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A preliminary study on macrofungal diversity in an arboretum and three plantations of the southwest coast of India

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Abstract

This inventory focused on the diversity of macrofungi in an arboretum and three plantations (*Acacia*, *Areca* and cashew) of the southwest coast of India during monsoon (June−September) and early post-monsoon (October−November) seasons. A total of 79 macrofungi in 53 genera was recovered from 15,000 m^2. The macrofungal species richness was higher in arboretum compared to plantations (30 vs. 17−22 species). The highest number of macrofungi were confined to the arboretum than the plantations (25 vs. 14−21 species), so also the core-group species (≥10 sporocarps/quadrat) (9 vs. 2−6 species). The richness of species as well as sporocarps were highest during June and decreased towards November. The macrofungal diversity was highest in *Areca* plantation and during monsoon period (August/September). Low species similarity was seen between the arobretum and plantations (0−12.8%), while the similarity increased from June through November (3.6−42.9%). About 50% of macrofungi possess economic value as ectomycorrhizal (25 species), edible (17 species) and medicinal (10 species). This survey revealed the macrofungal dependence on type of location and vegetation gives scope for their beneficial management.

Key words – Arboretum – diversity – macrofungi – plantations – South Indian coast

Introduction

Fungi are the most diverse group evolved parallel to plants and animals involve in several ecological services like organic matter decomposition, biogeochemical cycles and symbiotic association. They are capable to occupy and flourish in a variety of ecological niches due to their diversity, distribution, dissemination and adaptability. Although various estimates of fungi range between 0.5 and 9.9 million species, currently 1.5−3 million species has been accepted based on the plant-fungus ratio in different geographical regions (Cannon 1997, May 2000, Hawksworth 2001, 2012, Mueller & Schmit 2007). However, the recent fungal community analysis by molecular methods gave an estimate of 5.1 million species, which stands as median value of previous conventional range (0.5−9.9 million) (O'Brien et al. 2005). Now-a-days, macrofungal investigations are gaining tremendous importance owing to the economic benefits especially nutritional and bioactive potential (De Silva et al. 2013, Manna & Roy 2014). Estimated total macrofungi represents about 56,700 species worldwide and up to 850 species are known mainly from the Himalaya and Western Ghats of India (Manoharachary et al. 2006, Mueller et al. 2007). However, recent checklists

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revealed the occurrence of 616 species (in 112 genera) and 178 species (in 68 genera) of agarics in Kerala and Maharashtra States, respectively (Farook et al. 2013, Senthilarasu 2014). The biotic provinces of west and east coasts of India along with islands (Andaman, Nicobar and Lakshadweep) encompass up to an area of 13,000 km^2, which has been considered as one of the 10 biogeographic zones of the Indian Subcontinent (Rodgers & Panwar 1988, Mehta 2000). Due to meager or less intense studies on the macrofungi of the southwest coastal habitats of India, the current study focuses on the richness and diversity of macrofungi in an arboretum and three plantations in different seasons.

Study area

Southwest coast of Karnataka is known for a variety of commercially valuable plantations (e.g. *Acacia*, *Areca*, *Cacao*, cashew, *Casuarina*, coconut and rubber). Many spice-yielding plants (e.g. pepper and *Vanilla*) are also cultivated along with mixed tree species. The present study was carried out on macrofungal assemblage and diversity in an arboretum and three plantations established in typical lateritic soils of the southwest coast of India.

Four locations encompassing an arboretum and three plantations located about 5‒8 km from the Arabian Sea coast near Mangalore (Dakshina Kannada District, Karnataka State) were chosen for survey: arboretum (12°48′51.6″N, 74°55′38.3″E; 87.2 m asl; ~20 years old), *Acacia* (*Acacia auriculiformis* A. Cunn. ex Benth.) plantation (12°48'58.2″ N, 74°55'31.1″ E; 112.4 m asl; ~25 years old), *Areca* (*Areca catechu* L.) plantation (12°49'39.2″ N, 74°54'38.9″ E; 28.4 m asl; ~45 years old) and cashew (*Anacardium occidentale* L.) plantation (12°48'56.4″ N, 74°55'14.49″ E; 103.6 m asl; ~35 years old) and (Figure 1). The arboretum has been established about 20 years ago with endemic, endangered and near threatened tree species of the Western Ghats. This arboretum consists of about 2000 plants encompassing 57 tree species, 23 species of shrubs/woody climbers and 16 species of herbs/under shrubs (Shetty & Kaveriappa 2001, Bhat 2003; Rani et al. 2011). Except for arboretum, plantations although designated as *Acacia*, *Areca* and cashew, they are embodied up to 90% of designated tree species and the rest consists of native vegetation: *Borassus flabellifer* L., *Careya arborea* sensu Alston, *Caryota urens* L., *Casuarina equisitifolia* L., *Holigarna* sp., *Hopea ponga* (Dennst.) Mabberley, *Macaranga peltata* Roxb. Mueller, *Sapium insigne* (Royle) Benth., *Syzygium cumini* (L.) Skeels., *Tamarindus indica* L. and *Terminalia paniculata* Roth.).

Materials & Methods

Survey

The macrofungal survey was performed in six occasions at monthly intervals during monsoon (June‒September) and early post-monsoon (October‒November) seasons in 2012. The survey was carried out in random quadrats (25 × 25 m) at a distance of about 100 m in the arboretum and plantations. Sporocarps on soil, leaf litter, twigs, bark, wood, standing dead or live trees (bark or branches) in each quadrat were considered for sampling and enumeration. The mean sporocarps per quadrat in four locations (arboretum and three plantations) was presented by combining the data of six months sampling (n=6) and for each month by combining the data of four locations (n=4). The overall mean of sporocarp richness was assessed per quadrat (n=24) irrespective of the location or month.

