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Article

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Macrofungal assemblage with two tree species in scrub jungles of south-west India

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Abstract

Macrofungi are common and widespread in scrub jungles of southwest India during monsoon season. Assemblage of macrofungi in the vicinity of two tree species *Anacardium occidentale* (introduced) and *Terminalia paniculata* (native) were evaluated. Occurrence on different substrates (soil, leaf litter, wood, bark, seeds, live roots and insect) in and around trees was monitored at weekly intervals up to 12 weeks during southwest monsoon season based on the quadrat method. More number of macrofungi were associated with *Terminalia* compared to *Anacardium* (36 vs. 22 spp.) and 14 species were in common. The species richness ranged from 2-8, which was almost opposing between tree species on each week with a gradual decline. The sporocarp richness ranged from 3-61 in *Anacardium*, while it was from 8-132 in *Terminalia* with two peaks during week 4 and 7 followed by a steep decline. The species accumulation curve reached a plateau after four weeks in *Anacardium*, while it was exponential in *Terminalia* until 12 weeks. The Simpson and Shannon diversities were higher in *Terminalia* compared to *Anacardium* with low Pielou's equitability. In *Anacardium*, mushrooms were found on six substrates with a highest on soil as well as wood (9 spp.), while on seven substrates in *Terminalia* with a highest in soil (18 spp.). *Anacardium* was in association with one, while *Terminalia* with three ectomycorrhizal species. The pattern of distribution and diversity of macrofungi have been compared with earlier studies with different habitats of scrub jungles.

Key words – *Anacardium occidentale* – diversity – mushrooms – species richness – *Terminalia paniculata*

Introduction

Fungi are the most fascinating entities evolved along with plants and animals, but they have close affinity to animals than plants (Baldauf et al. 2013, Cannon et al. 2018). Being highly diverse indispensable component of terrestrial and aquatic ecosystems, they involve directly or indirectly in several ecosystem services especially breakdown of organic matter, biogeochemical cycles and mutualistic interactions. Macrofungi have drawn major attention of mycologists owing to their importance in nutrition, medicine, metabolites, mutualistic association and growth-promoting attributes. There is a notion that macrofungal diversity is higher in tropical than temperate regions owing to suitable abiotic environmental conditions as well as high diversity of angiosperms (Hawksworth 2001, Kark 2007, Mueller et al. 2007). The global macrofungal rough estimate by Mueller et al. (2007) is about 56,700 species. The Indian Subcontinent represented around 850 species of macrofungi (Manoharachary et al. 2005).

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Deccan Plateau of the Indian Subcontinent largely consists of scrub forests characterized by open woodland dominated by thorny short crown xerophytic shrubs along with grasslands. Towards the south west coast of India the lateritic scrub jungles are prominent in the undulating terrain (valleys and mountains) along with sacred groves, grasslands, plantations, agroforests and protected forests. However, nowadays these scrub jungles are dwindling owing to human interference like wood extraction, conversion into plantations/residential areas and laterite quarries. Owing the richness of biodiversity, the coastal belt of the Indian subcontinent has been considered as one of the 10 biogeographic zones consisting of several ecoregions (Singh & Chaturvedi 2017). Although for studies on macrofungi, the Western Ghats has drawn considerable attention of researchers (e.g. Natarajan et al. 2005, Manoharachary et al. 2015, Senthilarasu & Kumaresan 2016), however, investigations in the scrub jungles are fairly limited (e.g. De Souza & Kamat 2017, Sridhar 2018a). Macrofungi are common in the lateritic scrub jungles of southwest Karnataka during the southwest monsoon season, but the diversity is considerably less than the Western Ghat habitats (Karun & Sridhar 2014, 2016). Among the three prominent habitats (scrub jungles, coastal sand dunes and mangroves) of southwest Karnataka, a highest of 77% macrofungi have been reported from the scrub jungles (Sridhar 2018a). Surprisingly, the scrub jungles of Karnataka coast is recently known for several species of *Cordyceps,* which are common in the high altitude Himalayan belt (Dattaraj et al. 2018, Baral 2017). The main aim of this study is to compare the macrofungal assemblage and diversity with an introduced (*Anacardium*) and a native (*Terminalia*) tree species in scrub jungles during the southwest monsoon season.

