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A Review on Aeromycological Studies

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The present attempt has made to study the fungal flora available in the air, over agricultural fields and its impact on crop health. Furthermore this work also emphasizes on origin of the aeromycological research in India and abroad, past and current scenario of aeromycological work at national and International level, aeromycological studies over agricultural fields from India etc.

Keywords : Aerobiology, Aeromycology.

INTRODUCTION

Aerobiology studies small particles from biological origin in the air. Aeromycology is branch of Botany (Mycology) which deals with study of fungal flora in air. Aeromycology studies not only include fungal spores liberation from the sources transport and deposition, but also their effects on plants, animals, humans and even over food, building, work of art etc. Numbers of microscopic fungal spores are occurred in indoor and outdoor environment are commonly called as fungal bioaerosols. Singh and Dahiya (2008) reported more than 80000 fungal spores in air along with their dispersal mechanism and seasonal variation.

Fungal spores are dominating the other bioparticles in the air spora and fungal spores are mostly pathogenic, non-pathogenic as well as saprophytic in nature, living on dead and decaying organic remains of plants (Agrawal *et al.,* 1969). Fungi generally cause major diseases in plants. The importance of airborne micro fungi has long been recognized, especially in plant pathology. The disease incidence was greatly influenced by quantitative assessment of pathogens that is, fungi their prevailing meteorological parameters for disease development between the growth stages of the host plant and presence of pathogen.

Due to small size, fungal spores remain suspended in the a.mosphere for a long time and causes number of plant diseases, respiratory disorders (Woolcock *et al.,* 2001) and many other allergic ailments. Kasprzyk (2008) stated that, knowledge of concentrations of airborne fungal spores is especially important for agricultural and occupational medicine. Aeromycology has its application in agrobiology, particularly with respect to pathogenic fungi and in the conservation of the artistic heritage.

The propagative phase of fungi is spores of which many are adapted to air transport. In many species, however, the spores rarely get into the air and are carried by insects or are either seed or soil borne. Fungal spores often constitute a major component of airspora. The spores are extremely variable in shape, size and colour with or without ornamentations on the spore wall. Most of these range from 3-20µm while a few are upto 100µm diameter (Tilak, 1982).

Pathogenic fungal bioaerosols are responsible to cause severe plant diseases to crop plants and they reduce crop yield (Karne, 2013). Stakman and Christensen (1946) made an intensive study and established the relationship between aerobiology and plant diseases and emphasized its role in forecasting the disease. The study of aeromycology is important in plant pathology and in disease forecasting of plant diseases (Lohare and Kareppa, 2010). The study of fungal aerospora is important to understand the dissemination of pathogenic spores in the atmosphere and successful disease management.

Origin of the aeromycological research : Air is the way fungi use to transports their spores. Many fungi are crop pathogens and cause important economic losses, hazards. Airborne fungi can be migrated thousands of kilometers away from their sources. One of the most common problems to humans is allergy to fungi spores. By the contrary of pollen grains fungi spores are frequent in indoor environment. About 100 species of fungi regularly involved in human and animal mycoses. Toxic secondary metabolite produced by fungi and their production depend on the environmental conditions (Ana *et al*., 2002). The study of fungal air spora is important in order to understand its dissemination and spread in the atmosphere. Adequate information regarding the time and mode of the spread of the pathogens in air plays most important role in disease management of plants (Mishra and Srivastava, 1972). By keeping this in mind, it was thought to

study the effect of all these factors on the vegetation as well as on the microbes and their impact on health related problems of human being is utmost important.

Past and current scenario of aeromycological work: International level : Meier *et al.* (1933) of U.S. and Stepanov (1935) of U.S.S.R. was established Aerobiology as a special branch. The honour of pioneering experimental aerobiology goes to Miquel (1879) who explain the technique to analyse the microbial air population. He produced the first suction trap and noted its improved collection efficiency. Roger and Meir (1936) reported the collection of microorganisms from 36,000 feet. Rittenberg (1939) investigated the microbiology of marine air.

According to Roger (2003) fungi affect humans in complex ways and are capable of eliciting a number of disease responses, such as infectious, allergi: and irritant and toxic effects. Fungal exposure is unequivocally associated with exacerbations of asthma, although the role of fungi in causing the disease is yet to be determined. The association between home dampness and respiratory health effects is strong and fungal exposure is suspected to be associated with the linkage.