Morphological characteristics of each macrofungi were recorded on the sampling location, blotted and transferred into Ziploc bags for further study. They were assessed based on the microscopic examinations (Olympus CX41RF; magnification, 1000X) and the diagnostic keys (Jordan 2004; Phillips 2006; Mohanan 2011; Buczacki 2012; Tibuhwa 2012). For preservation, the blotted specimens were transferred into water-ethanol-formaldehyde (14:5:1) and additional blotted specimens were also oven-dried (55‒60°C) for preservation in Ziploc bags in dry condition. On each occasion, air (in shade) and soil temperatures (at 10 cm depth) were measured using mercury thermometer at each corner of the quadrat and average for each location (n=24) and each month (n=16) was calculated.

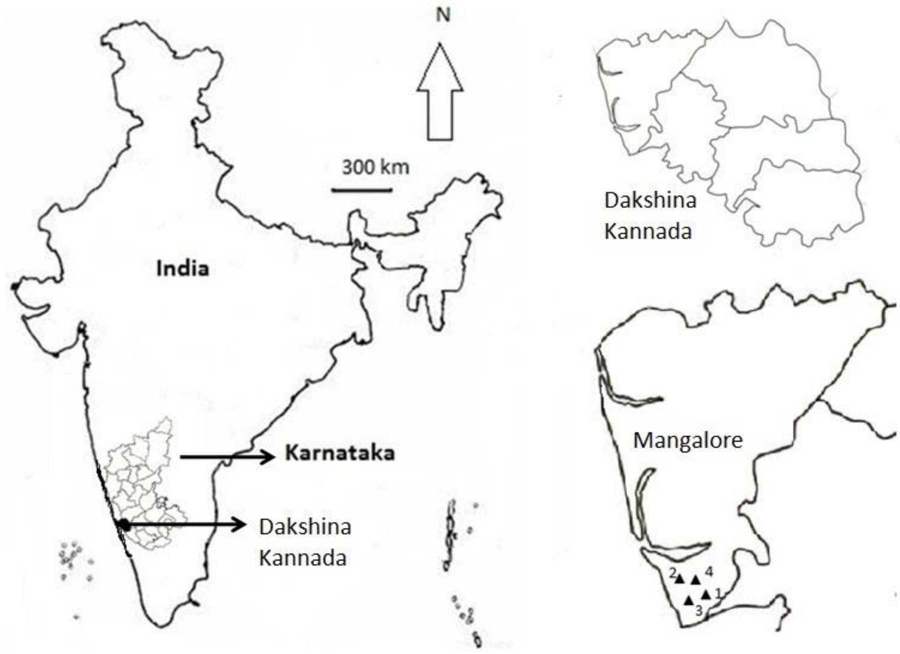

Fig. 1 – Map of the study area in the southwest coast of India (1, Arboretum; 2, 3, 4, *Areca*, cashew and *Acacia* plantations, respectively).

Data analysis

The mean number of sporocarps of each species per quadrat in each location (n=6) as well as in each month (n=4) were plotted along with overall mean number of sporocarps per quadrat irrespective of the location or month in the whole study (n=24).

$$MSL = (TSL \div TQ) \quad (1)$$

(where: MSL, mean sporocarps of a species per location in a quadrat; TSL, total sporocarps of a species in a location; TQ, total number of quadrats surveyed).

$$MSM = (TSM \div TQ) \quad (2)$$

(where: MSM, mean sporocarps of a species per month in a quadrat; TSM, total sporocarps of a species in a month; TQ, total number of quadrats surveyed).

$$MS = (TS \div TQ) \quad (3)$$

(where: MS, mean sporocarps of a species per quadrat; TS, total sporocarps of a species; TQ, total number of quadrats surveyed).

The number of macrofungi restricted to a specific plantation or month are referred as exclusive species, those have ≥10 sporocarps per quadrat are called core-group fungi and plotted plantation-and month-wise. Similarly, the total number of sporocarps per plantation (n=6) and per month (n=4) were compiled. The Simpson's diversity, Shannon's diversity (Magurran 1988) and Pielou's evenness (Pielou 1975) of macrofungi in different locations and months were calculated. The Sorensen's similarity coefficient (%) of macrofungi between different locations and months was determined based on Chao et al. (2005). The expected number of species, $E_{(s)}$, in a random sample of n sporocarps from a total population of N sporocarps was estimated for surveyed locations and months based on Ludwig and Reynolds (1988).

Results

The present study revealed occurrence of 79 macrofungal species in 53 genera (Table 1). Photographs of representative species are presented in Figure 2 and 3. Based on the sporocarp richness, *Marsmius spegazzinii* was most dominant followed by *Bossonectria fusispora* and *Xylaria hypoxylon*, which are restricted to one of the locations (arboretum, cashew plantation and *Acacia* plantation) and months (June, July and June), respectively.

Table 1 Occurrence of macrofungi in arboretum (ARB) and plantations (ARP, *Areca* plantation; CAP, Cashew plantation; ACP, *Acacia* plantation) during monsoon (June-Sept) and post-monsoon (October-November) seasons with overall mean sporocarps per quadrat (*, new records; MSL, mean sporocarps of a species per location in a quadrat; MSM, mean sporocarps of a species per month in a quadrat; MS, mean sporocarps of a species per quadrat).

