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Investigation of airborne fungi at different altitudes in Shenzhen University

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ABSTRACT

Aim: To investigate the richness of species or genera of airborne fungi, the amount of airborne fungi, and its seasonal variation at different altitudes in Shenzhen University. The effect of meteorological factors on airborne fungi was also analyzed. Methods: Slide-exposure method and open-plate method were used. Results: There were 27 genera or species of fungus spores identified. Among the identified fungal genus, *Cladosporium*, *Ustilago*, *Alternaria*, *Helminthsporium* and *Uredinales* were more prevalent. There were 18 genera of fungi colonies identified. Among which *Penicillium*, non-sporulating fungi, *Aspergillus*, *Saccharomyces* and *Cladosporium* were more common. The airborne fungal spores were present in the atmosphere of Shenzhen University all year round. The peaks of airborne spores appeared during April and October, while the lowest numbers were observed during January, July and December from March 2005-Febrary 2006. The highest volumes of fungi colonies were observed during April, October and September, while the lowest numbers were detected during in January, July and December or May from March 2005-Febrary 2006. The meteorological factors had no relationship between the total monthly spore count at 10 and 30 meter height. At 70 meter, the total spores count was negatively correlated with solar radiation. Conclusions: Most of the fungi spores decreased along with the increase of altitudes.

Keywords: Airborne Fungi; Open-Plate Method; Slide-Exposure Method

1. INTRODUCTION

Airborne fungi are one of the common allergens that induce respiratory hypersensitivity reaction [1-3]. The major allergic symptoms include asthma, rhinitis, bronchopulmonary mycoses and hypersensitive pneumonitis [4]. Airborne fungi also act as an indicator for the atmospheric bio-pollution. The presence of fungal propagules, volatiles and mycotoxins in the air can pose a health hazard in all segments of the population [5]. Fungi variety and concentration depends on various factors, including topography, time of day, meteorological parameters, seasonal climatic variation and type of vegetation [6-7]. Extensive investigations of airborne fungi had been done in many parts of the world [8-15]. In China, such studies had been done in different provinces [16-25].

But to our knowledge there are no published data on the airborne fungi at different altitudes in one place. Shenzhen city is located at 22°27'-22°52' N and 113°46'-114°37' E. The weather in Shenzhen is associated with high temperature and humidity throughout the year, which suits for the reproduction of airborne fungi. As a well developed city, Shenzen has a large number of tall buildings and mansions providing both working and living spaces. The aim of this work was to determine the concentration of airborne fungi present at different altitudes and the effect of seasonal variations, which will provide useful information on the air quality of residential areas.

2. METHODS

2.1. Slide-Exposure Method

The slide-exposure method based on the protocol adapted from Ye (1992) was used to determine the fungal spores [26]. Briefly, the slides with vaseline for spore sampling were set on the second floor (10 meter above ground level), the seventh floor (30 meter above ground level) and the sixtieth floor (70 meter above ground level) of the technological building in Shenzhen University (22°54′37" N and 113°93′77" E), respectively. Two slides were collected daily from March, 2005 to February, 2006. The slides were stained by basic fuchsin solu-

tion. Fungal spores were enumerated and identified by using a light microscope (OLYMPUS BH-2, Japan). The average spore counts of the two samples in each altitude were taken.

2.2. Open-Plate Method

The open-plate method was adapted based on Ye (1992) to determine the fungal colonies [26]. Briefly, the plates with Peptone Dextrose Agar, Potato Dextrose Agar and Czapek Dox Agar respectively were set on the same places as described above once during each month (total 12 times in one year). Three plates were opened for a period of 5 min at various altitudes, and then were incubated at 28℃ ± 1℃ for up to 5 days. The colonies were stained by lactic acid methylene blue solution and identified by colony and microscopic morphology. Colony counts were then converted to the colony forming units/m^3, CFU/m^3 = 5000N/A t (N: colony count; A: square of plate; t: exposure time) [27]. The total colony forming units of three plates at each altitude were added to obtain the total colony forming units at each altitude.

2.3. Statistical Analysis

The relationship between the monthly total spores count at various altitudes, the most common fungi and the monthly meteorological factors (average temperature: X1; average relative humidity: X2; average atmospheric pressure: X3; average wind speed: X4; rainfall: X5 and solar radiation: X6) were established respectively by means of stepwise multiple regression method (The data were analyzed using SPSS Version 12.0). The value of $p < 0.05$ was considered statistically significant. The meteorological data were obtained from Shenzhen meteorlogical administration (**Table 1**).

