**Introduction**

Aerial plant parts harbour hundreds of species of bacteria, yeast and fungi. When we consider that a large fraction of the earth's surface is covered with plants, that leaf surface often represent a substantial multiple of the soil surface area and that leaves and flowers often have complex topographical features on which colonization can occur, the potential population size of microbial association of plants is indeed impressive. Similarly, air is a carrier of numerous micro-organisms, dust and droplets. This is an essential medium for dispersal and inoculum for the micro-organisms inhabiting aerial plant surfaces. A very complex type of relationship exist between micro-organisms, leaf surface and the environment.

The leaf surface in open atmosphere is exposed to continuous air current which carries numerous fungal spores, along with various other microscopic objects both living and non living. A part of these spores is occasionally trapped by leaves through various devices viz hairs and sticky surface etc. Once the spore happens to fall upon a leaf surface some of them finding a suitable micro habitat and try to form colonies. The complicated processes occurring at the surface of the leaves have attracted the attention of physiologist and pathologist.

Geogray and Stedman (1953) studied that deposition of air borne spores on various freely exposed surfaces was much influenced by the type of spore, by the wind spread and aorientation and stickyness of the trap surface. According to Geogary (1971) spores reach the leaf in three ways (1) by dry wind (2) in rain drops (3) in rain splash droplets.

Last, in 1955 gave the term "phyllosphere" to denote the external leaf surfaces of plants, a term analogous to rhizosphere was coined by Ruinen (1956). Prasad and Bilgrami (1969) state that phyllosphere term is used to designate all those organisms (including fungi, bacteria, actinomycetes) which are in some way or the other under the influence of the exposed part of the plant, like leaf, stem, bud, flower and fruit etc. Bessems (1973) considered that the phyllosphere is the environment of micro-organisms on the wet surface and in the space between leaf sheath and stem. It is now accepted that phyllosphere is the environment and phyllosphere should be restricted to the zone near leaves and "Phylloplane" used when referring to actual leaf surface (Kerling (1958), Kendrick and Burgas (1962), Dickson (1965), Kapooria and Sinha(1969) Last and Warren (1972) Sharma (1973), and Mukerji 1974). It is well known that an active population of fungi exist on the
surface of physiologically active green leaves and this has been termed as phylloplane by Kerling (1958). Sharma (1973) states that phylloplane may be defined as the leaf surface medium, where a heterogeneity of micro-organisms grow, reproduce and multiply in dynamic equilibrium with the interacting micro and macro-environment of the leaf itself. The phylloplane is a natural habitat on the leaf surface which represent a heterogenous population comprising of both pathogen and nonpathogen (Laben 1965 Mukerji 1973, Mishra and Tiwari 1976). According to Lindow (2005) the aerial habitat influenced by plants is termed phyllosphere and inhabitate are called epiphytes.

Much of the interest in phyllosphere micro biology has been driven by the need to better understand the behaviour and control of the plant pathogen that are prominent members of this community. The spread of colonization survival and pathogenicity mechanism have been the subject of much research. Plant productivity can be effected by microbes (1) where as other produce phytohormones that have the potential to effect plant development and productivity (2) much less is understood about the identity or properties of numerous non pathogenic microbes that inhabit the phyllosphere. Such colonist apparently play important roles in modulating population size of deleterious microbes and some are being exploited as biological control agent for the disease.

Dickson (1976) has suggested that the phyllosphere and phylloplane fungi are distinguishable in to three categories viz (1) those colonising the available nutrient on the leaf surface (2) those occurring only when there is more tissue damage (3) those penetrating tissues of deeper layers. The first two categories usually consist of saprophytic fungi and the pathogens belong to the last one. It has been reported that Alternaria solani in Brinjal (Shukla 1981) and Alternaria alternata, Colletotrichum capsici, Drechslera australiensis and Drechslera hawaiiensis in chillies (Tripathi 1981) caused leaf disease through their appearance in phyllosphere and phylloplane in association with other non pathogens. Relationship of phyllospheres and phylloplane of the pathogenic micro-organism would be necessary to cause infection and disease in the host.

