



Fungal spores are an important component of library air

Alka Singh^a, Meenakshi Ganguli^b, A.B. Singh^{*a}

^aAerobiology Laboratory, Centre for Biochemical Technology, Delhi University Campus, Mall Road, Delhi 110007, India

^b26 Shamlu Marg, Bhopal MP, India

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Abstract

The airborne fungal spore types were studied in different libraries in Delhi, using an Andersen sampler and a Burkard personal sampler, for culturable and non-culturable fungi respectively. The concentration inside the libraries, before and after the agitation of books, were compared with outside air. The major contributors to the library air are *Cladosporium*, aspergilli/penicillia, smuts and *Alternaria*, varying from 50 to 14%. Some fungi (*Cladosporium*, *Alternaria*, smut, *Penicillium chrysogenum* and *nigricans*) showed seasonal occurrence, corresponding to their occurrence in the extramural environment. Aspergilli/penicillia, *Drechslera*, *Curvularia* and *Aspergillus flavus* had a significantly higher concentration ($P < 0.01$) inside the library, and recorded a significant increase in concentration after agitation of books. Air-conditioned libraries have low fungal spore concentrations, as compared to naturally ventilated libraries.

Keywords: Aerobiological survey; Library air; Fungi

1. Introduction

Fungal spores are a major component of indoor as well as outdoor environments and act as important biopollutants of working environments where the organic materials are conducive for fungal growth. Libraries have volumes of such suitable substrates in the form of old papers, binding fabrics, glue, dust and air coolers. Library workers suffer from allergic rhinitis and bronchial asthma while handling old books and periodicals (Aas, 1972). The cause could be dust or its constituents which settle on books and shelves. The importance of the microbial flora in the libraries of the world has been recently reviewed by Gallo (1993). However, most of the research done pertained to the deterioration of books.

In our previous study (Singh et al., 1990) we reported the prevalence of culturable fungi inside the library, and that in comparison with control air and the non-culturable forms were unrepresented. The present study thus intended to investigate the seasonal incidence of

culturable and non-culturable fungal spores in libraries as compared to outside air, and the change in their concentrations before and after agitation of books.

2. Materials and methods

2.1. Aerobiological sampling

The V.P. Chest Institute library was selected for carrying out the aerobiological investigations over a period of one calendar year from January to December 1990. Samples were collected at fortnightly intervals using an Andersen six-stage sampler (Andersen, 1958) and Burkard personal slide sampler (Burkard Manufacturing Co., UK). Both samplers are volumetric. The samplers were operated for 10 min before and after the agitation of books and periodicals. Simultaneously, samples were also collected just outside the library to act as a control. Sabourauds agar media and safranin stained glycerine jelly were used for trapping the fungi in Petri dishes and slides, respectively.

The exposed Petri dishes were incubated at $27 \pm 2^\circ\text{C}$ for 2–3 days. The colonies obtained were identified and counted. Glycerine jelly coated microslides were

* Corresponding author.

mounted and scanned under a Zeiss (Axioscope) microscope for the identification and counting of the fungal spores trapped. The counts were expressed as number per cubic meter of air sampled.

Besides regular sampling at the V.P. Chest Institute library, additional samples were also collected from five other libraries: the British Council Library (BCL), All India Institute of Medical Sciences Library (AIIMS), Delhi University Central Library (DCL), Delhi University Science Library (DSL) and National Medical Library (NML), all located in the Delhi area. Only culture plate sampling was carried out, using an Andersen sampler. The sampling times and procedure were the same as described above.

3. Results

3.1. Fungal types

The analysis of the sampled air yielded 74 fungal types, by both culture plate and slide studies. The percent contribution of predominant fungi in the library before agitation of books, after agitation of books and in outside air is analysed in Table 1. *Cladosporium* was the highest contributor with 49.9% before agitation, as compared to 48.2% after. In outside air, *Cladosporium* colonies made a similar contribution to inside air (49.6%). The colonies of *Penicillium chrysogenum*, *Penicillium oxalicum* and *Aspergillus flavus* had an

almost similar percent contribution in the air before agitation and after, varying from 5.5 to 2.8%. The concentration of *Aspergillus niger* increased by almost three times after agitation (8.3%), as compared to before agitation (3.2%), and was also higher than outside air (4.7%).