Different microorganisms such as fungi, algae and bacteria may have a negative effect on the preservation of artistic-historical heritage, especially when microclimatic conditions favour their development. Numerous museum complexes therefore employ systematic temperature and humidity monitoring, with the aim to prevent or slow down their growth (De Nuntiis *et al.*, 2004).

Many researchers also report interaction between microscopic fungi and arthropods on the surface of wall paintings, which increases their alteration (Hoffland *et al.*, 2004). These biological agents affect not only the aesthetical appearance but also the structure of materials. Contributing to their preservation therefore is the main goal of studies of the mycobiota carried out in heritage buildings (Aira *et al.*, 2007).

Meier *et al.* (1933) reported spores in air of United States. Meier (1933) carried out collecting microorganisms from the Arctic atmosphere. Ainsworth (1952) investigated the incidence of airborne *Cladosporium* in the London region. Paddy *et al.* (1955) studied fungi in air over the Atlantic Ocean. Gregory and Hirst (1957) observed the summer air-spora at Rothamsted in 1952. Gregory (1973) reported the microbiology of the atmosphere of England during 1961-1973. Frey and Duris (1962) carried out the studies of air borne fungal spores by slide and culture methods. Lacey (1962) reported the summer air-spora of two contrasting adjacent rural site. Moustafa and Kamel (1976) investigated the fungal spore diversity from Kuwait and Levetin and Horowitz (1978) noticed from Tulsa. Larsen (1981) studied fungal aerospora from Copenhagen and Al-Doory *et al.* (1982) from Washington. Lyon *et al.* (1984), Abdel-Hafez and El-Said (1989), Nussbaum (1990), Larsen and Gravesen (1991) and Abdel- Hafez *et al.* (1993) reported the effect of weather conditions on population of fungal aerospora.

Burge and Solomon (1978) reported sampling and analysis of biological aerosols. Banerjee *et al.* (1987) carried out indoor fungal flora from Durham, USA. Harriet *et al.* (1987) reported sampling and analysis of biological aerosols. Frinking (1991) carried out aerobiology of "closed" agriculture system. Shaheen (1991) reported aeromycology of Jordan. Rosas *et al.* (1992) carried out seasonal distribution of *Aspergillus* in the air of Mexico. Tan *et al.* (1992) observed variation in tropical airspora in Singapore. Sorlini (1993) has made aerobiology as general and applied aspects in the conservation of art works. The most frequent genera *Cladosporium, Alternaria, Aspergillus* and *Penicillium* in an urban and rural environment of East-France were noticed by Joel-Simeroy *et al.* (1993). Fungal airspora of Durban: a sub-tropical, coastal South African city were studied by Dames and Cadman (1994). Hirst (1994) carried out aerobiology at Rothamsted. Halwagy (1994) studied fungal airspora of Kuwait city during 1975-1987.

Past scenario of aeromycological work : National level Cunningham (1873) is the pioneer member of aerobilogical research in India. He published his book entitled "Microscopic Examination of Air". Prof. K. C. Mehta extensively investigated the wheat rust spores from air. Furthermore, he observed that rust spores were incapable of surviving during high temperature of summer in the plains of North India. The present knowledge of rust disease of cereals is only due to his researches. Among the plant pathogen wheat rust is the best aerobiologicaly investigated one. Later on Rajan *et al.* (1952) noticed the fungal spora from Kanpur.

Padmanabhan *et al.* (1953) studied the incidence of conidia of H*elminthosporium oryzae* in paddy field at Cuttak. Kalra and Dumbrey (1957) studied airspora of Army MedicalCampus, Pune. Airspora over potato fields at upper Shilong has been studied by Konger and Baruah (1985). Gupta *et al.* (1960) reported airborne spores from Jaipur. Dua and Shivpuri (1962), Karnik (1962) recorded atmospheric pollen and fungal spores at Delhi and Jalgaon respectively. Sreeramulu and Seshavataram (1962) studied spore content of air over paddy fields at Pentapadu (A.P.). Nair (1963) investigated atmospheric pollen and fungal spores and other vegetable matter at Vellore, Madras. Chaubal and Deodikar (1964) studied airborne spores around Poona.

