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Biodiversity of macrofungi in Yenepoya Campus, Southwest India

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Abstract

Public and private institutions usually possess land space for buildings, play grounds, gardens, avenues and natural vegetation. Such landscapes possess diverse flora, fauna and microbiota. Inventory of biodiversity in the vicinity constitutes first step to follow the status of habitat based on diversity, carrying capacity and further steps for conservation or rehabilitation. The current study assessed macrofungal diversity in the Yenepoya Campus of southwest India in continuation of assessment of flora and fauna. This preliminary inventory was carried out in 10 habitats (three plantations, bamboo thickets, gardens, acacia groves, avenue trees, lawns, dumped wood and termite mounds), which yielded 40 species of macrofungi belonging to 31 genera. Among them, twelve species were edible, twelve species were medicinal, two species were ectomycorrhizal and finally one species was entomophagous. Substrates supporting macrofungi include soil (particolous), humus (humicolous), woody debris (lignicolous) and insects (entomophagous). Results showed an abundance of five species (*Amylosprous campbellii*, *Daldinia concentrica*, *Lenzites betulina*, *Marasmiellus stenophyllus* and *Schizophyllum commune*), 13 others were common and 22 species were occasional. In addition to flora and fauna, inventory of saprophytic macrofungi (involved in recycling the organic matter) occurring in an institution surroundings help designating the habitat as healthy or regenerated or impoverished to follow appropriate measures to maintain the status quo, rehabilitation and conservation. This study suggests possibilities of domestication and utilization of several edible, medicinal and ectomycorrhizal fungi in this area.

Key words– Biodiversity, mushrooms, lateritic soil, leaf litter, woody litter.

Introduction

Biodiversity issues have gained importance after the Earth Summit 'Convention on Biological Diversity' (CBD) in Rio de Janeiro during June 1992. However, owing to the least concern on fungi, they have been designated as 'Orphans of Rio' (Minter 2010). In spite of such an impediment, interest on fungi as the 'fifth kingdom' has exploded globally to project their importance similar to flora and fauna. To fill the gap of CBD, the International Society for Fungal Conservation was set up to address several issues related to fungi (www.fungal-conservation.org).

Macrofungi or mushrooms are a fascinating group of visible fungi attracting the attention worldwide due to their diversity, morphology (shape and color) and economic value (nutrition, medicine and biomolecules). Most of them are epigeic, however some are hypogeic (e.g. truffles)

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and relay on animals for dispersal. Based on the plant-fungus ratio, Mueller *et al*. (2007) have predicted global macrofungi ranging between 53,000 and 110,000 species. Being saprotrophs, macrofungi grow on a wide range of substrates mainly soil, wood and leaf litter. Many of them develop a mutualistic association with roots of tree species as ectomycorrhizae. Owing to the economic importance of macrofungi in human nutrition, medicine and forestry, research has been intensified towards their diversity and utilization.

Diverse landscapes of the Western Ghats and west coast of India (e.g. grasslands; forests: shola, deciduous, moist-dry deciduous, evergreen, semi-evergreen, lateritic scrub jungles, mangroves; coastal sand dunes) provide suitable climatic conditions as well as substrates for growth and perpetuation of macrofungi. Checklists of the Western Ghats region of India include 616 species and 178 species of agarics in Kerala and Maharashtra states, respectively (Farook *et al*. 2013; Senthilarasu 2014). Mohanan (2011) has described up to 550 species of macrofungi from different regions of the Kerala State. Surveys in semi-evergreen and moist-deciduous forests of Karnataka yielded up to 315 species of macrofungi (Swapna *et al*. 2008). Checklist from the Western Ghats region of Maharashtra State documented 256 species of Aphyllophorales (Ranadive *et al*. 2011). On the other hand, Karun and Sridhar (2016) recorded 157 species of macrofungi from different forests of the Western Ghats of Karnataka. Up to 79 macrofungi (range 15-36 species) were recovered from the plantations, botanical garden and arboretum of the lateritic region of southwest Karnataka (Karun and Sridhar 2014; Pavithra *et al*. 2016). The coastal sand dunes and mangroves of Karnataka also consist of 64 and 46 macrofungi, respectively (Ghate and Sridhar 2016a, 2016b). There is a tendency of gradual decrease in the number of macrofungi from the Western Ghats forests towards the west coast (Western Ghats > coastal scrub jungles > coastal sand dunes > mangroves) (Karun and Sridhar 2014; Sridhar 2018). Even though the scrub jungles possess relatively less number of macrofungi than the Western Ghats, the old growth forests consist of diverse ectomycorrhizal, edible and medicinal fungi (Karun and Sridhar 2014).