The spores of aspergilli/penicillia together contributed almost in the same proportion before agitation (25.4%) as after (22.8%), with a much higher percent contribution to outside air (40.3%). The spores of *Alternaria* and smuts were the next major contributor with higher percent contribution after agitation as compared to before agitation and outside air. Other types include remaining fungi which contributed less than 1.0% to the total colony/spore concentration inside the library.

3.2. Seasonal periodicity

The monthly concentrations of the six dominant fungi isolated from culture plates and slides are shown in Figs. 1 and 2, respectively.

The colonies as well as spores of *Cladosporium* showed a seasonal predominance during November to March, with a peak (4140 spores m^{-3}) in February after agitation of books (Figs. 1, 2). An increase in their concentration was also observed in May. There was a slight increase on agitation of books as compared to before agitation and outside air concentrations.

In May the colonies and spores of *Alternaria* recorded a peak concentration of 1433 CFU m^{-3} and 4325 spores m^{-3} , respectively after agitation (Figs. 1, 2). A several fold increase in concentration was recorded after agitation. Outside air had higher concentration of *Alternaria* than before agitation.

Aspergillus niger and *Aspergillus flavus* did not show any seasonal pattern though peak concentrations of 588 CFU m^{-3} and 310 CFU m^{-3} , respectively were recorded in the summer months (Fig. 1). Both showed a several fold increase in concentration after agitation. The concentration before agitation of books and in outside air were similar, except in certain months when it was recorded higher in outside air.

The two penicillia, *Penicillium chrysogenum* and *Penicillium oxalicum* exhibited a seasonal trend, being predominant from August to November (Fig. 1). The peak concentrations of these species were recorded during October and November with 657 and 191 CFU m^{-3} , respectively.

The spores of aspergilli/penicillia had a peak concentration (5315 spores m^{-3}) in outside air in the month of September, while after agitation 3400 spores m^{-3} were recorded. The month of March showed an increase with concentration reaching 3770 spores m^{-3} after agitation (Fig. 2).

Smut spores were predominant from January to March (Fig. 2). The concentration increased 10-fold after agitation of books with 4860 CFU m^{-3} in

Table 1

Percent contribution of dominant fungal types to the total colony forming units and spores before and after agitation of books in the library and in the outside (control) environment

Types	CFUs			Spores		
	Be-fore	After	Out-side	Be-fore	After	Out-side
<i>Cladosporium</i>	49.9	48.2	49.6	35.6	21.6	25.7
Aspergilli/penicillia	^b	^b	^b	25.4	22.8	40.3
Smut	—	—	—	18.4	29.4	12.8
<i>Alternaria</i>	5.8	13.8	16.7	8.0	13.3	5.8
<i>Aspergillus niger</i>	3.2	8.3	4.7	^a	^a	^a
<i>Aspergillus flavus</i>	1.7	2.3	2.8	^a	^a	^a
<i>Penicillium chrysogenum</i>	2.5	3.2	5.5	^a	^a	^a
<i>Penicillium oxalicum</i>	2.4	2.2	3.2	^a	^a	^a
<i>Aspergillus versicolor</i>	2.2	2.3	2.8	^a	^a	^a
<i>Fusarium</i>	2.1	1.3	2.8	0.3	0.2	0.8
<i>Curvularia</i>	0.6	0.2	0.2	1.7	1.9	2.2
<i>Arthrinium</i>	—	—	—	1.9	1.0	1.2
<i>Drechslera</i>	1.2	0.9	1.5	1.4	1.4	1.1
Basidiospores	—	—	—	1.1	0.5	1.1
<i>Periconia</i>	—	—	—	1.0	1.5	1.1
<i>Pseudocercospora</i>	—	—	—	1.0	1.2	0.8
Other types	7.0	16.7	8.6	4.1	5.2	7.3

Dashes indicate not obtained.

^aIdentified as aspergilli/penicilli.

^bIdentified up to species level.

