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The present aerobiological study in Bangalore has been undertaken on account of the relatively high incidences of allergic disorders, among its population, with airborne fungal spores being recognized as one of the significant offenders. High fungal counts, in the air, account for increased allergic symptoms as reported by Flannigan et al. (1990). During the present study, over 150 types of airborne fungal spores have been recorded.

According to present investigations, fungal spores comprised a large portion of the aerospora. In the present studies, the ratio of occurrence of pollen to fungal spores in the air was 1:40. However, a high ratio of 1:56 and 1:27 were recorded by Agashe et al. (1988,1999) in Bangalore. Similar findings have been reported - in England, 1:75 by Hamilton (1959); in Parbhani, 1:8 by Talde (1969); 1:100 in Aurangabad by Tilak and Srinivasulu (1967); 1:4 in Ankapalle and 1.7:10 in Visakhapatnam by Subba Reddi, (1970). Thus, there seems to be no consistency in the ratio of pollen-to-fungal spores in air, either in different places or even during different years in the same place.

6.1 PREDOMINANT TYPES OF FUNGAL SPORES

During the current study, the most predominant airborne fungal spore types were Cladosporium sp., Smut spores, Nigrospora sp., Alternaria sp., Helminthosporium sp., Curvularia sp., Ascospores, Aspergillus sp., Penicillium sp., Basidiospores and Uredospores. Similar reports, where these spores constituted the major types, were published by Agarwal et al. (1969); Bhati and Gaur (1979); Subba Reddi (1970); Mullins (1974); Sinha et al. (1981);
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Vittal and Krishnamoorthi (1981); Chakraborty et al. (2000); Misra and Mandal (1994); Satheesh and Rao (1994); Singh and Pande (1994); Agashe et al (1999); Berman (2000) and Tripathi (2001). The majority of the predominant fungal spores were belonging to the Deuteromycotina group; the same has been recorded in the findings of Ayachi et al. (1992).

According to the present study, Cladosporium sp. spores were recorded as one of the most predominant types - reaching a maximum in the months of April, May and September. Cladosporium sp. alone, were recorded with a highest representation (78.55%) of the monthly average total in May and 20.2% representation throughout the year.

In the same way, the dominance of Cladosporium sp. spores have been recorded in different parts of the world by - Hamilton (1959); Kramer et al. (1959b); Shapiro et al. (1965); Ramalingam (1971); Subba Reddi (1974); Bhati and Gaur (1979); Vittal and Krishnamoorthy (1981); Chaubal and Kotmire (1982); Tilak (1982); Agashe et al. (1983); D'Amato et al. (1984); Hawke and Meadows (1989); Chari et al. (1994); Levetin (1995); Lipiec et al. (1998) and Berman (2000).

According to the present studies, Periconia sp. followed Cladosporium sp. in the order of predominance with a maximum record in the months of November, December and January. Periconia sp. spores alone were recorded with a highest representation (24.56%) in the month of December.

In the present investigations, Alternaria sp. spores were one of the predominant types - reaching a maximum in the months of April, May and
December. *Alternaria* sp. spores alone were recorded (10.94%) with a highest monthly representation in April.

However, Sandhu *et al.* (1964); Agarwal *et al.* (1969); Gaur and Kasana (1981); Singh and Babu (1983) reported that in a few incidences, *Alternaria* sp. replaced *Cladosporium* sp. in order of predominance.

However, Basidiospores forming a major constituent of the aerospora has been recorded - in England, nearly equaling *Cladosporium* sp. in number (Adams, 1964; Gregory and Hirst, 1957; Gregory and Sreeramulu, 1958; Hamilton, 1959; Lacey, 1962) and in the US (Kramer *et al.*, 1959a; Pady and Kramer, 1960a, 1960b).

In addition, lower concentration of fungal spores belonging to species of *Corynespora* sp., *Torula* sp., *Pithomyces* sp., *Trichoconis* sp., *Epicoccum* sp., *Cercospora* sp., *Spegazzina* sp., and *Pleospora* sp. were also recorded.

