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The Fungus Airspora of Visakhapatnam

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Exposure of 5.3 mm diameter glass rods for four consecutive years (April 1975–March 1979) revealed the kinds, frequencies and seasonal periodicities of the airspora. A total of 139878 spores, of which over 93% were assigned to 56 types, and 6424 hyphal bits per sq. cm trap area were recorded. The major types were *Cladosporium* (29%), 'aspergilli' (13%), *Nigrospora* (10%), *Alternaria* (9%) and *Curvularia* (7%). There was no spore-free season. Individual types and total spores exhibited seasonal trends. The recovery of total spores was 30% in cold season (Dec.–Feb.), 28% in southwest monsoon (June–Sept.), 25% in retreating southwest monsoon (Oct.–Nov.), and 17% in hot season (March–May). The Hirst spore trap run for a year revealed the circadian rhythms of 14 spore types which were grouped into four different patterns. Year to year variations in spore abundance were evident. Urbanising activity influenced airspora pointing to the need for periodic surveys.

Key Words: Fungus, Airspora, Aeroallergens, Visakhapatnam

Introduction

Fungus spores, which form a normal component of the earth's atmosphere, have been studied, if not for their own sake, mainly because most are potentially allergenic to atopic human beings and some are pathogenic to agricultural crops. About 4–5% of Indian population suffers from naso-bronchial allergy (Shivpuri 1973) and fungus spores have been incriminated as one of the causative factors (Shivpuri & Agarwal 1969). The existing aerobiological literature collated by Sreeramulu (1967) and Chanda and Mandal (1978) revealed the ubiquity of fungus spore populations in Indian air environment and the need to undertake extensive aeroallergen surveys all over the country.

Personal discussions with the clinicians revealed that respiratory allergies are common at Visakhapatnam (17°42′N and 82°18′E). The city being heavily industrialised, the problem of industrial air pollution is becoming acute. The chemical pollutants and the fungus spores are likely to interact with each other and synergistically affect human health (Newmark 1970, Nilsson & Nybom 1978). It is therefore imperative that a comprehensive

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knowledge of the airspora of Visakhapatnam should be at hand to institute control programmes to ameliorate the health of allergy sufferers. As the available information on fungus airspora of this city is rather meagre (Subba Reddi 1970), the present investigation has been contemplated with a view to providing a picture as comprehensive as possible.

Materials and Methods

Air sampling techniques

The vertical cylinder (5.3 mm diam.) trap installed on the roof of the Botany building *ca.* 10 m above ground level on the Andhra University campus, Visakhapatnam was intended to find out the composition, frequencies and seasonal periodicities of fungus airspora. Rod impactors for exposure and mounting the cellophane strips were prepared following the methods described by Ramalingam (1968) and Subba Reddi (1970). An 18 mm square transparent cellophane paper made sticky and wound round the rod acted as the trap surface. A cylinder was exposed at about 1700hr, each day and removed at about the same time the following day. The exposed cellophane strips were mounted on microscope slides and scanned across the stagnation line at 1 mm apart (each scan 180 μm wide). A total of 18 scans were made per each strip. The spores counted, were converted to an estimated number per sq cm of the trap area.

The Hirst spore trap operated continuously from February 1978 to January 1979 with its orifice placed 2 m above ground level in the Botanical Garden on the AU campus was meant for discerning the circadion periodicity patterns in the emission of fungus spores into the ambient atmosphere. The methods used for preparing slides for exposure in the trap and mounting them for study were as those described by Hirst (1953). The slides coated with vaseline-wax mixture were placed daily at about 1700 hr and air was sampled at the rate of 10 l/min. After exposure the slides were mounted in unstained solvar and scanned at right angles to the direction of the slide movement, corresponding to 2-hourly intervals. The spores counted on a traverse of 110 μm wide were then converted to an estimated number/m^3 air.

Identification of spores

The different fungus spores encountered, were identified mainly by a comparison with reference slides prepared following the method of Dring (1971) during the field survey to identify the sources. Further, several mycological papers and standard descriptions of fungi like those of Barnett (1960), Ellis (1971), Subramanian (1971), Barron (1972), and Kendrick and Carmichael (1973) have been helpful.

Whenever possible the individual spores were counted as to the genus and species. Group counts were taken for types like 'basidiospores', 'ascospores', 'uredospores', and 'chlamydospores'. The spores that could not be identified were lumped into 'undetermined group'.

Results and Discussion

Components of fungus airspora and their relative contributions (table 1)

In the 4-year period of this study with the cylinder trap an estimated total of 1,39,878 fungus spores, of which 1,30,141 were assigned to 56 spore types and the rest lumped into an 'undetermined group' were obtained along with 6,424 hyphal fragments/cm^2 of the trap surface. The most prevalent spore type was *Cladosporium* accounting for *ca.* 29% followed by 'aspergilli', *Nigrospora*, *Alternaria*, *Curvularia*, etc. The airborne fungi were classified into 'Universal Dominants', 'Geographic Dominants' and 'Local Dominants' (Morrow et al. 1964, Prince & Meyer 1976). The predominant spore types recorded now are

Table 1. *Components of the fungus airspora, their mean annual incidence (no./sq. cm.), per cent contribution along with their highest daily catches (no./sq. cm.) and per cent contribution to the day's total spore catch.*