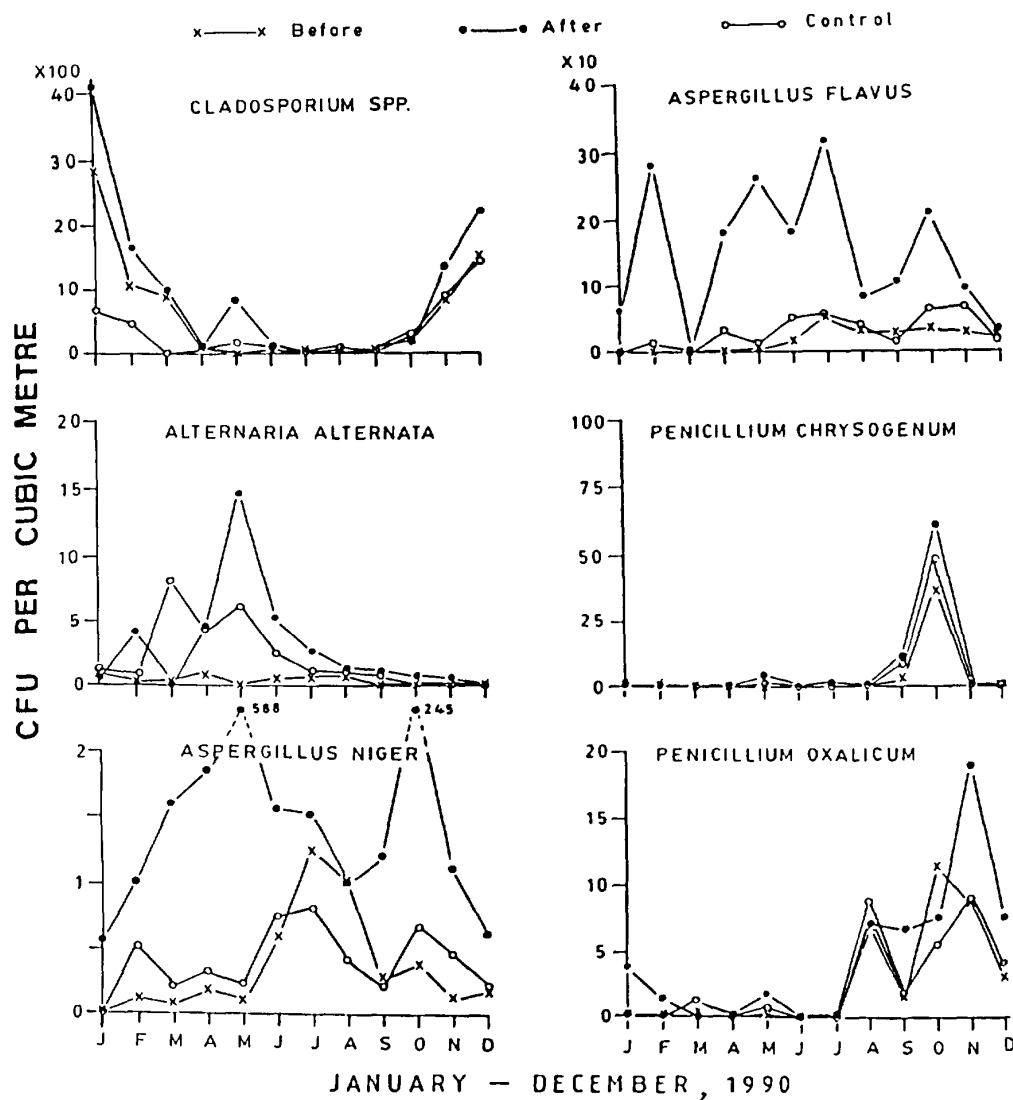


Fig. 1. Monthly concentration of dominant (culturable) fungi, before and after agitation of books in V.P. Chest Institute library, and outside air during January to December 1990.

February. *Curvularia* and *Arthrinium* exhibited a seasonal trend being predominant from June to October (Fig. 2). Their concentration increased on agitation of books, and the peak concentration inside the library was 205 spores m⁻³ and 180 spores m⁻³, respectively for these fungi.

3.3. Annual concentration

The annual concentration of dominant CFU and spore types are graphically presented in Fig. 3.

3.3.1. *Colony concentration.* *Cladosporium* was the most predominant fungus in the library air with two and a half times higher concentration (12 322 CFU m⁻³)

after agitation, than in outside air with 5157 CFU m⁻³. *Alternaria* was recorded in higher concentrations in outside air as compared to before agitation of books in the library, but after showed a 4-fold increase in concentration (3356 CFU m⁻³) (Fig. 3). *Aspergillus niger* was a major contributor after agitation showing a 5-fold increase (2100 CFU m⁻³) from before agitation of books. *Drechslera* and *Curvularia* had a greater annual concentration before agitation of books as compared to after and in outside air.