Prof. S. T. Tilak is the pioneer worker in aerobiology from Maharashtra. He discovered and developed many air samplers for quantitiative study of air spora like Tilak Air Sampler, Volumetric Continuous Tilak Air Sampler and Rotorod Tilak Air Sampler. Furthermore he published many books on aerobiology *viz.* Aerobiology in 1982, Air Monitoring in 1987, Atlas of Air Borne Pollen Grains and Fungal Spores in 1989 and Aerobiology revised edition in 1995.

Anand *et al.* (1981) investigated the fungal spora from Bangalore city and he interrupted this information in

immunotherapy. Bhalke (1981) studied the aerobiological survey over some agricultural fields at Aurangabad. Dixit and Gupta (1981) noticed seasonal and diurnal fluctuation of airspora from barley field. Gaur and Kasana (1981) investigated atmospheric microbial population of Modinagar. Jankibai and Subba Reddy (1981) studied airspora of Vishakhapatnam. Tilak and Bhalke (1981) studied aeromycology at Aurangabad. Narayan *et al.* (1982) observed the atmospheric microbes of Malleswaram market at Bangalore. Agashe (1983) observed the airspora of Bangalore. Babu (1983), Bhosale (1983), Patil (1983), Saibaba (1983) and Wankhede (1983) recorded airspora at Aurangabad.

Mutha Reddy and Ramanujan (1989) studied the aerobiology of Hyderabad (A.P.). Bhat and Rajasab (1988) recorded the airborne fungal spores from Gulberga, Karnataka. Kavishwar (1990) recorded aerobiological studies at Dhulia. Kotwal (1991) observed the airspora over grapevine yard at Nasik. Pandey and Tiwari (1991) conducted an extensive aerobiological survey at Raipur (C.G.). Mishra and Zamil (1991) studied indoor environment fungi from mills of Lucknow. Verma and Chile (1992) studied the seasonality and allergenic behaviour of certain fungi at Jabalpur.

Aeromycological studies over agricultural fields from India : The information on airborne allergenic fungal flora in rural agricultural areas is largely lacking. Adequate information is not available to the bioaerosol researchers regarding the choice of single versus multiple sampling stations for the monitoring of both viable and non- viable airborne fungi. There is no long-term study estimating the ratios of viable and non-viable fungi in the air and earlier studies did not focus on the fractions of airborne allergenic fungi with respect to the total airborne fungal load (Adhikari *et al.,* 2004).

Gadekar (2014) investigates the fungal aero-spora over *Sorghum* crop at Pune and reported that *Curvularia, Cladosporium, Helminthosporium, Cercospora,* smut, rust, *Nigrospor*a and *Alternaria* were the most dominant mycoflora. Common occurrerence of *Chaetomium* spores over jowar fields were investigated by Kavishwar (1990). Most commonoccurrence of *Alternaria* spores over jowar fields were studied by Navi *et al.* (2005) and Kanade *et al.* (2018a). Singh and Banopadhyay (2000) reported *Curvularia* spores were dominant over jowar fields. Sreenivasa *et al.* (2010) noticed common occurrence of *Aspergillus* along with *Sroghum* grains. Karne (2013a) reported 46 fungal spores over jowar fields and out of which 20 types (74.4%) were recorded as pathogenic and 25 types (81.5%) were recorded as allergenic. Patil and Mali (2017) investigated that *Alternaria, Plasmopara, Physarum*, uredospores, *Leptosphaeria* and *Cladosporium* spores were the most common over the *Sorghum* fields. Furthermore they reported that, the spore concentration of Deuteromycotina was found to be dominant. Aeromycoflora over the jowar fields from Barshi area were studied by Patil *et al.* (2016, 2016a) and Patil and Mali (2018) and reported 20 types of Ascomycotina fungi as domina fungal flora during kharif season.

According to Karne (2013a) many plant pathogenic fungi *viz. Alternaria, Puccinia, Cercospora, Helminthosporium, Colletotrichum,* smut spores, *Diplodia, Sclerospora, Stemphylium* and *Fusarium* were recorded almost all round the year. Further reported that 50 fungal spores over wheat fields and out of which 21 types (71.7%) were recorded as pathogenic and 25 types (85.8%) were recorded as allergenic. Badge and Mhatre (2017) studied the airborne fungal spores over some paddy fields in the Ratnagiri district of Maharashtra and recorded that Deuteromycotina contributed highest percentage and lowest percentage contribution was found to be that of Zygomycotina to the total airspora. Nasrin Begum and Sudhendu Mandai (2017) studied the aeromycofloral diversity over a paddy field in Birbhum district of West Bengal and reported the seasonal variation of fungal spores occurred highest in winter season followed by rainy and summer season. Further noticed that *Alternaria* sp. showed the highest percentage of occurrence followed by *Curvularia* sp., *Helminthosporium* sp., *Cladosporium* sp., *Nigrospora* sp., *Aspergillus fumigatus* and *A. niger*.

