

Potted plants in hospitals as reservoirs of pathogenic fungi

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Abstract

The soils of five potted plants cultivated within a hospital were investigated for the presence of fungal opportunistic pathogens of humans. A total of 16 potentially pathogenic species were isolated, including *Aspergillus fumigatus* at up to 53.5 colony-forming units (CFU) per gram dry soil and *Scedosporium apiospermum* (*Pseudallescheria boydii*) at up to 97.0 CFU/g. Other common species included *Phialophora verrucosa* and *Fusarium solani*. *Scedosporium inflatum*, a recently described emerging pathogen, is reported for the first time from an environmental source. The results of this study, in combination with previous case reports linking mycoses to potted plants and available information on the establishment and dispersal of fungal opportunistic pathogens in indoor habitats, indicate that indoor plant soils constitute a serious mycotic hazard to the immunosuppressed patient.

Introduction

The increasing importance in recent years of opportunistic fungal infections in immunocompromised patients [57] has led to a search for sources of fungal contamination within the hospital environment [85]. Important sources of infection include catheterization in the case of yeast infections [57], and inhalation of airborne spores and conidia in the case of infections caused by mold fungi [57, 89]. High numbers of aerially transmissible, infectious mold propagules have been shown to be associated with the entry of unfiltered or inadequately filtered outdoor air into hospitals [16, 55, 56, 58, 63], the presence of contamination in air conditioning or filtering equipment [1, 31, 35, 60, 79] and the disturbance of dust and other particulate materials during hospital renovation or reconstruction [1, 4, 15, 46, 47, 63]. In-hospital reservoirs of pathogenic mold

conidia have been shown to include cellulosic fireproofing materials [1] and dust collected within false ceilings [4, 15].

A number of studies by F. Staib and coworkers have shown in addition that the soils of cultivated indoor plants may be significant reservoirs of conidia of certain pathogenic *Aspergillus* species within hospitals [71, 76, 77]. This has been confirmed by other investigators [22, 33, 68]. Similar results have been obtained in studies of ornamental plants in office [62] and home [20, 44, 72, 75, 84] environments. Individual indoor plant soils have been linked to cases of aspergillosis caused by *Aspergillus fumigatus* [20, 33, 71, 72, 73, 74], *A. niger* [69, 73, 75], and *A. flavus* [72, 73]. Serological identity in immunodiffusion tests has been shown between antigens from *Aspergillus* isolates from human infections and antigens obtained from *Aspergillus* strains isolated from the plant soils suspected as inoculum sources [74].

Finally, on rare occasions, infections with *Sporothrix schenckii* [38, 70] and *Coccidioides immitis* [70] have been linked to indoor plant soils. Despite these findings, the overall significance of indoor plant soils as reservoirs of pathogenic fungi remains incompletely known, particularly with regard to fungi other than *Aspergillus*. Therefore, we carried out extensive mycological surveys of the soils of four common indoor plant species cultivated within a hospital in an attempt to elucidate the overall significance of soils as reservoirs of infectious fungal material.

Materials and methods

Five indoor plants cultivated in a corridor of a large urban hospital in Toronto, Canada, were chosen for study. They included two representatives of *Dieffenbachia amoena* (dumbcane), and one representative each of *Ficus benjamina* (weeping fig), *Chlorophyton comosum* (spider plant) and *Brassaia actinophylla* (Schefflera, umbrella plant). All plants grew in a climate-controlled area and had soil temperatures of 19 °C. They received natural light from a west-facing window, were watered weekly (twice weekly in the case of *C. comosum*), and were fertilized with a nitrogen-rich fertilizer once per month. All had been in the same corridor for over 1 year before sampling began.