### 6.2 SEASONAL CORRELATION

Unlike airborne pollen, fungal spores do not have specific seasons and are found throughout the year - but they exhibit diurnal, seasonal and annual variations. The same has been observed by Subba Reddi (1970); Ramalingam (1971); Vittal *et al.* (1981); Tripathi *et al.* (1982); Agashe *et al.* (1983); Singh and Babu (1983).

Although the fungal spore counts increase during the winter months, there are seasonal peaks for some of these genera in the months preceding summer and winter - in response to changes in temperature and relative humidity. In
the present studies, the highest monthly total count of fungal spores was recorded in the months of May, November and December, that is in summer and winter, the same has been reported by Singh and Pande (1994) too.

This may be due to the abundance of a few dominant types of airborne fungal spores. According to Ingold (1965), there are some fungi that have a saprophytic habit and an ability to grow on different substrates. These fungi are also aided in their dominance by an ability to produce enormous number of spores, which are adapted for passive dispersal.

Mullins (1974) reported the highest count in October, November and March; Bhat and Rajasab (1991) recorded maximum numbers during September to March; Satheesh et al. (1994) in November and December; Agashe et al. (1999) encountered high number of spores during April to July.

Accordingly, the lowest count of airborne fungal spores was in the month of March. However, Agarwal et al. (1969) reported the lowest counts in July-September and November-December; Mullins (1974) in January and June; Singh et al. (1987) from July to October; Satheesh et al. (1994) in May; Sateesh et al. (1997) in November to December; Agashe et al. (1999) in August and September.

In the present studies, the most predominant aerospora that accounted for the abundance of airborne fungal spores were Cladosporium sp., Alternaria sp., Smut spores, Nigrospora sp., Helminthosporium sp., Curvularia sp., Ascospores, Aspergillus sp., Penicillium sp., Basidiospores and Uredosporcs.
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In the current study, the highest spore density belonging to Cladosporium sp. were recorded in summer and rainy seasons. The highest (78.55%) was in summer. However, Agarwal et al. (1969) recorded the maximum number of Cladosporium sp. in rainy season and winter; Bhati and Gaur (1979) in summer; Mallaiah and Rao (1980) during winter; Ramalingam (1971) in rainy season and winter; Subba Reddi (1970) in rainy season and winter; by Sinha et al. (1982) in winter season; Raha and Bhattacharya (1994) in winter; Manjunath and Agashe (1994) recorded in summer and rainy season; Chakraborty et al. (2000) during rainy season and Lipiec et al. (1998) also in the rainy season, with the highest concentration exceeding a level of 20,000/m³.

The total monthly average numbers for spores of Alternaria sp. were higher in summer (10.94/m³) and winter (8.20/m³). According to the findings of Bhati and Gaur (1979), the highest counts for Alternaria sp. was in summer; Gaur and Kasana (1981) recorded it in rainy-winter season and summer-rainy season; Lipiec et al. (1998) recorded it in rainy season; Manjunath and Agashe (1994) recorded in summer and rainy season.

In the present studies, Smut spores have been trapped highest in winter (22.35%) and lowest in summer (4.05%). However, Agarwal et al. (1969) recorded highest catch of Smut spores in rainy season; Bhati and Gaur (1979) in summer; Ramalingam (1971) during winter and rainy season; Tilak et al. (1981) during winter. The prominence of this spore has been seen to vary over different years, being closely related to the abundance of the local sources; i.e. grasses and cereals.

Ascospores in the current investigation were highest in October (14.25%), i.e. the rainy season. Ramalingam (1971) has also noted an increase in
concentrations of ascospores in the rainy season; Tilak et al. (1981) recorded a maximum during winter; while Vishnu-Mittre and Khandelwal (1973) reported their peak in summer.

In the present studies, basidiospores reached their maximum in October (17.52%), rainy season and November (10.40%), pre-winter. Accordingly, Ramalingam (1971) has also recorded the highest concentrations of basidiospores in the rainy season. However, Subba Reddi (1970) recorded them at their highest in summer.