3. RESULTS

3.1. Airborne Fungal Spore Count at Three Different Altitudes

During the entire year, there were 2190 slides collected at three different altitudes. The total fungal spore counts at 10, 30 and 70 meters height were 4,102, 3,540 and 2,929.5 respectively. There were 27 genera or species identified belonging to the subphylum Zygomycotina family Mucoraceae: *Rhizopus* (0.17%); subphylum Ascomycotina family Sphaeriaceae: *Chaetomium* (0.39%); subphylum Basidiomycotina family Ustilaginaceae: *Ustilago* (13.04%), *Uredinales* (9.54%); subphylum Deuteromycotina family Moniliaceae: *Cladosporium* (16.45%), *Aspergillus* (0.59%), *Geotrichum* (0.52%), *Botrytis* (0.31%), *Trichothecium* (0.09%), family Dematiaceae: *Alternaria* (11.41%), *Helminthosporium* (11.37%), *Curvularia* (8.41%), *Stachybotrys* (5.38%), *Stemphylium* (4.58%), *Nigrospora* (1.93%), *Heterosporium* (1.02%), *Acrothecium sp*. (0.53%), *Papularia* (0.31%), *Clavispora* (0.22%), *Cercospora sp*. (0.09%), *Wardomyces* (0.05%), family Tuborculariaceae: *Fusarium* (0.85%), *Epicoccum* (0.48%), family Sphaeropsidaceae: *Hendersonia sp.* (4.18%), *Ascochyta sp*. (4.04%), *Diplodia sp*. (3.65%), *Sphaeropsis sp*. (0.20%) and unidentified spores (0.20%) (**Tables 2-4**).

At three different altitudes, the majority of spores were *Cladosporium*, *Ustilago*, *Alternaria*, *Helminthosporium* and *Uredinales*.

3.2. Fungal Colony Forming Units at Three Different Altitudes

During the entire year, the total of 53,473, 50,962 and 49,543 colony forming units at 10, 30 and 70 meters, respectively were collected, enumerated and then characterized into 18 genera or species. The common fungi belonged to the subphylum Zygomycotina family Mucoraceae: *Mucor* (0.31%), *Rhizopus* (0.31%); subphylum Ascomycotina family Sphaeriaceae: *Chaetomium* (0.51%), family Saccharomyetaceae: *Saccharomyces* (12.67%); subphylum Deuteromycotina family Moniliaceae: *Penicillium* (24.11%), *Aspergillus* (15.63%), *Cladosporium* (11.85%), *Trichothecium* (0.71%), *Trichoderma* (0.72%), *Botrytis* (0.51%), *Geotrichum* (0.31%), family Dematiaceae: *Alternaria* (5.11%), *Curvularia* (5.00%), *Helminthosporium* (1.22%), *Nigrospora* (0.51%), *Stachybotrys* (0.51%), family Tuborculariaceae: *Fusarium* (0.71%), family Sphaeropsidaceae: *Phoma sp*. (0.61%), non-sporulating fungi (18.28%) and unidentified colony (0.41%) (**Tables 5-7**).

Table 1. Averages of meteorological measurements: temperature (T), relative humidity (RH), atmospheric pressure (P), wind speed (WS), rainfall (R), and solar radiation (SR) in Shenzhen from March 2005-Febrary 2006.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
T (ºC)	17.2	23.1	27.2	27.8	29.4	28.5	28.8	26.2	22.9	16.7	16.2	17.8
RH (%)	71	74	76	78	71	79	72	64	67	50	69	72
P (hPa)	1016.6	1011.9	1005.6	1002.4	1004.3	1002.8	1007.2	1012.8	1014.4	1019.2	1016.4	1017.6
WS (m/sec)	2.1	1.8	1.8	1.7	1.7	1.9	2.2	2.4	2.2	2.7	2.6	2.3
R (mm)	48.3	42.9	379.2	469.9	326.6	587.3	231.8	21.3	14.0	9.0	20.6	48.0
SR (h)	759	881	1194	756	2264	1639	1495	1946	1798	1549	1202	912

Table 2. The identified airborne fungi genera or species and slide fungal spores count at 10 meter during 12 months.