Many institutions have shown interest to protect their vicinity and evaluate the extent of biodiversity. Some of them besides planting avenue trees use their land space to establish medicinal garden and arboretum to cultivate native as well as rare and endangered tree species. Such landscapes after a couple of decades produce a substantial amount of plant debris (leaf litter, woody litter, bark and inflorescence). The secondary product is the major substrate for growth and perpetuation of macrofungi. Besides, several tree species in scrub jungles are known to support ectomycorrhizal fungi (Pavithra *et al*. 2015, 2017). The Yenepoya (deemed to be University) (YU) in the coastal region of Karnataka showed concern to protect its greenery and initiated biodiversity auditing (e.g. plants, birds, butterflies and insects). At the outset several macrofungi were seen during the wet season on the campus, hence this inventory documents macrofungi on different habitats and substrates of the YU campus.

Materials and Methods

The macrofungal survey was carried out in the landscape of YU Campus spanning about 15.2 ha (12.81°N, 74.88°E; 22 m asl). The survey was confined to fortnightly intervals up to six months during monsoon and a post-monsoon period (June-November, 2016). On each sampling date, air (in the shade) and soil temperatures (at 10 cm depth) in five locations were measured by a mercury thermometer (N.S. Dimple Thermometers, New Delhi, India; Model # 17876; ±0.2°C). Similarly, humidity of air was recorded by Mextech Digital Thermohygrometer (Mumbai, India; Model # TM-1; accuracy, ±1%).

Some of the habitats suitable for the growth of macrofungi include bamboo thickets (*Bambusa burmanica*), *Acacia* groves, horticultural gardens, medicinal garden, plantations (*Areca*, banana and coconut), lawns and avenue trees. Besides, lateritic soil, humus, organic debris (woody litter, twig litter, bark litter, spathode of *Areca*, leaf litter, pods of *Acacia* and grass shreds), stubs/stumps of trees, dumped logs, standing dead trees and termite mounds are the potential substrates for growth of macrofungi. Each fungus was examined on first and subsequent sampling based on macroscopic and microscopic examinations (Olympus CX41RF; magnification, 1000X) using the diagnostic keys (Pegler 1990; Jordan 2004; Phillips 2006; Cannon and Kirk 2007; Mohanan 2011; Buczacki 2012; Tibuhwa 2012).

Results and Discussion

During the study period, air and soil temperatures ranged from 25.4-30.4°C and 25.5-27.5°C, respectively (Table 1). Humidity was higher during the first three months (June-August: 70-80.7%) than the latter months (September-November: 67.3-69.3%). Temperature and humidity regimes during the monsoon and post-monsoon period were ideal for the growth of macrofungi in different habitats as well as substrates. September month yielded the highest of 23 species followed by August (21 spp.), while in the first and last two months, fungal richness varied between 10 and 12 species (Fig. 1). A similar trend of species richness was seen in the Western Ghat forests of Karnataka (Karun and Sridhar 2014).

Table 1 Temperature and humidity during macrofungal survey in the Yenepoya Campus (June-November, 2016) (n=5; mean±SD).

	Humidity (%)	**Temperature (°C)**	
		Air	**Soil**
June 11	77.3±2.87	25.4±0.36	26.3±0.25
June 25	70.6±9.45	27.4±1.15	25.8±0.31
July 16	70.0±9.88	30.3±0.21	26.2±0.76
July 29	73.7±4.16	26.3±0.31	26.8±0.76
August 18	75.3±4.93	27.6±0.64	26.4±0.36
August 31	80.7±4.93	26.9±1.02	25.5±0.50
September 16	67.3±1.16	30.1±0.67	27.5±1.32
September 26	68.0±2.00	30.4±2.32	27.2±0.76
October 18	68.0±1.00	28.3±0.45	26.3±0.25
October 27	69.3±0.58	28.8±1.57	27.0±0.50
November 16	68.0±1.00	28.6±0.36	27.2±0.31