Materials & Methods

Study area

Location chosen for the study lies about 5-8 km from the Arabian Sea coast near Mangalore City (Dakshina Kannada District, Karnataka State) (12º48'58.2' N, 74º55' E; 104-112 m asl). The scrub jungle in this region has developed in about 50 years consisting of 70% natural vegetation

Macrofungal survey

The survey of macrofungi was performed in twelve occasions at weekly intervals during monsoon season (July-September 2018). In each week, abiotic features such as humidity (under the tree), air temperature (in shade) and soil temperature (at 10 cm depth) were measured under the canopy of tree species (Mextech Digital Thermohygrometer, Mumbai, India). Solitary trees of *Anacardium. occidentale* and *Terminalia paniculata* were located in the scrub jungles at least 50 m apart to perform the survey. In each week (7-11 am), different tree of the same species were surveyed by laying 25 m^2 quadrats (5 × 5 m) marked at the basin of each tree. Sporocarps occurring on the soil, wood, leaf litter, twigs, live roots, bark, seeds and insects were sampled, identified and enumerated. General morphological features of sporocarps of each fungus were recorded on the sampling spot. Selected sporocarps were blotted and brought to the laboratory in Ziploc bags for further study. Each species was examined for the diagnostic characteristic features using hand lens as well as the microscope (Olympus CX41RF) (Pegler 1990, Jordan 2004, Phillips 2006, Cannon & Kirk 2007, Wannathes et al. 2009, Mohanan 2011, Buczacki 2012, Aravindakshan & Manimohan 2015). To preserve the sporocarps, the blotted material was transferred into mixture of water-ethanol-formaldehyde (14:5:1), while the rest of the blotted material was oven-dried (55-60ºC) and preserved in dry condition.

Analysis of data

The total sporocarps in 12 quadrats (one quadrat per week per tree species), mean sporocarps per quadrat and per cent relative abundance of each species were documented along with their occurrence on the substrates. The diversity indices such as Simpson diversity, Shannon diversity and Pielou’s equitability were calculated for the macrofungi recorded in two tree species for 12 weeks (Pielou 1975, Magurran 1988).

Results

During the period of study, the humidity, air temperature and soil temperature ranged from 80-89%, 22.9-27.9ºC and 24.8-27.9ºC, respectively.

Macrofungal assemblage in the vicinity of *Anacardium occidentale*

Table 1 provides list of 22 species of macrofungi found in the vicinity of *Anacardium* (Fig. 1). Among them, eight species were exclusively associated with *Anacardium*. *Xylaria hypoxylon* was most dominant followed by *Marasmius rotula, M. haematocephalus, Tetrapyrgos nigripes, Coprinus* sp., *Marasmius* sp. 1 and *Clathrus delicatus*. The species richness ranged from 2-8 with a gradual decline from week 1 to week 12 (Fig. 2a). The sporocarp richness ranged from 8-61 with two peaks during 4th and 7th weeks (Fig. 2b). The species accumulation curve was exponential up to 4 weeks and thereafter attained almost plateau (Fig. 3). The Simpson diversity was 0.853, while the Shannon diversity was 3.376 with Pielou's equitability 0.757 (Table 2).

Table 1 Macrofungal assemblage in the vicinity of *Anacardium occidentale* (TS, total sporocarps in 12 quadrats; MS, mean sporocarps per quadrat; RA, relative abundance; Economic value: *, medicinal; **, ectomycorrhizal; Substrate: B, bark; L, leaf litter; R, live root; S, soil; T, twig; W, wood; $^{\Psi}$, also found in *Terminalia*).