Spore type	Mean annual total	Percent contribution to total fungus spores	Highest daily catch	Percent contribution to day's total spores
1	2	3	4	5
Cladosporium	10093	28.762	4894	98.00
Aspergilli	4495	12.810	5894	90.26
Nigrospora	3632	10.350	206	23.62
Alternaria	3297	9.396	200	76.34
Curvularia	2526	7.199	158	18.12
Basidiospores	1044	2.975	380	93.13
Ascospores	934	2.662	212	61.99
Helminthosporium	932	2.656	30	3.44
Periconia	891	2.539	124	64.58
Uredospores	729	2.078	56	50.90
Oidium	719	2.049	86	62.32
Trichoconis	489	1.393	94	10.77
Chlamydospores	365	1.040	—	—
Torula	274	0.781	60	29.70
Corynespora	193	0.550	22	0.58
Pleospora	182	0.519	16	11.11
Pringsheimia	170	0.485	80	13.69
Cercospora (Long)	162	0.462	22	5.98
Botryodiplodia	143	0.408	122	83.56
Phyllachora	124	0.353	—	—
Cercospora (short)	124	0.353	42	29.58
Bunt spores	123	0.351	—	—
Pithomyces sacchari	97	0.277	38	3.17
Sclerospora	75	0.214	10	10.87
Phaeotrichoconis	71	0.202	10	1.15
Tetraploa	70	0.200	6	1.80
Albugo	69	0.197	30	65.22
Pithomyces chartarum	66	0.188	16	36.36
Drechslera hawaiiensis	62	0.177	—	—
Pestalotia	59	0.168	20	5.95
Neovossia	58	0.165	12	17.65
Papularia	57	0.163	36	14.17
Phytophthora	39	0.111	10	2.92
Drechslera papendorfii	32	0.091	6	3.09
Stemphylium	31	0.088	6	3.13
Sporormia	26	0.074	4	42.17
Chaetomium	26	0.074	—	—
Hysterium	23	0.065	12	9.09
Beltrania	21	0.060	—	—
Leptosphaeria	18	0.051	—	—
Dendryphiella	15	0.044	—	—
Spegazzinia tessarthra	13	0.037	—	—
S. sundara	12	0.034	—	—
Pyricularia	12	0.034	—	—
Spegazzinia deightonii	9	0.026	—	—
Epicoccum	9	0.026	—	—
Fusarium	9	0.026	—	—
Dictyoarthrinium	9	0.026	—	—
Deightoniella	7	0.020	—	—
Cordana	5	0.014	—	—
Cephaliophora	5	0.014	—	—
Ganoderma	3	0.009	—	—
Duosporium	2	0.006	—	—
Diplocladiella	2	0.006	—	—
Dictyosporium	1	0.003	—	—
Beltraniella	1	0.003	—	—
Unidentified group	2434	6.936	—	—

among those predicted as the basic group of dominant genera of airborne fungus spores, but *Nigrospora* is includedin the geographic dominants.

Hyphal fragments were recorded in significant numbers in the United States (Pady & Kramer 1960), the UK (Hamilton 1959, Pady & Gregory 1963), Australia (Rees 1964) and in other localities in India (Ramalingam 1971, Shenoi & Ramalingam 1976) and also from Visakhapatnam (Subba Reddi 1970), and it was concluded that these fragments must be considered an important constituent of the airspora. The present study reinforces the above conclusion.

The Cardiff aerobiologists are of the opinion that the numbers of spores alone are misleading as it guides to the relative importance of aeroallergens (Hyde & Adams 1960, Hyde & Williams 1961, Hyde 1972). They stressed how the relationships between number and spore volume might be important in allergy, because larger sized spores, although numerically minor, might become the dominant group in terms of 'bulk concentration'. However, they did not stress enough that allergens that are superficial or migrated through the spore surface might be more potent in unit weight of small rather than large spores (Hirst 1973). Here, it would be more appropriate to mention that the variety of size was one of the features of the airspora that impressed Gregory (1973) and led him to stress how size would influence dispersal, and to divide spores into those that impacted on and those that filtered through foliage.

Differential spore counts (table 2)

The Deuteromycetous group in which 39 spore types were identified, preponderated and amounted to 87.93% of the identified catch. The second predominant group was Basidiomycetes with six types contributing to 7.13% followed by Ascomycetes with eight types making up 4.43% and Phycomycetes with three types accounting for 0.51%.

Of the three Phycomycetous spore types, *Sclerospora* could not be identified in the 1st year. One of the six Basidiomycetes, the bunt spore type, did not appear in the catches of 1978–79. *Phyllachora* of the Ascomycetes could only be identified in the last two years of this study. In the first two years too they might have appeared but might be included in the general group 'ascospores'. Of the 39 types of Deuteromycetes recognised, some were not consistent and dropped out of the spore calendar in every year; thus the number of types recognised in the 1st, 2nd, 3rd and 4th years respectively were 31, 34, 37 and 33.

Table 2 *Differential fungus spore counts*

	Year of study	No. of types recog-nised	Total spores No./ sq. cm	% Contribu-tion to total identified spores
Phyco-mycetes	1st	2	44	0.22
	2nd	3	189	0.37
	3rd	3	244	0.92
	4th	3	179	0.55
Asco-mycetes	1st	7	887	4.40
	2nd	7	1345	2.63
	3rd	8	1339	5.05
	4th	8	2192	6.78
Basidio-mycetes	1st	5	2293	11.38
	2nd	5	2821	5.51
	3rd	5	2429	9.16
	4th	5	1740	5.39
Deutero-mycetes	1st	31	16917	84.00
	2nd	34	46820	91.49
	3rd	37	22500	84.87
	4th	33	28202	87.28
Total	1st	45	20141	100.00
	2nd	49	51165	100.00
	3rd	53	26512	100.00
	4th	49	32313	100.00

Seasonal periodicity (table 3)

Based on the daily samples obtained with the cylinder trap over the entire study period, the monthly counts were computed taking 30 days uniformly for each of the months. The ultimate aim of a long-term aerobiological survey is to provide a basis for the reasonably accurate prediction of spore incidence for a day or so ahead. Measurements taken in single season would show great day to day fluctuation, although some indication of seasonal pattern is usually apparent. Therefore, to smoothen out the fluctuations, the counts of the same month over the period of 4 years were averaged and plotted as a function of time; additional curves were also drawn through the higher and lower points (figures 1 & 2). This kind of presenting the data gives a good indication of the most likely density to be

