Species richness and ecological characterization of wood-inhabiting agaric fungi on home-garden logs in semi-urbanized areas in Colombo suburbs

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Abstract

Agaric fungi found on fallen logs of different wood species in home gardens were studied. Species richness and their substrate preferences were determined by examining the fruit body formation, habit and frequency of their appearance on the different wood. The effects of temperature, rain and moisture on fruit body formation were also correlated. During the study period 36 fungal species were identified as wood-inhabiting agaric fungi on 25 home-garden wood species. Frequency of appearance of fruit bodies was directly related to the rainfall pattern, but amount of rainfall, temperature and relative humidity did not show any relationship. The highest species richness was found on *Cocos nusifera*, recording 16 agaric species. *Artocarpus heterophyllus, Tectonia grandis, Swietenia. macrophylla* and *Vitex altisima* showed resistance to macrofungal attack. *Schizophyllum commune* was observed on 16 wood species as the commonest agaric species while 17 agaric species recorded their preference to one particular wood species. Since there was a high diversity of wood decaying agaric species inhabiting most of the wood species in this semi-urbanized area, it is possible to cause considerable damage to valuable wood and wood products in service resulting in economic loss.

Key words: agaric fungi, fallen logs, species richness, wood-decay

Introduction

Wood is the natural habitat for most macrofungi, and wood inhabiting fungi have been studied extensively in forests (Hoiland and Bendiksen, 1996; Lindblad, 2000, Schmit, 2005; Brown *et al.*, 2006; Johan, 2006). Most studies have focused on decay causing polypores, molds and wood staining fungi (Lindblad, 2001; Yang, 2005; Linder and Burdsall, 2006). Though there is a considerable wood diversity along with valuable timber species in urbanized areas, as home-garden wood species, small woods, log yards and timber stores much attention has not been made on wood-decaying macrofungi on such habitats. But some studies have been carried out mainly on disease causing polypores in urban trees and ornamental trees (Lindblad and Ryvarden, 1999; Elliot and Broschat, 2001; Annesi *et al.*, 2003; Al-bahry *et al.* 2004) However, agaric fungi, specially in urban areas cause considerable damage to fallen logs and timbers by means of decaying (Jayasekera *et al.*, 2005).

Many wood-inhabiting macrofungi belong to the phylum Basidiomycota (Yang, 2005). A few of them belonging to the phylum Ascomycota. Fungi belong to these two phyla cause significant economic loss by decaying heartwood affecting the merchantable timber volume, while other wood-inhabiting microfungi are restricted to sapwood without causing any economic damage. The wood-inhabiting basidiomycetes are the climax colonizers in both the softwood and hardwood in untreated wood, and the major agents found in wood in a variety of terrestrial habitats (Boddy, 1991). Wood-decaying macrofungi utilize major structural components of wood tissues as their food source resulting in a weakening of the wood structure and loss of strength and volume.

Wood decay is totally dependent on the conditions to which the wood is exposed and if these conditions are favourable for fungal growth, speedy wood decaying processes can be observed. Moreover, susceptibility of wood species to decay varies and some species are resistant to decay due to extractives deposited in the wood cells. These extractives have some degree of toxicity to decaying organisms (Annesi, 2003). Knowledge of the wood species and the association of wood-decaying macrofungi along with ecological characters is a key factor for determining wood preservation methods, specially in outdoor environments. The main objective of this study was to evaluate activities of wood-inhabiting agaric fungi qualitatively and quantitatively as an integrated study of host specificity, species richness, substrate quality and related climatic factors.

Materials and Methods

Study area

This study was carried out in a semi-urbanized area in south and southeast of Colombo (Homagama, Maharagama, Piliyandala and Moratuwa area), Sri Lanka where the presence of home gardens and scattered small woods is the most characteristics feature. Though the area is semi-urbanized and moderately populated, wood species diversity is relatively high due to land use pattern and agroforestry practices, which maintain a high diversity of wood species. Home gardens in the study area consist mostly of hardwood species. No soft wood species were found except *Pinus caribia.* Hardwood species comprised both monocot and dicot woods.