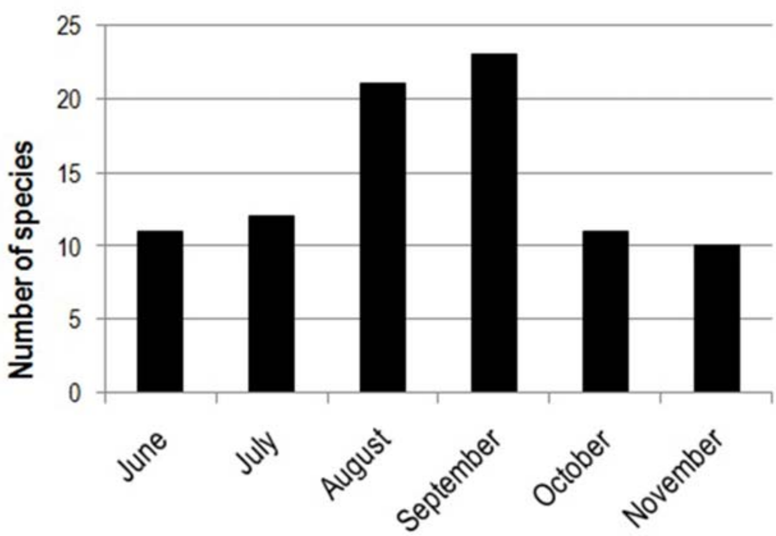

Fig. 1- Occurrence of macrofungi in different months during monsoon and post-monsoon seasons.

List of macrofungi, habitats, substrates, a period of occurrence, the extent of occurrence and salient features are given in Table 2. A total of 40 species belonging to 31 genera were recorded (Figs. 2 and 3). Five species were most abundant; those species include *Amylosprous campbellii, Daldinia concentrica, Lenzites betulina, Marasmiellus stenophyllus* and *Schizophyllum commune*. Except for *M. stenophyllus*, rest of them has been considered as medicinal. Twelve species were edible and medicinal, while only two species were ectomycorrhizal (Fig. 4). The overlapping fungi were four species as edible and medicinal (*A. campbellii*, *Lentinus dicholamellatus*, *L. squarrosulus* and *Termitomyces fuliginosus*); finally two species were edible and ectomycorrhizal (*Lycoperdon utriforme* and *Phlebopus marginatus*).

Table 2 Macrofungi in Yenepoya Campus (June-November, 2016) (*: + occasional, ++ common, +++ abundant).

Species	Habitat	Substrate	Occurrence*	Remarks
Agaricus sp. (Fig. 2a)	Lawns of playground and gardens	Soil	June (+)	Edible
Amylosporus campbellii (Berk.) Ryvarden (Fig. 2b)	Bamboo thicket	Bamboo wood	July-October (+++)	Edible and medicinal
Auricularia auricula-judae (Bull.) Quél (Fig. 2c)	*Acacia* groves and Bamboo thickets	*Acacia* wood and bamboo stubs	September (+)	Edible
Chlorophyllum molybdites (G. Mey.) Massee (Fig. 2d)	Medicinal garden	Soil	June (+)	Poisonous
Conocybe crispa (Longyear) Singer (Fig. 2e)	Lawns of playground and gardens	Soil	June and November (++)	
Coprinus disseminatus (Pers.) Gray (Fig. 2f)	Medicinal and horticulture gardens	*Acacia* wood and stubs of *Caryota urens* and banana remains	September (+)	Edible
Cystoagaricus trisulphuratus (Berk.) Singer (Fig. 2g)	Horticulture garden	Soil	July (+)	
Dacryopinax spathularia (Schwein.) G.W. Martin (Fig. 2h)	Horticulture gardens and bamboo thicket	Stubs of *Acacia* , bamboo, coconut and *Terminalia*	August (++)	Edible
Daldinia concentrica (Bolton) Ces. & De Not. (Fig. 2i)	Dumped wood and bamboo thickets	Stubs of *Acacia* and bamboo	July-November (+++)	Medicinal
Ganoderma applanatum (Pers.) Pat. (Fig. 2j)	*Areca* plantations and jack trees	Stumps of *Areca* and jack	July-November (++)	Medicinal
Ganoderma lucidum (Curtis) P. Karst. (Fig. 2k)	*Areca* plantations	Stumps of *Areca* and jack	July-November (++)	Medicinal
Gymnopilus lateritius (Pat.) Murrill (Fig. 2l)	Dumped wood	Logs and stubs of *Acacia*	August (+)	Medicinal
Gymnopilus terricola K.A. Thomas, Guzm.-Dáv. & Manim. (Fig. 2m)	Lawns of playground	Soil	June (+)	
Hexagonia tenuis Speg. (Fig. 2n)	Avenue trees	Twigs of gulmohar, gooseberry and *Pongamia*	August-October (++)	
Ileodictyon gracile Berk. (Fig. 2o)	Bamboo thickets	Humus, leaves and twigs of bamboo	June-September (++)	
Lentinus dicholamellatus Manim. (Fig. 2p)	Dumped wood	Logs and stubs of cashew and mango	August (+)	Edible and medicinal