Table 3 *Month-wise distribution and seasonal totals of the more frequent components of the fungus airspora*

Spore type	Year of study	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Total
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Albugo	1st	0	0	0	2	2	3	12	10	0	0	0	0	29
	2nd	0	0	0	7	42	19	6	25	13	0	0	0	112
	3rd	0	0	0	46	4	6	2	0	8	0	0	0	66
	4th	0	0	0	12	21	4	16	12	4	0	0	0	69
Ascospores	1st	185	0	6	23	91	119	35	23	4	0	5	10	501
	2nd	25	36	22	27	150	101	90	264	23	8	0	0	746
	3rd	10	10	80	26	61	144	198	108	35	48	68	64	852
	4th	60	6	166	348	697	101	108	64	4	0	28	56	1638
Pleospora	1st	2	0	6	6	22	80	36	0	2	0	5	0	159
	2nd	10	10	0	12	54	45	20	39	4	2	0	0	196
	3rd	0	0	16	44	17	28	25	14	8	4	0	4	160
	4th	4	4	10	27	79	36	39	14	0	0	0	0	213
Pringsheimia	1st	2	0	2	2	7	48	73	10	0	0	0	0	144
	2nd	2	0	0	6	10	45	144	33	2	4	0	0	246
	3rd	0	0	2	4	6	36	33	24	8	12	2	2	129
	4th	2	0	2	8	10	11	101	14	6	0	2	4	160
Basidiospores	1st	154	328	78	60	43	31	17	124	33	0	22	43	933
	2nd	169	440	32	190	44	45	40	82	52	2	0	4	1100
	3rd	54	84	381	266	31	36	109	148	6	8	2	136	1261
	4th	94	106	292	65	73	51	62	34	8	20	6	69	880
Uredospores	1st	24	19	2	2	26	3	4	19	65	16	112	60	352
	2nd	68	61	66	69	40	126	96	103	119	129	108	75	1020
	3rd	49	13	68	38	60	80	44	20	142	90	81	116	801
	4th	158	63	6	0	25	51	16	24	62	35	47	257	744
Chlamydospores	1st	0	93	19	54	84	0	0	185	0	0	22	0	503
	2nd	0	0	0	0	0	225	72	99	4	0	0	161	561
	3rd	0	0	16	0	69	14	0	26	81	65	36	0	307
	4th	0	0	36	25	27	0	0	0	0	0	0	0	88

(Contd)

Table 3 (*contd.*)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cladosporium	1st	746	126	834	0	218	0	0	8	10	136	4814	511	7403
	2nd	702	411	51	268	2854	248	7948	622	1532	1693	286	228	16847
	3rd	964	125	853	4	134	82	10	558	173	1198	394	218	4713
	4th	630	169	774	77	0	0	37	164	321	473	8134	628	11407
Aspergilli	1st	13	0	95	0	0	0	0	0	96	140	87	0	431
	2nd	0	36	0	694	272	764	600	2651	6198	142	20	63	11440
	3rd	0	2147	214	146	25	74	121	380	288	0	21	110	3526
	4th	236	179	218	303	315	0	104	644	109	167	272	36	2583
Alternaria	1st	183	155	272	115	492	105	36	41	73	42	318	326	2158
	2nd	247	643	531	418	504	255	544	391	119	161	169	134	4116
	3rd	373	372	540	376	263	282	319	278	123	152	190	218	3486
	4th	598	551	372	349	209	122	147	174	173	101	282	351	3421
Curvularia	1st	48	93	99	43	485	224	92	301	192	40	103	67	1787
	2nd	68	106	126	138	308	666	840	762	294	138	42	25	3513
	3rd	56	109	179	272	313	246	298	316	205	159	96	54	2303
	4th	108	98	182	125	300	171	485	162	406	136	186	142	2501
Nigrospora	1st	26	78	97	89	439	270	127	447	157	28	109	94	1961
	2nd	274	136	126	284	396	837	1516	863	376	198	46	60	5112
	3rd	45	119	247	244	455	754	668	490	280	190	73	40	3605
	4th	306	123	206	163	307	342	971	446	466	165	126	230	3851
Periconia	1st	18	0	35	8	7	3	0	10	21	70	174	19	365
	2nd	41	8	0	19	72	139	206	208	309	280	33	19	1334
	3rd	2	8	10	18	2	2	36	56	236	171	94	66	701
	4th	46	25	38	27	81	2	62	80	171	183	325	123	1163
Oidium	1st	2	0	0	4	22	29	21	105	15	16	147	146	519
	2nd	4	0	0	4	60	75	30	210	190	75	77	15	740
	3rd	12	0	2	28	12	42	192	80	119	92	173	326	1078
	4th	22	0	0	0	17	15	30	76	58	68	182	69	537
Trichoconis	1st	2	6	6	2	36	43	52	157	21	0	14	31	370
	2nd	31	0	0	4	8	64	220	249	12	2	2	4	596
	3rd	2	0	12	2	19	138	169	82	8	2	0	2	436
	4th	14	2	10	0	12	47	308	108	14	4	0	35	554

