Ectomycorrhizal basidiomata fruiting in lowland rain forests of Peninsular Malaysia

Su See Lee*
Roy Watling**
Yahya Noraini Sikin*

* Forest Research Institute
Malaysia
Kepong
52109 Kuala Lumpur
Malaysia

** Caledonian Mycological
Enterprises
Edinburgh EH4 3HU
Scotland
United Kingdom
or
Royal Botanic Garden
Edinburgh EH3 5LR
Scotland
United Kingdom

This paper examines the patterns of putative ectomycorrhizal basidiomata fruiting in a lowland rain forest and in a planted forest community in Peninsular Malaysia, and their relationship with local weather conditions from data collected over a period of 6 years in the rain forest and 7 years in the planted forest.

Photo 1.
Russula virescens (Schaeff.) Fr., a very common species growing in large troops under many dipterocarp species at FRIM and in Pasoh forest. This edible fungus is found throughout Europe, Asia and North America. Photo S.S. Lee.

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RÉSUMÉ

FRUCTIFICATION DES BASIDIOCARPES ECTOMYCORHIZIENS DANS LES FORÊTS OMBROPHILES DE FAIBLE ALTITUDE DE LA MALAISIE PÉNINSULAIRE

Les forêts ombrophiles de faible altitude de la Malaisie péninsulaire sont majoritairement peuplées de diptérocarpacées ectomycorhiziennes, l'une des plus importantes familles d'arbres de haute futaie d'Asie du Sud-Est. Les principaux groupes de champignons ectomycorhiziens symbiotiquement associés aux diptérocarpacées appartiennent aux taxons amanites, bolets, chanterelles et russules ainsi qu'à plusieurs taxons hypogés, tous de l'ordre des basidiomycètes. Le Professeur E. J. H. Corner a été le premier à mettre en évidence la fructification saisonnière des agarics dans la péninsule, mais sans présenter de données climatiques pour démontrer cette corrélation. Le présent article étudie les schémas de fructification des basidiocarpes ectomycorhiziens putatifs dans la forêt ombrophile de faible altitude et dans une forêt plantée de la Malaisie péninsulaire, ainsi que leurs relations avec les conditions climatiques locales, à partir de données recueillies sur six ans dans la forêt ombrophile et sur sept ans dans la forêt plantée.

Mots-clés : champignon ectomycorhizien, forêt ombrophile tropicale, fructification fongique, caractère saisonnier.

ABSTRACT

ECTOMYCORRHIZAL BASIDIOMATA FRUITING IN LOWLAND RAIN FORESTS OF PENINSULAR MALAYSIA

The lowland rain forests of Peninsular Malaysia are dominated by ectomycorrhizal Dipterocarpaceae, one of the most important families of timber trees in Southeast Asia. The main groups of ectomycorrhizal fungi involved in symbiotic associations with dipterocarps are members of the Amanitales, Boletales, Cantharellales, Russulales and several hypogeous taxa, which are all members of the Basidiomycota. Prof. E.J.H. Corner first highlighted the seasonal fruiting of agaric fungi in the peninsula but he did not present any climatic data to demonstrate this correlation. This paper examines the patterns of putative ectomycorrhizal basidiomata fruiting in a lowland rain forest and in a planted forest community in Peninsular Malaysia, and their relationship with local weather conditions from data collected over a 6 year period in the rain forest and 7 years in the planted forest.

Keywords: ectomycorrhizal fungi, tropical rain forest, fungal fruiting, seasonality.

RESUMEN

FRUCTIFICACIÓN DE LOS BASIDIOCARPOS ECTOMICORRÍCICOS EN LOS BOSQUES OMBRÓFILOS DE BAJA ALTITUD DE MALASIA PENINSULAR

Los bosques ombrófilos de baja altitud de Malasia peninsular están poblados mayoritariamente por dipterocarpáceas ectomicorrícicas, una de las más importantes familias de árboles de monte alto del sudeste asiático. Los principales grupos de hongos ectomicorrícicos simbióticamente asociados a las dipterocarpáceas pertenecen a los taxones amanitas, boletos, rebozuelos y russulas así como a varios taxones hipogeos, todos del orden de los basidiomicetos. El Profesor E. J. H. Corner fue el primero que evidenció la fructificación estacional de los agaricales en la península, pero sin presentar datos climáticos para demostrar esta correlación. El presente artículo estudia los esquemas de fructificación de los basidiocarpos ectomicorrícicos putativos en el bosque ombrófilo de baja altitud y en un bosque plantado de Malasia peninsular, así como sus relaciones con las condiciones climáticas locales, a partir de datos recogidos durante seis años en el bosque ombrófilo y durante siete años en el bosque plantado.

Palabras clave: hongo ectomicorrícico, bosque ombrófilo tropical, fructificación fúngica, carácter estacional.