Genera month or species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total spores
Rhizopus	0	0	0	2	0	0	2.5	0	0	0	0	0	4.5
Chaetomium	0	2	1	0	2.5	0	2	4.5	1.5	1.5	1	4	20
Ustilago	23.5	67.5	80.5	37.5	56.5	22.5	15	31	81	57.5	23.5	42.5	538.5
Uredinales	40.5	36	40	29	26.5	30.5	32	30.5	30	32.5	47.5	15.5	390.5
Cladosporium	47	21.5	19	90.5	103	52	32.5	52.5	15.5	97.5	72.5	22	625.5
Aspergillus	2.5	3	0	3	1	1	3	0	2	3.5	2.5	0	21.5
Geotrichum	6.5	0	0	2	0	0	2.5	0	3	0	2	1.5	17.5
Botrytis	0	2	1.5	0	3	2	0	1.5	3.5	0	0	5.5	19
Trichothecium	0	1	0	0	0	0	0	0	0	0	0	3	4
Alternaria	42	26.5	33.5	81	46.5	37	34.5	52	40	37	30	25.5	485.5
Helminthosporium	24	40.5	68	22.5	42	48	24.5	30	34	58	31.5	34	457
Curvularia	24	34	24.5	36.5	31.5	29	15	15.5	30.5	44	39.5	23	347
Stachybotrys	18	20	13	33	15	14.5	9.5	20	20.5	24.5	18	23.5	229.5
Stemphylium	15	15.5	15	18.5	16	14.5	13	15.5	23.5	17.5	21.5	20	205.5
Nigrospora	6.5	10.5	15	6.5	4	5.5	10	5	3.5	7.5	6	6.5	86.5
Heterosporium	5.5	0	1.5	6	2	2	1.5	0	5.5	5.5	0	0	29.5
Acrothecium sp.	2	0	2	3	3	3	2.5	3	4.5	0.5	1	4.5	29
Papularia	0	0	0	0	0	1.5	0	0	3.5	5	4.5	0	14.5
Clavispora	1	0.5	1	0	0.5	0	0	1	0.5	0	0	0	4.5
Cercospora sp.	0	0	2	0	0	0	1	0	0	0.5	0	1	4.5
Wardomyces	0	0	0	0	0	0	1	0	0	0	0	0.5	1.5
Fusarium	4	1.5	1	2.5	1.5	2	0	0	2.5	2.5	2.5	0	20
Epicoccum	2	2.5	1	2.5	0	1.5	0	2	2.5	5.5	0	2.5	22
Hendersonia sp.	15	16	27	18.5	15	9.5	13	10.5	19.5	16.5	9	24.5	194
Ascochyta sp.	9	7.5	11	16.5	7.5	10.5	15	15	17	15.5	19.5	23	167
Diplodia sp.	20	7.5	16	16.5	11.5	8	11	8	15.5	12	12	7	145
Sphaeropsis sp.	2.5	0	5	0	0	0	0	1	0	0	0	1.5	10
Unidentified spores	2.5	0.5	1	0	0	0	1	0.5	0	1	0.5	1.5	8.5
Total spores	313	316	379.5	427.5	388.5	294.5	242	299	359.5	445.5	344.5	292.5	4102

Table 3. The identified airborne fungi genera or species and slide fungal spores count at 30 meter during 12 months.