Bagwan (2010) reported *Aspergillus* species were dominantly occrred from the vegetable market of Udgir. Kumar *et al.* (2013) noticed that, *Aspergillus* sp., *Penicillium* sp. and *Alternaria* sp. spores were most abundant in vegetable market environment of Hapur, Uttar Pradesh. Concentration of air borne fungal spores in main fruit and vegetable market of Agra were studied by Garg *et al.* (2015) and reported *Aspergillus* flavus was found to be most dominant and frequent mould in the aerospora. Frequent occurrence of *Alternaria* was studied by Vijayalaxmi *et al.* (2001) over chilly, Kumar and Kolte (2006) over mustard and Saha *et al.* (2006) over brinjal fields. Lohare and Kareppa (2010) noted that Deuteromycetes dominated all other groups and its mean contribution was 71.76% over onion fields at Udgir (Maharashtra). The most predominant species found in store houses of onion were *Aspergillus niger, A. flavus, Botrytis* sp., *Fusarium oxysporum, Helminthosporium* sp., *Trichoderma* sp., *Mucor mucedo* etc. and from ginger were *A. niger, F. oxysporum, F. solani, F. zingiberi, Lasiodiplodia* sp and *Verticillium thebromae* reported by Juri Devi *et al.* (2010). According to Kapadi and Patel (2019) weather conditions play an important role in seasonal development of many plant diseases in tomato fields (*Lycopersicon esculentum* MilL). Further they reported that the high concentration of air born pathogenic fungal spores were responsible in diseases incidence in tomato crop *e.g.* early blight (*Alternaria solani)*, late blight (*Phytophthora species*), *Fusarium* stem rot *(Fusarium* species).

According to Thakur (2016) the meteorological parameters during monsoon have found to play significant role in determining the spore load in the air over *Phaseolus vulgaris* L. fields from Pune. Furthermore recorded that Deuteromycotina spores have been highest during all the months as compared to other groups of fungi.

Aeromycological investigation over a pomegranate fields at Ahamdpur district were studied by Kadam *et al.*

(2010) and total 61 fungal spore types were recorded and *Ustilago, Cercospora, Helminthosporium, Colletotrichum, Fusarium* and *Alternaria* as pathogenic to pomegranate were noticed. Singh *et al.* (1992) reported fungal air spora over a pomegranate fields from Imphal and concluded that, the diseases appeared in the November, probably due to temperature 25-28ºC. Highest concentration of Deuteromycetes spores (69.98%) to the total aerospora from pomegranate fields of Nashik were reported by Ahire *et al.* (2010). *Acaulopage, Albugo, Mucor* and *Rhizopus* noticed as chief fungal flora over pomegranate fields by Kadam and Khandia (2018). According to Aher *et al.* (2015) in the last several years fungal diseases has become a major concern to the pomegranate (*Punica granatum* L.) growers. Furthermore reported various air-borne fungal diseases of pomegranate like leaf spot caused by *Curvularia* and *Cercospora*, fruit rot caused by *Colletotrichum*, burning of fruits and leaves by *Alternaria alternate*. Deuteromycotina spores *viz. Alternaria, Aspergillus, Cercospora, Colletotrichum, Fusarium, Gloeosporium* and *Helminthosporium* were found dominantly and frequently over pomegranate fields (Kanade *et al.*, 2018a).

Babu (1983) investigated that *Hypoxylon* spores were most common over banana fields at Aurangabad. In Nashik, *Cercospora* contributed 5.27% over the groundnut fields were observed by Sonawane (2013). Kshirsagar *et al.* (2016) reported 58 spores over groundnut fields of Seed district and noticed that Deuteromycotina was dominanted the air spora. Aerobiological investigations were conducted for two consecutive kharif seasons of 2012 and 2013 at Newasa, Dist. Ahmednagar over ground nut fields by Sonawane *et al.* (2017) and reported that *Cladosporium* spore type was found to be the most dominant, followed by smut spores, *Alternaria, Aspergillus* and *Cercospora*.