The study area belongs to lowland wet zone of Sri Lanka with elevation less than 50 m having high relative humidity (70-80 %) and experiencing average monthly rainfall 119.5 mm with average rainy days 11 per month. The average temperature was recorded as maximum 32°C and minimum 25 °C (Source: Meteorology Department, Sri Lanka).

Macrofungal investigation

The study was carried out during the period from 2002 to 2004 and twelve home gardens having different wood species were selected randomly. Fallen logs were a common occurrence in these home gardens, and all logs were in contact with the ground, which provided a suitable substrate for wood-inhabiting macrofungi. More attention was therefore made on fallen logs for this study. Field data were recorded on the decaying stage of wood, distribution of fruit bodies on the substrate, habit, life span of the fruit body and frequency of appearance. Fresh specimens were collected for macroscopic and microscopic studies. Spore-prints were also prepared for further identification using fresh fruit bodies. Habitat association was determined examining fruit bodies on barks, sapwood and heartwood. Logs were categorized into four groups based on the condition of decaying stage; Stage 1 (S1); bark deteriorated and easily removable, Stage 2 (S 2) - incipient decay; wood appears sound but evidence of early decay is detectable when examined closely, Stage 3 (S3) - intermediate decay; decay is clearly recognizable and the loss of wood structure evident and Stage 4 (S4) -advanced decay; wood structure is drastically altered.

Data on monthly rainfall, number of rainy days per month, temperature and relative humidity were obtained from Meteorology Department, Sri Lanka. Agaric fungi were identified using standard keys and available literature (Lange and Hora,1963; Coomaraswamy, 1979; Courtecuisse and Duhem, 1995; Emberger, 2006; Kuo, 2007).

Results

Results showed that 36 wood-inhabiting agaric fungi were associated with 25 wood species of fallen logs in home gardens (Table 1). However, most sound woods were resistant to agaric fungal attack and susceptibility increased with the aging of logs. *Artocarpus. heterophyllus , Bridelia retusa, Lannea coromandelica. Swietenia macrophylla, Tectonia grande, Terminalia arjuna* and *Vitex altisimma* were susceptible to agaric fungal attack only at the advanced decay stage (S4) of logs. More species appeared on S2 and S3 stages of wood than that of S4. No agaric species were observed at S1 stage of wood. *Schizophyllum commune* was observed on most wood species at incipient stage (S2) of decay. Agaric species richness was high on *C. nusifera* whereas agaric species was limited to one on 17 wood species.

