
Ectomycorrhizal fungal diversity in three different forest types and their association with endemic, indigenous and exotic species in the Western Ghat forests of Thiruvananthapuram district, Kerala

C.K.PRADEEP AND K.B.VRINDA

Plant Systematics and Evolutionary Science Division, Tropical Botanic Garden & Research Institute (TBGRI), Palode, Thiruvananthapuram 695 562, Kerala

Three different forest types of Western Ghats coming under Thiruvananthapuram district of Kerala were selected as study area which includes the evergreen forests of Kallar, deciduous forests of TBGRI campus and exotic *Acacia* forests of Perayam. More than 160 collections of fungi were obtained from the three forest localities selected for the study. Four orders, 8 families and 35 taxa were identified. Highest number of ectomycorrhizal fungus (EMF) species was recorded from the evergreen forests (88%) and least from the exotic forest (12%). Of the total species collected twenty per cent species were common in both evergreen and deciduous forests.

Key words : Western Ghats, EMF, fungal diversity, symbiosis, endemic, indigenous, exotic

INTRODUCTION

Forests play an essential role in maintaining the environmental and bioresource stability and provide multipurpose benefit to the mankind. Mycorrhizal association is essential for forest trees. The ectomycorrhizal fungi (EMF) are essential for host plant nutrient uptake and play important roles in nutrient cycling and host productivity in many forest trees (Read *et al.*, 1992). Some ectomycorrhizal fungi form long lived symbiosis with the roots of higher plants (Allen, 1991). EMF diversity may equip both tree and forest to functionally adapt to changes in seasons and habitats. The vital role of EMF in forest establishment and recovery is well established in Europe and Pacific Northwest. So far, research in the tropics has been largely exploratory. There is scope to extend this exploratory work to identify the principally occurring mycorrhizal fungi and to relate them to the ecology of the plants with which they associate (Redhead, 1980).

Ectomycorrhizal fungi differ in their ability to associate with different host species. Some fungus species is restricted to specific genera. Some fungi may be able to form ectomycorrhiza with a wide range of hosts but are limited in distribution by

habitat requirements. The habitat requirements of these ectomycorrhizal fungi and their interaction with particular plant species are poorly understood. Our knowledge of distribution of EMF in India is meager. In Kerala, no effort has been made to understand the taxonomy, ecology and distribution of these invaluable biological resources. Despite their importance for natural forest stands as well as forest plantations, no EMF surveys have been conducted previously in Kerala prior to this study.

METHODOLOGY

Three different forest types of Western Ghats coming under Thiruvananthapuram district of Kerala were selected as study area which includes the evergreen forests of Kallar, deciduous forests of TBGRI campus and exotic *Acacia* forests of Perayam.

To study the natural occurrence of EMF in association with different forest tree species, extensive collections of fungal fruit bodies, from selected designated sites of ca one hectare with in each forest types, were made during the south-west and north-east monsoon seasons of 2006-2008. The EMF fruit bodies (mushrooms) collected were

brought to the laboratory. Standard taxonomic methodology (Singer, 1986) was followed for identification of mushrooms. The colour codes in descriptions are based on Kornerup and Wanscher (1978). The specimens were dried in a hot-air oven at 40-50° C and voucher specimens were deposited in the mushroom herbarium of TBGRI (TBGT).

Association of the fungus with the host tree species was established by linking mycorrhizae to fruit bodies. Mycorrhiza-to-fruit body links was suggested by the repeated association of a mycorrhizal type with a fruit body, or by directly tracing mycelia from the fruit body to the mycorrhiza. The tree species with which the fungal fruit body was associated was identified with the help of Angiosperm taxonomists at TBGRI.

OBSERVATIONS AND DISCUSSION

Many common mushrooms, for instance *Cantharellus*, *Laccaria*, *Russula* and *Amanita* are ectomycorrhizal. These fungi are specialized to co-occur with local tree species only, many of which are endemic to Western Ghats. In the present study, many ectomycorrhizal fungus species were found to be associated with the dominant tree species of the region, viz., *Hopea parviflora*, Bedd. *Vateria indica* Linn. *Myristica malabarica*, Lam *Dipterocarpus indicus* Bedd., *Terminalia paniculata* Roth. etc

More than 160 collections of fungi were obtained from the three forest localities selected for the study. Four orders, 8 families and 35 taxa were identified. Highest number of ectomycorrhizal species was recorded from the evergreen forests (88%) and least from the exotic forest (12%). Of the total species collected, 20% were common in both evergreen and deciduous forests.

CHECKLIST OF SPECIES

1. Ectomycorrhizal fungi of Exotic forest (*Acacia* plantation)

Amanita sp.

Pileus 3.5-6.5 cm diam., convex to plane to depressed in age, with light umbo; surface 'grey' (4B1-4C1) to 'greyish beige' (4C2) or 'greyish brown'