Genera month or species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total spores
Rhizopus	0	0	1.5	2.5	0	0	1	0	0	0	0	4	9
Chaetomium	0.5	1.5	2.5	0	1.5	0	1.5	2.5	0.5	1.5	0.5	1.5	14
Ustilago	26.5	33.5	59	47	26	22.5	16.5	25.5	68	62.5	24.5	32.5	444
Uredinales	34.5	30.5	31.5	32.5	15.5	24	26	23	23	40.5	31	22.5	335
Cladosporium	21.5	28.5	29.5	86	56.5	46	32.5	43	22.5	85.5	54	38.5	544
Aspergillus	1.5	2	2	2.5	2	3	0	2	3	1.5	0	2	21.5
Geotrichum	2	0	1	3	2	0	1.5	0	3.5	0	1	1.5	15.5
Botrytis	0	1.5	0.5	0	1.5	2.5	0	1	1	0	0	3	11
Trichothecium	0	0.5	0	0	2	0	0	0	0	0	0	1	3.5
Alternaria	37.5	23.5	21	56	40.5	28.5	31.5	42	23.5	34.5	24.5	29	392
Helminthosporium	16	32	62	45.5	36.5	43	14	27	27.5	44.5	24	24.5	397
Curvularia	20.5	24.5	32	36	33.5	36	17	17	23.5	38.5	34.5	16	329
Stachybotrys	12	17.5	18	18	20.5	16	12	17.5	15.5	25.5	19	7.5	199
Stemphylium	8	12.5	11	14	20.5	19.5	10	12	20.5	14	17	15	174
Nigrospora	8	7.5	10	10	3.5	4.5	7	4	1.5	9.5	4	8.5	78
Heterosporium	3.5	0.5	1.5	5.5	3.5	2.5	1	0	4.5	5.5	0.5	2	30.5
Acrothecium sp.	1	0	0	1.5	1.5	1	1.5	2.5	3.5	0	1.5	2	16
Papularia	0	1	0	0	1.5	2.5	0	0	2	3	2.5	0	12.5
Clavispora	1	1.5	0.5	1	0	0.5	0	0	1	1.5	1	1	9
Cercospora sp.	0	0	0.5	0	0.5	0	0	0	0	0	0	0	1
Wardomyces	0	0	0	0	0.5	0.5	0	0	0	0	0	0	1
Fusarium	2	2.5	2.5	4	2.5	4	1	0	4	4.5	1.5	0	28.5
Epicoccum	1	1	1	0	0	3.5	1.5	3.5	1	4.5	0	0	17
Hendersonia sp.	19	8.5	22	15.5	11	9	10	8	15	13.5	6	14.5	152
Ascochyta sp.	13	17.5	25.5	17	9	7.5	13	12	12	12	9.5	14.5	163
Diplodia sp.	13.5	14	21.5	12	7	6	6	10.5	10.5	12.5	9.5	5	128
Sphaeropsis sp.	0	0	2.5	0	2.5	0	0	0	1.5	0	0	2.5	9
Unidentified spores	1	1	0.5	0	1	1	0.5	0	0	0	0.5	2	7.5
Total spores	243.5	263	359.5	409.5	302.5	283.5	205	253	288.5	415	266.5	250.5	3540

Table 4. The identified airborne fungi genera or species and slide fungal spores count at 70 meter during 12 months.

Genera month or species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total spores
Rhizopus	0	0	0	3	0	0	0	0	0	0	1.5	0	4.5
Chaetomium	0	2	0.5	1	2	0	0	0.5	0	0	0	1	7
Ustilago	18.5	46.5	30.5	44.5	23.5	32	21	30.5	74.5	26.5	31	16.5	395.5
Uredinales	13	19	40.5	43.5	19.5	14.5	20.5	15	12	19.5	35.5	30	282.5
Cladosporium	29.5	16.5	95.5	88.5	33	36	19.5	36	20.5	65	65	65	570
Aspergillus	2.5	0	1.5	3.5	3	1.5	0	2.5	2	1.5	0	1	19
Geotrichum	3.5	0	1.5	5	5	0	0.5	0	3	0	1	2	21.5
Botrytis	0	0	0.5	0	0.5	2	0	0	0	0	0	0	3
Trichothecium	0	0	0	0	2.5	0	0	0	0	0	0	0	2.5
Alternaria	27	35	40.5	44.5	30	27	20	24	15.5	19.5	15	31	329
Helminthosporium	24.5	38	39	55	29.5	32.5	18.5	36	19	32	12	12	348
Curvularia	6	28.5	10	25	23	18.5	12.5	22	19.5	21	18.5	9	213.5
Stachybotrys	0	12	9.5	13.5	18.5	15.5	10	15	8.5	16.5	10.5	10.5	140
Stemphylium	4	6	8	9.5	12.5	10.5	6	7	12.5	9	10.5	9	104.5
Nigrospora	3	4.5	9	3.5	2	2	6	2	0.5	1.5	2	3.5	39.5
Heterosporium	8.5	1.5	2.5	2	6.5	5	0	1.5	7.5	6.5	2.5	4	48
Acrothecium sp.	1	0	1	1	1.5	0	0.5	1	2	2	0.5	1	11.5
Papularia	0	2	0	0	1	1.5	0	0	1.5	0	0	0	6
Clavispora	4	1	1.5	0.5	1	1	0	0	0	0	0	1	10
Cercospora sp.	0	0	3.5	0	0.5	0	0	0	0	0	0	0	4
Wardomyces	0	0	0	0	0	0	2	0	0.5	0	0	0	2.5
Fusarium	6	3.5	2	3	2.5	4.5	2.5	2.5	3	3.5	3.5	5	41.5
Epicoccum	0	2	2.5	0	0	1.5	1.5	1.5	0	0	3	0	12
Hendersonia sp.	13	6	11	8	7.5	7	7	5	10	8.5	4	8.5	95.5
Ascochyta sp.	5.5	7	13	8	16	5.5	8	9.5	5.5	8.5	6	5	97.5
Diplodia sp.	8	18.5	12.5	9.5	8.5	11	6.5	11.5	7.5	6.5	6.5	6.5	113
Sphaeropsis sp.	0	0	1.5	0	0	0	0	0	1	0	0	0	2.5
Unidentified spores	0	2	1	1	0	0	1	0	0	0	0	0.5	5.5
Total spores	177.5	251.5	338.5	373	249.5	229	163.5	223	226	247.5	228.5	222	2929.5