Soil samples were aseptically taken from each plant on April 15 and September 15, 1986. Only surface soils were taken, as only these soils were thought to be good potential sources of airborne propagules. Soils were sampled by serial dilution plating. Suspensions were plated out onto several media. For incubation at room temperature, suspensions were plated out onto the restrictive, general-isolation media Littman's oxgall agar (Difco Laboratories, Detroit, Mich.), and sorbose-yeast extract agar [5]. The latter medium, although less well known than many other restrictive media, has previously been shown to allow efficient isolation of yeasts [81] and filamentous fungi [5, 82] from soils and other natural substrata. To prevent the possible introduction of a

sampling bias, the relative amounts of sample inoculated onto each of the restrictive media was kept constant between plant soil samples.

In addition, two selective media were used: Sabouraud peptone-dextrose agar with an additional 30% sucrose, intended to select for moderately osmotolerant species, and Littman agar amended with 50 mg liter⁻¹ cycloheximide, intended to select for cycloheximide-tolerant species. All isolation media were amended with sufficient chloramphenicol, gentamicin, and/or chlortetracycline to inhibit bacterial growth. Plates were incubated at room temperature and examined after 7, 14, 21, and 28 d. In addition, a sample of Littman agar plates inoculated with relatively concentrated soil suspensions (1:10 and 1:100 dilutions) was incubated at 37 °C and examined as above. A sample of cycloheximide-supplemented Littman agar plates was also incubated at 37 °C. All fungal colonies (including yeasts) growing on all isolation media were subcultured to modified Leonian's agar [36] and identified according to standard references and procedures [10, 11, 29, 49].

For each soil sample examined as above, a sample of equal fresh weight was dried to desiccation in a drying oven. The presence of fungal propagules in microbially-processed soil samples was then calculated as colony-forming units (CFU) per gram dry soil.

Results

Of a total of 1646 isolates examined and identified, 232 (14.1%) belonged to species of human pathogenic significance [2, 21, 27, 40, 53, 87]. Common saprobic *Cladosporium* and *Penicillium* species recorded from a small number of dubious or highly unusual infections are excluded from this number. These and other saprobic fungi will not be dealt with in detail here. Table 1 gives the number of CFU/g dry soil of pathogenic fungi associated with each of the plants in April and September.

Aspergillus fumigatus, the most common cause of hyphomycetous opportunistic infections and the most virulent of the opportunistic molds [11],

Table 1. Fungal opportunistic pathogens isolated from soils of five different indoor plants cultivated within a hospital. Density of fungal propagules in plant soils in colony-forming units per gram dry soil. Data broken down by individual plant soil and by season of isolation trial.

Fungal species	FB ¹		BA		CC		DB1		DB2	
	S ²	F	S	F	S	F	S	F	S	F
<i>Aspergillus fumigatus</i>	14.3	53.5	—	—	—	—	15.4	11.8	10.0	—
<i>A. niger</i>	—	—	<10*	—	—	—	—	—	<10*	—
<i>A. sydowii</i>	—	—	—	—	—	—	—	4.2	—	—
<i>A. versicolor</i>	—	8.4	—	—	66.6	7.5	7.7	58.8	—	—
<i>Coniothyrium fuckelii</i>	—	—	—	—	—	—	—	—	—	6.2
<i>Exophiala jeanselmei</i>	—	17.1	—	—	—	—	—	—	—	—
<i>Fusarium oxysporum</i>	—	1.4	—	26.2	<10*	—	—	—	<10*	—
<i>F. solani</i>	7.1	1.4	60.0	10.5	<10*	—	—	2.4	10.0	—
<i>Lecytophora mutabilis</i>	—	2.8	—	—	—	—	—	—	—	—
<i>Paecilomyces lilacinus</i>	—	—	—	—	—	—	—	2.4	—	—
<i>P. marquandii</i>	—	2.1	—	—	—	—	7.7	—	—	—
<i>P. variotii</i>	—	—	—	—	—	—	—	—	5.0	—
<i>Phialophora verrucosa</i>	7.1	47.1	—	—	—	—	—	5.5	<10*	—
<i>Rhizopus microsporus</i>	—	—	—	—	—	—	—	—	—	1.6
<i>Rhodotorula minuta</i>	—	2.8	—	—	—	—	—	—	—	—
<i>Scedosporium apiospermum</i>	7.1	4.3	—	97.0	—	—	7.7	9.4	5.0	3.0
<i>S. inflatum</i>	—	2.1	—	5.9	—	—	—	—	—	—
Total fungal propagules	708	560	1680	653	2820	212	370	119	195	199

¹ Codes for individual potted plants: FB = *Ficus benjamina*, BA = *Brassia actinophylla*, CC = *Chlorophyton comosum*, DB1 and DB2 = *Dieffenbachia amoena*, two different individuals.