to 'yellowish brown' (5E3-5E4), streaked with innate radiating fibrils, viscid to sub viscid when young, becoming dry and glistening when old, occasionally with a single large patch of white universal veil tissue on the cap which soon disappears; margin irregular and undulating when old, non appendiculate, non-striate but rimose in many, becoming upturned with age. Context white, up to 4 mm thick, soft. Lamellae free, crowded with lamellulae of four lengths. Stipe 5-9 cm x 4-7 mm, central, equal or slightly tapering towards apex, white with 'hair brown' (5E4) surface fibrils below the annulus; context white, fibrous, unchanging. Annulus white, membranous, flaring, superior, striate on the upper part, smooth below, eventually collapsing on the stipe; basal bulb ovoid; universal veil saccate, white, membranous, 3-lobed, up to 3 cm high. Spores 8.8-10.5 x 6.5-7.5 µm, weakly amyloid to amyloid, hyaline, thin-walled, subglobose to broadly ellipsoid, smooth. Hymenophoral trama bilateral, divergent from a narrow central strand, hyphae cylindrical to inflated, mainly cylindrical on the central strand, inflated, up to 28 µm diam., thin-walled, hyaline. Universal veil on the pileus: filamentous, undifferentiated, septate hyphae 1.5-7.5 µm diam., branched. Partial veil: filamentous, undifferentiated hyphae, 1.6-4 µm diam., inflated cells common, terminal or in chains, clavate to broadly clavate, 12.8-62.4 x 7.2-16 µm. Stipe context acrophysalidic, filamentous, undifferentiated hyphae, 2.5-7.2 µm diam., acrophysalides 50-212.5 x 15-27.5 µm. Pileipellis filamentous, undifferentiated hyphae 3-9 µm diam., gelatinized, mostly radially arranged.

This species is placed in the subgenus *Lepidella* (E.J.Gillb.) Ves. *Emend* Corner & Bas section *Lepidella* (Fr.) Quel, of the Genus *Amanita* by virtue of its ellipsoid, amyloid spores, non-striate pileal margin and saccate volva. It is best recognized by the greyish to yellowish brown colours of the pileus, sometimes becoming almost white; white lamellae when fresh; the white stipe with an enlarged bulbous base and the well developed, free, marginal volva.

Habit & Habitat : Scattered on ground among litter under *Acacia auriculaeformis*.

Specimens examined : India, Kerala state, Thiruvananthapuram dist, Perayam: 26 April 2006, No. 9651; 2 June 2006, No. 9715; 13 April 2007, No.

10185; 16 April 2007, No. 10187; 17 April 2007, No. 10195; 20 April 2007, No. 10198; 24 April 2007, No. 10212; 25 April 2007, No. 10216; 16 May 2007, No. 10290.

It is found scattered in troops on the floor in association with the roots of *Acacia auriculaeformis*. This is a close relative of the famous death cap and is very dangerous. The early unopened button stage can be mistaken for a puffball.

***Amanita aureofloccosa* Bas, in Persoonia 5: 384.1969**

Habit & Habitat: Scattered on ground among litter under *Acacia auriculaeformis*.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Perayam: 16 Dec.2005, No. 1877; 8 May 2006, No. 4964; 31 May 2006, No. 5980; 30 May 2007, No. 9527; 6 June 2007, No. 9684

This toxic species of *Amanita* was found growing in association with *Acacia auriculaeformis*. It is easily recognized in the field by the bright pigmentation, absence of a volva, floccose remnants of the universal veil on the pileus and stipe surfaces and a large cottony annulus. Our collection agrees in every detail with the East African species described by Pegler (1977).

***Agaricus* sp.**

Pileus 3-8 cm diam., broadly parabolic with a flat apex in the bud, expanding convex and more or less appanate at a later stage, sometimes broadly and lowly umbonate or slightly depressed at the centre; surface uniformly 'clay' (5D5) and smooth in the button stage, entire at the disc, soon breaking in to appressed clay squamules, distributed almost in concentric rings on a white background which turns 'reddish white' (9A2) to 'pale red' ((A3) and finally 'reddish brown' (9D7) to 'oxblood red' (9E7) when exposed to heavy rain, the colour of squamules varying from 'dark blonde' (5D4), 'clay' (5D5) to 'mustard brown' (5E6), 'golden grey' (4C2) or 'sallow' (4D3) which gets washed off by rain making the surface smooth and glabrous and uniformly coloured white, becoming red when exposed to rain; margin

entire, appendiculate and exceeding the gills after rupture of the veil. Lamellae white in the bud, later 'pale red' (9A3) and then 'reddish brown' (9E6), free, up to 8 mm wide, ventricose, crowded, with lamellulae of different lengths; edge concolourous to the sides. During heavy rain pink droplets of water collect on the under side of the gills. Stipe 4.5-16.5 cm x 5-12 mm, central, cylindrical, equal with a clavate-bulbous base, with mycelial codons, solid, soon fistulose; surface white, smooth above, floccose at the base, without any apparent colour change on handling or bruising. Annulus superior, membranous, large, pendant, white to pale pinkish, pendant, up to 15 mm broad, with white cottony patches on the underside in young fruit bodies, soon collapsing. Smell pleasant, flowery. Odour like aniseed. Schaeffer reaction negative. Context unchanging, up to 6 mm wide, composed of loosely interwoven, thin-walled, mostly inflated hyphae, up to 22.5 µm wide, constricted at septa Spores 4-5.5 (6) x (2.5) 3-3.5 µm, ovoid to ovo-ellipsoid with a smooth, thick, fuscous wall. Basidia clavate, 18-21 x 6-8 µm, 4-spored. Lamella-edge sterile, cheilocystidia 12-23 x 6-8 µm, narrowly clavate to cylindro-clavate, often septate, thin-walled, hyaline. Pleurocystidia absent. Hymenophoral trama regular composed of thin-walled, 5-7.5 µm wide hyphae, inflated up to 22.5 µm. Subhymenium pseudoparenchymatous. Pileal cuticle with erect to sub erect tufts of projecting hyphae at the centre, an interrupted epicutis elsewhere.