Table 2 (Contd.)

Species	Habitat	Substrate	Occurrence*	Remarks
Lentinus squarrosulus Mont. (Fig. 3a)	*Areca* plantations	Logs of cashew	August (+)	Edible and medicinal
Lenzites betulina (L.) Fr. (Fig. 3b)	*Areca* and banana plantations	Logs and stubs of *Acacia*	June-November (+++)	Medicinal
Lycoperdon mammiforme Pers. (Fig. 3c)	Lawns of play grounds and gardens	Soil in lawns	June (+)	
Lycoperdon utriforme Bull. (Fig. 3d)	*Acacia* groves and *Areca* plantations	Soils under *Acacia* and mango trees	June (+)	Edible and ectomycorrhizal
Marasmiellus ignobilis (Berk. & Broome) Pegler (Fig. 3e)	*Areca* plantations	Stubs and wood of *Areca*	July and September (+)	
Marasmiellus stenophyllus (Mont.) Singer (Fig. 3f)	*Areca* and banana plantations	Logs of unknown wood	June-September (+++)	
Marasmiellus subaurantiacus (Berk. & Broome) Pegler (Fig. 3g)	Avenue trees	Logs and bark of *Terminalia*	August and September (++)	
Marasmius androsaceus (L.) Fr. (Fig. 3h)	*Areca* plantations	Humus and rotting spathode of *Areca*	August and September (++)	
Marasmius haematocephalus (Mont.) Fr. (Fig. 3i)	*Acacia* groves	Humus and leaf /pod litter of *Acacia*	August and September (+)	
Marasmius sp. (Fig. 3j)	*Acacia* groves	Leaves and pods of *Acacia*	September-November (++)	
Microporus vernicipes (Berk.) Kuntze (Fig. 3k)	*Acacia* groves and avenue trees	Wood of *Acacia* and *Terminalia*	September (++)	
Mycena rosea Gramberg (Fig. 3l)	Avenue trees	Humus and twig/leaf litter below mango trees	August-September (+)	
Omphalotus olearius (DE.) Singer (Fig. 3m)	Avenue trees	Soil below *Bougainvillea* and *Garcinia*	September (+)	Medicinal and poisonous
Phallus atrovolvatus Kreisel & Calonge (Fig. 3n)	Bamboo thickets and coconut plantations	Soil in basins of bamboo thickets and coconut	June (+)	
Phallus duplicatus Bosc (Fig. 3o)	Banana and coconut plantations	Soil and humus in basins of banana and coconut	June (+)	
Phlebopus marginatus Watling & N. Gerg. (Fig. 3p)	Bamboo thickets	Soil in bamboo thickets	October and November (++)	Edible and ectomycorrhizal
Polyporus sp. (Fig. 3q)	Lawns of playgrounds and gardens	Soil and on cicada	August and September (+)	Edible and parasitic
Pycnoporus cinnabarinus (Jacq.) P. Karst. (Fig. 3r)	*Acacia* groves	Logs, stubs, stumps of *Acacia*, jack and *Terminalia*	August-November (++)	Medicinal and yield pigment
Schizophyllum commune Fr. (Fig. 3s)	*Acacia* groves and bamboo thickets	Twigs, logs, stubs and stumps of *Acacia*, bamboo; grass culms	July-November (+++)	Medicinal
Scutellinia setosa (Nees) Kuntze (Fig. 2t)	*Areca*, banana and coconut plantations	Remains of coconut palms and banana	September (+)	

Table 2 (Contd.)