Aerial parts of the plant serve as the microhabitats for a variety of micro-organisms present in the air spora. The leaf surface accommodates microorganisms by providing a complete ecological niche where the exudates from leaves provide nutrition, moisture, pH and temperature etc. The micro-environment shows fluctuation in time as regards to its total complex. Different plant organs represent specific ecological niches depending upon the nature of their substrate and the micro-organism harboured by them (Sharma and Mukerji 1972, 73, 74a, 74b). On plant surface the microbes are brought by the agency of air. The green leaves exhibit a phenomenon of removing some of the microbes normally carried by wind. Once the leaves unfold a series of complex events follow due to interest between leaf surface exudates and microbes whose spore happen to colonize the leaf (Sharma, Mukarji 1974, Tiwari 1977). In conjunction with the microbial and host metabolism, physical factors (temperature, relative humidity light and air currents) also interact with the ecological niche of the leaf (Sharma and Mukerji 1974a). Generally pathogenic fungi are more common on the ageing parts than young parts (Sahu 1992, 1995, Tiwari 1977).

According to Hudson (1968) the first-colonisers of leaf are usually parasite but their development may be affected by the saprophytic microbial population in the phyllosphere. Phyloospheric microbiology of plants have attracted the attention of many scientist. Kerling studied (1964) in the phylloplane of leaves of rye and strawberry. Dickson (1965) studied the microflora associated with Helimione protulocoides. Last and Deighton (1965) studied non parasitic microbes colonizing green leaves. Sinha (1955) studied microbial complex of phyllosphere and disease control, he also studied the microflora on leaves of Capsicum annum, Solanum melangena, Solanum tuberosum and Lycopersicum esculentum plants. Hogg and Hudson (1966) worked on micro fungi on leaves of Faggus sylvatica. Mishra and Tiwari (1968) studied the plant height as a factor in relation to leaf surface mycoflora of Cassia tora. Kapooria and Sinha (1969) studied the phylloplane mycoflora of pearl millet and its influence of development of Puccinia pennisetiti. Qadeer(1969) studied the fungi associated with the living leaves of gram. Lamb and Brown (1970) studied the non parasitic microflora on leaf surface of Paspalum and Eucalyptus plants. Mishra and Shrivastava (1970 a,b,c) studied on Hordeum vulgare, Triticum aestivum, Oryza sativa, respectively and also studied Hibiscus rosasinensis.

Fungal spores are almost always present in this air but their number and types vary with time of the day, season and the environmental factor etc. Last (1955) studied seasonal incidence of *Sporobolomyces* on cereal leaves. Burrage (1971) studies microclimate at the leaf surface. Gregory (1971) studied the leaf as a spore trap. Sharma (1973b) worked on *Seasamum orientale* and *Gossypium hirsutin*. Diem (1974) worked on barley. Rikhy (1975) worked on *Triticum aestivum*, Collins and Hayes (1976) worked on Norway spruce. Kumar and Gupta (1976a) worked on three varieties of potato over a potato field.


The saprophytic phylloplane flora is of interest from different aspect such as its possible antagonistic action of fungal parasite, its importance for decomposition of plant material after leaf fall, its toxic properties for cattle, its role in nitrogen fixation and its function as a source for being air borne.

The first international symposium held in (1970) at the University of Newcastle at United Kingdom, since that date scientist working in this area and have met every five years in 1975, 80, 85, 90 and 2000. The symposium has continued not only to keep scientist active in the area but they informed their finding and speculation each conference publishing proceedings. The eighth symposium on the microbiology of aerial plant surface (phyllosphere 2005) held in Oxford, United Kingdom 24-27 July 2005. Like its predecessors, this symposium brought together scientist in diverse disciplines providing the sole venue where by phyllospheres microbiology as a whole addressed. Again like its predecessors since 1970 the proceedings of the symposium will be published in a book bringing the important habitat to the attention of the scientific community. This event will bring together researchers in the area of microbiology ecology, plant pathology, mycology, bacteriology, aerobiology, micrometry statistics, plant physiology, biochemistry, anatomy, microbial and plant molecular biology.

The following burning topics of the conference were:-

1. Aerobiology and leaf surface microbiology.
2. Spatial distribution and biofilms.
4. Biological control and pathogenicity.
5. Biodiversity and population genetics of phyllosphere communities.
6. Leaf colonization and dispersed.

Aerobiology is the multidisciplinary environmental science which deals information from plant science, science of weather forecasting, palaeontology, air pollution, geography, chemistry, remote sensing etc. The term aerobiology came into use during 1930s as a collective term for studies of air spores like
air borne fungal spores, pollen grains and other microorganisms. Gregory 1952 suggested the term "Air spora" to describe the fungal and pollen flora.