Habit & Habitat: Scattered on ground among litter under *Acacia auriculaeformis*

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Perayam: 30 Aug 2006, No. 9679; 31 Aug. 2006, No. 9698; 25 Oct. 2006, No. 10051.

This beautiful white *Agaricus* was found growing in troops in association with *Acacia auriculaeformis*. The mushroom has a flowery aroma and is edible. Although there is no distinctive reddening on exposure of the context or the pileal and stipe surfaces on bruising, this species is placed in subsection *Rufescerites* (Schaeff. & Moell.) Wasser, on account of the robust habit, large pendant squamose annulus, narrow ellipsoid spores and the negative Schaeffer reaction. The only other species of the section with similarities in the overall habit is

A. benesii (Pilát) Singer. This may be readily separated, however, by the context which discolors intensely blood-red on exposure. According to Cappelli (1984), *Agaricus benesii* is an extremely rare species and fruits in limited numbers in broad-leaved woods.

***Inocybe stuntzii* Grund, in Mycologia 67: 19-31. 1975**

Habit & Habitat: Scattered on ground among litter under *Acacia auriculaeformis*.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Perayam: 30 Aug. 2007, No. 4124.

Inocybe stuntzii was found growing in association with the roots of *Acacia auriculaeformis*. The pileus with brown disc on a yellowish ground, yellowish stipe, thick-walled yellow cystidia and smooth spores distinguish this *Inocybe*. The present collection agrees with the description of this species by Grund & Smith (1975).

2. Ectomycorrhizal fungi of evergreen & deciduous forests

***Amanita angustilamellata* (Hoehnel) Boedijn in Sydowia 5: 318.1951**

Habit & Habitat: Solitary or scattered on the forest floor in association with *Terminalia bellirica* (deciduous) and *Vateria indica* (evergreen, endemic to southern Western Ghats).

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 26 Dec. 2005, No. 1846; TBGRI campus: 7 May 2006, No. 2222; 18 May 2006, No. 2243; 6 Oct. 2006, No. 2578; Kallar: Oct. 2006, No. 2585; TBGRI campus: 27 Oct. 2006 No. 2662; Kallar: 15 April 2007, No. 8623; 18 April 2007, No. 8641; 19 April 2007, No. 8675; 15 Aug. 2007, No. 10481.

A. angustilamellata grows in association with both deciduous (*Terminalia bellirica* Roxb.) and evergreen (*Vateria indica* Linn.) host tree species. It is characterized by a greyish striate pileus, long exannulate stipe and sheathing white volva. This

species was originally described from Indonesia (Boedijn, 1951). This has also been reported from Sri Lanka (Pegler, 1986).

***Amanita elata* (Masseé) Corner & Bas in Persoonia 2: 286.1962**

Habit & Habitat: Solitary on ground associated with *Calophyllum calaba* Linn. *Tectona grandis* Linn. and *Terminalia paniculata* Roth.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 5 July 2006, No. 9800; TBGRI campus: 4 Aug. 2006, No. 9904; 14 Aug. 2006, No. 9924; Kallar 13 June 2007, No. 10317; 20 June 2007, No. 13360; TBGRI campus: 19 July 2007, No. 10452; Kallar 3 April 2008, No. 10832; TBGRI campus 10 April 2008, No. 10888; Kallar 16 April 2008, No. 10907; 14 July 2008, No. 11346; 9 Sept. 2008, No. 11884; TBGRI campus: 29 Oct. 2008, No. 12151; Kallar 25 Nov. 2008, No. 12301.

A. elata grows in both evergreen and deciduous forests. *Calophyllum calaba*, the evergreen host tree species is endemic to Western Ghats. *Tectona grandis* and *Terminalia paniculata* are deciduous host tree species associated with the fungus. The species was originally described from Singapore and it is common in the Western Ghats of Kerala. Greyish cap with sulcato-striate margin, exannulate stipe and marginate stipe base are characteristic features of the species. The present collection closely agrees with the description of Pegler (1986).

***Amanita griseofarinosa* Hongo in Mem. Fac. Liberal Arts Educ. Shiga Univ., Pt. 2, Nat. Sci. 11:39. 1961**

Habit & Habitat: Solitary on ground.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 20 June 2007, No. 10349; 16 July 2008, No. 11398.

Appendiculate pileal margin, bulbous stipe base, amyloid spores and unpleasant odour are characteristic of the species. The floccose grey squamules are easily removed on handling. It is somewhat close to *A. cinereoconica* but differs

significantly on having much slender basidiospores. *Amanita griseofarinosa* is associated with *Garcinia morella* and *Hopea racophloea* Dyer, evergreen, endemic trees of Western Ghats. The materials collected from Kerala are closely related to the description by Bas (1969).

***Amanita hemibapha* (Berk. & Br.) Sacc, Syll. Fung. 5:13. 1887**

Habit & Habitat: Solitary or gregarious on humus, being associated with forest trees like *Hopea parviflora*, *Vateria indica* and *Myristica fragrans*.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 17 Dec. 2005, No. 972; 31 March 2007, No. 4671; 4 May 2007, No. 5862; 3 May 2008, No. 10250; 10 June 2008, No. 10258; 12 Dec. 2008, No. 12360.

Amanita hemibapha has a wide range of association with both evergreen and deciduous trees. This is a close relative of the famous Caesar's mushroom and is an excellent edible species. *A. hemibapha* first described from Sri Lanka (Pegler, 1986) is a tropical relative of the *A. caesarea*. *A. hemibapha* belongs to strips *Hemibapha* of section *Vaginatae* (Fr.) Quel. The subglobose cells of the subhymenium form a layer of two (possibly three) cells below the lower basidia. The subhymenium of *A. caesarea* is roughly twice as thick (four to five cells thick).