Table 1. Wood-inhabiting agaric fungi on different wood species

Wood species	Fungal species and stage of wood-decay (S1- S4)
Albizia lebbeck	*Inocybe geophylla* (S2), *Marasmius lupuletorum* (S2), *Schizophyllum commune* (S2,S3)
Alstonia macrophylla	*Inocybe geophylla* (S2), *Marasmius lupuletorum* (S2), *Schizophyllum commune* (S2,S3) *Schizophyllum commune* (S3)
Anacardium occidentale	*Lentinus gigantius* (S3), *Schizophyllum commune* (S2)
Artocarpus heterophyllus	*Cantharellus formosus* (S4), *Lentinus lecomtei* (S4).*Marasmius umbraculum* (S4) *Volvariella volvacea* (S4)
Bambusa vulgaris	*Flammulina velutipes* (S2)
Bridelia retusa	*Pleurotus flabellantus* (S4)
Caryota urens	*Marasmius caryotae* (S3), *Coprinus disseminatus* (S3)
Cocos nucifera	*Cantharellus cibarius*(S3), *Collybia hariolorum* (S4), *Coprinus auricomus* (S4) *Coprinus disseminatus* (S2,S3) *Coprinus macropus* (S2), *Hydropus scabripes* (S4), *Hygrosphorus fuscoalbus* (S3), *Hyphalloma capnoides*.(S3), *Lentinus gigantieus* (S2), *Mycena galericulata* (S2,S3), *Mycena maculata* (S3), *Pholiota mutabilis* (S2), *Pluteus cervinus* (S3), *Psathyrella fulvescens* (S3), *Psathyrella hydrophillum* (S3), *Schizophyllum commune* (S2, S3)
Hevea brasiliensis	*Inocybe geophylla* (S2), *Lentinus sajor-caju* (S2), *Schizophyllum commune* (S2,S3)
Lannea coromandelica	*Coprinus laanii* (S3)
Leucaena leucocephala	*Schizophyllum commune* (S2)
Macaranga peltata	*Marasmiellus ramealis* (S2), *Mycena maculata* (S3), *Mycena galericulata* (S4)
Mangifera indica	*Cantharellus formosus* (S2), *Lentinus giganteus* (S2), *Marasmiu cohaerens* (S2,S3) *Neolentinus schaefferi*(S2), *Panellus mitis* (S2), *Schizophyllum commune* (S2,S3)
Melia dubia	*Schizophyllum commune* (S3)
Michelia champaka	*Favolus ciliaris* (S2, S3, S4), *Inocybe geophylla* (S3), *Schizophyllum commune* (S3, S4).
Nephelium lappaceum	*Schizophyllum commune* (S3).
Nerium oleander	*Cantharellus cibarius* (S3)
Pinus caribea	*Schizophyllum commune* (S2,S3)
Spondias dulielis	*Schizophyllum commune* (S3)
Swietenia macrophylla	*Schizophyllum commune* (S3)
Tabebuia	*Clitocybe gibba* (S2) *Lentinus conchatus* (S2,S3,S4), *Pleurotus ostreatus* (S2,S3)
Tectonia grandis	*Clitocybe gibba* (S2) *Lentinus conchatus* (S2,S3,S4), *Pleurotus ostreatus* (S2,S3)
Terminalia arjuna	*Schizophyllum commune* (S4)
Terminalia cattappa	*Schizophyllum commune* (S3)
Vitex altisima	*Lentinus lecomoti* (S4)

Most of agaric fungal fruit bodies appeared during the inter-monsoon seasons in the year i.e January to March and September to October (Figure 1). Moreover, the highest number of fruit bodies was formed in September - October period when the area received a relatively high rainfall similar to the southwest monsoon period. Though during the southwest monsoon, from May to August, the study area received heavy rainfall, the least no of agaric species were observed. Out of 36 species studied, *Favolus ciliaris*, *Cantharellus cibiaris*, *Coprinus auricomus, Schizophyllum commune* and *Lentinus sargo-caju* were recorded as the most frequently found agaric species on logs.

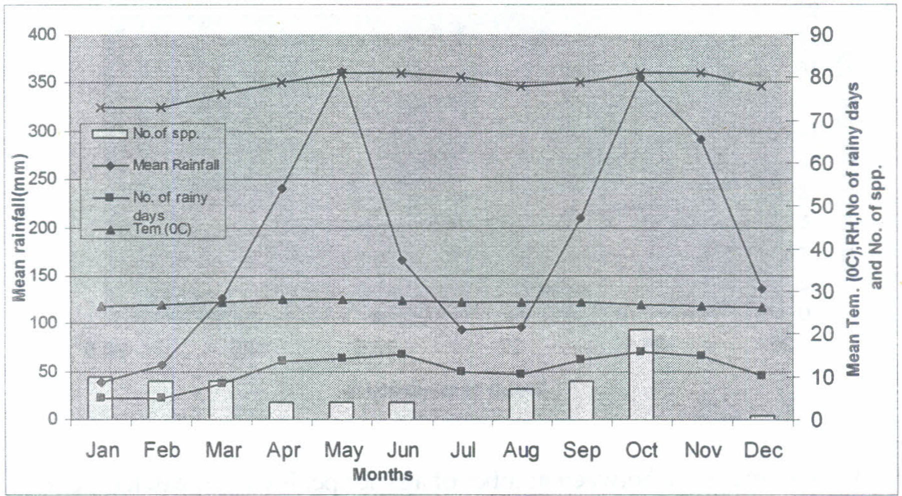

Figure 1. Agaric fruit body formation as influenced by climatic factors

However, there was no marked variation in mean temperature and relative humidity in the study area. Therefore, it was not possible to observe relationships between these two parameters and the fungal fruit body formation. Further, results showed that, fruit body formation was not dependent on the monthly mean number of rainy days. Correlation analysis revealed that there was no correlation ($r = 0.098$) between number of agaric species and rainfall (Figure 2). Moreover, a correlation ($r = -0.132$) was not observed between number of agaric species and mean temperature (Figure 3).