Aerobiology is applied significance which is a synthesis of human, plant and animal pathogen, immunology, ecology, microbiology, biodeterioration etc. Aerobiology involves today man made and natural air pollution, particularly those affecting biological systems as a matter of fact, thus aerobiology deals which gaseous pollutant viz, $\text{SO}_2$, $\text{NO}_2$, $\text{CO}_2$, Ozones, air borne heavy metals and the particularly , bacteria, fungal spore, pollen grains, plant hairs, trichomes, minute seeds and their parts, algal fragments and other microscopic component. The size range of air borne components in aerobiology, ranges from 0.0001 micrometer in smokes to 1 cm in case of air born insects.

The aerobiological pathway includes transport, deposition and impact of these organisms on plant and animals including human beings. The frequency of allergic disease phytopathological impact and crop epidemiology assume much higher dimension in our country.

The environmental factors also affect the micro-organism like temperature, altitude, relative humidity, rain fall, wind velocity. Many plant pathogens are also transported from one field to another through air and the spread of many fungal disease of plants can be predicted by measuring the concentration of air borne fungal spore. India is not only a subcontinent of rich biodiversity but also has various geoclimatic zones. In a given zone there are experienced marked seasonal fluctuation in temperature and relative humidity. Consequently the source and nature of spores differ in different areas and in different seasons of a given area. The microbial spore get transferred in to the atmosphere through leaves of the plant during hot and dry days. High temperature, low lying lands, relative humidity and dynamic wind are favourable for dispersing microbes. The positive energy in the leaves is supportive in dispersing the microbes having negative energy. Raindrops settles the microbes present in the air. These drops disperse the microbes present on the sick plants to healthy plants. The rain drops 1-2 mm has too much energy proceating the spore surviving up tp 60-90 minute in the wind.

The defeat of German army during first world war by British has been attributed to the famine on the wind. This indicates the magnitude of the impact of these pathogens on the wind. The concentration and variety of air spora often vary widely depending on the type of vegetation in the surrounding area, season, climate and other natural and man made phenomenons (Ganguly 1992).
In 1951 Jacob elaborated the term aerobiology to include dispersion of insect population, fungal spores, bacteria, virus molds and pollen i.e. all forms of life both plants and animals that are borne and transported partially or wholly by atmosphere. I.U.B.S. has defined the aerobiology as a scientific discipline focussing on the transport of organism and biologically significant materials of the atmosphere. In 1997 Edmonds defined the aerobiology as a scientific and multidisciplinary approach, focussing on the transport of organisms and biological significant material.

In 1883 Miquel started experiments of aerobiology and gave the technique to analysed microbiol population. Meier et al. (1933) gave the term aerobiology. Ehrenberg (1872) first time published his work on composition of air spora (Microorganism).


In the present day, International Association of aerobiology are working in various aspects of aerobiology. International Advisory Board of aerobiology is also working at it. Board members are from all over world. All over world many Aerobiological Associations have emerged. In Europe the first created Nordic Aerobiological Federation as N.A.F, B.F.A. from British, F.A.A., from French, A.I.A. from Italy, (PAAA) from America, I.A.S from India.

These associations give the latest information and the increasing number of scientists to compare the procedures, evaluate ideas, clear-up and deepen the fundamental advanced aerobiology. The association specially through national and international conferences increases the flow of information in the subject among its members, conferences and symposia also flavour the otherwise cold reason of science with a tinge of personalities and scientist working in the particular field. Through these associations, mental climate is created in the people for the receptivity to more complicated scientific achievements which could benefit them.
India can claim to be one of the pioneer countries in aerobiological research, as the first publication appeared in 1873 by Dr. Cunnigham who reported the occurrence of airborne bioparticles in Calcutta Jail. After a half century this aeromycology work was initiated by Mehta (1952). He studied the dissemination and spread of wheat rust spores. Padmanabhan (1953) studied the occurrence of conidia of *Helminthosporium oryzae* responsible for the famous Bengal famine, in the air over paddy field at Cuttak. Mehta studied the uredospores of three rust of wheat and barley at 62 location in country by kites, aeroplanes and aeroscope. Rajan et al. (1952) at Kanpur. Kerla and Dumbray (1957) at Pune they were also pioneer workers of air borne fungi.