	TS	MS	RA (%)	Substrate
Xylaria hypoxylon (L.) Grev.*$^{\Psi}$	114	9.50	31.2	S, B, T, W
Marasmius rotula (Scop.) Fr.	45	3.75	12.3	L, W
Marasmius haematocephalus (Mont.) Fr.$^{\Psi}$	43	3.58	11.8	L, T
Tetrapyrgos nigripes (Fr.) E. Horak$^{\Psi}$	27	2.25	7.4	L, T
Coprinus sp.	22	1.83	6.0	S
Marasmius sp. 1$^{\Psi}$	21	1.75	5.7	S, L, T, W
Clathrus delicatus Berk. & Broome	20	1.67	5.5	W
Microporus vernicipes (Berk.) Kuntze$^{\Psi}$	17	1.41	4.7	W
Mycena adscendens Mass Geest.	16	1.33	4.4	L
Hexagonia tenuis (Fr.) Fr.$^{\Psi}$	10	0.83	2.7	W
Lenzites betulinus (L.) Fr.$^{\Psi}$	7	0.58	1.9	W
Geastrum triplex Jungh.** (*)$^{\Psi}$	4	0.33	1.1	R, W
Hygrocybe astatogala R. Heim ex Heinem.$^{\Psi}$	3	0.25	0.8	S
Marasmius spegazzinii (Kuntze) Sacc. & Syd.	3	0.25	0.8	L, T
Phellinus gilvus (Schwein.) Pat.	3	0.25	0.8	B, W
Entoloma serrulatum (Fr.) Hester$^{\Psi}$	2	0.17	0.6	S
Marasmius sp. 2$^{\Psi}$	2	0.17	0.6	L
Mycena sp. 2$^{\Psi}$	2	0.17	0.6	S
Tremella fuciformis Berk.	2	0.17	0.6	W
Conocybe apala (Fr.) Arnolds	1	0.08	0.3	S
Lepiota sp.$^{\Psi}$	1	0.08	0.3	S
Mycena sp. 1$^{\Psi}$	1	0.08	0.3	L

Macrofungal assemblage in the vicinity of *Terminalia paniculata*

Thirty six macrofungi recorded in the vicinity of *Terminalia* is listed in Table 3. Twenty two species were exclusively associated with *Terminalia* (Fig. 4). *Marasmius haematocephalus* was most dominant followed by *Tetrapyrgos nigripes, Xylaria hypoxylon, Mycena adscendens, Cordyceps* sp., *Marasmius guyanensis* and *Geastrum triplex*. Species richness ranged from 2-7 with gradual decline towards week 12 (Fig. 2a). The sporocarp richness ranged from 8-132 with two peaks at 4th and 7th weeks (Fig. 2b). The species accumulation curve raised exponentially throughout the study period (Fig. 3). The Simpson diversity was 0.901, while the Shannon diversity was 3.391 with Pielou's equitability 0.760 (Table 2).

Comparison of trees

The macrofungal assemblage showed higher species as well as sporocarp richness in *Terminalia* compared to *Anacardium* (Table 2). In both trees altogether 44 species were recorded and 14 species common to both tree species (Tables 1, 3). *Marasmius haematocephalus, Tetrapyrgos nigripes* and *Xylaria hypoxylon* were the top four species in both trees. The species richness although similar in both trees, they were opposing in all weeks except for weeks 6 and 12 (Fig. 2). The sporocarp richness was consistently lower in *Anacardium* than *Terminalia* with two peaks during 4th and 7th weeks. The highest sporocarps were found during 4th week in *Anacardium*, while it was during 7th week in *Terminalia*. The species accumulation curve became almost plateau after 4th week in *Anacardium*, while it was exponential in *Terminalia* (Fig. 3). The Simpson and Shannon diversities were higher in *Terminalia* than *Anacardium* with low Pielou's equitability (Table 2).

Fig. 1 – Selected macrofungal assemblage in *Anacardium occidentale*: *Entoloma serrulatum* on soil (a) and its gills (b); *Lenzites betuninus* on wood (c) and its tooth pattern (d); *Marasmius* species on twig (e); growth stages of *Microporus vernicipes* on wood (f) and its porous ventral view (g); *Tetrapyrgos nigripes* on twig with pileus dorsal and ventral views (h); *Tremella fuciformis* on wood (i) and perithecia of *Xylaria hypoxylon* on wood (j).