Phaeotrichoconis	1st	0	0	0	0	2	17	4	14	4	0	5	0	46
	2nd	0	2	35	8	6	9	24	23	6	4	0	0	107
	3rd	2	8	16	6	4	12	2	6	0	0	4	0	60
	4th	12	0	0	2	12	4	18	6	12	2	4	0	72
Helminthosporium	1st	55	51	27	16	101	48	27	115	104	28	35	108	715
	2nd	202	69	85	51	104	148	196	173	96	71	55	31	1281
	3rd	66	75	125	64	60	106	113	120	88	77	60	56	101
	4th	172	58	70	56	46	17	51	34	47	24	39	106	720
Corynespora	1st	0	2	6	6	29	3	2	27	15	4	22	7	123
	2nd	4	19	9	16	24	39	50	4	8	12	11	8	204
	3rd	12	13	21	22	52	54	25	22	15	4	9	18	267
	4th	12	10	18	8	13	9	18	26	19	7	32	6	178
Cercospora (short)	1st	9	0	0	2	0	20	25	0	0	0	5	2	63
	2nd	2	2	3	0	0	79	38	4	40	4	0	15	187
	3rd	6	2	0	2	2	56	52	28	0	0	0	0	148
	4th	24	0	0	0	0	19	30	8	0	0	6	10	97
Cercospora (long)	1st	0	2	0	0	2	0	2	6	0	0	16	10	38
	2nd	27	2	3	2	10	19	46	49	8	15	0	2	183
	3rd	10	0	2	8	4	16	4	36	27	19	11	18	155
	4th	16	12	0	2	8	17	35	10	47	13	62	48	270
Tetraploa	1st	2	2	0	6	10	0	2	2	8	0	3	5	40
	2nd	2	0	6	8	2	6	20	10	13	12	0	2	81
	3rd	2	2	10	6	4	2	6	8	17	10	0	4	71
	4th	8	2	2	6	13	4	18	8	12	4	4	6	87
Pithomyces sacchari	1st	2	0	0	0	0	0	0	2	0	0	60	60	124
	2nd	0	0	0	23	10	30	16	21	25	15	4	0	144
	3rd	0	0	0	0	4	20	8	52	17	0	6	0	107
	4th	0	0	6	0	0	2	0	0	4	0	0	0	12
Pithomyces chartarum	1st	0	0	4	0	14	6	2	6	2	0	0	5	39
	2nd	6	0	3	0	2	15	22	10	4	10	2	6	80
	3rd	2	2	2	6	8	4	10	4	6	2	19	2	67
	4th	4	10	2	0	2	11	12	2	6	7	15	8	79

(Contd)

Table 3 (*contd.*)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Torula	1st	0	4	2	27	0	3	102	39	98	0	60	5	340
	2nd	2	12	0	2	36	13	58	41	40	54	7	0	255
	3nd	56	0	12	16	4	14	19	24	100	10	2	8	265
	4th	0	10	6	4	40	0	55	10	29	2	9	71	236
Botryodiplodia	1st	7	6	0	0	10	3	0	66	8	4	0	2	106
	2nd	0	2	0	2	28	30	8	29	4	2	0	0	107
	3rd	4	2	25	16	4	128	12	16	4	0	0	12	223
	4th	2	4	0	12	84	13	0	2	10	2	2	6	137
Unidentified group	1st	218	80	294	29	108	91	21	92	121	18	639	290	2001
	2nd	157	102	57	88	668	944	716	523	282	167	124	31	3859
	3rd	45	570	325	320	213	330	175	152	125	167	167	72	2661
	4th	90	115	112	73	219	109	177	60	80	11	41	129	1216
Total spores	1st	1755	1049	1912	570	2397	1181	698	2080	1157	578	6941	1824	22142
	2nd	2053	2183	1160	2328	5864	5130	13668	7625	9853	3242	1010	918	55034
	3rd	1774	3687	3345	2052	1875	2770	2676	3088	2190	2553	1575	1588	29173
	4th	2654	1578	2606	1743	2688	1189	2971	2202	2169	1453	9832	2444	33529
Hyphal fragments	1st	174	115	87	41	67	65	25	328	219	106	215	374	1816
	2nd	200	271	196	109	148	167	236	268	228	236	117	65	2241
	3rd	142	79	134	142	52	114	73	92	219	150	86	104	1387
	4th	180	150	54	25	19	39	76	40	150	57	58	132	980