Table 5. The identified airborne fungi genera or species and colony forming count at 10 meter during 12 months.

Genera month or species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total colony
Mucor	0	157	157	0	0	0	0	0	0	0	0	0	314
Rhizopus	0	0	0	0	157	0	0	0	0	0	0	0	157
Chaetomium	0	0	0	0	0	157	0	0	157	0	0	0	314
Saccharomyces	157	472	786	944	472	629	157	472	315	315	472	472	5663
Penicillium	157	944	1258	2674	472	786	315	315	2202	1887	1415	472	12897
Aspergillus	315	472	315	2045	315	1573	315	315	1101	1887	472	157	9282
Cladosporium	786	1258	472	315	472	315	315	472	629	315	315	629	6293
Trichothecium	0	157	0	0	0	0	0	157	0	0	0	0	314
Trichoderma	0	315	0	0	315	0	0	0	0	0	0	0	630
Botrytis	0	0	157	0	0	0	0	0	0	157	0	0	314
Geotrichum	0	0	0	0	0	0	0	157	315	0	0	0	472
Alternaria	0	0	629	157	157	0	0	315	315	157	157	0	1887
Curvularia	0	0	315	0	157	0	0	0	157	629	0	157	1415
Helminthosporium	0	157	157	0	0	315	0	157	0	0	157	0	943
Nigrospora	0	0	0	0	0	0	0	0	157	0	0	0	157
Stachybotrys	0	0	157	0	0	0	0	0	0	157	0	0	314
Fusarium	0	157	0	157	0	0	0	0	157	0	0	0	471
Phoma sp.	0	0	157	0	0	0	0	157	0	0	0	0	314
Non-sporulating fungi	0	629	629	2045	629	1101	157	944	1887	1415	786	786	11008
Unidentified fungi	157	0	0	0	0	0	0	0	0	0	157	0	314
Total colony	1572	4718	5189	8337	3146	4876	1259	3461	7392	6919	3931	2673	53473

Table 6. The identified airborne fungi genera or species and colony forming count at 30 meter during 12 months.