3.3.2. *Spore concentration.* Spores of *Cladosporium* were the major contributor, followed by aspergilli/penicillia, smut and *Alternaria*, with maximum

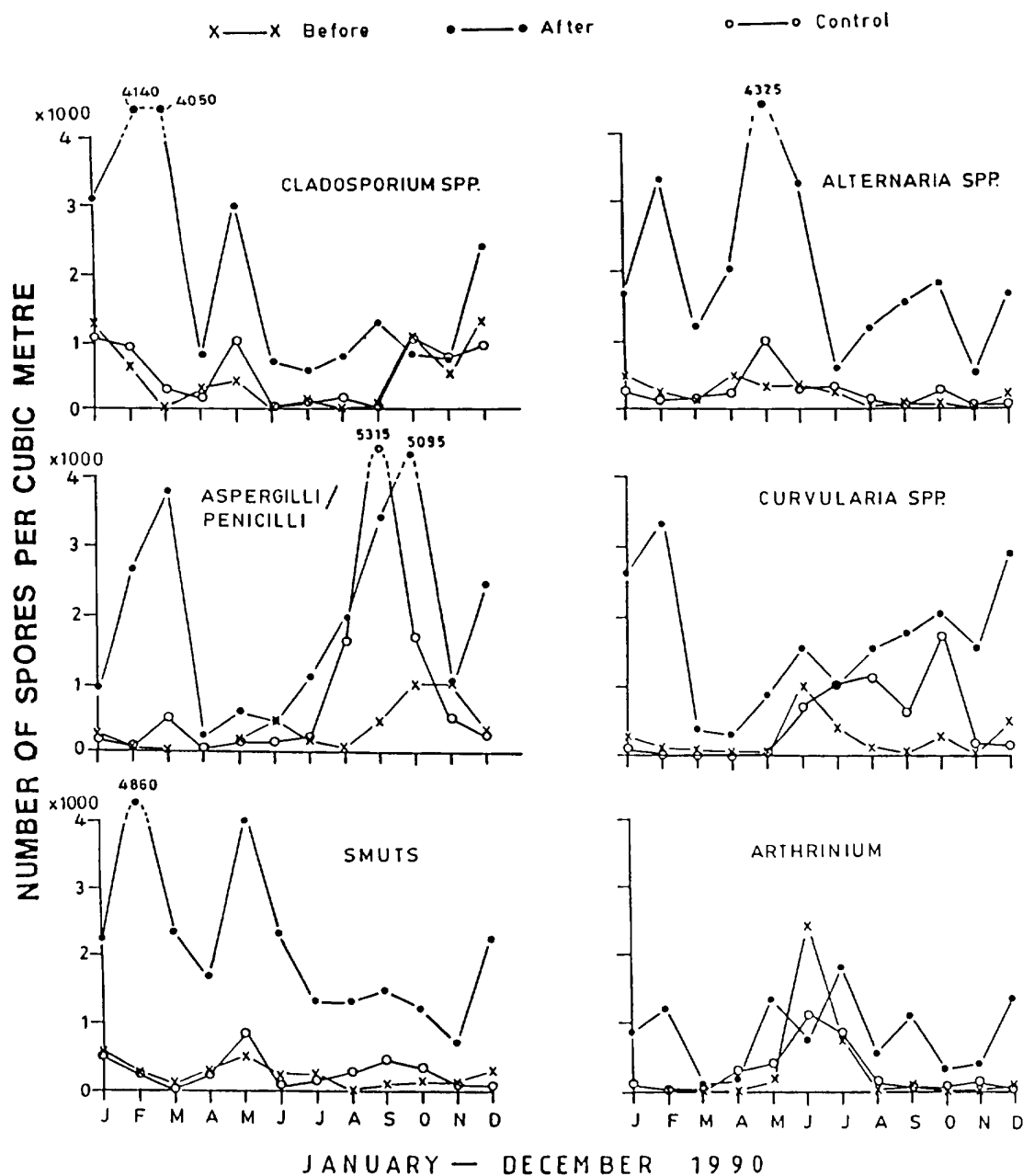


Fig. 2. Monthly concentration of culturable and non-culturable spore types, before and after agitation of books in V.P. Chest Institute library, and outside air during January to December 1990.

concentrations of 23 655 spores m^{-3} , 30 610 spores m^{-3} and 13 820 spores m^{-3} , respectively, after agitation of books (Fig. 4). The smut and *Alternaria* had a 10-fold increase in their concentration after agitation. The concentration of *Curvularia*, *Arthrini*, *Drechslera*, basidiospores and *Periconia* was also comparatively high after agitation than before agitation of books.