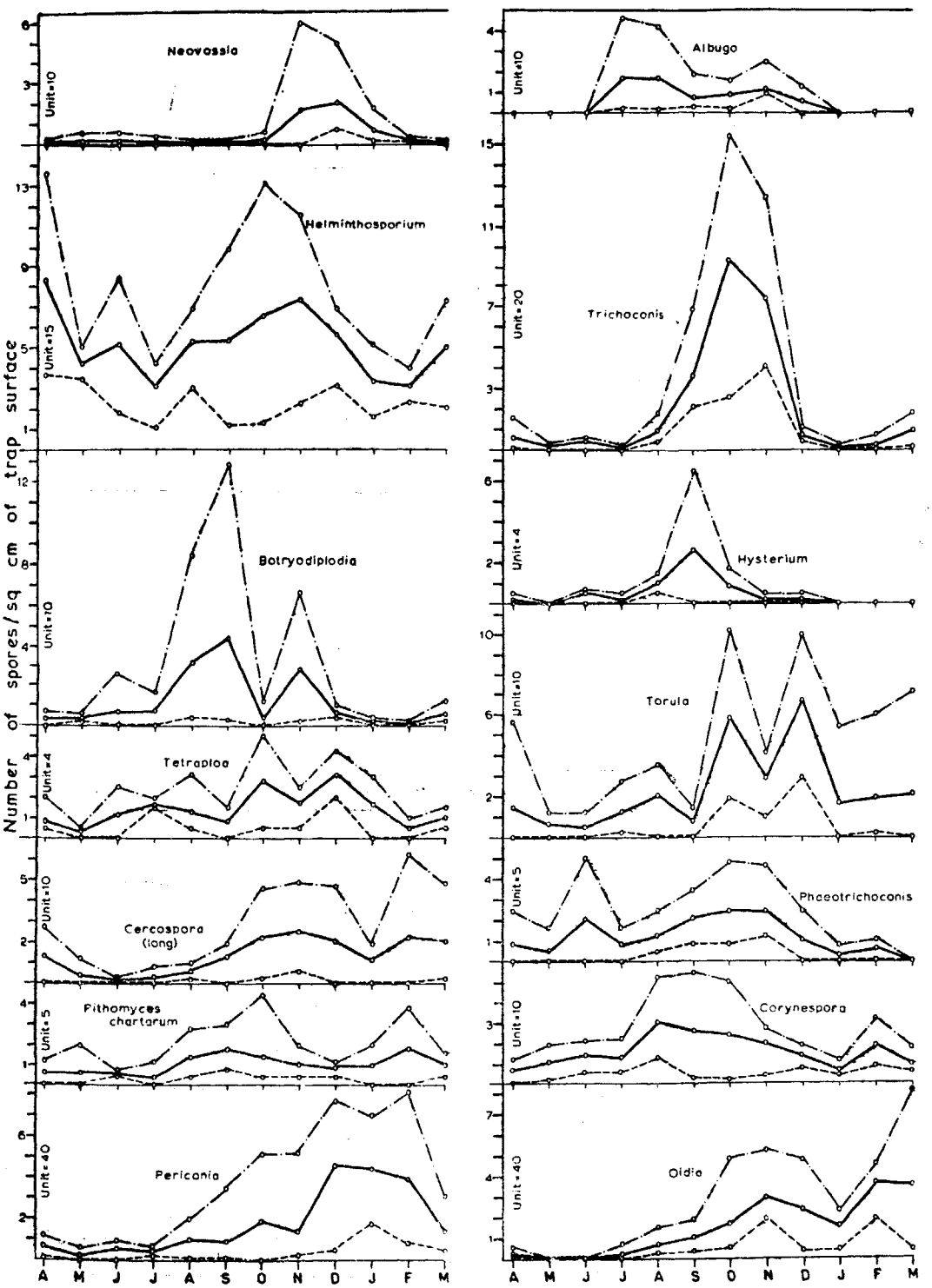

Figure 1 Mean seasonal curves of maximum, minimum and average incidence of different fungus spore types

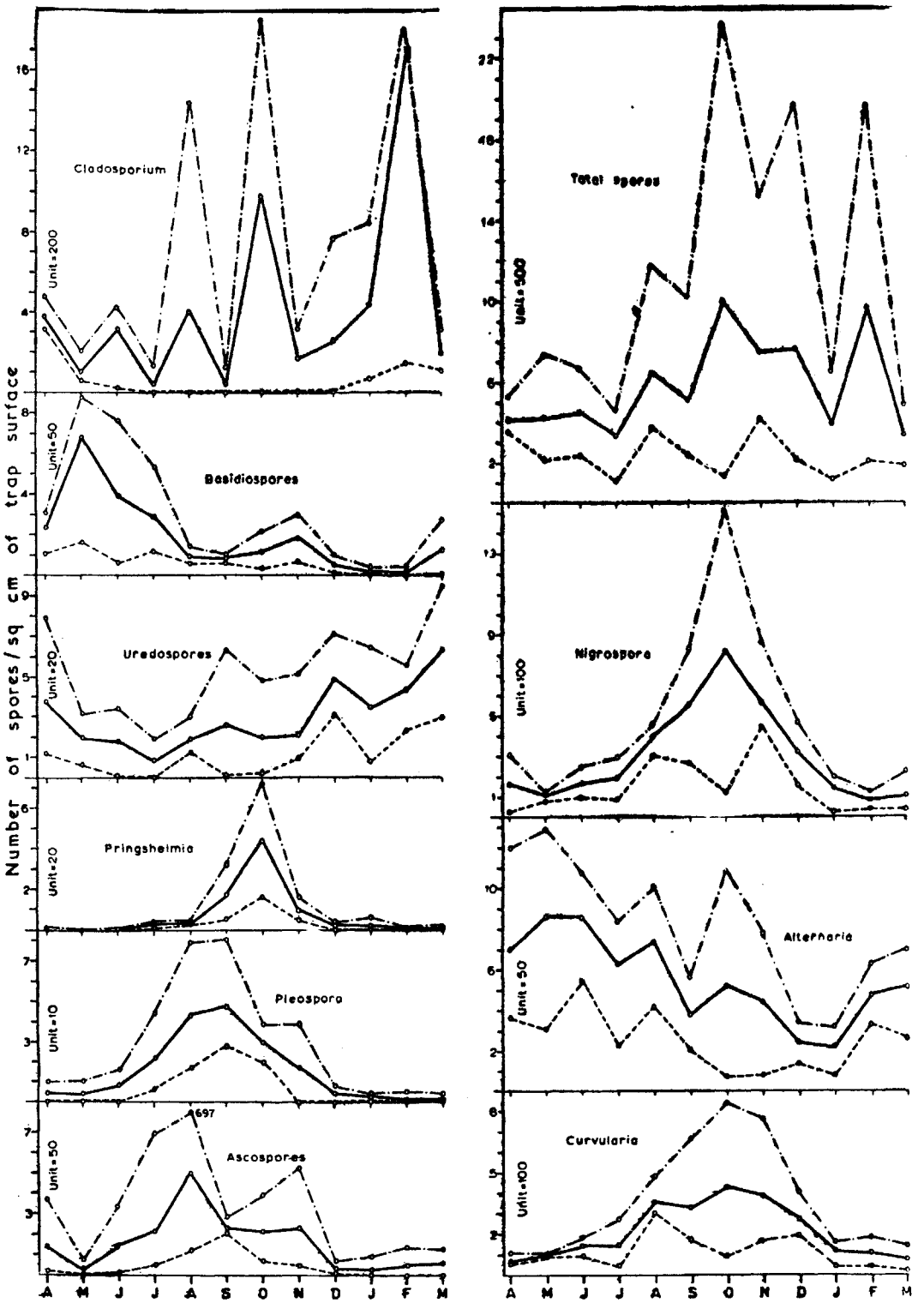

Figure 2 Mean seasonal curves of maximum, minimum and average incidence of different fungus spore types and total fungus airspora

expected and the probable range about this mean (Ogden et al. 1974, Solomon 1976).