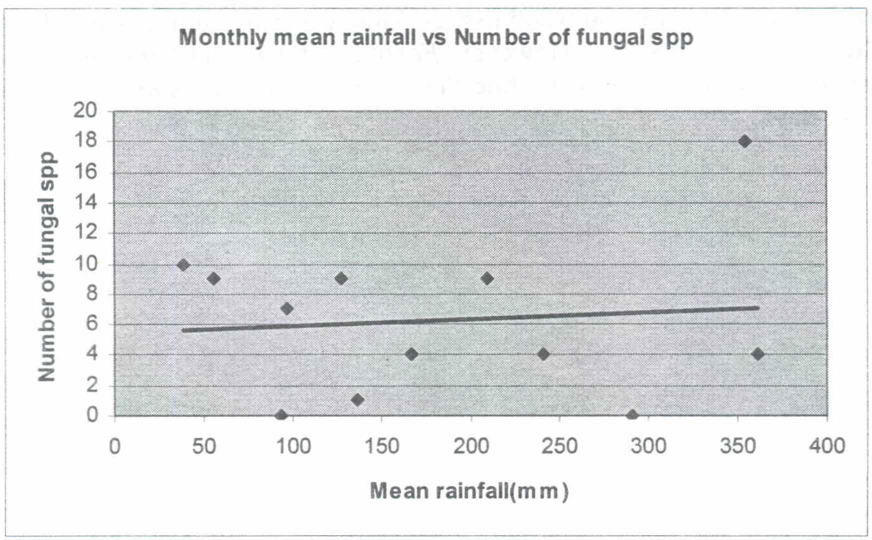

Figure 2. Correlation between number of agaric species and rainfall (mm)

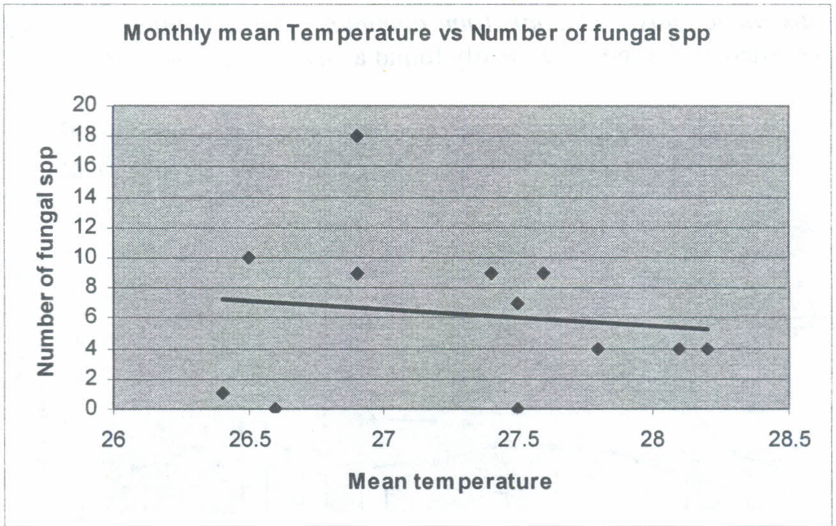

Figure 3. Correlation between number of agaric species and mean temperature (^{0}C)

Fruit bodies of wood-inhabiting agaric fungi were observed as solitary fruit bodies, clustered or massive on the wood substrate (Table 2). The habit of fruit body formation is an important morphological feature for identification of agarics. *Schizophyllum commune* showed a wide host range by attacking 16 wood species whereas 17 agaric species showed host specificity by selecting only one host. Seven agaric species preferred more than one wood species. Most wood-inhabiting fungi colonized on wood tissues while some of them inhabited on both bark and wood tissues. Most wood-inhabiting agaric fruit bodies lasted for one day. However, *Favolus ciliaris* and *Schizophyllum commune* lasted for 1-3 weeks while *Pleurotus* spp. and *Lentinus* spp. lasted for 3-7 days.