Species	Habitat	Substrate	Occurrence*	Remarks
Termitomyces fuliginosus R. Heim (Fig. 3u)	Termite mounds	Termite mound	July (+)	Edible and nutraceutical
Tetrapyrgos nigripes (Fr.) E. Horak (Fig. 3v)	*Acacia* groves	Twigs and pods of *Acacia*	August (+)	
Volvariella bombycina (Schaeff.) Singer (Fig. 3w)	Banana plantations	Humus and leaves of banana	July (+)	Edible
Xylaria multiplex (Kunze) Fr. (Fig. 3x)	Gardens and avenue trees	Stubs of unknown trees	August-November (++)	Medicinal

Fig. 2- Recorded taxa, for more detalis please check Table 2. Sporocarps of *Agaricus* sp. (a), *Amylosporus campbellii* (b), *Auricularia auricula-judae* (c), *Chlorophyllum molybdites* (d), *Conocybe crispa* (e), *Coprinus disseminatus* (f), *Cystoagaricus trisulphuratus* (g), *Dacryopinax spathularia* (h), *Daldinia concentrica* (i), *Ganoderma applanatum* (j), *Ganoderma lucidum* (k), *Gymnopilus lateritius* (l), *Gymnopilus terricola* (m), *Hexagonia tenuis* (n), *Ileodictyon gracile* (o) and *Lentinus dicholamellatus* (p).

Fig. 3- Recorded taxa, for more detalis please check Table 2. Sporocarps of *Lentinus squarrosulus*(a), *Lenzites betulina* (b), *Lycoperdon mammiforme* (c), *Lycoperdon utriforme* (d), *Marasmiellus ignobilis* (e), *Marasmiellus stenophyllus* (f), *Marasmiellus subaurantiacus* (g), *Marasmius androsaceus* (h), *Marasmius haematocephalus* (i), *Marsmius* sp. (j), *Microporus vernicipes* (k), *Mycena rosea* (l), *Omphalotus olearius* (m), *Phallus atrovolvatus* (n), *Phallus duplicatus* (o), *Phlebopus marginatus* (p), *Polyporus* sp. (q), *Pycnoporus cinnabarinus* (r), *Schizophyllum commune* (s), *Scutellinia setosa* (t), *Termitomyces fuliginosus* (u), *Tetrapyrgos nigripes* (v), *Volvariella bombycina* (w) and *Xylaria multiplex* (x).

Macrofungi were confined to 10 different habitats (three plantations, bamboo thickets, *Acacia* grooves, gardens, avenue trees, lawns, wood dumps and termite mounds) (Fig. 5). *Areca* plantations yielded the highest record of 10 species, followed by bamboo thickets, gardens (9 spp. each) and *Acacia* groves (8 spp.), while rest of the habitats consists of 1-6 species. *Areca* plantations are common in the southwest coast; their floor remains wet almost throughout the year and this seems to be an excellent habitat for the cultivation of edible and medicinal macrofungi to generate additional income by farmers. Similarly, the bamboo thickets are also suitable habitat to raise desired macrofungi.

Macrofungi preferred three major substrates (soil, leaf litter and wood). Among them, woody substrates showed the highest of 22 species followed by soil (18 spp.) and leaf litter (7 spp.) (Fig. 6). The overlapping fungi were the highest of five species in soil and leaf litter (*Ileodictyon gracile, Marasmius androsaceus, M. haematocephalus, Mycena rosea* and *Volvariella bombycina*); two species preferred soil and wood (*I. gracile* and *Mycena rosea*); two species preferred wood and leaf litter (*Coprinus disseminatus* and *I. gracile*). The only fungus *I. gracile* was common to wood, soil and leaf litter. Among the substrates, *Acacia* wood was highly promising due to a yield of four edible and five medicinal fungi, while the bamboo wood yielded four edible and two medicinal fungi (see Table 2). This indicates that *Acacia* and bamboo woody material could be used for cultivation of economically viable macrofungi. *Acacia* and bamboo groves could also be maintained by selective felling, which leads to support macrofungi in woody debris as well as stubs. The same serve as suitable material for furniture as well as crafts, waste materials generated during wood processing will be suitable feedstock for the cultivation of desired macrofungi.