The highest counts of Helminthosporium sp. were recorded during winter, summer and rainy seasons; and Curvularia sp. during rainy season, respectively. While Subba Reddi (1970) found it between winter-summer for Helminthosporium sp. and from rainy-winter for Curvularia sp., Ramalingam (1971) recorded the highest numbers of Helminthosporium sp. between summer-winter and Curvularia sp. increased in winter and rainy seasons.

It is known that the number of fungal spores in the atmosphere of a given locality alters quantitatively, as well as qualitatively, with variations in the climatic conditions associated with seasonal changes.

A critical analysis of the maximum-minimum occurrences and the peak of various allergenically significant airborne fungal spores as detailed above, clearly indicate that there are great variations.

Weather factors - particularly the microclimates of the region and vegetation patterns have a great impact on the growth and proliferation of the fungi. They also affect the production, liberation and dissemination of fungal spores.
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in the atmosphere. These factors certainly have an influence on allergic manifestations brought about by fungal spores.

6.3 CORRELATION WITH METEOROLOGICAL FACTORS

The fact that changes in weather conditions affect spore contents of the atmosphere, both qualitatively and quantitatively, has long been recognized. As early as 1872, in the course of his microscopic examinations of the air, Cunningham (1873) observed how rainfall brings about a short period change in atmospheric spore contents.

In the present studies, when the average maximum temperature increased to 26-28°C, the spore taxa and total spore counts reached their maximum (Graph 7 A and B). A further gradual rise in temperature to 29-30°C had a negative effect on the total spore taxa and spore counts. When the average maximum temperature increases to 32-33°C, favorable conditions for fungi to produce spores are created. During these favorable conditions in the present investigations, the total spore counts went up to 500/m³.

During the present study, an average minimum temperature of 16°C had a favorable influence on the total number of taxa and spore counts. However, there was a sharp decrease in total spore taxa and spore counts with an increase in the average minimum temperature reaching up to 20°C. A further increase in the average minimum temperature affected the spore taxa negatively and total spore counts positively (Graph 8 A and B).

From the results of the current study, on correlation of average maximum and minimum temperatures to total spore taxa as well as spore counts, it is
clear that there is an optimum temperature range that is favorable for fungal growth and spore production. This finding supports the findings of Eversmeyer (1973); according to him the sharp decrease in spore concentrations were probably due to the reduced spore production when temperatures increased beyond an optimum suited for fungal growth. The differences in the counts corresponding to the differences in temperatures have been clearly illustrated in the present findings.

During the present investigation, the Deuteromycotina group contributed the most to the summer month's aerospora; i.e Cladosporium sp., Alternaria sp. Since Basidiomycotina and Ascomycotina do not discharge their spores in dry weather conditions, they do not contribute to the total concentration of fungal spores during summer.

In the current studies, the average humidity exhibits an optimal region. The taxa and spore counts get affected adversely when the average humidity rises beyond or falls below this optimal range. When average humidity was low or high, there was a decrease in the diversity and density of spores. However, when the humidity was between 50-65%, there was a noticeable increase in diversity and density of spores (Graph 9 A and B). Based on these results of the present studies, it can be said that for optimal fungal growth and fungal spore production a particular range of average relative humidity should exist. However, this might not be the single reason for the rise in the spore counts and taxa as other weather parameters can also contribute to this. Agarwal and Shivpuri (1974) have also found, that relative humidity does not affect the spore concentrations independently in the atmosphere to a significant level.
In the present investigations, the result shows that the total monthly rainfall has an effect on the spore taxa and total spore counts (Graph 10 A and B). An increase in rainfall decreases the spore taxa and total spore counts. The low diversity and density of fungal spores in atmosphere during rains according to Mishra and Kamal (1971); and Eversmeyer (1973); is because of the rain, washing down most of the fungal spores.