Agaric species	Habit	No. of wood species attacked	Life time of fruit body (days)	Type of substratum
Cantharellus cibarius Fr.	clustered	2	7	Wood
Cantharellus formosus Corner	clustered	2	7	Wood
Clitocybe gibba (Pers:Fr) Kummer	clustered	1	2-3	Wood
Collybia hariolorum (Bull:Fr) Quelet	solitary	1	1	Wood
Coprinus auricomus Patouillard	clustered	1	1	Wood
Coprinus disseminatus (Pers:Fr) SF Gray	massive	2	1	Bark &Wood
Coprinus laanii Kits van Waveren	massive	1	1	Bark & Wood
Favolus ciliaris Mont.	clustered	1	14-21	Wood
Flammulina velutipes (Curt:Fr) Karsten	clustered	1	2	Wood
Hydropus scabripes	solitary	1	1	Wood
Hygrosphorus fuscoalbus (Lasch:Fr) Fr	solitary	1	1	Wood
Hypholloma capnoides (Murrill) Singer	clustered	1	1	Bark & Wood
Inocybe geophylla (Fr:Fr) Kummer	clustered	2	1	Wood
Lentinus conchatus (Bull:Fr) Schroeter	clustered	1	7	Bark & Wood
Lentinus gigantieus Berk.	clustered	3	7	Wood
Lentinus lecomtei Fr.:Fr.	clustered	1	7	Wood
Lentinus sajor-caju (Fr.:Fr.)Fr.	clustered	1	7	Bark & Wood
Marasmius caryotae	clustered	1	1	Bark & Wood
Marasmius cohaerens (Pers:Fr) Cke&Q	solitary	1	1	Wood
Marasmius lupuletorum	Solitary/ clustered	1	1	Wood
Marasmiellus ramealis (Bull:Fr) Singer	solitary	1	1	Bark & Wood
Marasmius umbraculum	clustered	2	1	Wood
Mycena galericulata	solitary	1	1	Wood
Mycena maculata	solitary	2	1	Wood
Mycena grisea (Scap:Fr) SF Gray	clustered	1	1	Wood
Neolentinus schaefferi (Weinm) Redhead	clustered	1	3-5	Bark & Wood
Panellus mitis (Batsch:Fr) Singer	clustered	1	1	Bark
Pholiota mutabilis	clustered	1	1	Bark & Wood
Pleurotus flabellantus (Schaeff.:Fr) P.Kumm.	clustered	1	3-5	Wood
Pleurotus ostreatus (Jacqi:Fr) Kummer	clustered	1	3	Bark & Wood
Pluteus cervinus (Sch:Fr)Kummer	clustered	1	1	Wood
Pluteus nanus (Pers:Fr Kummer	solitary	1	1	Wood
Psathyrella fulvescens (Romagness) Romagness	solitary	1	1	Wood
Psathyrella hydrophillum (Fries) Maire	clustered	1	1	Wood
Schizophyllum commune Fries	clustered	16	7-14	Bark & Wood
Volvariella volvacea (Bull:Fr) Singer	Solitary/ clustered	1	1-2	Wood

Table 2. Ecological and biological characteristics of agaric species on different wood species

Discusion and Conclusion

This study revealed that agaric fungi are colonizing wood species at or after the incipient decay stage and that sound wood was free from agaric fungal invasion. The wood-decay basidiomycetes form the climax of the succession of colonizing microorganisms on normal wood in ground contact, but they appear late in the succession (Dickinson,1982; Lindblad, 1998). A total of 36 wood-inhabiting agaric fungal species were associated with 25 wood species in home gardens in the study area (Table 1). *S. commune* was the commonest agaric species across the study area attacking 16 wood species. Further, *Cantharellus cibaris*, *Favolus ciliaris*, *Coprinus auricomus*, *Lentinus sajor-caju and Mycena spp.* were frequently found as active wood decaying agarics. Osono *at el.* (2002) reported that similar agaric fungal species were identified as more active wood decomposers in cool temperature deciduous forests. From this study it is evident that some of the active wood-decaying agaric genera found on logs are common also in leaf litter decomposition. Afyon *et al.* (2005) have identified *S. commune* as the most common species and *Pholiota lenta*, *Pluteus tricuspidatus*, *Pruteus umbrosus* are wood-decaying macrofungi in coniferous broad leaf forests in the western Black Sea Region. Therefore, these agaric species can be considered as common wood decaying fungi, which can survive in a wide range of climatic conditions.