Intensive studies on aeromycology, in India can be said to have started with the work initiated by Sreeramulu at Visakhapatnam in (1959) using hirst volumetric spore trap. Subsequently two new centers one at Aurangabad and the other at Mysore came in to existence while the former was initiated by Tilak in (1966) the latter was started by Ramalingham in (1968). Aurangabad holds a unique place in the development of aerobiology in India and the credit goes to Tilak who trained a large number of students, who in tum established several new centers of aerobiological research. After retirement of Tilak aerobiological studies at Aurangabad are being continued by Pandae. Aerobiological studies were initiated during mid seventies at the Bose institute Calcutta by Chanda and Agashe. Chanda and his students carried out extensive aerobiological studies in the eastern part of India. The biozones selected for study include places located in the foot-hills of Eastern Himalayas and also places of high altitude. Currently Bhattacharya is continuing aerobiological work at Bose Institute, after the retirement of Chanda since its inception in (1973) Bangalore centre has been involved in conducting aerobiological studies in relation to allergy. Three other centres came in to existence more or less at the same time. These were Allahabad (Nautiyal and Midha), Nagpur (Chitaley, Patil), Gorakhpur (Misra) and Lukhnow (Vishnumit) and Khandel wal. After the Sreeramulu in (1974) in aerobiological work at Visakhapatnam is being continued by Subba Reddy and Janki Bai. Aeromycological studies at Madras were started by Vittal with volumetric sampler in (1976). The earlier studies were reviewed by Nair and Sreeramulu. Many centers came up during eighties and these include Gwalior (Jain) Jabalpur (Oomachan and Verma) Santinekatan (Mandal and Bhattacharya) Manipur (Singh Bodhgaya (Misra) Gulberga (Rajasab.) Trivandram (Ravindran), Raipur (Tiwari et al).


Many workers studied other fields of aeromycology like cave library, poultry, hospital, bakery. Sree ramulu (1961) studied concentration of fungus spores in the air inside a cattle shed. Tilak and Kulkarni (1972) studied the microbial content of air inside and outside the cave at Aurangabad. Rati et al. (1980) studied air spora of a poultry shed at Maysore. Tilak and Vishwe (1975) worked...


Several books have been published on various aspects of aerobiology, Nilson (1973) Tilak (1982, 87, 89), Agashe (1994) Tilak et al. (2005).

Exudation of nutrients through the cuticle of leaves and young shoot is not so copious as that through the uncuticularized epidermis of young roots. For this reason phyllosphere population of microorganisms are smaller than those of root surface. Another factor which reduce size and variety of leaf surface population is the occasional low relative humidity of the atmosphere, which does not favour infection by fungal pathogens.

The surface of the shoot secretes/excretes certain exudates which may directly effect the surface micro-organisms some of which may be pathogenic some of the surface microorganism may cause the production of "phytoalexine" in the host and bring about change in the reaction between the host and parasite. Kerr and Flentje (1957) showed that the surface microflora is influenced by the host on which it occurs due to the varying nature of exudates. Kovacs and Cucchi (1964) studied the effect of vine potato sugarbeet and apple leaf exudates on Aspergillus niger. Kovac and Szeoke (1956) showed that exudates from several plants could either decrease or increase the germination of Botrytis, "Ascochyts and puccinia" spores depending upon the exudation concentration. Leaf exudates contain a variety of chemicals, some of which are stimulatory to particular microorganisms, while others are inhibitory. Sharma and Sinha (1971) studied the effect of the leaf exudates of sorghum varieties varying in susceptibility and maturity on the germination of Colletotrichum graminicola causing anthracnose of the host. Grover and Batra (1967) studied the effect of a fungicide antagonist in leaf exudates. Hislop and Cox (1969) studied the effect of captan on the non parasitic microflora of apple leaves. Dunn et al. (1971) studied the effect of glucose in leaf exudates upon the biological activity of some fungicides. The development of phylloplane mycoflora is not only under the influence of the host, but is also subject to its
The microorganisms themselves also produce self-inhibitory and self-stimulatory substances, bringing about a great influence on their own germination. Kapooria and Bhadur (1966) studied the production of self-inhibitory substance by germinating uredospores of *Puccinia purpurea*. Sinha et al. (1967) studied the self-inhibition and self-stimulation of uredospore germination in case of *Puccinia pennisetii* and *Uromyces ciceris-arietini*. Bhadur and Sinha (1966) studied the leaf exudates of gram (*Cicer arietinum*) and their effect on the germination of uredospore of *Uromyces ciceris-arietini*. In 1970 they studied the influence of leaf exudate of gram on spore germination of *Uromyces ciceris arietinti*. Dickinson (1953) was the first report that the germinating rust spores produce a volatile substance which, under certain conditions inhibit germ tube elongation. Allen (1955) studied the phenomenon of self inhibition in greater details in *Puccinia graminis* var *tritici* Rox. Le Roux and Dickinson (1957) showed self inhibition of germination is uredospores as well as in aeciospores of *Puccinia sorghi*. Several hosts are known to contain preformed chemical compound which are inhibitory to pathogens and are termed "Phytoncides". Some of these are volatile and influence the micro-organism present on the surface of the host plants. Nikitiana (1961) studied the phytoncide in leaves and fruits of apple and pear varieties. Tokin (1960) called the phytoncides as destroyers of microbes. Shephed et al. (2005) worked on phylloplane of tobacco are defensive proteins on aerial surface.

