded during senescent stage and minimum number was observed during seedling stage¹⁰⁷. Aerial surveys over cotton field at Ahmedapur (Maharashtra) showed *Ramularia areola*, *Cercospora sp.*, *Helminthosporium sp* and *Alternaria sp* to be pathogenic to the cotton crop¹⁰⁸. Hedge et al¹⁰⁹ carried out studies at Ugarkhura and Dharwad (Karnataka) and reported load of uredospores of *Phakopsora pachyrhizi* 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 Karnataka¹¹⁰.

The knowledge of aerobiology of fungal plant pathogens in India has been reviewed recently by Vittal¹¹¹.

Indian Aerobiological Society

The researchers working in the field of aerobiology joined hands in 1980 at Calcutta to form Indian Aerobiological Society. Some of the aerobiologists who were instrumental in the formation were S. Chanda, S.T. Tilak, S.N. Agashe, A.B. Singh, C.S. Reddy and few others. The Society has since been providing guidance for aerobiological researches in India, interacting with similar organizations such as International Association of Aerobiology (IAA) and World Allergy Organisation (WAO). The IAS publishes *Indian journal of Aerobiology* with two issues in a year and organizes seminar symposia, workshops regularly in different parts of the country.

CONCLUSIONS

In conclusion, the progress in the field of aerobiology has been very impressive in the last 25

years. However it was not possible to cover all the paper published in this article, but an attempt has been made to review selected publication from different geographical locations of India. The rapid development in the field of aerobiology has resulted in the understanding of prevalence of different allergens. This information can be linked with immunological and clinical studies so that it is of direct significance to both the patients and allergy practitioners.

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