² Codes for seasonal sampling. S (spring) = April 1986, F (fall) = Sept. 1986.

* Damage done in shipping to a small number of phials bearing soil subsamples for desiccation prevents calculation of exact figure.

was strongly associated with certain plant soils. Greatest numbers were isolated from the soil of *Ficus benjamina*, particularly in September when 53.5 CFU/g were found. Smaller numbers were found associated with *Dieffenbachia amoena* plants. Continuity was evident in *A. fumigatus* populations between seasons in the *F. benjamina* plant and one of two *D. amoena* plants. Interestingly, no colonies at all were obtained from the remaining two plant species in either April or

September. *A. fumigatus* was isolated regularly in low numbers from Anderson samples of airborne fungal propagules throughout the hospital in which the study took place, particularly in autumn, and was expected to sediment out in small numbers onto the surface soils of plants. The populations of *A. fumigatus* propagules in plant soils did not show the even distribution pattern such sedimentation would be expected to bring about. It should be noted that the *Brassia*

actinophylla plant, which contained no *A. fumigatus*, was immediately adjacent to the infested *F. benjamina*, was of a similar size and was planted in similar soil in a pot of similar diameter.

Other *Aspergillus* species were also isolated from plant soils. *A. niger*, which occasionally causes opportunistic infections [e.g., 17, 24, 42, 43, 75], was isolated in low numbers, as was *A. sydowii*, a species best known as a pathogen from nail infections [86]. *A. versicolor*, a species also associated with nail infections [14] but occasionally seen in other aspergilloses [53], was isolated from several plant soils, particularly when soil suspensions were plated on hyperosmotic medium. The aggressive opportunistic pathogen *A. flavus*, although occasional in air samples, was never isolated from plant soil samples.

The most abundant pathogen in the plant soils in general was *Scedosporium apiospermum*, the anamorph (conidial state) of the well-known opportunist *Pseudallescheria boydii*. The anamorphic name is used here because some but not all isolates examined produced the *P. boydii* state after 1 month on Leonian's agar or Sabouraud's peptone-glucose agar. In our experience, this is true of *S. apiospermum* isolates obtained from human infections as well. The presence in *B. actinophylla* soil of 97.0 CFU/g *S. apiospermum* made this fungus one of the most common species (pathogenic or nonpathogenic) in the soil. Other plant soils harboured smaller quantities of *S. apiospermum* propagules. A comparison sample of over 7000 fungi isolated from air by Anderson sampling within the same hospital throughout the year yielded no colonies of *S. apiospermum*.

A second species of *Scedosporium* was also obtained from plant soils. *S. inflatum* is a recently described [37] agent of mycotic arthritis and subcutaneous infections [61]. Apart from the isolates obtained here from in-hospital plant soils, the species has only been isolated from human clinical material. The plant isolates were studied in detail by Malloch (pers. comm.) and Salkin *et al.* [61] and found to be indistinguishable from clinical isolates.

Phialophora verrucosa, long known as an agent of chromoblastomycosis and phaeohyphomycosis

in humans [2, 53], was also strongly represented in one plant soil (*Ficus benjamina*) and present in two others. Unlike the *Aspergillus* species, this fungus has no record as an agent of nosocomial infections. It was not isolated from air samples.