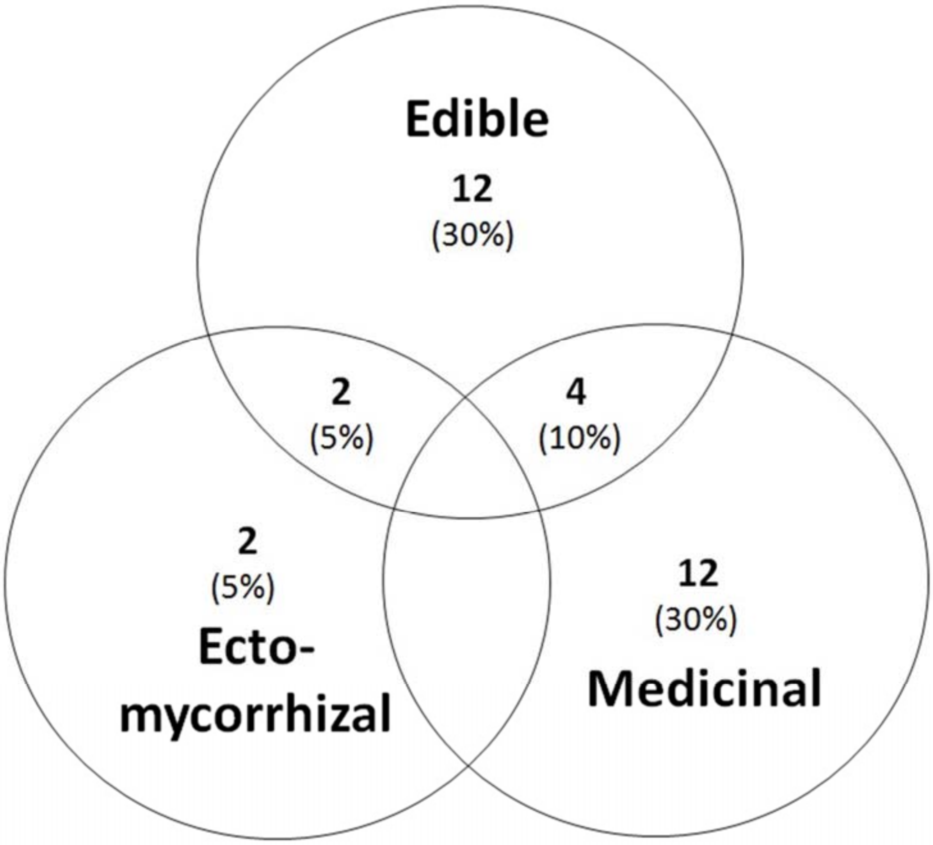

Fig. 4- Venn diagram showing distribution of edible, medicinal and ectomycorrhizal macrofungi.

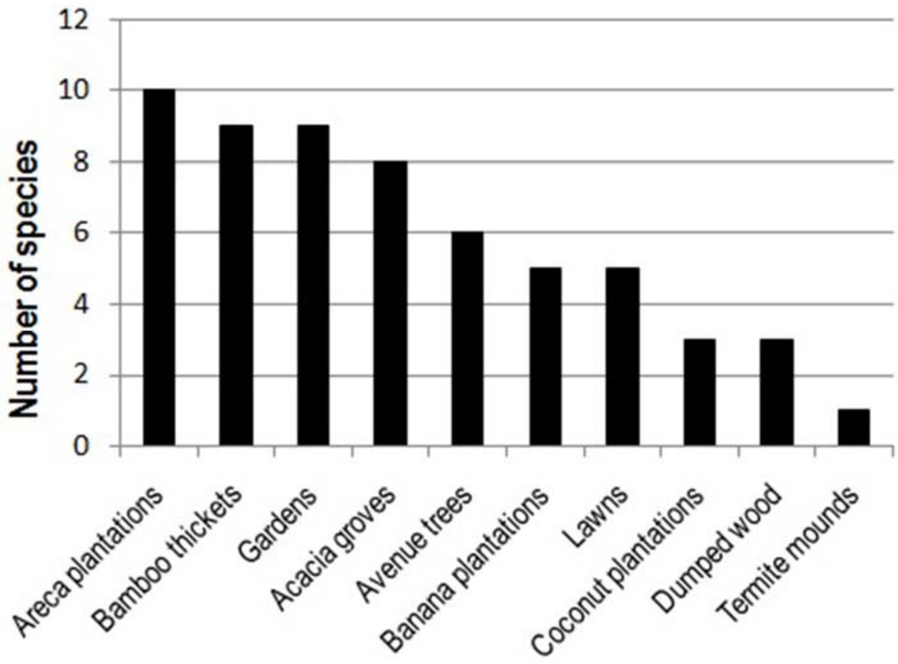

Fig. 5- Occurrence of macrofungi in different habitats.