Introduction

Trees of the ectomycorrhizal Dipterocarpaceae family dominate the tropical rain forests of Malaysia. Members of this family are some of the most important sources of timber in Malaysia and Southeast Asia, accounting for about 80% of the timber exported from the region. As with other mycorrhizal symbioses, the dipterocarp ectomycorrhizal association has been demonstrated to enhance phosphorus uptake and improve seedling growth in several dipterocarp species (Lee, Alexander, 1994; Yazid *et al.*, 1994). Some members of other tropical lowland rain forest tree families, i.e. Fagaceae, Leguminosae and Myrtaceae, are also known to be capable of forming ectomycorrhizas. However, information on these associations is lacking for Malaysian and Southeast Asian rainforests.

Based on basidiomata observations, the main groups of ectomycorrhizal fungi involved in symbiotic associations with dipterocarps are members of the Amanitales, Boletales, Cantharellales, Russulales and several hypogeous taxa — all members of the Basidiomycota (Ogawa, 1992; Smits, 1994; Watling, Lee, 1995, 1998; Watling *et al.*, 1998).

Prof. E.J.H. Corner was the first to highlight the seasonal fruiting of agarics in Peninsular Malaysia in a paper published in 1935. He stated that generally the first fruiting season of the year extended from March to May, with a less regular second season from some time in August to October or November, coinciding with the return of wet weather after relatively dry periods of several weeks (Corner, 1935; 1988). Although he stated that the exact dates of fruiting could vary from place to place depending on local weather conditions, he did not present any weather data to confirm this correlation.

Here we examine the patterns of putative ectomycorrhizal basidiomata fruiting in a lowland rain forest and in a planted forest community in Peninsular Malaysia, and their relationship with local weather conditions from data collected over a period of 6 years in the rain forest and 7 years in the planted forest. Information on the fruiting seasons would be useful to determine the best times for observing and collecting such basidiomata for further studies, e.g. isolation into culture for various experimental purposes such as ectomycorrhizal synthesis experiments, and for investigations on their biology and ecology (Watling *et al.*, 1998). Such information could also be used by students/visitors/mushroom collectors wishing to observe or collect mushrooms in lowland rainforests of Peninsular Malaysia and in the preparation of pamphlets and guidebooks.

Materials and Methods

Between 1992 and 1997, putative ectomycorrhizal fungi were collected in Pasoh Forest Reserve, a lowland dipterocarp forest located approximately 140 km southeast of Kuala Lumpur, the capital of Malaysia, under the auspices of various joint collaborative projects. The lowland rain forest of Pasoh is floristically very rich, i.e. a total of 335 256 stems 1 cm dbh and greater, belonging to 814 species, 294 genera and 78 families have been recorded within a 50 ha area. Common plant families in this forest include the Euphorbiaceae, Annonaceae, Dipterocarpaceae, Leguminosae and Burseraceae (Kochummen, 1997). Fungi were collected in March every year and also in early September 1995 and late August 1996, coinciding with the beginning of the two predicted annual rainy spells of February-March and July-August. During each visit of about 3 days duration, collections were made along the Main Trail, Nature Trail, around Ecological Plot 1 and the Arboretum (Watling *et al.*, 1998).

Between 1993 and 1999, putative ectomycorrhizal basidiomata were collected weekly in the Cryptogamic Garden and surrounding area on the FRIM campus and along the main road leading into FRIM, where various tree species including

Photo 2.
Pisolithus aurantioscabrosus Watling, a newly described fungus from the lowland rainforest at Pasoh, Negeri Sembilan, Peninsular Malaysia.
Photo S.S. Lee.

Photo 3.
Ectomycorrhizas of *Pisolithus aurantioscabrosus* traced from a basidiome to roots of trees in Pasoh forest.
Photo A. Taylor.

the dipterocarps *Hopea odorata* and *Dryobalanops aromatica* had been planted as avenue trees. Trees in the Cryptogamic Garden and surrounding areas were planted in the late 1920s and belong to the Casuarinaceae, Dipterocarpaceae, Lauraceae, Lecythidaceae and Myrtaceae families. In addition, weekly collections were also conducted in the Dipterocarp Arboretum on the FRIM campus where various species of dipterocarps had been planted in rows in the late 1920s. However, due to unavoidable circumstances, no collections were made on the FRIM grounds between March and April 1995.

The collection methods were based on those traditionally employed by confirmed agaricologists (Henderson *et al.*, 1969). Collections were documented with sketches and/or photographs and described and dried either in silica gel or in a ventilated hot air oven at 45 °C. Some of the material is housed in the herbarium of the Royal Botanic Garden, Edinburgh, while others are housed at FRIM, Kepong.

Table I.
Number of species of putative ectomycorrhizal fungi collected annually between 1992 and 1997 from Pasoh Forest Reserve, Negeri Sembilan, a lowland rain forest in Peninsular Malaysia.