Substrate preference

The macrofungi were highest on the soil in both tree species (9-18 spp.) followed by wood (9-11 spp.), leaf litter (8-10 spp.), twigs (8 spp.) and live roots (4-5 spp.) (Tables 1, 3, Fig. 5). Bark, seeds and insects were colonized by only one or two species. A maximum of 14-24 species preferred single substrate, while two substrates preferred by 6-10 species. *Xylaria hypoxylon* colonized by four substrates in both trees, *Marasmius* sp. 1 was also colonized by four substrates in *Anacardium*. *Marasmius* sp. 3 preferred three substrates in the vicinity of *Terminalia*.

Table 2 Richness and diversity of macrofungal assemblage of two tree species.

	Anacardium	***Terminalia***
Species richness	22	36
Sporocarp richness	366	767
Simpson diversity	0.853	0.901
Shannon diversity	3.376	3.391
Pielou's equitability	0.757	0.760

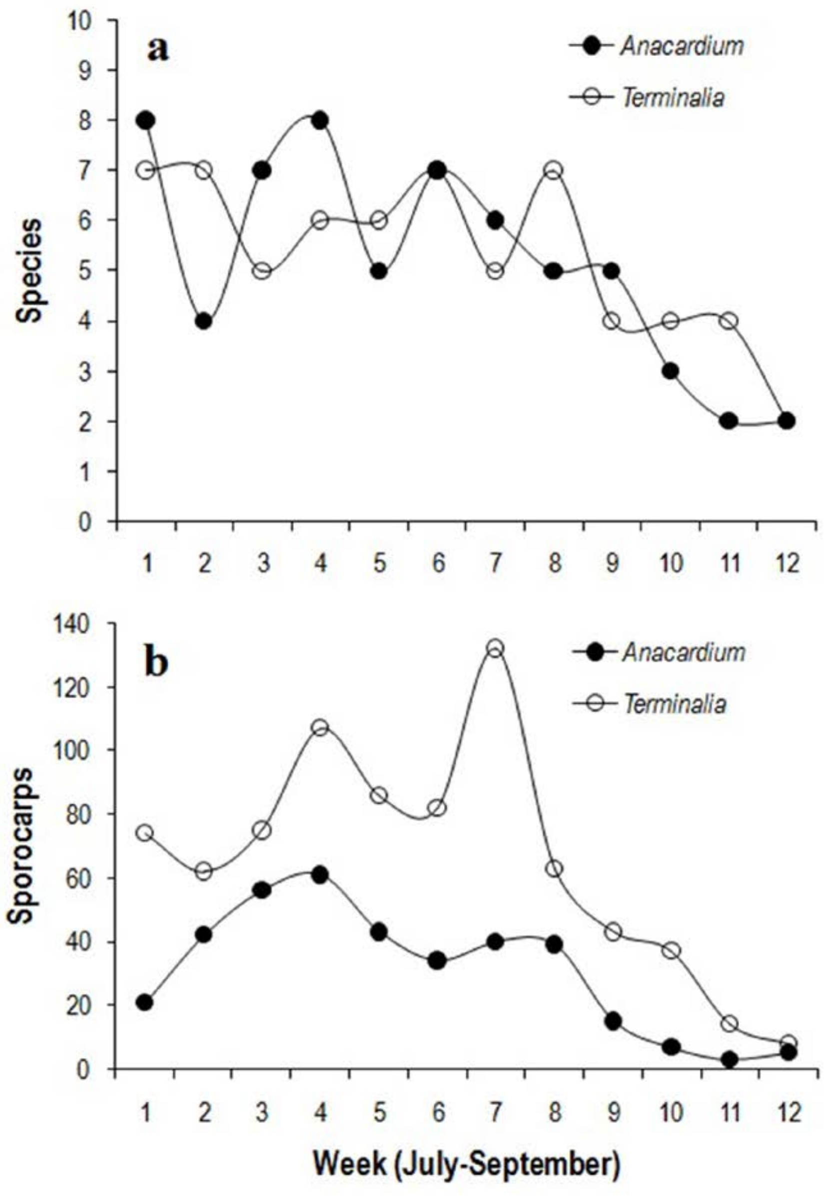

Fig. 2 – Fluctuations of species of macrofungi (a) and their sporocarps (b) in two tree species.