There was no spore-free day during the entire study period. By months, on the average, October witnessed maximal incidence. Climatic season-wise *ca.* 53% of the total fungus airspora was recovered in the wet period (June–November) and *ca.* 47% in the dry period. Of the 53% in the wet period, *ca.* 28% was recovered in the southwest monsoon (June–September) and the rest in the retreating southwest monsoon (October–November). Of the 47% in the dry period, *ca.* 30% was encountered in the cold season. (December–February) and the rest in the hot season (March–May).

Among the Phycomycetous group the sporangia of *Sclerospora* and *Albugo* showed a definite seasonal trend in their incidence with counts from June to August and from July to December respectively, but those of *Phytophthora* were caught intermittently throughout the year excepting in April. No average peak was evident with these because of the relatively low catches.

Among the Ascomycetes, the group 'ascospores' was recorded in almost all the months, though they were absent on some days of a month. Higher frequency was during July–November. *Pringsheimia* was seen mainly in September–November and *Pleospora* in July–November with occasional counts in other months. The season of *Hysterium* was limited to June–December with higher incidence in September. Ascospores of *Sporormia* and *Chaetomium* were caught spasmodically in almost all the months, and those of *Leptosphaeria* from April–October. *Phyllachora* occurred mainly from November to March with occasional counts in some other months. *Oidium* was recorded over a major part of the year and was more frequent during November–December and in March.

Among the Basidiomycetes, the categories 'basidiospores' and 'uredospores' occurred all through the year; the former frequented more during April–July and the latter during December–April. *Neovossia* was seen mainly during November–January though sporadic in other months. Bunt spores were caught though not regularly from May to December. The smut spores were trapped though irregularly in all the months excepting in April. *Ganoderma* was caught on three occasions in 1978–79 only.

Among the Deuteromycetous group, *Cladosporium* was recorded in almost all the months of the year with its seasonal maxima in February. The category 'aspergilli' was significant over a major part of the year but more so during November–December. The conidia of *Nigrospora*, *Curvularia* and *Alternaria* were perennial in their occurrence. The former two were more numerous during August–December while the latter showed no such demarcation. The conidia of *Periconia* were caught over a major portion of the year with more frequency during October–March. *Helminthosporium* frequented all through the year in good numbers. *Trichoconis*, though occurred in almost all the months of the year, was more frequent during September-November. *Corynespora*, *Tetraploa*, *Cercospora* (long) and *Pithomyces chartarum* were almost evenly distributed over all the months of the year. *Cercospora* (short) was restricted mainly to September–October with low counts being encountered sporadically in other months. *Botryodiplodia* was present in almost all the months, but more commonly during July–December and peaking in September. *Torula* appeared almost throughout the year with greater frequency in October–December. *Phaeotrichoconis* was found year round except in March. *Pestalotia*, *Stemphylium*, *Pithomyces sacchari*, *Drechslera papendorfii*, *Papularia*, *Spegazzinia tessarthra*, *S. sundara*, *S. deightonii*, *Dictyoarthrinium*, *Beltrania*, *Beltraniella*, *Dendryphiella*, *Dictyosporium*, *Cephaliophora*,

Duosporium and *Diplocladiella* were represented in the catches, some in appreciable numbers, almost sporadically in different months of the year.

Most of the hyphal fragments observed, were brown and thick walled, and were the broken conidiophores. Occasionally, the conidiophores of *Periconia* species, some with conidia at the tip and some with conidia on the lateral side were seen; the latter was recognisable as that of *P. lateralis*. Hyaline hyphae were not observed. When the mean by months was calculated from the average counts of each month, it could be seen that counts higher than the mean of 134/cm² were registered during April–May and November–March; hence these periods were considered as witnessing higher incidence of hyphal fragments.

Lacey (1962) and Subba Reddi (1970) showed that the ecology of an area has a major influence on its airspora. It is therefore likely that the seasonal variations now recorded for the different elements of the fungus airspora depended on the seasonal growth of vegetation and concurrent weather. Thus the seasonal rhythm of *Sclerospora, Phytophthora, Albugo,* 'uredospores', *Trichoconis, Neovossia, Oidium,* smut spores depended on the seasonal development of the host plants and prevalence of suitable weather conditions that aid in infection, sporulation and subsequent discharge. Spore types like *Cladosporium, Nigrospora, Curvularia, Alternaria, Periconia* depended on the availability and prevalence of dead and decaying vegetable matter and occurred throughout the year, as such substrata are available all through the season at Visakhapatnam; the highest incidence of these spore types coincided with the abundance of such substrata. The seasonal changes observed in the catches of 'basidiospores', 'ascospores', *Pleospora, Pringsheimia* could be related to the rainfall distribution and the resultant humid conditions.

But for minor variations which could be relatable to differences in the growing season of vegetation and in the meteorological conditions, the observed seasonal periodicities are in general agreement with the earlier reports (Sandhu et al. 1964, Sreeramulu & Ramalingam 1966, Agarwal et al. 1969, Subba Reddi 1970, Ramalingam 1971, Tilak & Srinivasulu 1971, Shenoi & Ramalingam 1976).