Fusarium solani and *F. oxysporum*, species both known as agents of disseminated infections in hospitalized patients [3, 8, 54, Richardson *et al.*, in press [52]] were present in several of the plant soils in quantities up to 60 CFU/g. *Fusarium* species were rare in air samples, and *F. oxysporum* and *F. solani* in particular were not isolated. Opportunistic *Paecilomyces* species were present in very low numbers in plant soils, indicating probable random influx from the air, where they were not infrequently encountered. *Coniothyrium fuckelii*, recently reported from a liver infection in a leukemic patient [27], was an uncommon isolant from one *D. amoena* plant.

Zygomycetes of pathogenic significance were very poorly represented in the plant soils. One isolate of *Rhizopus microsporus*, a species containing some potentially pathogenic variants hitherto known as *R. rhizopodiformis* [64], was obtained. The isolate appeared to belong to *R. microsporus* var. *microsporus*, not var. *rhizopodiformis*. The primary Zygomycetous colonizers of the plant soils were nonpathogenic species of *Mortierella*. Another group of fungal opportunistic pathogens very poorly represented were the yeasts. The only *Candida* species present in the soils was the nonpathogenic *C. antarctica*. *Rhodotorula minuta* was found in quantities of 2.8 CFU/g in *F. benjamina* soil, but this common yeast has only been cited (under the now-synonymous names *R. pallida* and *R. marina*) in a single case of opportunistic *Rhodotorula* infection [59]. *R. rubra* is the species most often cited in connection with opportunistic *Rhodotorula* infections [12, 66].

Finally, *Exophiala jeanselmei*, an important agent of phaeohyphomycosis [87], was isolated in low numbers from *Ficus benjamina* soil.

The ease of detecting the presence of many of the opportunistic pathogens mentioned above was greatly increased by using selective media or conditions. This is illustrated in Table 2 with iso-

Table 2. The effect of selective isolation media and techniques on the efficiency of detecting opportunistic pathogens in indoor plant soils. Percentage of total isolates in different isolation trials made up by specified fungus (In brackets: total number of fungi isolated in trial).

Fungus	Plant	RT ¹	L37	CYC	37/CYC	OSM
<i>Aspergillus fumigatus</i>	<i>F. benjamina</i>	4.0 (399)	49.0 (51)	– (72)	– (6)	– (31)
<i>A. fumigatus</i>	<i>D. amoena</i>	2.7 (74)	41.7 (12)	– (18)	75.0 (4)	2.8 (36)
<i>A. versicolor</i>	<i>D. amoena</i>	– (74)	– (12)	– (18)	– (4)	38.9 (36)
<i>Exophiala jeanselmei</i>	<i>F. benjamina</i>	– (399)	– (51)	11.1 (72)	– (6)	– (31)
<i>Fusarium oxysporum</i>	<i>B. actinophylla</i>	0.6 (338)	– (47)	– (31)	– (1)	16.1 (31)
<i>F. solani</i>	<i>B. actinophylla</i>	1.2 (338)	– (47)	– (31)	– (1)	6.5 (31)
<i>Phialophora verrucosa</i>	<i>F. benjamina</i>	0.5 (399)	– (51)	30.6 (72)	– (4)	– (31)
<i>Scedosporium apiospermum</i>	<i>B. actinophylla</i>	1.8 (338)	70.2 (47)	– (31)	100 (1)	– (31)

¹ Codes for isolation techniques: RT = general restrictive isolation media, room temperature; L37 = Littman agar, 37 °C; CYC = Littman agar + cycloheximide, room temp.; 37/CYC = Littman agar + cycloheximide, 37 °C; OSM = hyperosmotic (30% sucrose) medium, room temp.

lation data for all pathogenic species obtained in quantities of 10 CFU/g or more by any technique in the September sample. The proportion of *A. fumigatus* isolates in the total assemblage of micro-fungi obtained from *F. benjamina* and *D. amoena* by dilution plating at 37 °C. was much greater than the proportion of isolates obtained by dilution plating on general-isolation media at room temperature. This relationship was highly significant ($p < .001$, X^2 statistic). *S. apiospermum* also formed a highly significantly ($p < .001$) increased proportion of the total fungal isolates obtained in 37 °C dilutions, in comparison with dilutions incubated at room temperature. (In statistical testing the *S. apiospermum* isolates from *B. actinophylla*, shown in Table 2, were compiled with the smaller numbers of isolates from *F. benjamina* and *D. amoena*.) It should be noted that neither *A. fumigatus* nor *S. apiospermum* was isolated in significantly greater numbers per gram dry soil by dilution plating at 37 °C ($p > .05$, Student's *t*-test on logarithmically transformed data). They were simply more convenient to detect and enumerate because of the selective inhibition of other organisms.