***Amanita magniverrucata* Thiers & Ammirati, Mycotaxon 15: 161. 1982**

Habit & Habitat: Terrestrial, associated with *Xanthophyllum arnottianum* Wijht

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 2 Nov. 2007, No. 10066; 30 April 2008, No. 10931.

This species was placed in *Amanita* sect. *Lepidella*. The large white to pale brownish pyramidal warts is very characteristic. The frequently rooting bulb, the delicate annulus, and the elliptic to elongate spores are also distinctive features in combination with the volval warts. *A. magniverrucata* is associated with the evergreen tree *Xanthophyllum arnottianum* endemic to Western Ghats. It is reported from

Canada, Pacific coastal states of USA, California etc (Tulloss, 2009).

***Amanita volvata* (Pk.) Lloyd Volvae : 15.1898**

Habit & Habitat: Solitary on ground under *Hopea parviflora*.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 20 July 2006, No. 9848; 28 July 2006, No. 9867; 5 July 2007, No. 10407.

A. volvata is associated with *Hopea parviflora*, an evergreen host tree species, endemic to southern Western Ghats. The fungus is characterized by a whitish pileus with occasional brownish disc, whitish, floccose patches of volval remnants and exannulate stipe with a saccate, thick, membranous volva.

***Boletellus ananas* (M.A. Curtis) Murrill, Mycologia 1: 10. 1909**

Habit & Habitat: Solitary at the base of *Holigarna arnottiana* Hook. f. an evergreen tree species endemic to Western Ghats.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 16 Dec. 2005, No. 8006; 14 June 2006, No. 8959. 20 Sept. 2006, No. 9265; 23 Sept. 2006, No. 9277; 26 Dec. 2006, No. 9632; 31 Dec. 2007, No. 9781; 24 Nov. 2007, No. 10145; 3 May 2008, No. 10252; 23 Oct. 2008, No. 10657

This striking bolete is recognized in the field by its red-pink squamose pileus, membranous marginal appendiculae, bright yellow, rapidly blue-staining hymenophore, evanescent trama, and fruiting habit. These features are consistent with those of *B. ananas* as described from Guyana (Mayor *et al.*, 2008). Microscopically *B. ananas* is distinguished by large basidiospores with cross striae on the ridges and spirally encrusted hyphae in the marginal appendiculae and stipe trama. *Boletellus ananas* occurs in evergreen forest in association with *Holigarna arnottiana* which is endemic to Western Ghats. *Boletellus ananas* is recorded for the first time from India.

***Boletus chrysenteron* Fries. *Epicr. Syst. Myc.*
415.1838**

Habit & Habitat: Solitary to gregarious in soil in mixed forests. This bolete forms mycorrhizal associations with *Holigarna arnottiana* which is endemic to Western Ghats.

Specimens examined : India, Kerala state, Thiruvananthapuram dist., Kallar: 18 April 2006, No. 590; 13 July 2006, No. 933; 18 July 2006, No. 1007; 2 Aug. 2006, No. 1134; 18 Aug. 2006, No. 2031; 7 Sept. 2006, No. 2361; 8 Nov. 2006, No. 2681; 11 April 2007, 2828; 19 April 2007, No. 2928; 19 Sept. 2007, No. 3239; 14 May 2008, No. 3835.

Boletus chrysenteron is an edible fungus distinguished by the olive brown colour of the dry, tomentose to velutinous pileus, the aerolate condition of the mature pilei in which reddish pigments develop in the cracks, the yellowish to pallid stipe, which characteristically develops reddish areas with age, and the nontruncate spores. Young specimens of *Boletus chrysenteron* often have a dark, dry surface, and tomentose thin flesh that turns a blue color when slightly cut or bruised. Stipe have no ring, are bright yellow and the lower part is covered in coral-red fibrils and has a constant elliptical to fusiform diameter throughout its length. The cream colored stem flesh turns blue when cut.

It is commonly known as 'The Red Cracking Bolete'. *Boletus chrysenteron* occurs in evergreen forest in association with *Holigarna arnottiana* which is endemic to Western Ghats

***Cantharellus cibarius* Fries, *Syst. Mycol.* 1:
318.1821**

Habit & Habitat: Solitary, gregarious or occasionally subcaespitose on soil.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 23 May 2006. No. 1860; 19 July 2006, No. 2245; 4 Aug. 2006, No. 9897; 15 Aug. 2007, No. 10474; 16 July 2008, No. 11411.

C. cibarius is usually associated with evergreen plants like *Hopea parviflora* and *Myristica*

malabarica (evergreen, endemic to southern Western Ghats). Commonly known as the 'Golden Cantharelle', is one of the most popular of the edible fungi. They are quite distinctive in appearance and so not easily confused with other species. Their gills are fold like rather than plate-like, thick, blunt, shallow, well spaced, decurrent and forked. The fruity odour, golden orange colour, firm flesh and wavy cap margin at maturity are characteristic features. They are rich in vitamin D and in pigment carotene.

***Inocybe cutifracta* Petch in *Ann. Roy. Bot. Gard., Peradeniya* 201. 1917**

Habit & Habitat: On ground, among litter, in dense groups in association with a variety of evergreen and deciduous plants like *Vateria indica*, *Aporusa lindleyana* Baill. and *Terminalia paniculata*.