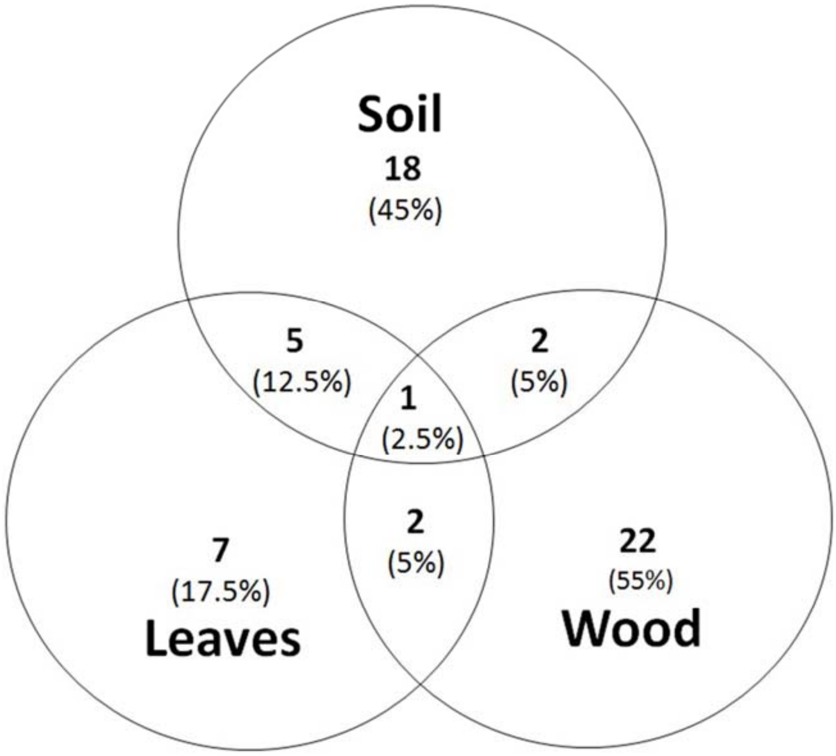

Fig. 6- Venn diagram showing distribution and substrate preference of macrofungi.

Interaction of fungi with plants helps to develop mutualistic associations (e.g. mycorrhizal and endophytic). In the current study, two macrofungi were ectomycorrhizal with tree species *Acacia, Areca, Mangifera* (*Lycoperdon utriforme*) and *Bambusa burmanica* (*Phlebopus marginatus*). Cultivation of suitable host tree species supports a variety of ectomycorrhizal fungi (e.g. *Artocarpus*, *Holigarna*, *Phyllanthus*, *Syzygium* and *Vateria*) (Pavithra *et al*. 2015, 2016). In the YU Campus, many native trees like *Artocarpus*, *Caryota*, *Garcinia*, *Mangifera* and *Terminalia* have spread over supporting many macrofungi. One of the edible *Polyporus* sp. grew on the soil as well as infected the insect cicada (see inset Fig. 3q).

Conclusions

Assessment of soil, humus, leaf litter and woody debris in 10 habitats (three plantations, bamboo thickets, gardens, acacia groves, avenue trees, lawns, dumped wood and termite mounds) of Yenepoya Campus in southwestern India yielded 40 species of macrofungi (31 genera); they group twelve edible species, twelve medicinal elements, two ectomycorrhizal and only one entomophagous fungus. The occurrence of five species was abundant, 13 species were common and 22 species were occasional. Assessment of flora, fauna and fungi in a specific region helps to understand the status of habitat as healthy or regenerated or impoverished facilitating the follow-up biodiversity conservation measures for a healthy environment. This study demonstrated occurrence of interesting macrofungi in such institutional surroundings and also suggests possibilities of domestication of edible, medicinal and ectomycorrhizal fungi.

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