In the present studies, there's a marginal increase in the density and diversity of spores just after the rains, in the month of October (Graph 10 A and B). This increase was mainly due to the presence of ascospores. Since the colored ascospores, non-septate and septate, were usually recorded at their maximum diversity following the rains. However, according to Tilak and Srinivasulu (1971), the peak concentration of ascospores was in the month of September - associated with heavy rainfall and high percentages of relative humidity; by Levitin and Horowitz (1977), ascospores are typically present in highest concentration during rainy periods.

It has also been accepted that rainfall has an immediate impact on the ascospore release, this is supported by the results of Sreeramulu and Ramalingam (1964, 1966), the rains led to a spurt of ascospores in atmosphere. According to Ingold (1953), this was due to the fact that ascospores are released by hydrostatic pressure.

According to the results obtained during the present studies, they show that low wind speeds have a positive effect and when wind speed increases it had a negative effect on the total spore taxa and total spore counts (Graph 11 A and B). This is caused due to the wind dislocating the spores from their sources of origin and distributing them across the atmosphere.
In the present studies, an increase in the average cloud cover had a negative effect on total spore taxa. When the average cloud cover increased the total types of spores decreased (Graph 12 A). However, an optimal cloud cover between 4-6 octas has a positive effect on the density of spores (Graph 12 B). Anything lower or higher than this optimal average, affects the density of spores negatively.

6.4 BANGALORE MOLD WATCH

For the first time in Asia, a regular mold-monitoring graph along with comments was published in mass media and made available to the general public. This effort spanned over two years and received rave reviews and enormous interest in the aerospora of our region. It was appreciated by discerning audiences like clinicians and the general public as well. There were lots of interactions about the results of the 'Bangalore Mold Watch' with patients, allergy specialists and the general public. In view of this alone, it would be a viable option to continue this effort in the future.

This interest contributed to the need for a spore calendar that can show the prevalence of allergenic spores across different seasons in our region. As the distribution and density of aerospora varies from region to region, having different meteorological conditions, each region becomes almost unique in its composition of aerospora. This made it necessary for producing a separate fungal spore calendar for the Bangalore region as a follow-up to an earlier effort, Agashe and Vidya (1999). This would add to our existing knowledge-base on the allergenic fungal spores of Bangalore region.

There's also a need for an atlas, illustrating the different types of fungal spores found in our region. Hopefully, this first step would lead towards an
active effort in trying to identify different fungal spore types of our region by the use of images. The monitoring of the aerospora becomes more important and is vital in controlling allergies in our region. This effort should encourage future researchers to continue this monitoring activity.

6.5 PREDOMINANT TYPES OF FUNGAL COLONIES

The major types of fungal colonies recorded during the present investigations were *Alternaria alternata*, *Cladosporium herbarum*, *Aspergillus fumigatus*, *Aspergillus niger*, *Aspergillus oryzae*, *Cladosporium cladosporioides* and *Penicillium glabrum*. The same have also been recorded by Mullins (1974); Khandelwal et al. (1988); Verma and George (1997); Pugalmaran and Vittal (1999). *Cladosporium herbarum* was the most dominant fungal colony in the findings of the present investigation. The same was reported by Siva Sankara Rao (1986).

*Aspergillus* sp. spores were the most dominant fungal colony in the present studies. The same was reported according to Kumar et al. (1994), Nigam (1997) and Shrivastava (1994). *Aspergillus niger* was the most common type. This was also found to be predominant in Kansas by Kramer et al. (1960a), in Calcutta by Sinha et al. (1984), in Madras by Vittal and Ponnusamy (1982). But, *Aspergillus fumigatus* was reported to be dominant at Cambridge (Hudson, 1969); *Aspergillus nidulants* at Mysore (Rati and Ramalingam, 1976); *Aspergillus flavus* at Barcelona (Calvo et al., 1980).

In the present studies, 1822 number of colonies were isolated comprising of 31 fungal species. Agarwal and Shivpuri (1974) obtained 29605 colonies (112 types); Bhati and Gaur (1979) isolated 7278 colonies (30 types) and Kumar et
al. (1994b) isolated 3673 colonies (142 types); Vittal and Ponnusamy (1982) recorded 699 colonies (48 species).