Macrofungus	Mean sporocarps/quadrat										Mean sporocarps/ quadrat (n=24) (MS)
	Location (n=6) (MSL)				Month (n=4) (MSM)						
	ARB	ARP	CAP	ACP	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	
Marasmius spegazzinii (Kuntze) Sacc. & P. Syd.	200.0	–	–	–	300.0	–	–	–	–	–	50.00
**Byssonectria fusispora* (Berk.) Rogerson & Korf	–	–	50.0	–	–	75.0	–	–	–	–	12.50
Xylaria hypoxylon (L.) Grev.	–	–	–	50.0	75.0	–	–	–	–	–	12.50
Geastrum sp.	–	31.7	–	–	40.0	7.5	–	–	–	–	7.92
**Marasmius guyanensis* Mont.	14.5	–	16.0	–	–	21.8	24.0	–	–	–	7.63
Ileodictyon gracile Berk.	30.0	–	–	–	–	–	40.0	5.0	–	–	7.50
**Amanita* sp.	5.0	22.5	–	–	37.5	3.8	–	–	–	–	6.88
Mycena vitilis (Fr.) Quél.	18.3	–	–	5.0	30.0	5.0	–	–	–	–	5.83
Trametes versicolor (L.) Lloyd	20.3	–	–	–	–	30.0	0.5	–	–	–	5.08
Crepidotus uber (Berk. & M.A. Curtis) Sacc.	20.0	–	–	–	30.0	–	–	–	–	–	5.00
*Unidentified (Basidiomycete)	20.0	–	–	–	–	30.0	–	–	–	–	5.00
Lenzites vespacea (Pers.) Pat.	–	–	–	19.0	2.3	3.8	6.3	6.3	5.0	5.0	4.77
Microporus xanthopus (Fr.) Kuntze	18.7	–	–	–	–	–	–	13.3	8.8	6.0	4.68
Xylaria nigripes (Klotzsch) Cooke	–	15.8	–	–	–	15.0	8.8	–	–	–	3.96
Termitomyces umkowaan (Cooke & Massee) D.A. Reid	–	–	–	13.2	–	–	19.8	–	–	–	3.30
Daldinia concentrica (Bolton) Ces. & De Not.	–	–	–	12.8	–	–	10.0	7.5	1.8	–	3.21
**Hygrocybe* sp.	11.7	–	–	–	–	–	–	17.5	–	–	2.92
**Mycena* sp.	–	–	–	11.7	17.5	–	–	–	–	–	2.92
Termitomyces clypeatus R. Heim	–	11.0	–	–	–	–	16.5	–	–	–	2.75
**Micromphale inodorum* Dennis	–	–	–	10.8	–	12.5	3.8	–	–	–	2.71
Psathyrella myceniformis Dennis	–	9.8	–	–	–	–	–	–	14.8	–	2.46
Scleroderma citrinum Pers.	3.8	–	–	5.0	7.5	5.8	–	–	–	–	2.21
Geastrum triplex Jungh.	–	–	–	7.8	–	–	8.3	3.5	–	–	1.96

Scutellinia setosa (Nees) Kuntze	–	7.7	–	–	–	–	–	11.5	–	–	1.92
Marasmius epiphyllus (Pers.) Fr.	7.5	–	–	–	–	–	11.3	–	–	–	1.88
Amauroderma conjunctum (Lloyd) Torrend	–	–	–	7.3	–	–	6.5	3.8	0.8	–	1.84
**Gymnopilus* sp.	–	–	7.0	–	10.5	–	–	–	–	–	1.75
Laccaria laccata (Scop.) Cooke	7.0	–	–	–	–	–	–	10.5	–	–	1.75
Psathyrella lithocarpi A.H. Sm.	–	7.0	–	–	–	–	–	–	–	10.5	1.75
**Clitocybe* sp.	6.8	–	–	–	1.0	–	–	0.5	8.8	–	1.71
**Marasmiellus* sp.	–	–	–	6.7	10.0	–	–	–	–	–	1.67
Marasmius abundans var. *aurantiacus* Corner	6.7	–	–	–	10.0	–	–	–	–	–	1.67
Lentinus squarrosulus Mont.	–	–	5.8	–	1.3	7.5	–	–	–	–	1.46
Trogia infundibuliformis Berk. & Broome	5.7	–	–	–	8.5	–	–	–	–	–	1.42
Boletus edulis Bull.	5.0	–	–	–	7.5	–	–	–	–	–	1.25
**Clavaria* sp.	5.0	–	–	–	–	–	7.5	–	–	–	1.25
Pisolithus albus (Cooke & Massee) Priest	–	4.5	–	–	3.8	2.5	–	–	–	0.5	1.13
Hexagonia tenuis Speg.	–	–	4.3	–	–	–	–	–	5.0	1.5	1.08
**Lepiota* sp.	–	–	–	4.2	–	6.3	–	–	–	–	1.05
**Marasmius araucariae* var. *siccipes* Desjardin, Retn. & E. Horak	–	4.2	–	–	–	–	–	6.3	–	–	1.05
**Thelephora palmata* (Scop.) Fr.	–	–	3.3	–	5.0	–	–	–	–	–	0.83
**Hydnum* sp.	–	2.7	–	–	–	3.8	–	–	0.3	–	0.68
Clavulinopsis dichotoma Corner	–	–	2.7	–	–	–	–	4.0	–	–	0.67
**Crepidotus* sp.	–	2.7	–	–	–	–	4.0	–	–	–	0.67
**Hebeloma* sp.	2.5	–	–	–	3.8	–	–	–	–	–	0.63
**Macrolepiota* sp.	–	2.3	–	–	–	–	0.5	1.5	1.0	0.5	0.58
Astraeus hygrometricus (Pers.) Morgan	–	2.2	–	–	–	–	3.3	–	–	–	0.55
**Agaricus* sp.	–	2.0	–	–	3.0	–	–	–	–	–	0.50
Pluteus conizatus (Berk. & Broome) Sacc.	–	2.0	–	–	–	–	–	–	–	3.0	0.50
Tremella reticulata (Berk.) Farl.	–	–	–	1.8	–	–	1.8	1.0	–	–	0.46
Entoloma haematinum Manim., Leelav. & Noordel.	1.5	–	–	–	–	–	–	–	2.3	–	0.38
**Irpex* sp.	–	–	1.5	–	2.3	–	–	–	–	–	0.38
Leucocoprinus birnbaumii (Corda) Singer	–	–	1.3	–	2.0	–	–	–	–	–	0.33