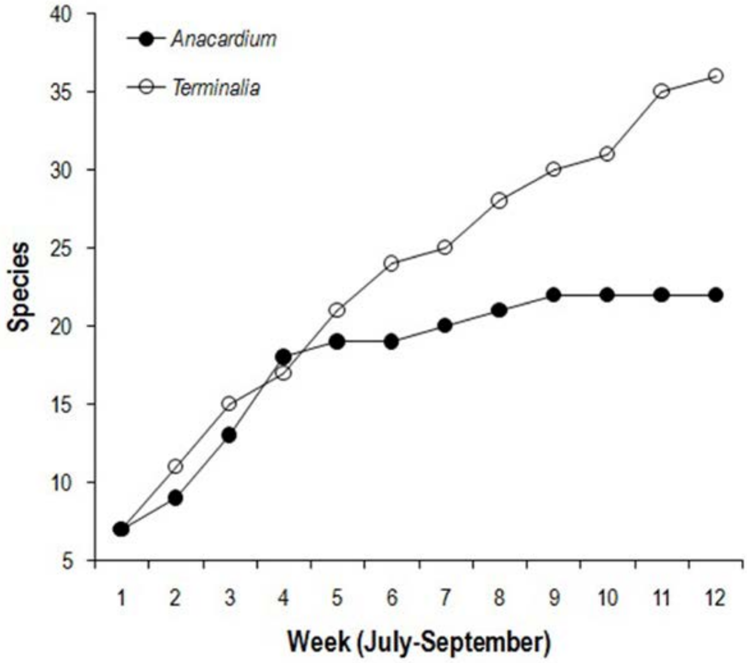

Fig. 3 – Macrofungal species accumulation curves in two tree species.

Table 3 Macrofungal assemblage in the vicinity of *Terminalia paniculata* (TS, total sporocarps in 12 quadrats; MS, mean sporocarps per quadrat; RA, relative abundance; Economic value: *, edible; **, medicinal; ***, ectomycorrhizal; Substrate: B, bark; I, insect; L, leaf litter; R, live root; S, soil; Se, seed; T, twig; W, wood; $^{\Psi}$, also found in *Anacardium*).

	TS	MS	RA (%)	Substrate
Marasmius haematocephalus (Mont.) Fr.$^{\Psi}$	143	11.92	18.6	L, T
Tetrapyrgos nigripes (Fr.) E. Horak$^{\Psi}$	140	11.67	18.3	L, W
Xylaria hypoxylon (L.) Grev.**$^{\Psi}$	72	6.00	9.4	L, T, W, Se
Mycena adscendens Mass Geest.	53	4.42	6.9	L
Cordyceps sp.	48	4.00	6.3	I
Marasmius guyanensis Mont.	48	4.00	6.3	L
Geastrum triplex Jungh.*** (**)$^{\Psi}$	39	3.25	5.1	S, R
Marasmius rotula (Scop.) Fr.	33	2.75	4.3	L, T
Lenzites betulinus (L.) Fr.$^{\Psi}$	31	2.58	4.0	W
Marasmius katangensis Singer	31	2.58	4.0	S
Clathrus delicatus Berk. & Broome	19	1.58	2.5	W
Marasmius sp. 2$^{\Psi}$	11	0.92	1.4	L
Coprinus plicatilis (Curtis) Fr.*	10	0.83	1.3	S
Marasmius crinipes Antonin, ryoo & H.D. Shin	10	0.83	1.3	L
Auricularia auricula (L.) Underw.*	8	0.67	1.0	W
Marasmius sp. 3	8	0.67	1.0	S, L
Microporus vernicipes (Berk.) Kuntze$^{\Psi}$	8	0.67	1.0	W
Laccaria fraterna (Sacc.) Pegler***	6	0.50	0.8	S, R
Clathrus sp.	5	0.42	0.7	W
Hexagonia tenuis (Fr.) Fr.$^{\Psi}$	5	0.42	0.7	W
Cyathus striatus (Huds.) Willd.	4	0.33	0.5	Se
Marasmius sp. 1$^{\Psi}$	4	0.33	0.5	S, L

Table 3 Continued.