An aeromycological survey over sunflower filed from Kada, Dist. Seed was under taken by Pathare *et al.* (2010). Furthermore reported that during the period of investigation the spores of *Alternaria* were almost continuously found in the atmosphere and this fungal spore contributed 13.75% width total concentration of 70364/m^3 of air. Kshirsagar and Pande (2012) found the prevalence of spores of *Cladosporium* over sunflower fields from Rajuri. Allapure (2016) recorded 32 fungal spore types from sunflower field in Udgir region and noticed dominant spore type as *Cercospora* (13.22%), *Aspergillus* (9.52%), *Alternaria* (7.34%), *Nigrospora* (7.34%), *Leptosphaeria* (7.16%), rust spores (6.58%), *Cladosporium* (4.23%), *Claviceps* (4.23%), smut spores (4.23%), *Fusarium* (3.29), *Curvularia* (3.23%), *Bitrimonospora* (2.46%) and basidiospore (2.46%).

According to Kanade *et al.* (2018) *Alternaria, Mucor, Aspergillus, Cladosporium, Helminthosporium,* smut spores, conidia, chlamydospores or thallospores were observed as extremely abundant over sugarcane fields. Aeromycological investigation over a sugarcane fields at Ahamdpur district were studied by Kadam *et al.* (2010) and during the investigation total 61 fungal spores types were recorded and *Ustilago, Cercospora, Helminthosporium, Colletotrichum, Fusarium* and *Alternaria* as pathogenic to sugarcane were recorded. Aeromycological survey of air borne fungi over sugarcane fields were done by Nanda and Nayak (2015) at Paducheri (Chennai) and recorded 18 fungal species belongs to 10 genera among the recorded fungi Deuteromycotina members were found as predominant followed by Zygomycotina and Ascomycotina. Singh *et al.* (1992) reported fungal air spora over a sugarcane fields from Imphal and conduded that, the diseases appeared in the November. It was probably due to temperature 25-28°C and occurrence of the smut spores was 16.38%. Occurrence of *Dendryphiopsis* spores over sugarcane fields were reported by Bhagwan (1983) from Nanded. Highest concentration of Deuteromycetes spores (69.98%) to the total aerospora from sugarcane fields of Nashik were reported by Ahire *et al.* (2010). *Acaulopage, Albugo, Mucor* and *Rhizopus* noticed as chief fungal flora over sugarcane fields by Kadam and Khandia (2018).

Cercospora sp., *Helminthosporium* sp., *Ramularia areola* and *Alternaria* sp. reported pathogenic to the cotton crop by Jaganath and Gaikwad (1998) at Ahmedpur, Maharashtra. Bembrekar and Bodke (2013) noticed 17 types of fungal spores belonging to the Ascomycetes over cotton fields during the kharif seasons from Nanded.

CONCLUSION

As fungal spores are microscopic they remain suspended in the atmosphere for a long time and causes number of plants, animals and allergic diseases (Woolcock *et al.,* 2001). Many researchers of aeromycology unanimously agreed with the chief contribution of Deuteromycotina spores in the atmosphere of majority all types of agricultural fields (Kanade *et al.*, 2018a). In India *Alternaria, Rhizopus, Helminthosporium, Aspergillus, Cladosporium* and *Cutvulerie* are allergic fungi and cause various diseases in plants as well as in humans (Shivpuri, 1982). Karne (2011) noticed that *Alternaria, Puccinia, Cercospora*, *Helminthosporium, Colletotrichum* and *Fusarium* were plant pathogenic fungi and found throughout the year over agricultural fields and infects the healthy crop. In Marathwada region percentage contribution of *Helminthosporium* was reported by Vaidya (1990) were 3.07 and by Jadhav (1990) were 2.23 from agricultural fields. Bisht *et al.* (2002) investigated that smut spores were most commonly observed over many cereal fields and grasses. Fungal diseases cause rotting of fruits, spot diseases of leaves and fruits and fruits discolouration etc. Ultimately there is reduction in the prize of the fruit in the market. *Aspergillus* was the most frequent genus along with *Cladosporium, Penicillium* and *Alternaria* spores were also fairly abundant from fruit market environment of Nagpur (Kakde *et al.,* 2001). Therefore, study of aeromycology is utmost important to understand the broadcasting of allergic and pathogenic spores and their successful disease management.

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