**Psilocybe* sp.	–	–	–	1.3	2.0	–	–	–	–	–	0.33
**Marasmius acerosus* Y.S. Tan & Desjardin	–	–	–	1.2	1.8	–	–	–	–	–	3.00
Otidea alutacea (Pers.) Massee	–	1.2	–	–	–	–	1.8	–	–	–	3.00
Pycnoporus sanguineus (L.) Murrill	1.2	–	–	–	–	–	1.5	0.3	–	–	3.00
Amanita angustilamellata (Höhn.) Boedijn	1.0	–	–	–	–	0.5	0.5	0.5	–	–	0.25
**Marasmius* sp.	1.0	–	–	–	1.5	–	–	–	–	–	0.25
Omphalotus olearius (DC.) Singer	1.0	–	–	–	–	1.5	–	–	–	–	0.25
Ramaria pallida (Schaeff.) Ricken	1.0	–	–	–	–	–	–	1.5	–	–	0.25
Scleroderma verrucosum (Bull.) Pers.	1.0	–	–	–	–	1.5	–	–	–	–	0.25
Boletus hongoi T.N. Lakh. & Sagar	0.8	–	–	–	1.3	–	–	–	–	–	0.21
Lentinus polychrous Lév.	–	0.8	–	–	–	–	–	–	–	1.3	0.21
Pluteus pulverulentus Murrill	–	–	0.8	–	–	–	1.3	–	–	–	0.21
**Pluteus* sp.	–	–	0.8	–	–	–	1.3	–	–	–	0.21
Entoloma brihadum Manim., A.V. Joseph & Leelav.	–	–	0.7	–	1.0	–	–	–	–	–	0.17
**Ganoderma colossus* (Fr.) C.F. Baker	–	–	–	0.7	–	–	–	1.0	–	–	0.17
Macrolepiota dolichaula (Berk. & Broome) Pegler & R.W. Rayner	–	0.7	–	–	1.0	–	–	–	–	–	0.17
Macrolepiota rhacodes var. *bohemica* (Wichanský) Bellù & Lanzoni	–	0.7	–	–	1.0	–	–	–	–	–	0.17
Amanita aureofloccosa Bas	–	0.5	–	–	0.8	–	–	–	–	–	0.13
Amylosporus campbellii (Berk.) Ryvarden	0.5	–	–	–	–	0.8	–	–	–	–	0.13
Entoloma vanajum Manim., A.V. Joseph & Leelav.	–	–	0.5	–	–	–	0.8	–	–	–	0.13
**Gerronema* sp.	–	–	0.5	–	–	0.8	–	–	–	–	0.13
Inocybe agardhii (N. Lund) P.D. Orton	–	–	0.5	–	–	0.8	–	–	–	–	0.13
Lycoperdon utriforme Bull.	0.2	–	–	0.2	–	–	0.5	–	–	–	0.09
Boletus reticulatus Schaeff.	0.3	–	–	–	0.5	–	–	–	–	–	0.08
Lepista hyalodes (Berk. & Broome) Pegler	–	0.3	–	–	–	–	–	–	–	0.5	0.08
Phallus merulinus (Berk.) Cooke	–	0.3	–	–	–	0.5	–	–	–	–	0.08

Location

Among the locations, by pooling six monthly observations, arboretum consists of the highest number of macrofungi (30 species: 6.5 species/quadrat) (Figure 4A). Among the top 10 species, four species were restricted to arboretum and one species each was confined to *Areca*, cashew and *Acacia* plantations. The exclusive species (those species confined to a specific location: 25 vs. 14–21 species) and core-group species (those species possess ≥10 sporocarps per quadrat: 9 vs. 2–6 species) were also highest in the arboretum (Figure 4B).

Sporocarp richness was also highest in the arboretum compared to plantations (2496 vs. 580–958) (Figure 5A). Expected number of species against the number of sporocarps based on rarefaction curves, the arboretum stands first followed by *Areca*, *Acacia* and cashew plantations (Figure 6A). *Areca* plantation showed the highest diversity followed by *Acacia* plantation, arboretum and cashew plantation (Table 2). The Sorensen similarity coefficient between the locations ranged between 0 and 12.8%. *Areca* vs. cashew/*Acacia* and cashew vs. *Acacia* showed no similarity, while arboretum vs. *Areca/*cashew*/Acacia* showed similarity of 3.9%, 4.4% and 12.8%, respectively (Table 3). The air temperature was higher than the soil temperature in all the locations. Arboretum showed the lowest air as well as soil temperatures, while it was reverse in *Areca* plantation (Figure 7A).

Fig. 2 – Sporocarps: a, *Amanita* sp. (edible and ectomycorrhizal); b, *Amauroderma conjunctum* (medicinal); c, *Boletus edulis* (edible and ectomycorrhizal); d, *Byssonectria fusispora*; e, *Clavaria* sp.; *f*, *Daldinia concentrica* (medicinal); g, *Entoloma brihadum* (ectomycorrhizal); h, *Ganoderma colossus* (medicinal); i, *Geastrum triplex* (ectomycorrhizal); j, *Geastrum* sp.; k, *Lenzites vespacea.*

Fig. 3 – Sporocarps: a, *Leucocoprinus birnbaumii*; b, *Lycoperdon utriforme* (edible and ectomycorrhizal); c, *Macrolepiota rhacodes* var. *bohemica* (edible); d, *Marasmius spegazzinii*; e, *Mycena vitilis*; f, *Omphalotus olearius*; g, *Pluteus pulverulentus*; h, *Pycnoporus sanguineus* (medicinal); i, *Ramaria pallida*; j, *Scleroderma citrinum* (ecotomycorrhizal); k, *Tremella reticulata* (edible); l, *Xylaria hypoxylon* (medicinal).