	Year							
	1992	1993	1994	1995		1996		1997
Fungal families	Mar.	Mar.	Mar.	Mar.	Sept.	Mar.	Aug.	Mar.
Amanitaceae	5	7	9	8	3	1	14	11
Boletaceae	7	18	7	6	1	3	10	21
Cantharellaceae	4	2	5	1	3	1	1	6
Chamonixiaceae	0	0	0	0	1	0	0	0
Clavulinaceae	0	0	0	0	0	0	0	1
Cortinariaceae	4	0	2	0	4	0	1	1
Elasmomycetaceae	0	0	0	0	0	1	0	0
*Entolomataceae	2	4	1	1	1	0	3	1
Gauteriaceae	1	0	0	0	0	1	1	0
Gomphaceae	0	0	1	0	0	0	0	0
Hydnaceae	0	0	0	0	1	1	0	1
Hymenochaetaceae	0	0	0	0	0	1	0	0
Hymenogastraceae	0	0	0	1	0	0	2	1
Russulaceae	59	12	22	29	33	4	3	4
Pisolithaceae	1	0	0	1	0	0	0	0
Sclerodermataceae	2	0	0	3	6	1	3	5
Thelephoraceae	1	0	0	0	0	0	0	0
Tricholomataceae	1	2	1	2	2	0	1	1
Total	**87**	**45**	**48**	**52**	**55**	**14**	**39**	**53**

* Including possible saprophytes.

Photo 4.
Lactarius sumstinei Peck, found in Pasoh forest but not at Kepong. It is known to occur in Guangdong, China, and North America.
Photo S.S. Lee.

Photo 5.
Amanita angustilamellata Corner & Bas, a fungus that is commonly encountered in lowland rainforests growing under a variety of dipterocarp hosts.
Photo S.S. Lee.

Results and Discussion

Pasoh forest reserve

Over the 6 year period from 1992 to 1997, a total of 296 fungal entities, distributed in 18 families were recorded, with many collections that could not be identified to known species (Lee *et al.*, in press). One important discovery was a new Pisolithaceae species, i.e. *Pisolithus aurantioscabrosus* (Photo 2) which formed ectomycorrhizas (Photo 3) with roots of trees in Pasoh forest. Although collections were made at approximately the same time(s) each year, the number of species collected varied considerably from a high of 87 in March 1992 to a low of 14 species in March 1996 (Table I). While the 107 species encountered in 1995 can be attributed to two collections that year, the following year only 53 species were recorded, despite the

Photo 6.
Boletus aureomycelinus Pat. & Baker, a fungus considered uncommon by Corner (1972) but widely distributed in Peninsular Malaysia growing under a variety of dipterocarp species. It is a common fungus in the FRIM grounds.
Photo S.S. Lee.

Photo 7.
Lactarius gerardii Peck can be found growing under several dipterocarp species in the FRIM grounds. This fungus is found in Japan and is widely distributed in North America.
Photo S.S. Lee.

fact that two collections were carried out at about the same times as the previous year. In fact, the number of species found in just one short visit in 1992 (87 species), far exceeded the numbers collected during two separate visits in 1996. Fungi that could be identified to the species level are listed in Table II. The detailed results of the collections from Pasoh forest are presented in a forthcoming publication (Lee *et al.*, in press).

Cryptogamic garden and surroundings

In the much smaller area of the Cryptogamic Garden and surroundings, a total of 79 fungal entities from seven families of putative ectomycorrhizal fungi were collected between 1993 and 1999. Of these, only 43 or about 54% could be identified to the species level (Table II), with members of the Russulaceae being the most problematic in the absence of suitable keys and monographs (Table III). The number and species of fungi encountered were much lower than at Pasoh forest, but this could be expected in view of the smaller area covered and the lower number and variety of potential host trees in the Cryptogamic Garden and surroundings. For example, *Lactarius sumstinei* (Photo 4) was found several times at Pasoh but never at Kepong. The number of species encountered each year was variable despite regular weekly visits being made to the area throughout the 7 years, with the exception of March and April 1995. The highest number of species was found in 1994, where 49 species were recorded while the lowest number of species (19) was found in 1998 (not taking into account 1995, when no collections were made during the predicted main fruiting seasons) (Table IVa).

Dipterocarp arboretum

The lawns of the Dipterocarp Arboretum at FRIM are mowed regularly and, as mowing destroys emerging and existing basidiomata and may also have an effect on fruiting frequency, data from the arboretum are considered incomplete. Nevertheless, a total of 42 putative ectomycorrhizal entities were collected during the study period, many in common with the Cryptogamic Garden and surrounding areas, for example, *Amanita angustilamellata* (Photo 5), *Boletus aureomycelinus* (Photo 6), *Russula virescens* (Photo 1) and *Lactarius gerardii* (Photo 7). The highest number of collections (31) was made in 1994, while there was only one collection in 1998, in a pattern similar to that of the Cryptogamic Garden and surroundings (Tables IVa and IVb). In an earlier study carried out at the FRIM Arboretum between 1972 and 1974, 58 species of fungi were recorded (Hong *et al.*, 1984), of which 28 could be considered putative ectomycorrhizal fungi.