Specimens examined : India, Kerala state, Thiruvananthapuram dist., TBGRI campus. 9 July 2007, No. 6004; Kallar: 9 July 2007, No. 6008.

Petch first described *I. cutifracta* from Peradeniya, Sri Lanka (Petch, 1917). The rimose pileal surface, smooth spores and absence of metuloidal cystidia places this species in sect. *Rimose* (Fr.) Quel., and it is closely allied to *I. virosa*, differing in the larger spores, nature of cheilocystidia and smaller habit. The capitate cheilocystidia are a distinctive feature of the species.

I. cutifracta grows in association with a variety of evergreen and deciduous plants like *Valeria indica*, *Aporusa ludleana* and *Terminalia paniculata*. This is closely related to *I. virosa* in general appearance, but is reported to be edible (Singer, 1986).

***Inocybe ianthinifolia* Pegler, in *Kew Bull. Addl. Ser.* 9:534. 1983**

Habit & Habitat: Solitary on the forest floor.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 8 Nov. 2008, No. 10743.

I. ianthinifolia was originally described from Guadeloupe, Lesser Antilles (Pegler, 1983). This is

a rare species and we have only a single collection. *Inocybe ianthinofolia* grows in association with the evergreen tree *Hopea parviflora*.

***Inocybe ingae* Pegler, in *Kew Bull. Addl. Ser.* 9:531. 1983**

Habit & Habitat: Solitary on soil.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 8 Nov. 2008, No. 10746.

I. ingae grows in association with the evergreen tree species *Xanthophyllum arnottianum* endemic to Western Ghats. *I. ingae* is a rare species, originally described from Martinique (Pegler, 1983).

***Inocybe patchii* Boedijn in *Sydowia* 5: 223. 1951**

Habit & Habitat: On ground, among litter, scattered around the base of *Hopea parviflora*.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 6 Nov. 2006, No. 2918; 13 Nov. 2006, No. 3119; 8 Nov. 2007, No. 10749; 10 June 2008, No. 11044; 16 July 2008, No. 11413; 7 Aug. 2008, No. 11651; 24 Sept. 2008, No. 11988; 29 Oct. 2008, No. 12145.

Petch originally described this fungus from Sri Lanka. (Pegler, 1986). The abruptly acute umbo, the lack of veil remnants on pileus and stipe and the stellate spinose spores are characteristic of this species. *Inocybe patchii* was collected from Kallar evergreen forest, growing in association with *Hopea parviflora* which is endemic to southern Western Ghats. The Kerala material is in close agreement with the Sri Lankan collection (Pegler, 1986).

***Inocybe purpureoflavida* Vrinda & Pradeep, *Mycotaxon* 64:1-6. 1997**

Habit & Habitat: Solitary or scattered along the river side, in association with *Hopea parviflora*.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar. 7 July 2006, No. 2224; 27 Oct. 2006, No. 2607; 3 April 2008, No. 10825; 26 June 2008, No. 11243; 5 Aug. 2008, No.

11594; 17 Sept. 2008, No. 11908; 23 Sept. 2008, No. 12054; 25 Nov. 2008, No. 12171; 30 Nov. 2008, No. 12184; 31 Nov. 2008, No. 12295.

This highly distinctive of *Inocybe* (Fr.) Fr. Section *Marginatae* Kuhner, with a purplish tinted pileus is closely related to another south-east Asian species, *Astrosporina corneri* Horak, described from Sabah (Horak, 1979). The spores offer the best means of separation, being larger with far more prominent nodules in *I. purpureoflavida*. *Inocybe purpureoflavida* is further separated by the macrocharacters, particularly the non umbonate pileus and the bulbous stipe base. This beautiful purple coloured species of *Inocybe* grows solitary or scattered in association with *Hopea parviflora*.

***Inocybe squamata* J. Lange in *Dansk. bot. Ark.* 2(7): 39. 1917**

Habit & Habitat: Solitary, scattered or in groups on soil, in association with *Hopea parviflora*.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 10 Nov. 2008, No. 12233.

Inocybe squamata is a large, striking *Inocybe* with squamose cap and mottled colours, making it quite distinct from other species. This species is not so far recorded from India Our collection agrees in all respects with the material described from Montana (Cripps, 1997). This rare *Inocybe* was found growing scattered in association with *Hopea parviflora*

***Inocybe virosa* Vrinda & Pradeep, *Mycotaxon* 67: 171-174. 1996**

Habit & Habitat: Terrestrial, solitary or in groups, in association evergreen *Hopea parviflora* (endemic to southern Western Ghats), and deciduous trees like *Aporosa lindleyana*, *Terminalia paniculata* Roth and *Xylia xylocarpa* (Roxb.) Taub.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., TBGRI campus. 7 July 2006, No. 2234; Kallar: 6 Oct. 2006, No. 2583; 15 Nov. 2006, No. 3295; 9 Oct. 2006, No. 10021; 17 July 2007, No. 10438; TBGRI campus 16 Aug. 2007, No. 10505; Kallar 26 Sept. 2007, No. 10580; 15 Oct.

2007, No. 10611; 16 July 2008, No. 11546; 28 July 2008, No. 11546; 26 Aug. 2008, No. 11841; 28 Aug. 2008, No. 11854; TBGRI campus 1 Sept. 2008, No. 11856; 9 Sept. 2008, No. 11891; Kallar 15 Sept. 2008, No. 11908; 17 Sept. 2008, No. 11919; 18 Sept. 2008, No. 11927; 23 Sept. 2008, No. 11977; 24 Sept. 2008, No. 12001; 16 Oct. 2008, No. 12088; TBGRI campus 20 Oct. 2008, Kallar No. 12113; 23 Oct. 2008, No. 12127; 31 Nov. 2008, No. 12187.