Genera month / or species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total colony
Mucor	0	0	0	0	0	157	0	0	0	0	0	0	157
Rhizopus	0	0	0	0	0	157	0	0	0	0	0	0	157
Chaetomium	0	157	0	0	0	0	0	0	0	0	0	0	157
Saccharomyces	157	629	472	1101	629	315	629	315	315	315	472	315	5664
Penicillium	315	1101	1573	2045	629	629	472	629	2045	2359	1101	472	13370
Aspergillus	472	472	1573	1730	315	315	629	472	629	629	315	315	7866
Cladosporium	472	472	315	472	315	1101	0	629	315	315	157	157	4720
Trichothecium	0	0	157	0	0	0	0	0	0	315	0	0	472
Trichoderma	0	0	0	0	0	157	0	0	0	0	0	0	157
Botrytis	0	157	0	0	0	0	0	0	0	0	0	0	157
Geotrichum	0	0	0	0	0	0	0	0	0	0	0	0	0
Alternaria	0	315	0	157	0	472	0	157	944	315	157	157	2674
Curvularia	0	157	315	0	0	157	0	629	315	786	472	472	3303
Helminthosporium	0	157	0	0	0	0	157	0	0	157	0	0	471
Nigrospora	0	0	0	0	0	0	0	0	315	0	0	0	315
Stachybotrys	0	157	0	0	0	0	0	0	0	0	0	0	157
Fusarium	0	0	0	0	0	157	0	0	0	0	0	0	157
Phoma sp.	0	0	0	0	0	0	0	0	157	157	0	0	314
Non-sporulating fungi	472	315	1258	2516	315	629	0	786	1415	1730	472	629	10537
Unidentified fungi	0	0	0	0	157	0	0	0	0	0	0	0	157
Total colony	1888	4089	5663	8021	2360	4246	1887	3617	6450	7078	3146	2517	50962

Table 7. The identified airborne fungi genera or species and colony forming count at 70 meter during 12 months.

Genera month / or species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total colony
Mucor	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhizopus	0	157	0	0	0	0	0	0	0	0	0	0	157
Chaetomium	0	157	0	0	0	0	0	0	0	157	0	0	314
Saccharomyces	472	1258	786	786	315	629	315	786	786	944	472	629	8178
Penicillium	472	315	1730	2045	944	944	472	472	629	1415	944	472	10854
Aspergillus	472	315	472	1258	315	786	472	472	786	944	629	0	6921
Cladosporium	786	472	1101	629	472	629	315	472	786	472	629	472	7235
Trichothecium	0	0	0	0	0	0	0	0	157	157	0	0	314
Trichoderma	0	0	0	157	0	0	0	0	0	0	157	0	314
Botrytis	0	0	0	0	0	157	0	0	0	0	157	0	314
Geotrichum	0	0	0	0	0	0	0	0	0	0	0	0	0
Alternaria	0	472	472	472	157	315	0	472	315	157	157	315	3304
Curvularia	0	0	0	157	157	472	0	157	786	944	0	315	2988
Helminthosporium	0	0	0	157	157	0	0	0	157	0	0	0	471
Nigrospora	0	0	0	0	0	0	0	0	315	0	0	0	315
Stachybotrys	0	0	0	0	0	157	0	0	0	0	157	0	314
Fusarium	0	157	315	0	0	0	0	0	0	0	0	0	472
Phoma sp.	0	0	0	0	0	0	0	0	0	0	157	157	314
Non-sporulating fungi	0	315	629	1573	786	786	472	315	315	629	315	472	6607
Unidentified fungi	0	0	0	0	0	0	0	0	0	157	0	0	157
Total colony	2202	3618	5505	7234	3303	4875	2046	3146	5032	5976	3774	2832	49543

3.3. Effect of Seasonal Variations on the Total Airborne Fungi in One Year

The airborne fungal spores were present in the air around Shenzhen University throughout the year. The distribution curve of total airborne fugal spores peaked in April and October, and dropped to the lowest values in January, July and December (**Figure 1**). The distribution curve of the total colony forming unit spiked in April, October and September, and fell to the lowest values in January, July and December (**Figure 2**).

3.4. The Effect of Seasonal Variations on Airborn Fungi at Three Different Altitudes

At 10, 30 and 70 meters height, increased levels of total airborne fugal spores was observed during April and October, while lower levels were observed during January, July and December (**Figure 3**). The concentration of fungal spores decreased with respect to the increase in the altitude. The number of spores at 70 meters was lower compared to the levels observed at 30 and 10 meters during September and October.

The distribution curve of fungal colony at 10, 30 and 70 meters height indicated a sharp increase during four months from January to April. The distribution curve of the fungal colonies at 10 and 70 meters reached to its lowest point during July, January, December, and at 30 meter height similar levels were observed in July, January and May (**Figure 4**).

3.5. The Relationship between the Airborne Fungal and Meteorological Factors

The monthly meteorological measurements: average temperature, average relative humidity, average atmospheric pressure, average wind speed, rainfall and solar radiation had no observable relationship between the total spore count at 10 and 30 meters height. At 70 meters height, the total spore count was negatively correlated with solar radiation ($Y = 342.191 - 0.718\ X6$, $r = 0.602$, $p < 0.05$).