Data from both the Cryptogamic Garden and the Dipterocarp Arboretum revealed that in the FRIM grounds ectomycorrhizal fungi could be found throughout the year, with the exception of December, where none were encountered throughout the 7-year study period (Figure 1). November was generally a poor month for fungi, with collections being made only twice over the 7 years, in 1995 and 1998, and only two and one species were collected, respectively. In general, it appeared that there are two main seasons for fruiting of putative ectomycorrhizal fungi at Kepong, i.e. February-March and August-September, with the first season sometimes starting earlier in January and the second season extending from June until October, thus corroborating Corner's earlier observations (Corner, 1935). However, in 1999 only one season was observed in the latter half of the year. In the report by Hong *et al.* (1984), fungi were collected from the arboretum throughout the year, with the largest collections being made in March-April and September-October. However, these collections included both saprophytes as well as putative ectomycorrhizal fungi, and no distinction was made between periods when the two groups of fungi were collected.

Table II.
Identified putative ectomycorrhizal fungi collected between 1992 and 1997 from Pasoh Forest Reserve, and between 1993 and 1999 from the Cryptogamic Garden and surroundings at FRIM, Kepong, Peninsular Malaysia.

Species collected from Pasoh	Species collected from the FRIM grounds
Amanitaceae	Amanitaceae
Amanita sp. 2 Corner & Bas	*Amanita angustilamellata* (Höhn.) Boedijn
Amanita sp. 6 Corner & Bas	*Amanita* sp. 1 Corner & Bas
Amanita alauda Corner & Bas	*Amanita* sp. 6 Corner & Bas
Amanita centunculus Corner & Bas	*Amanita cinctipes* Corner & Bas
Amanita cinctipes Corner & Bas	*Amanita elata* (Massee) Corner & Bas
Amanita demissa Corner & Bas	*Amanita fritillaria* f. *malayensis* Corner & Bas
Amanita elata (Massee) Corner & Bas	*Amanita gymnopus* Corner & Bas
Amanita hemibapha ssp. *similis* (Boedijn) Corner & Bas	*Amanita hemibapha* ssp. *similis* (Boedijn) Corner & Bas
Amanita gymnopus Corner & Bas	*Amanita mira* Corner & Bas
Amanita mira Corner & Bas	*Amanita perpasta* Corner & Bas
Amanita modesta Corner & Bas	*Amanita pilosella* Corner & Bas
Amanita obsita Corner & Bas	*Amanita princeps* Corner & Bas
Amanita pilosella Corner & Bas	*Amanita sychnopyramis* Corner & Bas
Amanita privigna Corner & Bas	*Amanita tjibodensis* Boedijn
Amanita sychnopyramis Corner & Bas	*Amanita virginea* Massee
Amanita tjibodensis Boedijn	
Amanita tristis Corner & Bas	
Amanita vestita Corner & Bas	
Amanita virginea Massee	
Amanita xanthomargaros Corner & Bas	
#*Limacella singaporeana* Corner	
Boletaceae*	Boletaceae*
Boletus destitutus Corner	*Boletus aureomycelinus* Pat. & Baker
Boletus fumosipes Peck	*Boletus pernanus* Corner
Boletus nigroviolaceus Heim	*Boletellus emodensis* (Berk.) Singer
Boletus peltatus Corner & Watling	*Strobilomyces velutipes* Cooke & Massee
Boletus peltatus var. *decolorans* nom. prov.	*Phylloporus bellus* var. *cyanescens* (Massee) Corner
Boletus pernanas Pat. & Baker	*Phylloporus brunneolus* Corner
Boletus phaeocephalus Pat. & Baker	
Boletus polychrous Corner	
Boletus tristior Corner	
Boletus tristis Pat. & Baker	
Boletus tristiculus Massee	
Boletus valens Corner	
Boletellus emodensis (Berk.) Singer	
Heimiella retispora (Pat. & Baker) Boedijn	
Phylloporus bellus var. *cyanescens* (Massee) Corner	
Phylloporus bogoriensis Hoehn.	
Phylloporus brunneolus Corner	
Phylloporus orientalis var. *brevisporus* Corner	
Phylloporus orientalis var. *orientalis* Corner	
Phylloporus parvisporus Corner	
Phylloporus rufescens Corner	
Pulveroboletus frians (Corner) Horak	
Pulveroboletus icterinus (Pat. & Baker) Watling	
Rubinoboletus ballouii (Peck) Heinemann & Ram.	
R. ballouii var. *fuscatus* (Corner) Hongo	
Strobilomyces mollis Corner	
Strobilomyces velutipes Cooke & Massee	
Tylopilus maculatus (Corner) Watling & Lee	
Tylopilus spinifer (Pat. & Baker) Watling & Lee	
Cantharellaceae	
Cantharellus ianthinus Corner	
Cantharellus lilacinus Cleland & Cheel	
Cantharellus odoratus (Schw.) Fr.	
Cantharellus omphalinoides Corner	
Craterellus cornucopioides var. *mediosporus* Corner	
Gloeocantharellus okapaensis Corner	