Season

Monthly survey by pooling four observations from each location, the number of species (31), exclusive species (23) and core-group species (10) were highest during early monsoon (June) and decreased gradually thereafter (Figure 4C, D). The richness of sporocarps was highest in early monsoon (June: 2476) and thereafter it decreased sharply (Figure 5B). The rarefaction curves revealed that the expected number of species against the number of sporocarps was highest during early monsoon (June) (Figure 6B). Among the seasons, late monsoon showed the highest diversity (August, Shannon diversity; September, Simpson diversity), while it was least during the early post-monsoon (November) (Table 2). Sorensen similarity coefficient of species amongst the months ranged between 3.6% (June vs. August) and 42.9% (August vs. September; September vs. October) (Table 3). The air temperature was lowest in June and attained a peak in November, while the soil temperature was lowest in August and almost stable in rest of the months (Figure 7B).

Core-group and beneficial fungi

Altogether 28 species belonged to core-group in different locations or months of survey (Table 1). Among them 19 species were restricted to one of the locations, while 27 species were in high proportion at least in one of the months surveyed. Among 79 species, about 50% (38 species) are beneficial as ectomycorrhizal (25 species), edible (17 species) and medicinal (10 species) (Table 4). Some species have duel benefits like ectomycorrhizal/edible, ectomycorrhizal/medicinal and edible/medicinal. Majority of the ectomycorrhizal and edible fungi preferred to grow on soils, while the medicinal fungi preferred woody litter.

Table 2 Species richness, diversity and evenness of macrofungi in different locations and months (*, Expected number of species out of 100 random number of sporocarps; −, less productive in location or in month).

	Species richness		Diversity		Pielou's
	Observed	$E_{(s100)}$*	Simpson	Shannon	evenness
Arboretum/Plantation					
Arboretum	30	19	0.751	3.138	0.639
Areca plantation	22	19	0.877	3.522	0.790
Cashew plantation	17	−	0.685	2.420	0.619
Acacia plantation	15	15	0.854	3.318	0.812
Month					
June	31	17	0.736	2.936	0.593
July	22	17	0.847	3.347	0.751
August	24	19	0.895	3.727	0.813
September	18	−	0.897	3.574	0.857
October	10	−	0.816	2.733	0.832
November	09	−	0.777	2.509	0.792

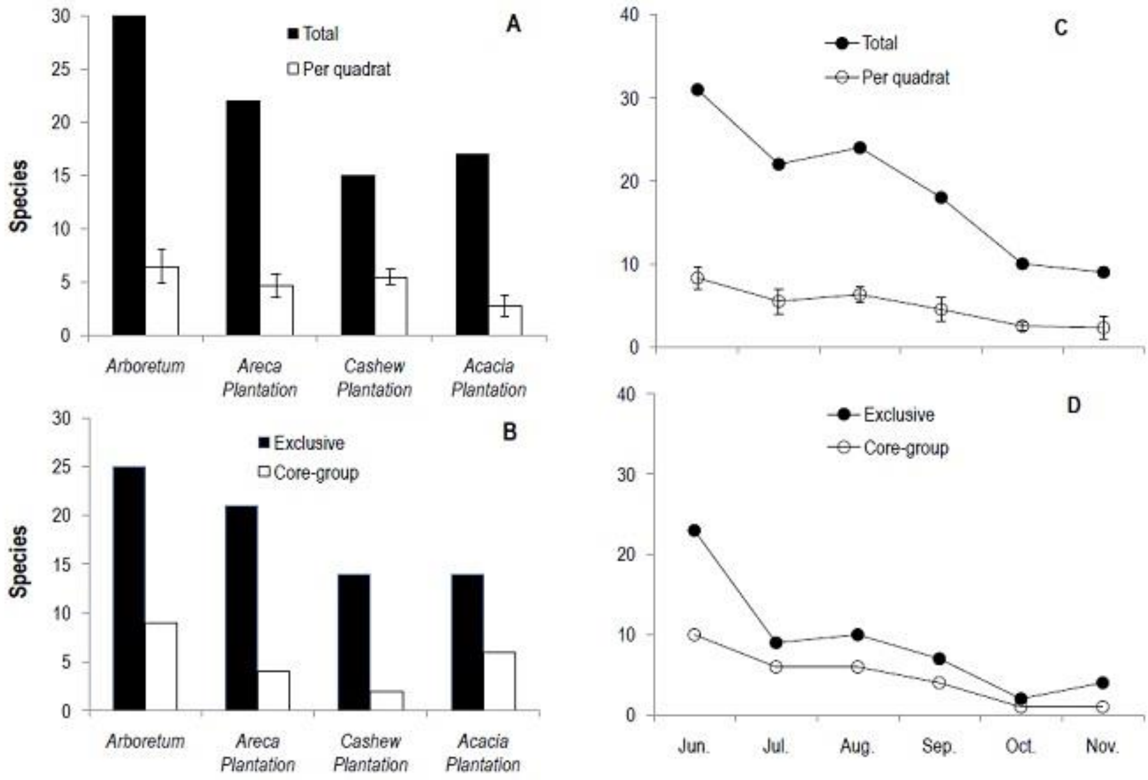

Fig. 4 – Total species, species per quadrat, exclusive species and core-group species in different locations (A, B) and months (C, D) (species/quadrat in plantations, A: n=6, mean±SE; species/quadrat in months, C: n=4, mean±SE).