3.4. Comparative fungal concentration in different libraries

The concentration of dominant CFUs from the six different libraries studied in Delhi are graphically presented in Fig. 4. *Cladosporium* was predominant in all the libraries with maximum concentration (8311 CFU m^{-3}) in NML, the concentration increasing on

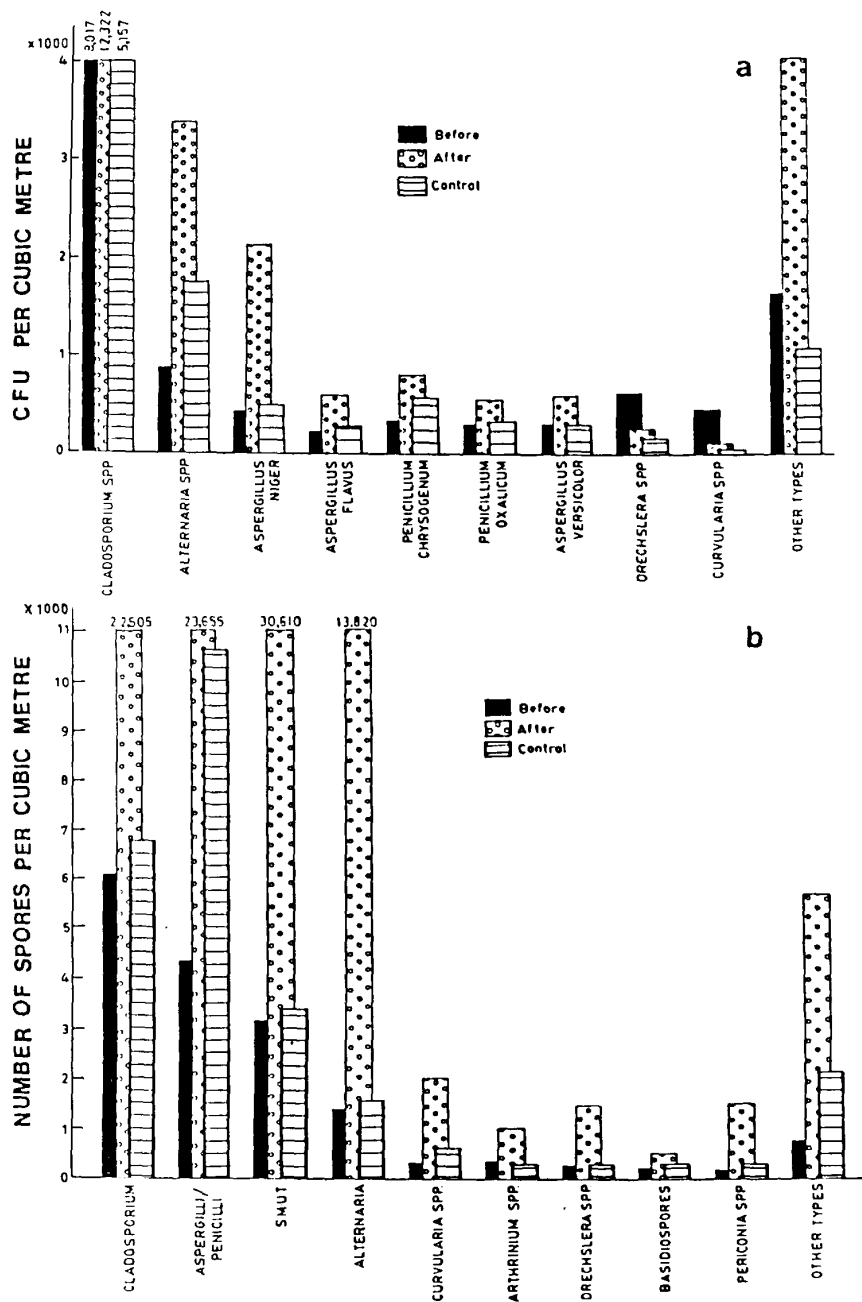


Fig. 3. Annual concentration of different fungal types, before and after agitation of books in a library during January to December 1990. (a) Culturable fungi (CFU m⁻³) and (b) non-culturable types (spores m⁻³).