Moreover, results showed that a few agaric species were living on different wood species showing a wide host range whilst most species were found on only one wood species reflecting their host specificity. In contrast, Linblad (2000) reported that most wood rotting fungi have broad host ranges in tropical areas. However, his results were based on wood-inhabiting Aphylophorales.

C. nusifera harboured 16 agaric species, and the fungi attacked the bark, sapwood and heartwood. Higher susceptibility of monocot wood to decay fungi under natural environmental conditions may be due to the structural difference of wood from that of dicot. Results showed that *C. nusifera* was the preferred wood substrate for agaric fungal inhabitants in this area. Since *C. nusifera* is extensively used in indoor and outdoor constructions and the furniture industry, it is essential that the timber should be treated with preservative chemicals to prevent invasion by wood-decay fungi.

Agarics were not found on *A. heterophyllus, T. grandis, S. Macrophylla* and *V. altisima* until the logs reached the advanced stage of decay, demonstrating their resistance to agaric fungi. It is suggested that the accumulated toxic substances (extractves) in wood cells are attributed to the resistance of these wood species to agaric fungal attack (Levy, 1982). Because differences in the chemical constituents of the cell walls or cell contents may affect the ability of wood-decaying fungi to utilize them as a nutrient source (Brown *et al.*, 2006). Hence, these resistant wood species can be graded as durable wood species for use of outdoor environments. However, some agarics colonized only at the advanced stage of decay on durable wood species. At this later stage, the wood is susceptible to fungal invasion due to drastically altered wood structure and lack of toxic substances in wood cells. In terms of species richness, more agaric species were found on less decayed wood (83%) than well-decayed wood across the study area.

Since the climatic factors *i.e* physiological and ecological conditions were favorable for fungal invasion and development in the study area, wood-inhabiting fungi were observed throughout the year. In addition, high species richness was observed after the cessation of rain because moistened wood fibres provide an ideal internal environment for fruit body formation. However, the number of rainy days and mean rainfall were not directly related to the fruit body formation, but the pattern of rainfall is the most significant factor for the growth of agaric fruit bodies. Therefore, even the area experiencing heavy rainfalls during the southwest monsoon season, the least number of agaric species were observed. This is because during this monsoon season, continual heavy showers with winds experience throughout the day are not favourable for fruit body formation. But during the inter-monsoon period only afternoon showers experience and a pattern of continual rain cannot be observed, that is more favourable for the agaric fungal fruit body formation. Once the wood exposes to continual heavy showers for longer period, wood fibers get saturated. Under such situations basidiomycetes cannot colonize and time is required for bacteria to destroy the pit membrane to give rise to aerobic conditions favourable for basidiomycete colonization.

Lentinus spp. were identified as brown rot causing fungi while *Pleurotus spp. Mycena spp.* and *S. commune* were white rot causing species. *Lentinus* spp. were found only on old logs of *B. retusa and V. altisima* not on sound wood. Old age tissue colonization by agaric fungi demonstrates that *B. retusa* and *V. altisima* are resistant to brown rots. However, *M. indica* and *C. nusifera* were colonized by *Lentinus spp.* at the incipient decay stage, because these wood species are not resistant to brown rot fungi. Since most wood species are subject to decay by the enzymatic activities of macrofungi under outdoor environmental conditions, treating wood with wood preservatives can enhance durability of wood in service. Most of wood-decaying agaric fungi found in semi-urbanized tropical region are also common species in different types of forests in other parts of the world. Therefore, more attention should be made on wood-decaying agaric fungi, especially on the commercial timber, which are extensively used in urban areas.

S. commune, L. giganties, P. ostreatus and *V. volvaceae* are edible mushrooms and these are cultivated (except *S. commune*) on a commercial scale. It is evident that relevant sawdust can be used as the substratum for cultivation of edible mushrooms.

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