Discussion

The southwest coast of India consists of valleys and mountains in the proximity of the Arabian Sea with several distinct biomes (coastal sand dunes, estuaries, mangroves, oceanic/estuarine islands, sacred groves, scrub jungles, grasslands, arboreta, monoculture plantations, mixed plantations and medicinal gardens) in lateritic region with soil texture mainly sandy loam, loamy sand and loam. The present study serves as baseline data on the macrofungal assemblage and diversity in southwest coast of India and complements the studies carried out in other coastal regions of the tropics.

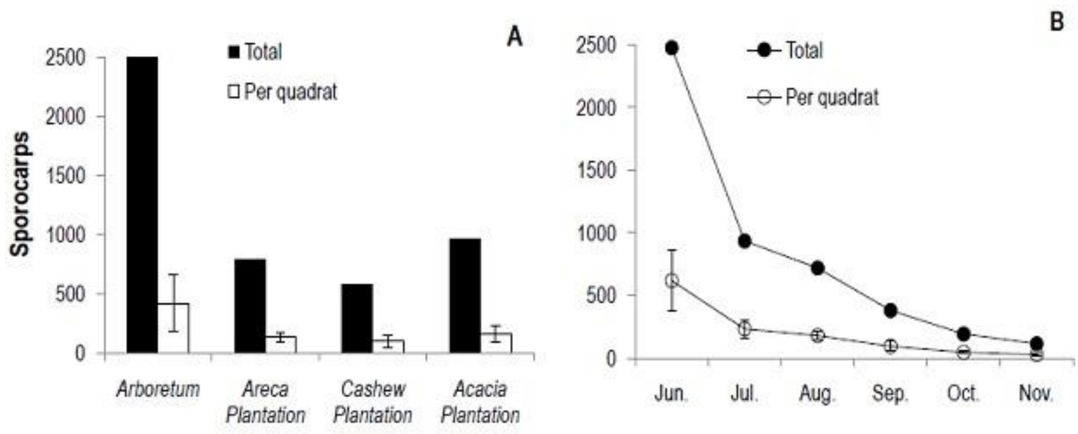

Fig. 5 – Total sporocarps, and sporocarps per quadrat in different locations (A) and months (B) (sporocarps/quadrat in locations, A: n=6, mean±SE; sporocarps/quadrat in months, B: n=4, mean±SE).

Table 3 Sorensen similarity coefficient (%) of macrofungi in locations and months (ARB, Arboretum; ARP, *Areca* plantation; CAP, Cashew plantation; ACP, *Acacia* plantation).

Plantation				**Month**					
	ARP	CAP	ACP		Jul.	Aug.	Sep.	Oct.	Nov.
ARB	3.9	4.4	12.8	Jun.	26.4	3.6	8.0	9.8	10.0
	ARP	0	0		Jul.	21.8	10.0	9.8	10.0
		CAP	0			Aug.	42.9	23.5	12.1
							Sept.	42.9	22.2
								Oct.	42.1

Table 4 Importance (mycorrhizal, edible and medicinal) and substrate preference (F, coconut fronds; L, leaf litter; S, soil; T, twigs; W, wood) of macrofungi (core-group fungi are in bold-face).

Ectomycorrhizal	**Edible**	**Medicinal**
Agaricus sp. (S)	***Amanita* sp.** (S)	*Amauroderma conjunctum* (S, W)
Amanita angustilamellata (S)	*Amylosporus campbellii* (T)	*Amylosporus campbellii* (T)
A. aureofloccosa (S)	*Astraeus hygrometricus* (S)	***Daldinia concentrica*** (W)
***Amanita* sp.** (S)	*Boletus edulis* (S)	***Trametes versicolor*** (W)
Amauroderma conjunctum (S, W)	*B. hongoi* (S)	*Ganoderma colossus* (W)
Astraeus hygrometricus (S)	*B. reticulatus* (S)	*Lentinus polychrous* (W)
Boletus edulis (S)	*Hydnum* sp. (W)	*L. squarrosulus* (W)
B. hongoi (S)	*Lentinus squarrosulus* (W)	*Pycnoporus sanguineus* (T)
B. reticulatus (S)	*Lepista hyalodes* (F)	***Xylaria hypoxylon*** (T)
Clavaria sp. (S)	*Lycoperdon utriforme* (S)	***X. nigripes*** (S)
Clavulinopsis dichotoma (S)	*Macrolepiota dolichaula* (S)	
Entoloma vanajum (S)	*M. rhacodes* (S)	
E. brihadum (S)	*Macrolepiota* sp. (S)	
Geastrum triplex (S)	*Phallus merulinus* (S)	
Laccaria laccata (L, S)	***Termitomyces clypeatus*** (S)	
Lepiota sp. (S)	***T. umkowaan*** (S)	
Lycoperdon utriforme (S)	*Tremella reticulata* (W)	
Macrolepiota dolichaula (S)		
M. rhacodes (S)		
Macrolepiota sp. (S)		
Pisolithus albus (S)		
Scleroderma citrinum (S)		
S. verrucosum (S)		
Thelephora palmata (S)		
Xylaria nigripes (S)		