agitation of books at all the sites (Fig. 4). *Aspergillus* species were high at VPCI library (3389 CFU m⁻³) and at DSL (3310 CFU m⁻³). Their concentration increased 4-fold after agitation of books. *Alternaria* had the highest concentration (790 CFU m⁻³) in DCL, and the concentration increased on agitation of books. *Fusarium* showed a higher concentration before agitation of books as compared to after in VPCI and DSL libraries. All the

other fungi recorded as 'Other types' had a maximum concentration in NML, with 2465 CFU m⁻³ after agitation of books.

4. Discussion

The indoor environment had high concentrations of fungal spores, the source being mainly outdoors but also

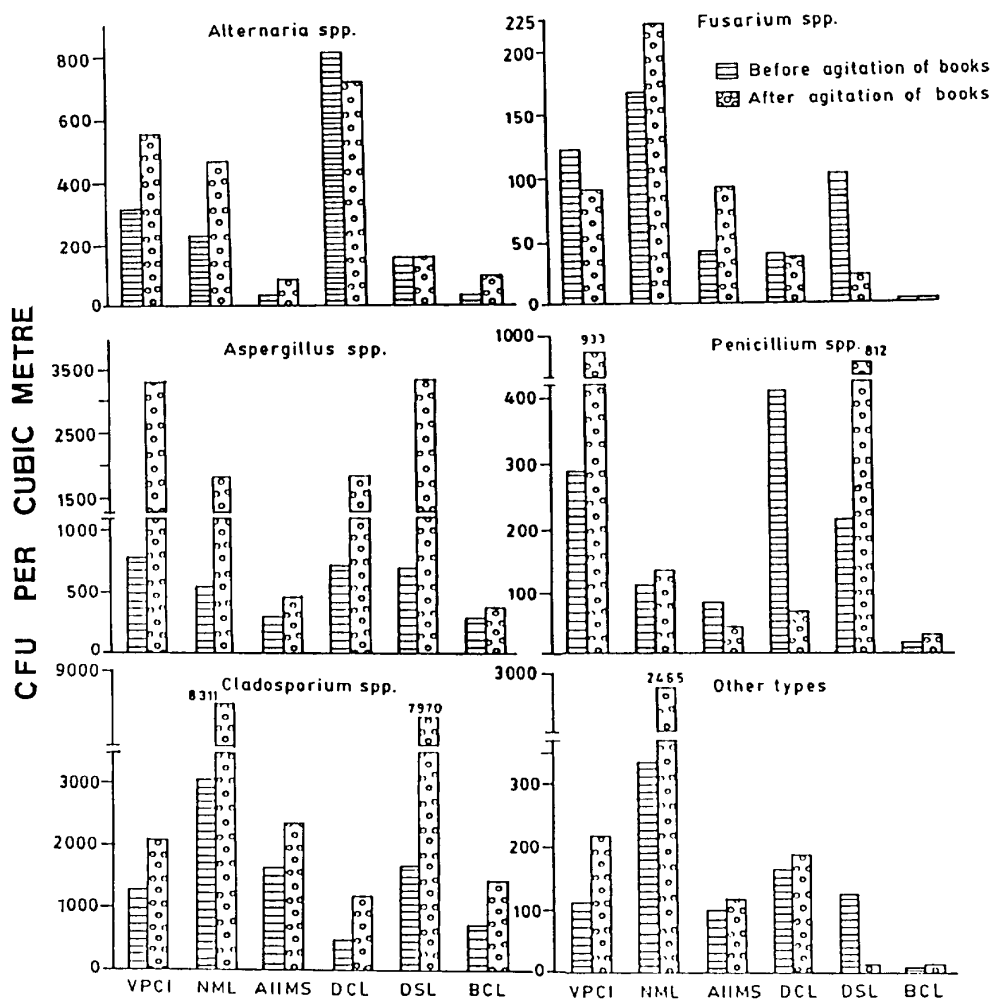


Fig. 4. Relative concentration of different fungal colonies isolated before and after agitation of books in six different Delhi libraries.

partly indoors. In libraries these fungi cause degradation of books and periodicals, and cause respiratory dysfunction among workers (Gallo, 1993).