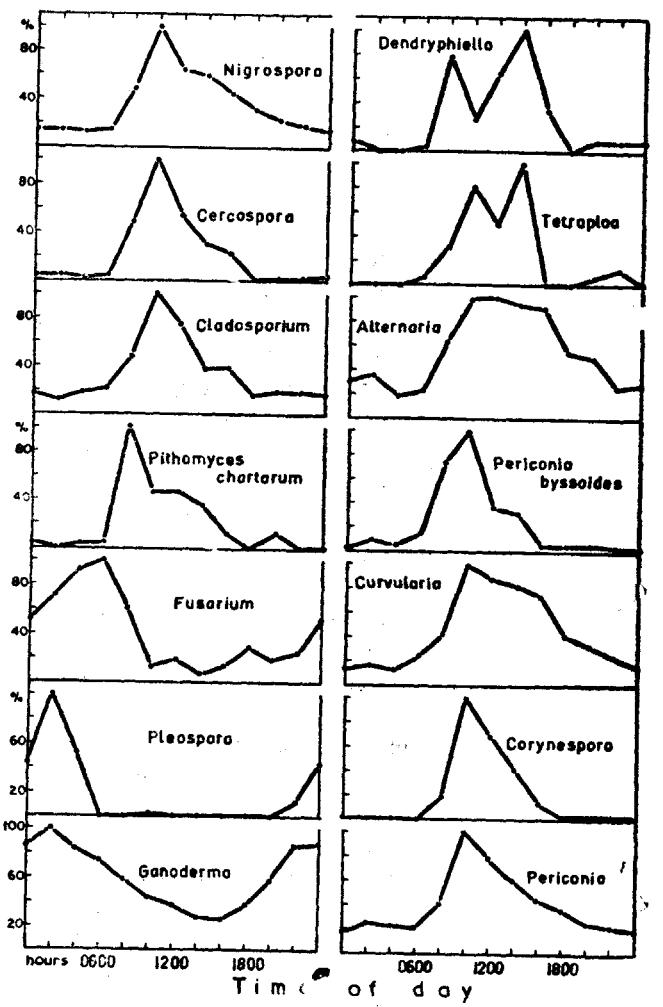

Figure 3 Mean circadian periodicity curves of different fungus spore types expressed as percentages of the peak arithmetic mean concentration

Circadian periodicity

Figure 3 illustrates the mean circadian periodicities of 14 fungus spore types constructed from the percentages of the peak arithmetic mean concentrations obtained with the Hirst spore trap. Of these types, *Pleospora* occurred mainly during night time and *Tetraploa* during day time. The other types appeared in appreciable numbers all through the circadian cycle. Table 4 gives the dynamics of spore concentrations in the observed circadian cycles. A perusal of figure 3 indicates that the rise in concentration levels was rather rapid with *Corynespora*, *Cercospora* (long), *Nigrospora* and *Pithomyces chartarum*, while it was rather gradual with the rest. Similarly the fall in concentration levels from the peak was rather sudden by the next two to four hours and thereupon gradual with *Fusarium* and *Pleospora*. However, with the rest the decline was gradual from the peak hour onwards.

Circadian rhythms have been identified for many of the constituents of the airspora by investigators in various countries. In nearly all of these investigations spore concentrations have been related not only to the time of day but also to various weather factors. In fine weather, each type of spore in season tends to be at its climax at particular time of day. It is thus possible to distinguish broadly between the dry spora and wet spora, the former comprising the spores whose release appears to be followed by low humidities and latter by high humidities. Of the 14 spore types, now studied, *Ganoderma*, *Fusarium* and *Pleospora* typified the wet spora, while others represented the dry spora.

Gregory (1973) recognised four circadian periodicity patterns for the airborne spores. The 14 spore types could be classified under these patterns as follows:

1. Night pattern : *Ganoderma*, *Fusarium*, *Pleospora*
2. Post-dawn pattern: *Cladosporium*, *Nigrospora*, *Curvularia*, *Corynespora*, *Periconia*, *P. byssoides*, *Cercospora* (long), *Pithomyces chartarum*
3. Middle-day pattern: *Alternaria*
4. Double-peak pattern: *Tetraploa*, *Dendryphiella*

Interpretations of the circadian periodicities are not always clear. Some reflect a circadian rhythm in liberation mechanism and others reflect a daily change in meteorological factors (Gregory 1967, Ingold 1971). As spore release is particularly governed by weather parameters and their incidence in air almost so, the circadian periodicity patterns may differ from place to place. Thus the double-peak pattern described for *Cladosporium*, *Curvularia*, *Periconia* and *Alternaria* (Rich & Waggoner 1962, Sreeramulu & Ramalingam 1966, Shenoi & Ramalingam 1975) is not realised in the present study. *Cladosporium* and *Nigrospora* reported as middle-day types at Mysore (Shenoi & Ramalingam 1975) behaved as post-dawn types at Visakhapatnam. Such a shift in peak concentrations could be expected because the weather at Visakhapatnam becomes dry rather quickly after sunrise than at Mysore. The night pattern recorded for *Ganoderma* and *Fusarium*, and the double-peak pattern for *Dendryphiella* and *Tetraploa* are in agreement with other reports (Sreeramulu 1963, Sreeramulu & Ramalingam 1962, 1966, Shenoi & Ramalingam 1975, Subba Reddi & Janaki Bai 1977).

Year to year variation in spore abundance

An examination of the annual figures set out in table 3 shows that wide fluctuations occurred in the abundance of total as well as the individual components of the fungus airspora. In order to assess the magnitude of variations

Table 4. *Dynamics of spore concentrations in the observed circadian cycles*

Spore type	Period of higher concentration (hr)	Peak mean concentration (No./m³)	Time (hr) of peak mean concentration	No. of days included in the mean	Highest hourly concentration (No./m³)	Time (hr) of highest hourly concentration
Ganoderma	2000-0800	140	0200	110	1200	0200
Pleospora	2400-0400	170	0200	20	730	0200
Fusarium	2400-0800	100	0600	129	4220	0800
Pithomyces chartarum	0800-1400	90	0800	10	230	0800
Cladosporium	0800-1600	1150	1000	151	47280	1200
Cercospora (long)	0800-1400	100	1000	108	1340	1000
Nigrospora	0600-1400	140	1000	159	960	1600
Periconia	0800-1800	140	1000	209	1300	1200
P. byssoides	0800-1400	630	1000	21	3300	1000
Corynespora	0800-1400	140	1000	122	1300	1200
Curvularia	0800-2000	100	1000	160	1260	1400
Alternaria	0800-2000	50	1200	155	770	1000
Tetraploa	0800-1400	60	1400	12	260	1400
Dendryphiella	0800-1600	60	1400	16	430	1400