Species collected from Pasoh	Species collected from the FRIM grounds
Chamonixiaceae	
Chamonixia mucosa (Petri) Corner & Hawker	
Clavulinaceae	
Clavulina cartilaginea (B. & Per.) Corner	
Cortinariaceae	Cortinariaceae
Inocybe aequalis (Horak) Turnbull & Watling	*Inocybe aequalis* (Horak) Turnbull & Watling
Inocybe angustifolia Corner & Horak	*Inocybe corneri* (Horak) Garrido
Inocybe aurantiocystidiata Turnbull & Watling	*Inocybe lutea* Kobayasi & Hongo
Inocybe avellanea Kobayasi	*Inocybe paleotropica* Turnbull & Watling
Inocybe sphaerospora Kobayasi	
Elasmomycetaceae	
Zelleromyces malaiensis (Corner & Hawker) A.H. Smith	
Entolomataceae+	
Entoloma caeruleoviride Corner & Horak	
Entoloma corneri Horak	
Entoloma flavidum (Massee) Corner & Horak	
Entoloma pallido-flavum (Hennings & Nyman) Horak	
Leptonia decolorans var. *decolorans* (Horak) Largent	
Leptonia mougeotti (Fr.) P.D. Orton	
Nolanea cystopus (Berk.) Pegler	
Nolanea maderaspatana Pegler	
Hydnaceae	
Hydnum repandum L. : Fr.	
Hymenochaetaceae	
Coltricia oblectans (Berk.) Cunn.	
Hymenogastraceae	
Dendrogaster cambodgensis Pat.	
Russulaceae	Russulaceae
Lactarius gerardii Peck	*Lactarius gerardii* Peck
Lactarius hygrophoroides Berk. & Curt.	*Lactarius subplinthogalus* Coker
Lactarius subplinthogalus Coker	
Lactarius subserifluus Longyear	
Lactarius sumstinei Peck	
Lactarius vellereus (Fr.) Fr.	
Russula alboareolata Hongo	*Russula alboareolata* Hongo
Russula crustosa Peck	*Russula albonigra* (Krombh.)
Russula cyanoxantha (Schaeff.) Fr.	*Russula cyanoxantha* (Schaeff.) Fr.
Russula heterophylla (Fr.) Fr.	*Russula delica* Fr.
Russula japonica Hongo	*Russula eburneoareolata* Hongo
Russula nauseosa f. *japonica* Hongo	*Russula heterophylla* (Fr.) Fr.
Russula pallidospora (Bl. in Romagn.) Romagn.	*Russula japonica* Hongo
Russula subnigricans Hongo	*Russula nigricans* (Bull.) Fr.
Russula violeipes Quél.	*Russula senecis* Imai
Russula virescens (Schaeff.) Fr.	*Russula singaporensis* Singer
	Russula violeipes Quél.
	Russula virescens (Schaeff.) Fr.
Pisolithaceae	
Pisolithus aurantioscabrosus Watling	
Sclerodermataceae	Sclerodermataceae
Scleroderma columnare Berk. & Br.	*Scleroderma columnare* Berk. & Br.
Scleroderma echinatum (Petri) Guzmán	*Scleroderma leptopodium* Har. & Pat.
Scleroderma leptopodium Har. & Pat.	*Scleroderma sinnamariense* Mont.
Scleroderma sinnamariense Mont.	
Thelephoraceae	Tricholomataceae
Sarcodon thwaitsei (B. & Br.) Maas Geest.	*Laccaria vinaceoavellanea* Hongo

Probably not mycorrhizal.
* Some species of *Boletellus*, *Strobilomyces* and *Phylloporus* are known to form ectomycorrhizas but many may not be ectomycorrhizal. Those listed here are suspected of forming ectomycorrhizas, hence the use of the term putative.
+ Contains possible saprophytes.

Table III.
Families and genera of putative ectomycorrhizal fungi collected between 1993 and 1999 from the Cryptogamic Garden and surrounding areas, Forest Research Institute Malaysia, Kepong, Malaysia.

Family/Genus	No. of species	No. species identified to known taxa
Amanitaceae		
Amanita spp.	17	15
Boletaceae		
Boletus spp.	6	2
Boletellus sp.*	1	1
Strobilomyces spp.*	2	1
Phylloporus spp.*	2	2
Cantharellaceae		
Cantharellus sp.	1	0
Cortinariaceae		
Inocybe spp.	4	4
Russulaceae		
Lactarius spp.	3	2
Russula spp.	39	12
Sclerodermataceae		
Scleroderma spp.	3	3
Tricholomataceae		
Laccaria sp.	1	1
Total	**79**	**43**

* Some species of *Boletellus*, *Strobilomyces* and *Phylloporus* are known to form ectomycorrhizas but many may not be ectomycorrhizal. Those listed here are suspected of forming ectomycorrhizas.