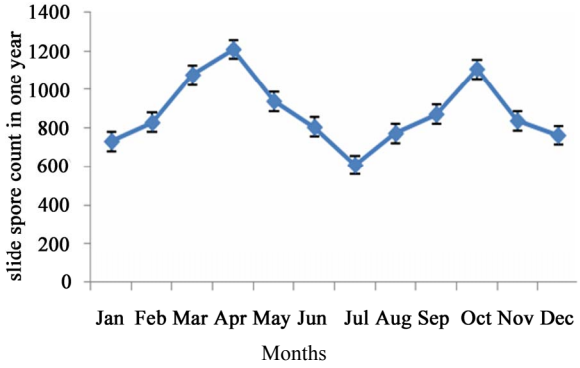

Figure 1. The distribution of slide spore count during a 12 month period.

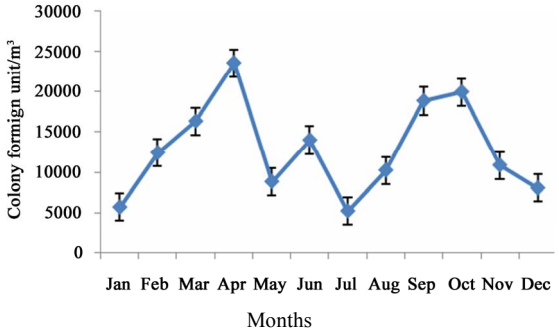

Figure 2. The distribution of colony forming count during a 12 month period.

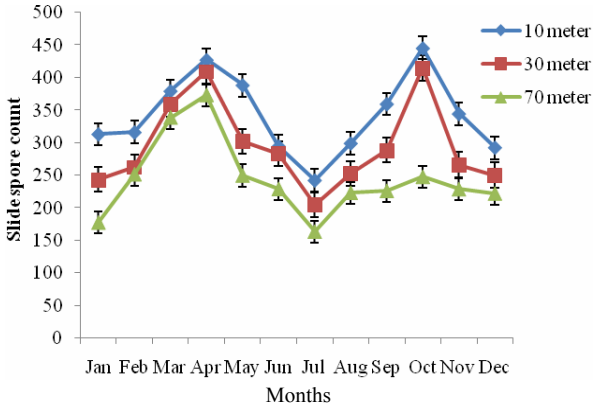

Figure 3. The distribution of slide spore count at three altitudes during a 12 month period.

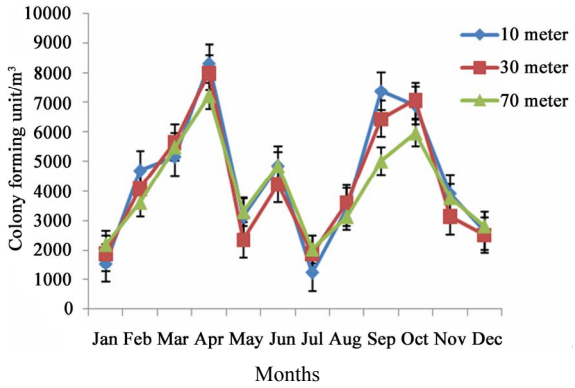

Figure 4. The distribution of colony forming count at three altitudes during a 12 month period.

The total monthly spore count of *Cladosporium*, *Ustilago*, *Alremaria* had no relationship between the meteorological factors. The spore counts of *Holminthsporium* was negatively correlated with solar radiation ($Y = 156.026 - 0.409\ X6$, $r = 0.602$, $p < 0.05$). The spore count of *Uredinales* was negatively correlated with average wind speed and rainfall ($Y = 176.894 - 35.314\ X4 - 0.099\ X5$, $r = 0.805$, $p < 0.05$).