	TS	MS	RA (%)	Substrate
Agaricus sp.	3	0.25	0.4	S
Amauroderma conjunctum (Lloyd) Torrend**	3	0.25	0.4	S, W
Marasmius dendrosetosus Shay & Desjardin	3	0.25	0.4	T
Mycena sp. 2$^{\Psi}$	3	0.25	0.4	S
Scleroderma sp.***	3	0.25	0.4	S, R
Entoloma serrulatum (Fr.) Hester$^{\Psi}$	2	0.17	0.3	S
Ganoderma lucidum (Curtis) P. Karst.**	2	0.17	0.3	S, W
Hygrocybe astatogala R. Heim ex Heinem.$^{\Psi}$	2	0.17	0.3	S
Lenzites vespaceus (Pers.) Pat.	2	0.17	0.3	W
Leucocoprinus sp.	2	0.17	0.3	S
Mycena sp. 1$^{\Psi}$	2	0.17	0.3	S, L
Ramaria sp.	2	0.17	0.3	S
Lepiota sp.$^{\Psi}$	1	0.08	0.1	S
Leucoagaricus sp.	1	0.08	0.1	S

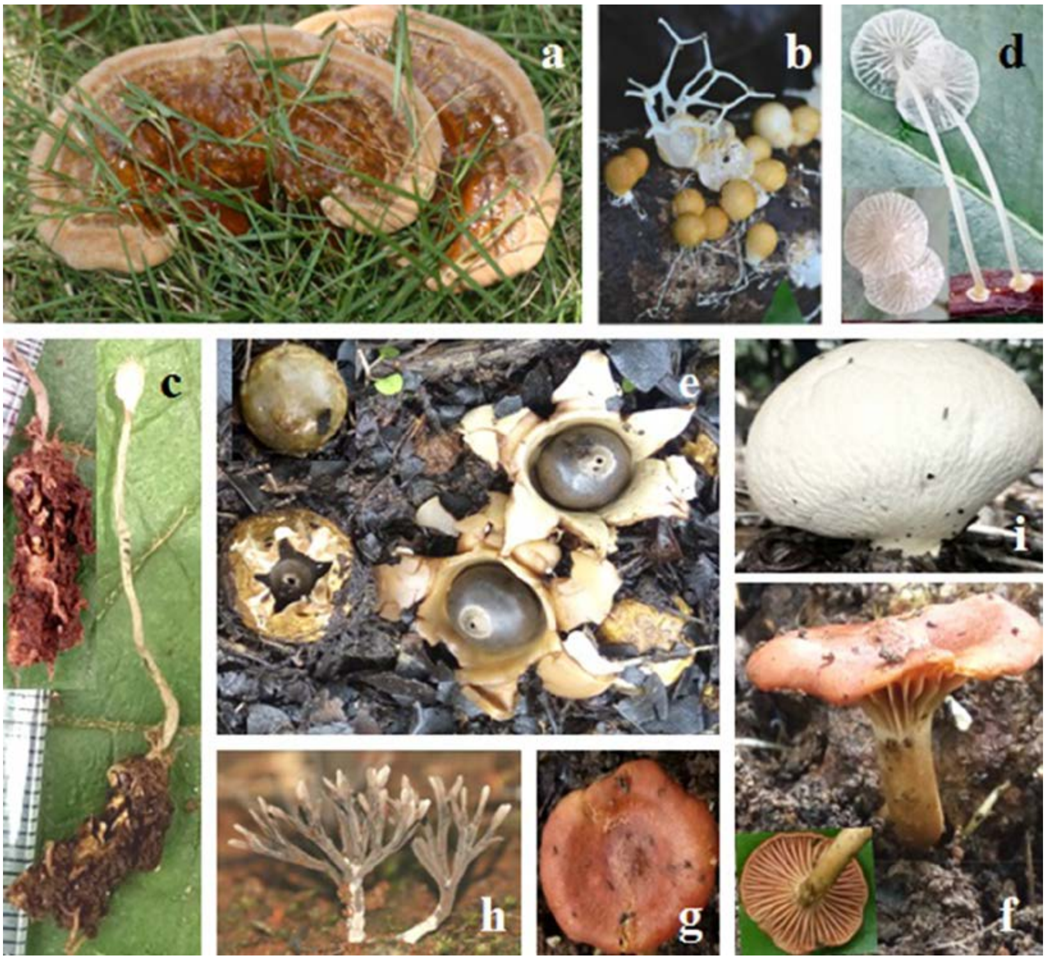

Fig. 4 – Selected macrofungal assemblage in *Terminalia paniculata*: Aerial view of *Amauroderma conjunctum* on wood (a); immature and mature *Clathrus delicatus* on wood (b); *Cordyceps* sp. on grass hopper with emerging perithecium (c); *Mycena adscendens* on leaf litter with dorsal and ventral views pileus (d); *Geastrum triplex* on live roots (e); *Laccaria fraterna* on live roots with ventral view (f) and dorsal view (g) pileus; *Ramaria* sp. on soil (h) and *Scleroderma* sp. on live roots (i).

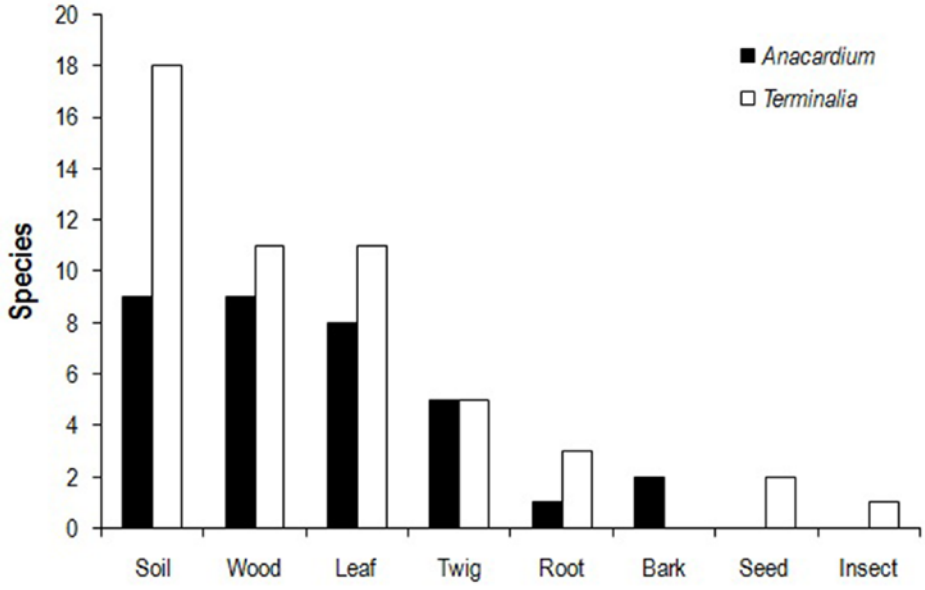

Fig. 5 – Occurrence macrofungi on different substrates in the vicinity of two tree species.

Discussion

Richness and diversity

So far the scrub jungles of southwest coast of Karnataka showed occurrence of up to 89 species belonging to 59 genera of macrofungi, which is higher compared to the coastal sand dunes as well as mangroves (Sridhar 2018b). In the present survey, *Anacardium* yielded 22 species (in 16 genera) representing about 25% of macrofungi occurring in scrub jungles, while *Terminalia* yielded 36 macrofungi (in 24 genera) representing up to 40%. Interestingly, the scrub jungles consist of maximum macrofungi (40 spp.) compared to plantations like arboretum (38 spp.), botanical garden (23 spp.), *Acacia* plantation (13 spp.) and *Anacardium* plantation (12 spp.) (Sridhar 2018b).