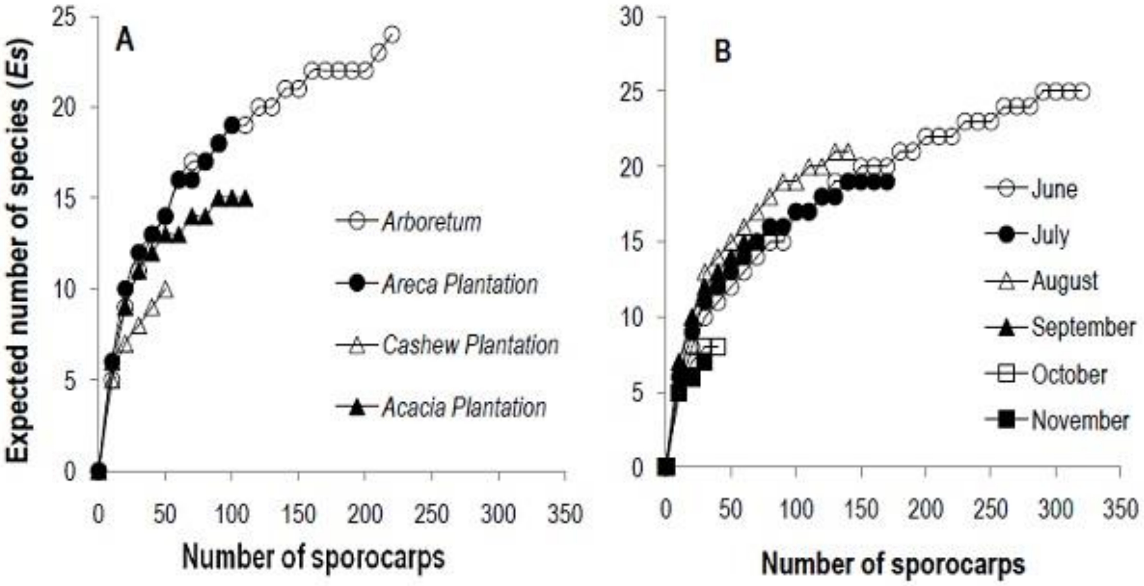

Fig. 6 – Rarefaction curves of macrofungal expected number of species [$E_{(s)}$] against the number of sporocarps in different locations (A) and months (B).

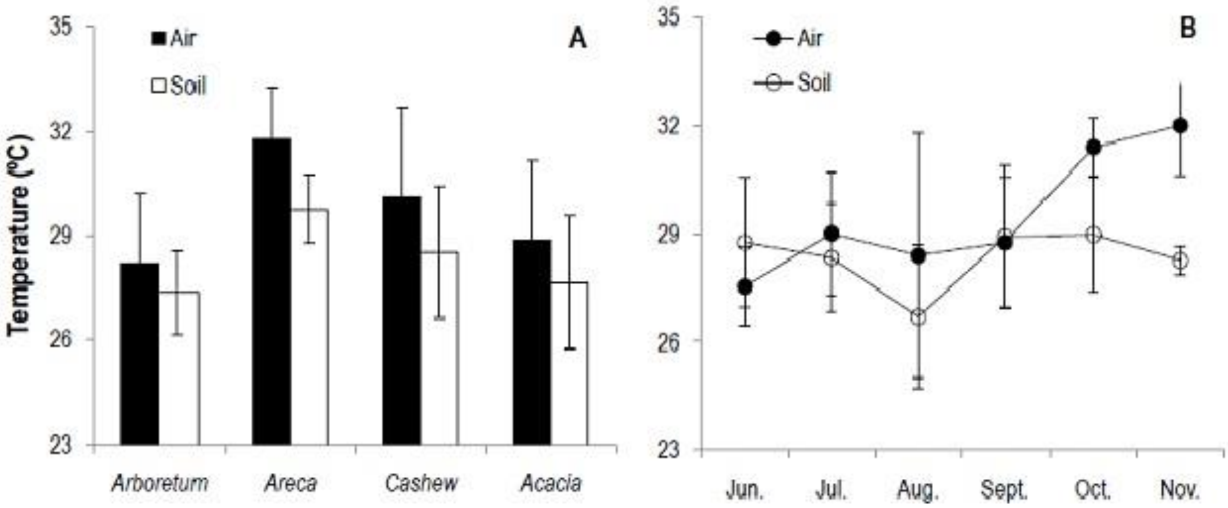

Fig. 7 – Air and soil temperature (ºC) in four locations (n=24, mean±SD) (A) and different months (n=16, mean±SD) (B) during macrofungal survey.

Location

Macrofungal composition of a specific geographical location depends on several edaphic factors (e.g. richness of tree species, canopy cover, surface area, nature of substrate, moisture regime, temperature and soil qualities). The present study explored the macrofungal diversity in four locations with contrasting edaphic features resulting in diverse and distinct location-dependent macrofungal assemblages. Out of 79 species recovered, only four were common to two locations (*Amanita* sp., *Lycoperdon utriforme*, *Marsmius guyanensis* and *Scleroderma citrinum*), while the rest were confined to a specific location reflecting the low species similarity between the locations. Thus, arboretum and plantations have a major impact on the macrofungal assemblage and needs further evaluation to manage them in favor of macrofungal perpetuation for economic gains. The *Acacia*, *Areca* and cashew plantations studied embodied up to 90% pure stands and the rest consists of native tree species might also influenced the macrofungal assemblage and distribution.

Although arboretum with diverse tree species has highest number of macrofungi and sporocarps, it was not as diverse as *Areca* and *Acacia* plantations due to single species dominance (*Marasmius spegazzinii*). Similarly, the cashew and *Acacia* plantations were also showed single species dominance (*Byssonectria fusispora* and *Xylaria hypoxylon*, respectively). The species accumulation curve against the number of sporocarps was higher in arboretum and *Areca* plantation compared to other plantations depicts the macrofungal assemblage dependence on arboretum or specific plantation in the southwest coast. Relatively, the lowest air and soil temperatures might have favored the highest number of sporocarps in arboretum, while the highest air and soil temperatures might have resulted in high diversity in *Areca* plantation. However, impact of other edaphic factors specific to a location cannot be ruled out.