Apart from these self inhibitory and self stimulatory problems the phylloplane micro-organisms have also an interacting influence. In nature interactions are known to take place between pathogenic and saprophytic microbes as well as within the pallogenic themselves. Heuvel (1971) studied the antagonisms between pathogenic and saprophytic *Alternaria* species on bean leaves. McBride (1971) studied the microorganism interaction in the phyllosphere of larch. The early infection of leaf blade by *Helminthosporium sativum* was found to inhibit the later development of *Septoria passerinii* in the leaf sheath of barley. (Morton and Peterson, 1960), Wibe and Morton, (1962). Bhatt and Vaughan (1963) studied the interrelationship among fungi associated with strawberries in Oregon. Chu-Chaw (1970) studied the biological interactions on the host surface influencing infection by *Botrytis cinerea* and other fungi. Barnes (1971) studied the inhibition of *Erysiphe Polygonum* on clover surface by saprophytic spore. Bomberg (1931) showed that a bacterium isolated from corn when mixed with smut spore of *Ustilago zeae* reduced the infection rate of corn and inhibited the germination of chlamydospires. Last (1955) reported that in the beginning *Sporobolomyces* colonies were isolated from the entire surface of the leaves. Yuen et al. (2001) bean
rust biological control using bacterial agents, Zhan and Yuen (1999) studied Biological control of *Bipolaris sorokiniana* on tall fescue by *Stenotrophomonas maltophila* strain. Weindling (1934) noted that *Gliocladium fimbriatum* was an active antagonist against *Rhizoctonia solani* and some other fungi. Leben (1964) noted that bacterium obtained from cucumber leaves is able to reduce the incidence of the anthracnose pathogen *Colletotrichum lagenarium*. Mercier and Lindow (2001) studied field performance of antagonistic bacteria identified in a novel laboratory assay for biological control of fire blight of pear. Braun et al. (2000) studied Biological control of *Pseudomonas syringae* the causal agent of basal kernel blight of barley by antagonistic *Pantoea agglomerans*. Antagonism properties also studied by Singh and Sinha (1962) studied the micro-organisms of some vegetable surface and tissue and their antagonism. Agarwal and Gupta (1966a) studied the micro-organisms antagonistic to *Alternaria solani* pathogenic to chillies. They also studied the effect of *Streptomyces griseus* (Krainsky). Waksman et al. Henriei on the population of *Colletotrichum capsici* (syd). Butler and Bisby, present on the surface of host chilli plants (1966b). Fokkema (1973) noted the role of saprophytic fungi antagonism against *Drechslera sorokiniana* (*Helminthosporium sativum*) on agar plates and on rye leaves with pollen. Fokkema and Lorbeer (1974) studied the interaction as between *Alternaria porri* and the saprophytic mycoflora of onion leaves. Fokkema and Meulen (1976) studied the antagonism of yeast like phyllosphere fungi against *Septoria nodorum* on wheat leaves. Simard et al. (1958) showed antagonism between the apple scab fungus pathogens, *Venturia inaequalis* and three *Penicillium* isolated found on the dead leaves of apple. Newhook (1951, 57) isolated organisms antagonistic to *Botrytis cinerea* from lettuce and tomato.

*Curcuma longa* is one of the most important and ancient spices of India. It has been highly esteemed as a condiment dyestuff and medicine. It is now a commercial crop of India.

The present investigation was carried out with the following objectives:-

1. Determination of the periodic composition of the leaf surface mycoflora.
2. Periodic composition of air spores.
3. Correlation of their periodic variation.
4. Studies on the colonisation pattern frequency and abundance of the leaf surface mycoflora.
5. Studies on the colonisation pattern frequency and abundance of the air mycoflora.
6. Effect of leaf tissue sap leaf exudates on the leaf surface mycoflora.
7. Studies on the mutual interaction amongst leaf surface fungal organisms.