In both tree species, those macrofungi possess relative abundance above 5% represented by almost similar species in earlier studies (Karun & Sridhar 2014, Greeshma et al. 2016, Pavithra et al. 2016). Our study showed two peaks of species and sporocarp richness, which is also reflected in earlier studies in the scrub jungles. *Anacardium* plantation showed the least diversity of macrofungi among the five habitats monitored (Karun & Sridhar 2014). In our study also the diversity was lower in *Anacardium* compared to the *Terminalia* and the species accumulation curve also became almost plateau after four weeks of survey. However, cashew trees possess several interesting macrofungi worth further monitoring. In a previous study on macrofungi of *Anacardium* plantation adjacent to the scrub jungle, a total of 15 species were recorded (Karun & Sridhar 2014). Among them, only one species (*Hexagonia tenuis*) is common to the present study. *Anacardium* plantation represented two ectomycorrhizal fungi (*Entoloma brihadum* and *E. vanajum*) and one edible as well as medicinal fungus (*Lentinus squarrosulus*) (Karun & Sridhar 2014). Earlier and present observations demonstrated that *Anacardium* supports many more macrofungi in scrub jungles. Our study showed that *Cyathus stratus* and *Xylaria hypoxylon* have association with live seeds under the canopy of *Terminalia*. It is likely that these species are endophytic and adapted vertical mode of transmission. *Xylaria hypoxylon* is also known to grow on live seeds of different plants in scrub jungles denotes its endophytic lifestyle of perpetuation (unpublished observations).

Economic value

Among the macrofungi recorded, about 18% are commercially valuable (e.g. edible, medicinal and ectomycorrhizal). Two edible (*Coprinus plicatilis* and *Auricularia auricula*) four medicinal (*Amauroderma conjunctum, Cordyceps* sp., *Geastrum triplex* and *Xylaria hypoxylon*) and three ectomycorrhizal (*G. triplex, Laccaria fraterna* and *Scleroderma* sp.) macrofungi were found associated with *Terminalia*, whereas *Anacardium* was found associated with *G. triplex* as well as *X. hypoxylon*. Two ethnically edible as well as ectomycorrhizal macrofungi like *Astraeus odoratus* and *Amanita* sp. have been reported in the vicinity of scrub jungles (Karun & Sridhar 2014, Greeshma et al. 2015, Pavithra et al. 2015). The latter was also one of the ectomycorrhizal species mutualistic to *Anacardium* in scrub jungles. However, among 89 species macrofungi recorded in the scrub jungles, the highest number was of edible macrofungi (26%) followed by ectomycorrhizal fungi (24%) and medicinal fungi (16%) (Sridhar 2018b). This observation is also similar to another such study on macrofungal associations carried out in the lateritic region of the West Bengal (Pradhan et al. 2010).

Recent study reveals that scrub jungles of southwest India consist of several species of *Cordyceps* (Dattaraj et al. 2018). Among them, one of the *Cordyceps* species was found underneath the canopy of *Terminalia* by colonizing the grass hopper (Fig. 4c). Besides, from the lateritic regions of the west coast, two more species of *Cordyceps* were recorded (e.g. on coconut root grub: *Leucopholis coneophora*) in Kerala coast (Kumar & Aparna 2014, Prathibha 2015). Similar to coconut root grub, *Anacardium* also suffers from stem and root borers (e.g. *Batocera rufomaculata*, *Plocaederus ferrugineus* and *P. obesus*). Thus, there is ample scope to look into the macrofungal association with larva and adults of such borers in scrub jungles as a measure of biological control.

Conclusions

The present study revealed the occurrence of 44 species belonging to 29 genera of macrofungi in the vicinity of two tree species in the scrub jungles of southwest India, which is close to 50% of the macrofungi recorded in the scrub jungles. The assemblage consists of two edible, four medicinal and three ectomycorrhizal macrofungi. Occurrence of insect dwelling *Cordyceps* species provides new hope for biological control of insect pests as well as to acquire novel metabolites. The present study demonstrated that the scrub jungles are potential sites of several economically valuable macrofungi, which are dependent on the climatic conditions and enrichment of soil by the accumulated organic matter. Further intense efforts are warranted to demonstrate the importance of scrub jungles of southwest India as repository of valuable macrofungi and to suggest strategies for understanding conservation measures.

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