4. DISCUSSION

4.1. Comparison of Airborne Fungi in Shenzhen University and Other Regions

The most common fungi documented in many Chinese districts were *Alremari*, *Cladosporium*, *Ustilago*, *Uredinales*, *Aspergillus*, *Penicillium*, *Holminthsporium*, *Fusarium* and *Saccharomyces* [16-25]. Similar observations were documented in many other countries as well [7-9,12,14,28,29]. The top five genera of fungi spores in our study were *Cladosporium* (16.45%), *Ustilago* (13.04%), *Alremaria* (11.41%), *Holminthsporium* (11.37%) and *Uredinales* (9.54%). While the top five genera of fungi spore in Guangzhou were *Alremaria* (27.49%), *Ustilago* (17.26%), *Uredinales* (6.95%), *Holminthsporium* (6.09%) and *Fusarium* (4.99%). *Cladosporium* only took up 0.77% in Guangzhou [16]. The top five genera of fungal colony in our study were *Penicillium* (24.11%), *Aspergillus* (15.63%), *Saccharomyces* (12.67%), *Cladosporium* (11.85%) and *Alremaria* (5.11%). The top five genera of fungi colony in Guangzhou were *Cladosporium* (21.60%), *Penicillium* (19.71%), *Alremaria* (5.54%), *Rhizopus* (5.05%) and *Aspergillus* (4.43%). The non-sporulating fungi in our study area and in Guangzhou were 18.28% and 30.79%, respectively [16]. This indicates that the fungal spore count differs according to time and place.

The concentration of fungal spores changed with seasonal variation in many districts in China during April to October [16-25]. The concentration of fungal spores in Guangzhou was high during April, September and October, and the lower during January, July and December [16]. Similar results were observed in our study.

4.2. Comparison of Airborne Fungal Spores at Different Altitudes

Our results showed that the total spore count decreased with the increase in height. However, the total genera of fungi did not decrease with the height. The fungi with larger spore sizes, such as *Holminthsporium*, *Alremaria*, *Ustilago* and *Curvularia* were concentrated at 10 meters height. While the fungi with smaller spore sizes such as *Cladosporium* was concentrated at 70 meters. The count of *Aspergillus* didn't show much difference at 30 or 70 meters height. Chakraborty (2001) [13] reported that the smaller spores were dominant at greater heights and larger spores and conidia were more prevalent at lower levels. Furthermore, the distribution of fungal spores at different altitude was influenced by their shapes [30].

4.3. The Relationship between the Airborne Fungi and Meteorological Factors

The distribution of airborne fungi spores can be affected by various factors including meteorological factors. The effect of meteorological factors on the count of airborne fungal spores varied from one fungal taxon to another. Most airborne fungi have a strong relationship with temperature; however, *Aspergillus*/*Penicillium* hyphal fragments were positively correlated with wind speed. In comparison with other airborne fungi, *Leptosphaeria* and unidentified *Ascomycetes* were more closely correlated with rain and relative humidity during the growing season [31]. *Alternaria* and *Cladosporium* are positively correlated with temperature and duration of sunlight. However, *Ustilago* indicated a positive correlation with relative humidity and negative correlation with wind speed [32]. *Alternaria* and *Cladosporium* showed a positive association with temperature, duration of sunlight and accumulated rainfall, but negatively correlated with daily rainfall [33].

In our results, the meteorological factors had no observable relationship between the total monthly spore count and altitude. At 70 meters, the total spore count was negatively correlated with solar radiation. The total monthly spore count of *Cladosporium*, *Ustilago*, *Alremaria* had no observable relationship between the meteorological factors. The spore count of *Holminthsporium* was negatively correlated with solar radiation, while the spore count of *Uredinales* was negatively correlated with average wind speed and rainfall. In this study, the temperature, relative humidity, atmospheric pressure did not affect the total spore concentrations. It may be due to the subtropical climatic location of Shenzhen. The meteorological data showed that the temperature, relative humidity, atmospheric pressure did not change drastically in Shenzhen during the entire year. Therefore, seasonal variations did not affect the distibution of the fungal spores significantly.

5. CONCLUSIONS

There were 27 genera or species of fungus spores and 18 genera of fungi colonies identified in a given year. The airborne fungal spores were present in the atmosphere of Shenzhen University all year round. The peaks of airborne spores appeared during April and October, while the lowest numbers were observed during January, July and December. The highest volumes of fungi colonies were observed during April, October and September, while the lowest numbers were detected during in January, July and December or May. The meteorological factors had no relationship between the total monthly spore count at 10 and 30 meter height. At 70 meter, the total spores count was negatively correlated with solar radiation. Most of fungi spores decreased along with the increase of altitudes.

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