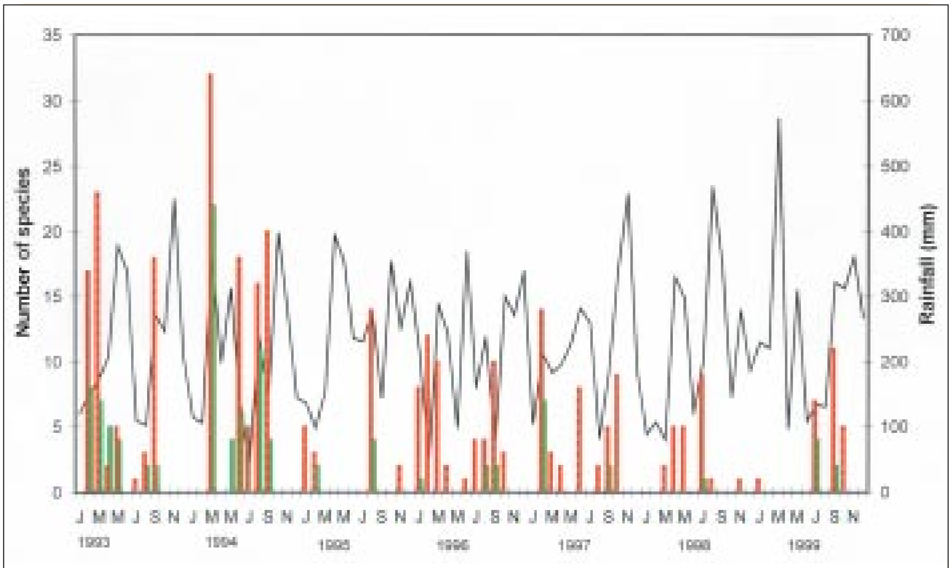


Figure 1.
Monthly rainfall and number of species of putative ectomycorrhizal fungi collected from the Cryptogamic Garden and Dipterocarp Arboretum in the FRIM campus, Kepong, Malaysia, between 1993 and 1999.

From our present data, fruiting of putative ectomycorrhizal fungi at Kepong appeared to follow the weather pattern suggested by Corner (1935, 1988), i.e. coinciding with the return of wet weather after relatively dry periods of several weeks. This pattern was particularly evident in 1993, 1994, 1997 and 1998 (Figure 1). We did not collect saprophytic fungi, but Corner (1935) indicated that fruiting of saprophytic species also complied with the twice-yearly season when a “run of fungus” developed in synchrony with these weather patterns.

1992 was an exceptionally good year for fruiting of putative ectomycorrhizal fungi in Pasoh forest but unfortunately there was no comparable data for Kepong. With the exception of a poor season in 1996, the number of collections remained relatively stable at Pasoh throughout the study period. In contrast, the number of collections from Kepong generally declined after 1994 for unknown reasons.

As in Europe and North America, erratic fruiting appears to be a feature of the Malaysian lowland rain forest. Some possible reasons for this phenomenon are suggested here. Frequency and abundance of fruiting may be influenced by seasonal or local weather patterns or microclimatic changes, and/or host-fungus relationships. Exceptional weather conditions may also influence normal fructification patterns (Arnolds, 1995) and, according to Corner (1962-1963), short dry spells at frequent intervals and one or two heavy storms which are not followed by a wet period may give poor results. It is also possible that fungal mycelia require a certain length of time for accumulation of sufficient energy for basidiomata production. Grazing or feeding intensity by animals and soil invertebrates could also influence fruiting. Other factors known to affect mushroom production are soil com-

Table IVa.
Number of species of putative ectomycorrhizal fungi collected annually between 1993 and 1999 from the Cryptogamic Garden and surrounding areas at FRIM, Kepong.

Fungal families	Year 1993	1994	1995*	1996	1997	1998	1999
Amanitaceae	12	8	4	6	7	8	9
Boletaceae	2	6	1	1	1	2	2
Cantharellaceae	1	0	0	0	0	0	0
Cortinariaceae	2	2	0	0	1	0	0
Russulaceae	24	31	10	20	16	6	9
Sclerodermataceae	1	1	1	2	1	2	1
Tricholomataceae	1	1	0	0	0	1	0
Total	**43**	**49**	**16**	**29**	**26**	**19**	**21**

* Collections were not made in March and April.

Table IVb.
Number of species of putative ectomycorrhizal fungi collected annually between 1993 and 1999 from the Dipterocarp Arboretum, FRIM, Kepong.