The rimose pileal surface, smooth spores and absence of metuloidal cystidia places this species in sect. *Rimosae* (Fr.) Quel., and is closely allied to the widespread species, *I. fastigiata* (Schaeff.:Fr.) Quel., but differing in the colour of the basidiomes and the spore size. It seems to be close to *I. cutifracta* Petch, described from Peradeniya, Sri Lanka (Petch, 1917), but differs in the habit, size of the spores and shape of the cheilocystidia. *Inocybe virosa* grows in association with a wide variety of evergreen as well as deciduous trees like *Hopea parviflora*, *Aporosa lindleyana*, *Terminalia paniculata* and *Xylia xylocarpa*.

***Laccaria laccata* (Scop. ex Fr.) Cooke in *Grevillea*, 12: 70. 1884**

Habit & Habitat: Solitary to gregarious, terrestrial.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 29 June 2006, No. 2211; 1 Aug. 2006, No. 2416; 3 Aug. 2006, No. 2422 & 2425; 16 Oct. 2006, No. 2592 & 2593; 6 Nov. 2006, No. 3017; 7 July 2008, No. 11307; 19 Aug. 2008, No. 11803; 21 Aug. 2008, No. 11815; 6 Nov. 2008, No. 12227.

Laccaria laccata is an edible species and found growing scattered densely gregarious in the woods and is capable of forming ectomycorrhizal associations with a number of evergreen host species of which *Hopea rachoploea*, *Ficus beddomei* King, *Vateria indica* Linn. *Hopea parviflora* etc are endemic to Western Ghats. The small to medium stature, greyish orange pileus colour, flesh coloured lamellae and finely striate stipe with white basal mycelium characterize *Laccaria laccata*.

***Russula aciculocystis* Kauffman ex Bills & Miller in *Mycologia* 76(6)990. 1984**

Habit & Habitat: Single to scattered on soil under *Myristica malabarica*, *Vateria indica*. and *Calophyllum apetalum* Willd.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 11 Aug. 2006, No. 4049; 23 Aug. 2006, No. 4074; 4075, 4076; 25 Aug. 2006, No. 4092.

This beautiful fungus grows in association with *Vateria indica*, *Myristica malabarica* and *Calophyllum apetalum*. The sticky, striate, red pileus, white to pale pink stipe and the spores with a more or less with a complete reticulum are the distinguishing characters. *R. aciculocystis* is common in the evergreen forests of Kallar during rains.

***Russula adusta* (Pers. ex Fr.) Fr. *Stirpium Agri. Femsionensis Index* : 57, 1825.**

Habit & Habitat: Grows in woods on ground.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 5 May 2006, No. 4645; 6 May 2006, No. 4654; 6 July 2006, No. 6132; 7 Aug. 2006, No. 6452.

Discolouration of the flesh when cut, bruised or handled; distinct or odd smell (non mushroomy); granular or brittle flesh and the slimy or sticky surface and blackening all over with age makes the species distinct. This is an edible species (but not recommended) growing in association with trees like *Myristica malabarica* (evergreen, endemic to Western Ghats.) and *Hopea parviflora* (evergreen, endemic to southern Western Ghats).

***Russula congoana* Pat. *Bull. Soc. Mycol. Fr.* 30:336. 1914**

Habit & Habitat: Solitary on soil.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 19 July 2007, No. 10444; TBGRI campus: 17 Oct. 2008, No. 10628; Kallar: 7 May. 2008, No. 10938; 16 June 2008, No. 11116; 17 June 2008, No. 11142; 24 June 2008, No. 11218.

A very striking species easily recognized by the carmine red pileus and the heavy ornamentation of

the spores. *R. congoana* is a small red capped edible species which has red colour on the stipe surface. It grows in both deciduous and evergreen forests. Associated tree species are *Pongamia pinnata* Pierre (deciduous) and *Hopea parviflora* (evergreen, endemic to southern Western Ghats).

Russula delicula Romag. Bull. Soc. Mycol. Fr. 61: 30. 1946

Habit & Habitat: Scattered on ground under *Vateria indica* and *Hopea parviflora*

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 15 Nov. 2006, No. 4249.

Blum (1962) recognized *delicula* as a variety of *R. delica*, but did not make a valid new combination. This pale coloured *Russula* was collected from the forests of Kallar growing in association with evergreen trees like *Hopea parviflora* and *Vateria indica*

Russula laurocerasi Melzer Casop. Cesk. Houb. 2: 243. 1921

Habit & Habitat: Solitary, scattered or gregarious in deciduous and evergreen woods.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 27 April 2006, No. 4300; TBGRI campus: 10 July 2006, No. 6026.

Russula laurocerasi is distinguished by its more or less marked odour of bitter almonds. The globose spores (7.5-10 x 7.5-9 μ m) are also very distinctive having more or less well-developed, sometimes branching, wings up to 2 μ m high connecting a large proportion of the warts. This distinct species of *Russula* is found scattered in association with *Artocarpus hirsuta* Lam. (deciduous) and *Hopea parviflora* (evergreen).