S. inflatum (not included in Table 2) was isolated only at 37 °C, while *A. versicolor*, *F. oxysporum*, and *F. solani* were most readily detected on Sabouraud agar with 30% sucrose. Similarly, in the April sample, *A. niger* and *F. oxysporum* were isolated only by this technique. Finally, the detection of pathogenic dematiaceous fungi (*E. jeanselmei*, *P. verrucosa*) was greatly facilitated by the use of cycloheximide-amended medium. This was also true of some dematiaceous species not known as human pathogens, e.g., *Exophiala pisciphila*. Cycloheximide-amended Littman agar incubated at 37 °C yielded few fungi, but most isolates obtained represented pathogenic species.

Discussion

The indoor plant soils under study proved to be surprisingly rich sources of fungal opportunistic pathogens. This was especially apparent when appropriate selective isolation techniques were used, as noted above. The epidemiological significance of finding such fungi in hospital plant soils must be discussed in light of certain biological differences among the fungi themselves.

As mentioned previously (see Introduction) there is now a well-established record, at least in Europe, of indoor plants serving as sources of pathogenic and allergenic *Aspergillus* species in hospitals and homes. For example, Staib *et al.* [76] tested 181 indoor plants representing 51 species and found that 66.7% of the plants (46 species) yielded *Aspergillus fumigatus* in the surface soils. According to Staib [70] and Staib *et al.* [77], plants which are found to be potent sources of pathogenic *A. fumigatus* conidia are typically located near a heat source, e.g., a radiator. Thus, *Aspergilli*, especially *A. fumigatus*, can be selected for as thermotolerant species in plant soils subject to repeated warming above room temperature [77]. In the present study, we have shown that even indoor plant soils with temperatures of 19 °C., slightly lower than standard room temperature, can support *A. fumigatus* populations generating substantial numbers of propagules. The number of *Aspergillus* propagules in such soils appears not to be directly related to influx from the ambient air of the hospital. Some of the plants investigated in the present study appeared to support a constant, rather than sporadic, colonization by *A. fumigatus* although actual numbers of propagules fluctuated. Such constancy has also been suggested by Staib *et al.* [75]. It must be noted that the techniques used in the present study may underestimate the constancy of fungal colonization in the plant soils, since colonization of the subsurface soil may be more constant than colonization of the surface soil.

The dispersal of potentially pathogenic *Aspergillus* propagules in hospitals is particularly problematic because members of this genus have dry, aerially-dispersed conidia. Thus, infectious propagules may enter air in large numbers when the species' habitats are disturbed, leading to the inhalation by patients of relatively concentrated inoculum. As Rhame *et al.* [51] have shown, the occurrence of *Aspergillus* infectious in hospitals appears to be more directly related to the presence of microfoci of pathogenic inoculum than to the background presence of propagules in the ambient air. In investigating the role of indoor plants as sources of concentrated *Aspergillus*

propagules, Staib *et al.* [77] showed that the dissemination of *Aspergillus* conidia from indoor plant soils by air movement alone was greatly facilitated if surface soils were allowed to dry thoroughly. Recently, Smith *et al.* [68] have demonstrated that potted plants infested with *Aspergillus* species shed a significant number of propagules into the adjacent air.