Fungal families	Year 1993	1994	1995*	1996	1997	1998	1999
Amanitaceae	5	6	1	0	1	0	0
Boletaceae	2	4	0	1	1	0	0
Russulaceae	14	20	5	4	6	1	4
Tricholomataceae	1	1	0	0	0	0	0
Total	**22**	**31**	**6**	**5**	**8**	**1**	**4**

* Collections were not made in March and April.

paction, disturbance of the litter layers by activities such as raking, depletion of usable nutrients, quantity of carbohydrates available to ectomycorrhizal fungi for fruiting, and fire (Pilz *et al.*, in press).

Members of the Russulaceae family were always the most numerous in each year's collections, with the exception of 1997 in Pasoh forest and 1998 in the Cryptogamic Garden at Kepong when few members of this family were found. As in the tropical lowlands of Africa (Buyck *et al.*, 1996), Russulaceae are the most dominant ectomycorrhizal fungi in lowland forests of Malaysia. Much work remains to be conducted on the taxonomy of Malaysian Russulaceae as many specimens collected have distinctive differences in morphology and life-strategies as compared with temperate and West African taxa. At Pasoh forest, members of the Boletaceae and the Amanitaceae were the next most frequently collected species, followed by members of the Cantharellaceae (Photo 8) and Cortinariaceae (Photo 9). Members of other families were less frequently encountered and often only single specimens were found, e.g. *Scleroderma sinnamariense* (Photo 10). At the Cryptogamic Garden, members of the Amanitaceae family were generally a distant second to the Russulaceae, except in 1998 and 1999. Several hypogeous fungi were also collected from Pasoh forest, e.g. *Arcangeliella* sp. (Photo 11) but none were found in Kepong.

Photo 8.
One of the several unidentified species of *Cantharellus* found in lowland rainforests of Peninsular Malaysia.
Photo R. Watling.

Photo 9.
Inocybe aequalis (Horak) Turnbull & Watling, found growing with several members of the Dipterocarpaceae family both at FRIM and in Pasoh forest.
Photo S.S. Lee.

Over the 7 years that collections were conducted at Kepong, 34 species of fungi (or 39%) were only collected once. In comparison, at Pasoh, where collections were only made during short annual visits over a 6 year period, 85% of the fungi were only collected once. This suggests that the same fungus is more likely to be encountered again if more frequent and regular collections are carried out in the same area. The fact that many fungi were only encountered once throughout the collecting period at both sites also indicates that, while fungal fruiting is stimulated by seasonal weather patterns, other factors are also important in determining when a particular fungus fruits. More significant results could likely be obtained by conducting regular collections over a much longer study period than that available to the present researchers. Repeated monitoring over multiple fruiting seasons is required to adequately estimate habitat or site productivity, because there is substantial annual variation, often weather related, in productivity among fruiting seasons (Pilz *et al.*, 1999).

Collection and identification of basidiomata in dipterocarp forests is a challenge due to high mycorrhizal fungal diversity, and periodic, unpredictable and evanescent basidiomata development. As in Australian forests, understanding the ecology and measuring ectomycorrhizal basidiomycete communities is hampered by the cryptic nature of these fungi, many of which cannot be cultured, have hypogeous basidiomata or only produce them rarely or under certain conditions (Trappe, 1977; Tommerup, Bougher, 2000). The results of this study show that fruiting of putative ectomycorrhizal fungi at Kepong coincided with the return of wet weather after relatively dry periods of several weeks. However, in the absence of detailed data from other locations in Peninsular Malaysia, we are not sure whether the same pattern would apply elsewhere. Rather than relying on the spasmodic and often unpredictable production of basidiomata, future research should utilise PCR-RFLP (polymerase chain reaction-restriction fragment length polymorphism) identification of fungi for rapid and more accurate analysis of ectomycorrhizal fungal communities present on root tips in tropical rain forests.

References

ARNOLDS E., 1995. Problems in measurements of species diversity of macrofungi. *In:* Microbial Diversity and Ecosystem Function. D. Allsopp, R.R. Colwell & D.L. Hawksworth (ed.), CAB International, Oxford, United Kingdom, p. 337-353.

BUYCK B., THOEN D., WATLING R., 1996. Ectomycorrhizal fungi of the Guinea-Congo Region. Proceedings of the Royal Society of Edinburgh, United Kingdom, 104B, 313-333.

CORNER E.J.H., 1935. The seasonal fruiting of agarics in Malaya. Gardens' Bulletin, Straits Settlements, 9: 79-88.

CORNER E.J.H., 1962-1963. Fungi. Proceedings of the Linnean Society of London, United Kingdom, 175, 40-42.

CORNER E.J.H., 1972. Boletus in Malaysia. Government Printing Office, Singapore, 263 p.

Photo 10.
Scleroderma sinnamariense Mont., a distinctive bright yellow fungus commonly encountered in lowland rainforests growing under dipterocarps. Note the yellow rhizomorphs extending into the soil.
Photo S.S. Lee.

Photo 11.
Arcangeliella sp., a hypogeous fungus found in Pasoh Forest Reserve, Peninsular Malaysia.
Photo S.S. Lee.