Russula leelavathyii Vrinda & Pradeep in Mycotaxon 62:389. 1997

Habit & Habitat: Solitary to scattered on sandy soil along river banks.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 10 July 2006, No. 5959; 9 July 2006, No. 5998; 14 July 2006, No. 6070; 18 July 2006, No. 6248; 4 Sept. 2006, No. 6664; TBGRI campus: 5 Sept. 2006, No. 6671; Kallar 10 Sept. 2006, No. 6675; 23 Oct. 2006, No. 6813; TBGRI campus 27 Oct. 2006, No. 6819; Kallar: 22 Sept. 2007, No. 7911; 27 Sept. 2007, No. 8020; 11 Oct. 2007, No. 8160; 25 Oct. 2007, No. 8287; TBGRI campus: 18 April. 2008, No. 8492; 19 April 2008, No. 8674; Kallar 20 June 2008, No. 8988; 2 Sept. 2008, No. 11857.

This species is found growing in large numbers along the riverside in sandy soil in association with *Hopea parviflora* and *Artocarpus hirsuta*. The furcate lamellae together with lack of lamellulae would indicate the species to belong in the section *Heterophyllae* and the epithelial pileipellis places this species with subsection *Pseudoepithelinae* Buyck. The subsection proposed by Buyck (1990), comprises pantropical species only, and this is the first record of a species from the Indian subcontinent. It most closely approaches *R. moyersoeni* Buyck, from Venezuela, in the overall habit and pigmentation but can be separated by virtue of the white pileus, smaller spores with a finer ornament, the lack of pileal macrocystidia and the presence of caulocystidia.

Russula luteotacta Rea Trans. Worcestershire Naturalists' Club 1:416. 1897

Habit & Habitat: Solitary to scattered on soil under Dipterocarpous trees.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 13 April 2006, No. 4254; 27 April 2006, No. 4298.

Colour of the cap varies with age and weather to white, cream, red or reddish or pink. The flesh is granular or brittle. It grows in the woods in association with *Vateria indica* and *Hopea parviflora*, both endemic to Western Ghats.

Russula mariae Peck, Ann. Rep. N. Y. State Mus. 24: 74. 1872

Habit & Habitat: Scattered on soil among fallen leaves.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 18 May 2006, No. 719.

This *Russula* was named after the French Mycologist Maire. Our species closely resembles *R. mariae*, described by Bills & Miller (1984) from North America. This beautiful red coloured *Russula* species grows in association with *Hopea racploeai* Dyer.

***Russula periglypta* Berk. & Br. In *Journ.Linn. Soc, Bot.* 11: 566. 1871**

Habit & Habitat: Scattered on ground, often in rings associated with the roots of *Vateria indica*.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 6 April 2006, No. 113; 7 June 2006, No. 153.

Discoloured basidiomes may develop pink, red or blackish mottling on the pileal surface. The absence of lamellulae, the viscid pileus with a tuberculato-pectinate margin; and greyish violet colouration of the cap distinguishes this species. It is often found growing in large rings.

***Russula purpureonigra* Petch in *Ann. Roy. Bot. Gard., Peradeniya* 6: 200. 1917**

Habit & Habitat: Scattered on sandy soil, riverside under *Myristica malabarica*

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 2 May 2006, No. 2998; 4 Aug. 2006, No. 4421; 3 Sept. 2006, No. 4794; 16 Sept. 2006, No. 4809; 2 April 2008, No. 6272.

The whole basidiomes turn black when handled or bruised. The colour changes are best assessed by rubbing the stem surface (which usually happens in the course of picking and handling the mushroom) and by slicing the mushroom in half. This white *Russula* species grows on sandy soil, in association with the roots of *Myristica malabarica*.

***Russula romagnesiana* Shaffer in *Mycologia* 56. 1964**

Habit & Habitat: Scattered on ground growing in large numbers often in rings under evergreen trees like *Vateria indica* and *Hopea parviflora*.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 29 Sept. 2006, No. 8057; 1 Oct. 2006, No. 8092; 4 Oct. 2006, No. 8106; 13 April 2007, No.8606; 4 Sept. 2007, No. 9791; 8 April 2008, No. 10856; 18 April 2008, No. 10865; 19 April 2008, No. 10870; 9 May 2008, No. 11075; 16 June 2008, No. 11131; 19 June 2008, No. 11176; 20 June 2008, No. 11177; 24 June 2008, No. 11216; 26 June 2008, No. 11223.

The medium to large cream coloured cap, cream adnate cuticle, growth habit, small spores with a partial reticulum and encrusted hyphae on pileipellis are the diagnostic characters. Our collection exactly matches with the materials described from Michigan (Shaffer, 1964). *Russula delicula* is a closely related species but it differs from *R. romagnesiana* in having larger spores and sub erect hairs in pileipellis. The species is found growing in large numbers often in rings under evergreen trees like *Vateria indica* and *Hopea parviflora*

***Strobilomyces floccopus* (Fr.) Karsten *Bidr. Finl. Nat. Folk* 37:16. 1828**

Habit & Habitat: Solitary to scattered under *Holigarna arnottiana*, Hook. f. an evergreen tree species endemic to Western Ghats.

Specimens examined: India, Kerala state, Thiruvananthapuram dist., Kallar: 19 April 2006, No. 605 ; 4 June 2006, No. 857; 13 June 2006, No. 898; 16 July 2006, No. 1093; 17 Nov. 2006, No. 2729; 19 May 2007, No. 3837; 9 July 2007, No. 6016; 2 Sept. 2007, No. 6652; 18 April 2008, No. 8643.