Season

Among the sampling months, monsoon season (June−September) showed high assemblage of macrofungi, which decreased in post-monsoon season (October and November). Due to single species dominance during early monsoon (June and July: *Marasmius spegazzinii* and *Byssonectria fusispora*, respectively), the late monsoon (August and Septebmer) showed high diversity. However, the monsoon season (June−September) is most important period for macrofungal richness and diversity in the southwest coast of India and needs specific management practices in favour of maximizing macrofungal resource. The species accumulation curves against the number of sporocarps were also high during June–August revealing the best period for monitoring macrofungal richness in the southwest coast. A sudden drop in temperature (air and soil) during early monsoon, availability of high quantity of organic matter (e.g. leaf and woody litter) and intermittent thunderstorms might have favored high species richness and diversity of macrofungi.

Ecological factors

A wide spectrum of substrates like monocot/dicot debris, fine/medium/coarse woody debris, bamboo thickets, network of monocot/dicot roots and grasses/sedges favors macrofungal assemblage in the southwest India. Likewise, humicolus-/particolous-/coprophilous-termite association are also dependent on the type of organic matter in a specific location. The ecological factors of the locations studied differed from each other especially the nature of organic matter, moisture regime and termperture profiles. The locations studied are influenced by least (arboretum), moderate (*Acacia* and cashew) and high (*Areca*) human interference. However, in addition to application of organic matter (mixed leaf litter with farmyard manure), *Areca* plantation receives watering during dry season might have also influenced the macrofungal diversity.

Among the locations, periodic episodes of burning usually occur during the post-monsoon and summer months especially in *Acacia* and cashew plantations (either accidentally or deliberately), which might have resulted in poor macrofungal richness compared to arboretum and *Areca* plantation. Although burning reduces the overall diversity of macrofungi especially the saprophytes (ectomycorrhizal fungi survive underneath the soil in root system) due to loss of accumulated organic matter, there is a notion that burning stimulates the growth of selected macrofungi (e.g. *Astraeus hygrometricus*) (Sysouphanthong et al. 2010). However, in the present study, *A. hygrometricus* was confined to *Areca* plantation as an ectomycorrhizae as well as traditional source of food. The yield of *A. hygrometricus* was highest during July in the eastern lateritic region of India (Manna & Roy 2014). This fungus is also ectomycorrhizal in trees like *Alnus*, *Eucalyptus* and *Pseudotsuga* and proliferates during rainy season (Trappe 1967; Molina 1979; Malajczuk et al. 1982). In the present study, fire damage of cashew plantations resulted in fruiting of plenty of *Gymnopilus* sp. especially on the partially burnt woody debris on the onset of monsoon (June). Similarly, the *Gymnopilus junonius* was predominant in partially burnt woody material in bamboo thickets in our study (Karun et al. 2014).

Beneficial fungi and traditional knowledge

This study revealed up to 50% of the macrofungi recovered are commercially valuable.

Ectomycorrhizal fungi were highest (25 species) followed by edible fungi (17 species) and medicinal fungi (10 species). Occurrence of more ectomycorrhizal and edible macrofungi in the present study corroborates with earlier observations in the lateritic region of West Bengal in northeast India (Pradhan et al. 2010). Edibility of some of the macrofungi is a tradition in southwest India. For example, *Amanita* sp. ('Motte-anabe' in vernacular language Kannada, meaning 'egg mushroom') is a delicacy. The typical ecological niche of *Amanita* sp. is soil with pebbles on lateritic bed. This mushroom was recorded in arboretum and *Areca* plantation during early monsoon (June−July) in our study. It is believed that this mushroom erupts during early monsoon with thunder storms and forayed on stony soils beneath trees as it is ectomycorrhizal [*Acacia auriculiformis* A. Cunn. ex Benth., *A. mangium* Willd., *Hopea ponga* (Dennst.) Mabberley and *Terminalia paniculata* Roth.]. *Amanita* sp. will be collected and consumed at egg or dumbbell stage. Recently it has been traced as the second most abundant mushroom in less and moderately disturbed coastal sand dunes of the south-western India (Ghate et al. 2014). Like *Amanita* sp., a variety of *Astraeus hygrometricus* ('Kall-anabe', meaning 'stone mushroom') is also prominent throughout the monsoon season (June−September) in lateritic soils and consumed before the basidiocarp matures. This fungus was found in *Areca* plantation in the month of August and likely *Areca* trees serve as host. Termite-dependent fungus, *Termitomyces clypeatus* was found in *Areca* plantation due to application of farmyard manure and also presence of termite mounds in the bunds. Likewise, *Termitomyces umkowaan* was commonly associated with termite mounds in *Acacia* plantations (Karun & Sridhar 2013). The majority of medicinal macrofungi found in our study preferred lignocellulosic wastes (twigs and woody litter) for their perpetuation indicating the importance of woody litter (fine, medium and coarse) in arboretum and plantations.

Conclusions

Due to steep and eroding terrain, the forests and plantations of southwest coast require specific management strategies (e.g. rainwater harvest and water conservation by terracing, construction of trenches and bunds). Practice of maintaining a strip of forest zone will be usually followed in some areas to cater the needs of green manure, organic debris for plantations (especially *Areca*, coconut, rubber and mixed plantations) seems to play an important role in macrofungal richness and diversity. Retention of organic matter (leaf, wood and other litter) on the soil in forests and plantations supports the growth of macrofungi during rainy season. Deliberate burning for deweeding should be discourged in forests and plantations as it is detritimental to macrofungal population. This study revealed nearly 26 species (encompassing nine core-group species) as new records to the west coast of India. Up to nine species of commercially viable macrofungi were also recovered outside the locations surveyed in this study (edible: *Clitocye gibba, Lentinus dicholamellatus, Phallus merulinus, Pleutotus djmor, P. eöus, Termitomyces eurrhizus, T. heimii, T. schimperi*; ectomycorrhizal: *Amanita elata*), Thus, the coastal forests and plantations are potenetial source of economically valuable macrofungi and deserves further insight to derive benefits.

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