in the spore abundance from year to year the range of variation and the difference were computed from the mean annual figures and from the yearly totals of those fungus spore types encountered in considerable frequency and hyphal bits (table 5). The total spores preponderated in the 2nd year of this study, and varied between 63.32% of their 4-year average in 1975–76 and 157.37% in 1976–77. The total Phycomycetous spores recorded in 1977–78 were greater than in other seasons. They ranged from 27–149% of average. The total Ascomycetous spores abounded in the 4th year and ranged from 62–152% of average. The spores of Basidiomycetes recorded in 1976–77 outnumbered those in other seasons, the range of variation being from 75–122% of average. The spores of Deuteromycetes were much more frequent in 1976–77 than in other years. They varied from 59–164% of average. Among these four groups, the Basidiomycetous spores were steady in their annual variation followed by Ascomycetes, Deuteromycetes, and Phycomycetes. Of the individual spore types, *Phyllachora*, *Pleospora*,'basidiospores', *Torula* and *Trichoconis* were relatively steady. The principal spore type, *Cladosporium*, showed rather wide variation and ranged between 47% in 1977–78 and 167% in 1976–77. These variations are attributable only in part to concurrent weather. The fact that the vertical cylinder trap is somewhat sensitive to wind speeds may also be responsible for some of these fluctuations. Similar variations in the year to year incidence of fungus spores were reported from the UK (Hyde 1972).

If one of the conditions conducive to sensitisation to a particular allergen is under repeated exposure over several years to high concentrations then, other things being equal, the relatively steady types are perhaps more

Table 5 *The range of variation in spore abundance fromthe four-year average spore incidence*

Spore type	Range of variation (%)	Difference
Phyllachora	91.13–108.87	17.74
Pleospora	87.36–117.03	29.67
Basidiospores	84.29–120.79	36.50
Torula	86.13–124.09	37.96
Trichoconis	75.66–121.88	46.22
Alternaria	65.81–125.53	59.72
Helminthosporium	76.72–137.45	60.73
Pithomyces chartarum	59.09–121.21	2.12
Tetraploa	57.14–124.29	67.15
Curvularia	70.74–139.07	68.33
Pringsheimia	75.88–144.71	68.83
Corynespora	63.73–138.34	74.61
Oidium	74.18–149.93	77.75
Botryodiplodia	74.13–155.94	81.81
Phaeotrichoconis	64.79–150.70	85.91
Nigrospora	53.99–140.75	86.76
Uredospores	48.29–139.91	91.63
Cercospora (short)	50.81–150.81	100.00
Drechslera hawaiiensis	48.39–151.61	103.22
Periconia	40.97–149.72	108.75
Albugo	42.03–162.32	120.29
Cladosporium	46.69–167.09	120.40
Ascospores	53.64–175.37	121.73
Chlamydospores	24.11–153.70	129.59
Pithomyces sacchari	12.37–148.45	136.08
Cercospora (long)	23.46–166.67	143.21
Pestalotia	54.24–206.78	152.54
Papularia	42.11–207.02	164.91
Sclerospora	26.67–205.33	178.66
Neovossia	31.03–232.76	201.73
Aspergilli	9.59–254.51	244.92
Bunt spores	0.00–300.81	300.81
Total fungus spores	63.32–157.37	94.05
Hyphal fragments	61.02–139.54	78.52

likely to affect large numbers of people than all those types whose incidence fluctuates very violently from year to year and adds to the difficulty of both of diagnosis and of assessing the effects of treatment.

Effect of urbanisation on fungus airspora

Comparison of the results obtained in an earlier survey from April 1966 to March 1968 (Subba Reddi 1970) and those of the present study revealed a considerable decline in the spore numbers (figure 4) indicating that increasing urbanisation has had an effect on the airspora. Due to industrialisation of the city, demand for residential houses increased with the result the neighbouring sub-urban and rural areas have been intensively used for extensive building construction. This has drastically curtailed available sites for growth of herbaceous flora, and consequently the vegetable matter for the growth of fungi, thus reducing the quantity of airborne fungus spores. Introduction of new plant taxa however added new components to the air-spora. For example, *Phyllactinia subspiralis*, a

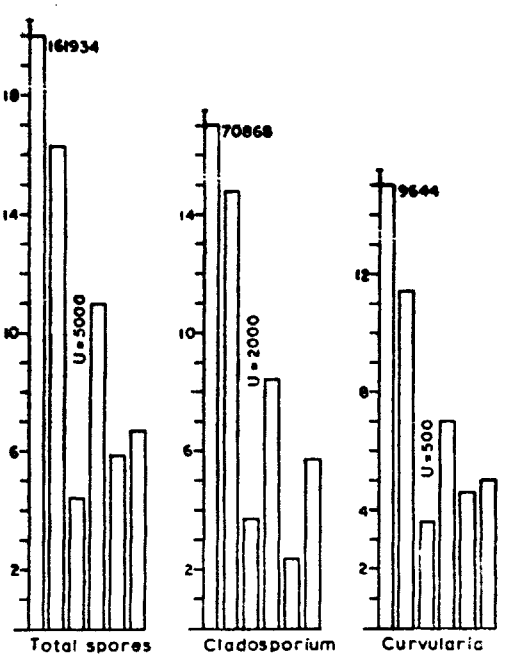

Figure 4 Relative numbers of fungus spores caught in different consecutive years of study: 1966–67 1967–68 (Subba Reddi 1970), 1975–76, 1976–77, 1977–78 and 1978–79 (present study)

powdery mildew hitherto not known in this area has been introduced along with *Dalbergia sissoo* which has been planted along roadsides. The conidia of this fungus did appear in the air; separate counts were not maintained but included under *Oidium.*

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