Species of *Strobilomyces* are shaggy to scaly, blackish or grayish mushrooms with partial veils and woolly stems. They are commonly called as "Old Men of the Woods". Their flesh stains pinkish or orange red when sliced, and then slowly turns black. The black pigmentation, wooly pileus and stipe, rufescence on injury, and globose spores with reticulate ornamentation are diagnostic. It is associated with the endemic tree *Holigarna arnottiana* in the Kallar forests.

Two undescribed species of fungi were collected under *Acacia*: *Agaricus* sp. and *Amanita* sp. *Agaricus* specimens were found growing in troops on ground in association with *Acacia auriculaeformis* A. Curn. Edibility of the species was tested and was found to be excellent. The *Amanita* sp. collected was a close relative of the famous *Amanita phalloides* or the "death cap". An interesting new species of *Auritella* was collected from Kallar evergreen forest. The species was associated with *Dipterocarpus indicus* Bedd. which is endemic to Western Ghats.

The study conducted so far indicates that Russulaceae is by far the most species rich ectomycorrhizal family represented by 12 species. It was followed by Cortinariaceae with 9 species and Amanitaceae with 8 species. Strobilomycetaceae was represented by 2 species while Agaricaceae, Boletaceae, Cantharellaceae and Tricholomataceae were represented by single species.

Out of the 160 individual collections made from the three different forests, maximum number of ectomycorrhizal species was collected from the evergreen forests (88%). Of the total species collected, 20% were common both in the evergreen and deciduous forests and 12% of the collections were confined strictly to exotic plantations. The mycorrhizal symbiotic tree species were native plants, many endemic to Western Ghats. Some tree species form mycorrhizae with more than one fungus and a fungus may associate with more than one tree. It is observed that, many ectomycorrhizal fungus species were found to be associated with the dominant tree species of the area viz., *Hopea parviflora*, Bedd. *Vateria indica* Linn, *Myristica malabarica*, Lam. *Dipterocarpus indicus* Bedd. *Terminalia paniculata* Roth. etc.

It is observed that ectomycorrhizal symbiosis occurs wherever potential host plant exists or trees are able to exist in many habitats because of partnership with ectomycorrhizal fungi. Particular species of mycorrhizal fungi can occur across many forest types, it is becoming evident that particular assemblages or communities of mycorrhizal fungi are characteristic of each forest types.

ACKNOWLEDGEMENT

The authors are thankful to the Ministry of Environment and Forests, Govt. of India, New Delhi for financial assistance.

REFERENCES

- Allen, M.F. 1991. *The ecology of Mycorrhizae*. Cambridge University press, Cambridge.
- Bas, C. 1969. Morphology and subdivision of *Amanita* and a monograph of its section *Lepidella*. *Persoonia* **5**: 285-579
- Bills, G.F. and Miller, O.K. 1984. Southern Appalachian Russulas-I. *Mycologia* **76**:975-1002.
- Blum, J. 1962. *Les Russules*. Editions Paul Lechevalier. 228 p
- Boedijn, K.B. 1951. Notes on Indonesian fungi. The genus *Amanita*. *Sydowia* **5**: 317-327.
- Buyck, B. 1990. New taxa of Tropical Russulae: *Pseudoepithelinæ*. Subsect. nov. *Mycotaxon* **39**: 317-327.
- Cappelli, A. 1984. *Agaricus* L: Fr. ss. Karsten (*Psalliota* Fr.) *Fungi Europaei* 1-558.
- Cathy, L. and Cripps. 1977. The genus *Inocybe* in Montana aspen stands. *Mycologia*. **89**(4): 670-688.
- Grund, L. W., and D. E. Stuntz. 1975. Nova scotian *Inocybes*. III. *Mycologia* **67**:19-31.
- Horak, E. 1979. *Astrosporina* in Indomalaya and Australia. *Persoonia* **10**.157-205.
- Mayor, J.R.; Tara, D.; Fulgenzi, Terry; Henkel, W and Halling, Roy E. 2008. *Boletellus piakaii* sp. nov. and a new distribution record for *Boletellus ananas* var. *ananas* from Guyana *Mycotaxon* **105**. 387-398.
- Kornerup, A and Wanscher, J.H. 1978. *Methuen Handbook of Colour*, p. 252, Methuen and Co. Ltd., London.
- Pegler, D. N. 1977. A preliminary agaric flora of East Africa. *Kew Bull. Addit. Ser.* **6**: 1-615.
- Pegler, D. N. 1983. A preliminary agaric flora of Lesser Antilles. *Kew Bull. Addit. Ser.* **9**: 1-668.
- Pegler, D. N. 1986. Agaric flora of Sri Lanka. *Kew Bull. Addit. Ser.* **12**: 1- 519.
- Petch, T. 1917. Additions to Ceylon Fungi. *Ann. Roy. Bot. Gard., Peradeniya* **6**: 195.
- Read, D.J., Lewis, D.H. and Fitter, A.H., 1992. *Mycorrhizas in Ecosystems*. Wallingford, UK: CAB. International.
- Redhead, I.F. 1980. Mycorrhiza in natural tropical forests. In: Mikola, P. Ed. *Tropical Mycorrhizal Research*. Oxford, U.K. Clarendon Press. Pp. 127-142.
- Rodham E. Tullos 2009. *Amanita magniverrucata* - revision of an interesting species of *Amanita* section *Lepidella*, *Mycotaxon* **108**: 93-104
- Shaffer, R.L. 1964. The subsection *Lactarioideae* of *Russula*. *Mycologia* **56**: 201-231.
- Singer, R. 1986. *Agaricales in modern taxonomy*. J. Cramer, Germany 981pp

(Accepted for publication August 06, 2010)