It is also possible that a significant release of propagules from plant soils occurs during watering. Kaitzis [23] showed that the act of watering *Ficus* plants grown in hydroculture within a hospital increased the number of airborne particles over the plants by more than 50-fold. The dispersal of fungal propagules, including yeast cells, in or on aqueous aerosols is well known [e.g., 65]. With all fungal dispersal factors taken into account, indoor plants must be regarded as having the potential to be highly potent sources of pathogenic *Aspergillus* conidia.

Most of the remaining opportunistic pathogens present in the plant soils in this study (*Scenedesporium* spp., *P. verrucosa*, *Fusarium* spp., *E. jeanselmei*) were fungi which bear their conidia in slimy heads. These sorts of conidia are often dispersed in nature through water movement or the activity of arthropods and other animals. Also, however, propagules of this sort of fungus are always present in air samples, even though they are generally greatly outnumbered by the propagules of dry-spored species. Their presence may be due to the dispersal by air movement of conidia whose slimy coating has dried, or to the aerosolization process mentioned above. Although none of the wet-spored fungi isolated in this study have been explicitly documented as causing nosocomial infection, they have been shown in many individual case reports to cause infection in hospitalized, immunosuppressed patients [e.g., 7, 13, 67, 88], and patients with indwelling catheters [25, 26, 41, Richardson *et al.*, in press [52]] and aortic implants [19, 78]. What proportion of these infections originated within the hospital is a matter which requires further investigation. However, a recent review of hyalohyphomycotic infections caused by *Fusarium* species (excluding onychomycosis, oculo-

mycosis, and mycetoma) concluded that in 30 out of 37 cases surveyed the infection was likely nosocomial in origin [39]. The isolation of *Exophiala jeanselmei* from contaminated surgical equipment has been reported by Potel *et al.* [50], and a case of *Exophiala (Wangiella) dermatitidis* infection subsequent to surgery (penetrating keratoplasty) has also come to light [32]. *S. apiospermum* (sometimes recorded under the now-disused names *Petriellidium boydii*, *Allescheria boydii* and *Monosporium apiospermum*) has been reported from post-surgical infections [18, 30, 34] and as a cause of infection subsequent to an injection of anaesthetic into the spinal column [6].

Wet-spored opportunists are associated with various niches within human dwellings: for example, *Exophiala* species and other 'black yeasts' appear to be associated with sinks and drains [45]. *Fusarium* species, as important plant pathogens, are commonly associated with plant material in general [11], while *Pseudallescheria boydii* (and alternate state *S. apiospermum*) linked to human infection has been isolated from a shower curtain [53]. In our own laboratory, we have dealt with a case where *S. apiospermum* was found growing profusely in a canister left out catch the drip from the cooling system of a piece of machinery within an operating theatre. The importance of environmental mold contamination in operating theatres as a factor in the development of such infections as fungal prosthetic valve endocarditis has been recognized [48].

The wet-spored opportunistic fungi isolated in this study belong to species which are relatively common. They are by no means ubiquitous, however, and the presence of potent reservoirs of inoculum within hospitals is surely a matter of concern. Wet-spored opportunistic fungi, like the pathogenic yeasts, are likely to be highly dangerous when they come into contact with wounds, burns, catheterization sites, surgical apparatus or environs, or graft and transplant material. Indoor plant soils can be expected to be highly stable reservoirs of such organisms, and may be sources for temporary colonization of less stable habitats, e.g., room dust, sinks and drains, and equipment

subject to periodic disinfection. In connection with this possibility, it is interesting to note that in the present study, some sedimentation plates put down to detect airborne fungal propagules near the indoor plants were rapidly discovered and invaded by a colony of ants. The presence of these insects, unknown to the scrupulous cleaning staff of this modern hospital third floor, showed how easily wet-spored fungi could be disseminated within hospital settings.

In the last two decades, various organic materials, including flowers [83], vegetables [28], and even damp wooden wall material [80] have been recognized as potential hazards to the immunosuppressed patient. The results of the present study reaffirm the suggestion that indoor plants should also be considered potentially hazardous to such patients [9, 33, 76]. This is true not only when the plants are maintained near heat sources but even under the most moderate, controlled indoor conditions.

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