The highest numbers of fungal colonies were isolated in January – February, April and September; with the lowest in October-November. However, Ramachandra (1998), reported highest in February and the lowest in July and October. Apart from *Cladosporium* sp. and *Aspergillus* sp., the other fungi that were observed at low frequencies: *Dreschlera graminea, Penicillium glabrum, Curvularia lunata, Alternaria alternata, Monilia* sp., *Nigrospora sphaerica* and *Pestalotiopsis disseminata*.

In the present studies, the maximum numbers of fungal colonies were isolated when two peak periods were observed in incidences of the fungal spores. The major peak period was in January-February (winter), when there was a rise in the moisture levels of the atmosphere. The other major peak period was seen in April and September with the onset of the harvesting period, when the temperatures get relatively higher. These conditions are suitable for the growth of fungi. Simultaneously, the dead and dried plant residues serve as a suitable substrate for fungal colonization and fungal growth. The vegetation also got enriched due to the germination of seasonal herbs and crops. All these conditions combined together make it potent for fungal growth.

In the present investigation, there were considerable variations in fungal colonies. This was probably because of the loss of viability of spores, due to long distances of travel, irradiation and desiccation. Considerable decrease of fungal colonies was seen in October-November. However, according to Chautbal and Kotmire (1982), a marked decrease in the total number of spores is seen during summer when the temperature is maximum and humidity minimum. Similar decrease is continued during the rainy season when, though the
relative humidity is maximum, the rainfall has a cleansing effect in the atmosphere.

### 6.6 SOURCE OF FUNGAL SPORES

The conditions during the post-rainy and winter seasons were most favorable and the maximum airborne fungal species were recorded during this period. Particularly the temperature, moisture and adequate food substrates encouraged fungal growth.

In the post-rainy months, dead and decaying materials together with the soil provide an ideal habitat for fungal growth. During the winter months, plant debris is the primary parent stock for aerospora, with the soil playing a secondary role. A few parasitic forms also find their way to the air from different hosts (Plate 13).

The parasitic forms also grow widely on different crops and wild plants during this part of the year, when the vegetation is quite rich. The seasonal grasses and other herbaceous plants dry and decompose in the winter season, when the moisture level and temperature are favorable for decomposition. These substrates provide ample opportunity for the saprophytes to colonize and multiply, which later on, after dissemination, make the atmosphere considerably richer.

The conditions are different in summer, when the temperature is very high and the moisture - very low. The dead materials, in absence of sufficient moisture, do not decay in profusion. This makes it inconvenient for the growth of fungi on them. The localities are also poor in the seasonal herbs.
Photographs of source of the airborne fungal spores.

1. Parasite mushroom on tree bark.
2. Infected stem of the tree.
3. Leaf litter.
4. Infected leaf.
5. Infected leaf.
6. Infected leaf.
and crops that can harbor the parasitic forms. In summer, the major contribution is made by Cladosporium sp. and Alternaria sp. spores. They are prevalent on both living and dead plant matter, requiring only a suitable temperature range and low moisture levels. The wide prevalence of these forms on various substrates with their heavy spore spawning habit, accounted for their dominance in the summer months.

### 6.7 ALLERGIC FUNGAL RHINOSINUSITIS

In the present investigations, fungal cultures were derived from nasal secretions. The same was observed by Cody (1994); Ponikau et al. (1999). Among these fungal colonies Aspergillus fumigatus and Candida albicans were the most predominant. The same was reported by Aher et al. (2000); Aspergillus fumigatus by McCann et al. (2002). However, Cody (1994) found Dematiaceous fungi to be the most predominant type; Schubert et al. (2000, 2001) found Bipolaris spicifera to be the most prevalent fungus; Matsuwaki et al. (2001) reported a case of allergic fungal sinusitis (AFS) caused by Penicillium sp. and Cladosporium sp.

By nature, the Candida yeast is endogenous to humans from birth. They cause cutaneous, subcutaneous and disseminated fungal infections. Aspergillus sp. spores are widespread as they can adapt to a wide range of environmental conditions and their heat-resistant conidia provide a good mechanism for dispersal.