The percent contribution of *Cladosporium*, *Drechslera* and *Fusarium* was greater before agitation, while smut, *Alternaria*, *Aspergillus niger*, *A. flavus* and *Penicillium chrysogenum* contributed more after. Interestingly, the ratio of contribution of these fungi remained unchanged after agitation, although the concentration increased considerably. This could be because fungal spores, along with dust, accumulate on shelves and books, and are dispersed on agitation, resulting in higher contribution of different fungi. The major contributors to both indoor and outdoor air were similar. This confirms our previous observation (Singh et al., 1990) and those of others (Tripathi, 1987; Tilak and Pillai, 1988).

Some of the fungi showed seasonality, corresponding

to their seasonal occurrence in the extramural environment. This is so because the major source for fungi, in libraries with natural ventilation, is from outside air. *Cladosporium* was predominant during winter months, *Alternaria* during summers, while *Penicillium* species were predominant during autumn, which is in accordance to our previous study (Singh et al., 1990). The high concentration of *Cladosporium* and *Penicillium* in winter has also been reported by other workers from the outdoor air of Delhi (Agarwal and Shivpuri, 1974; Gupta et al., 1993).

The monthly concentrations for most of the fungi were similar before agitation and in outside air with slight variations. This is further proof of the outdoor source of fungi. Because of the lack of regular cleaning these fungal spores become concentrated on the books and periodicals that are not consulted frequently. This

is evident by the several fold increase in the concentration of the spores of *Aspergillus niger*, *Aspergillus flavus*, smuts and *Curvularia* on the agitation of books.

Spores of *Alternaria* showed a several fold increase in concentration after agitation, but colony counts did not show considerable increase, probably because of the colonies of *Aspergillus niger* and *Aspergillus flavus* spreading on the Petri dishes, thus inhibiting the growth of *Alternaria*. In our previous study (Singh et al., 1990) there had also been no increase in colony concentration of *Alternaria* after agitation. The increase in the concentration of *Alternaria*, smut and *Curvularia* had gone unrepresented because of the lack of representation of non-culturable types. Burge et al. (1978) have also reported an increase in concentration of *Aspergillus niger* after agitation. At times the concentration before agitation and after is quite similar, and even lower after. The reason could be that the library had been vacuum cleaned a day before the sampling was done. After agitation of books the concentration was lowered because of the dispersal of the spores resulting in dilution in that area.

The annual concentration clearly showed that *Alternaria* spores had a 10-fold increase in concentration after agitation, while colony counts registered only a 4-fold rise. Smuts also recorded a 10-fold increase in concentration. The fungi which had a significantly higher ($P < 0.01$) concentration inside the library as compared to outside air, and also showed an increase in concentration after agitation of books were: aspergilli/penicillia, *Drechslera*, *Curvularia* and *Aspergillus flavus*. Thus, these are the major fungi to which users are exposed while going through old periodicals.

Different libraries showed a similar fungal flora, but varied in concentration. BCL, which is air conditioned, showed very low concentrations, with very slight changes in concentration after. This indicates the differences in maintenance in various libraries. The most contaminated libraries were VPCI and NML with very high concentrations of most of the dominant fungi, both libraries were naturally ventilated. A knowledge of indoor mycoflora will help in the identification of allergenic fungi (Jarvinen et al., 1979; Samet et al., 1987; Burge, 1990; Losada, 1992). It is therefore suggested that centrally air-conditioned libraries provide low fungal counts and air-conditioning should be the practice.

A prolonged exposure to high concentrations of irritant dusts with their various contaminants, might promote allergic sensitisation among workers or individuals visiting these places.

We can therefore conclude that (i) the major contributors to the library environment are *Cladosporium*, aspergilli/penicillia, smuts, *Alternaria*, (ii) some fungi showed a seasonal occurrence, (iii) the concentration of aspergilli/penicillia, *Drechslera*, *Curvularia* and *Aspergillus flavus* had a significantly higher concentration inside the library as compared to the control, (iv) that smuts, *Alternaria*, and *Aspergillus niger* showed several-fold increases in concentration after agitation of books, and (v) air conditioned libraries have low concentrations of fungal spores.

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