CORNER E.J.H., 1988. Higher fungi. *In:* Key Environments: Malaysia. G. Gathorne-Hardy, Earl of Cranbrook (ed.), IUCN, Pergamon Press, Oxford, United Kingdom, p. 88-101.

HENDERSON D.M., ORTON P.D., WATLING R., 1969. British fungus flora. agarics and boleti: introduction. HMSO, Edinburgh, United Kingdom, 58 p.

HONG L.T., THILLAINATHAN P., ARSHAD OMAR, 1984. Observations on the fruiting and growth of some agarics in a dipterocarp stand. Malayan Nature Journal, 38: 81-88.

KOCHUMMEN K.M., 1997. Tree flora of Pasoh Forest. Malayan Forest Records n° 44, Forest Research Institute Malaysia, Kepong, Malaysia, 462 p.

LEE S.S., ALEXANDER I.J., 1994. The response of two dipterocarp species to nutrient additions and ectomycorrhizal infection. Plant and Soil, 163: 299-306.

LEE S.S., WATLING R., TURNBULL E. Diversity of putative ectomycorrhizal fungi in Pasoh forest reserve. *In:* Pasoh: Ecology and natural history of a lowland tropical rain forest in Southeastern Asia. Springer, Tokyo, Japan (in press).

OGAWA M., 1992. Mycorrhiza of dipterocarps. *In:* Proceedings of the BIO-REFOR Tsukuba Workshop, 19-21 May 1992. BIO-REFOR, IUFRO/SPDC, Tsukuba, Japan, p. 55-58.

PILZ D., MOLINA R. Commercial harvests of edible mushrooms from the forests of the Pacific Northwest United States: issues, management and monitoring for sustainability. Forest Ecology and Management, 5593 (in press).

PILZ D., SMITH J., AMARANTHUS M.P., ALEXANDER S., MOLINA R., LUOMA D., 1999. Managing the commercial harvest of the American matsutake and timber in the southern Oregon Cascade Range. Journal of Forestry, 97 (2): 8-15.

SMITS W.T.M., 1994. Dipterocarpaceae: mycorrhizae and regeneration. Thesis, Agricultural University Wageningen, Wageningen, Netherlands. The Tropenbos Foundation III, Tropenbos Series, 9, 243 p.

TOMMERUP I.C., BOUGHER N.L., 2000. The role of ectomycorrhizal fungi in nutrient cycling in temperate Australian woodlands. *In:* Temperate Eucalypt Woodlands in Australia: Biology, Conservation, Management and Restoration. R.J. Hobbs, C. Yates (ed.), Surrey Beatty & Sons, Chipping Norton, Australia, p. 190-224.

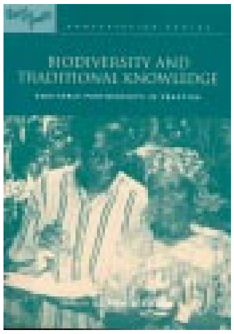
TRAPPE J., 1977. Selection of fungi for inoculation in nurseries. Annual Review of Phytopathology, 15: 203-222.

WATLING R., LEE S.S., 1995. Ectomycorrhizal fungi associated with members of the Dipterocarpaceae in Peninsular Malaysia – I. Journal of Tropical Forest Science, 7 (4): 657-669.

WATLING R., LEE S.S., 1998. Ectomycorrhizal fungi associated with members of the Dipterocarpaceae in Peninsular Malaysia – II. Journal of Tropical Forest Science, 10 (4): 421-430.

WATLING R., LEE S.S., TURNBULL E., 1998. Putative ectomycorrhizal fungi of Pasoh Forest Reserve, Negri Sembilan, Malaysia. *In:* Conservation, Management and Development of Forest Resources. Proceedings of the Malaysia-United Kingdom Programme Workshop, S.S. Lee, Y.M. Dan, I.D. Gauld & J. Bishop (ed.), 21-24 October 1996, Kuala Lumpur. FRIM, Kepong, p. 96-104.

YAZID M.S., LEE S.S., LAPEYRIE F., 1994. Growth stimulation of *Hopea* spp. (Dipterocarpaceae) seedlings following inoculation with an exotic strain of *Pisolithus tinctorius*. Forest Ecology and Management, 67: 339-343.



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Comme l'exportation du bois contribue pour une part de plus en plus importante au PIB des pays concernés, ceux-ci n'envisagent pas de réduire le rythme d'extraction. On ne peut donc que tenter de limiter les effets indirects de l'exploitation industrielle des forêts.
À la recherche de solutions pragmatiques, les onze auteurs ont concentré leurs efforts sur un territoire bien délimité en zone de forêt dense humide tropicale : le plateau méridional camerounais au nord de la Réserve de faune du Dja, qui est occupé par le peuple Badjoué. Les uns ont étudié le système de production des Badjoué : agriculture itinérante sur brûlis, pêche, chasse, récolte du vin de palme. D'autres ont expérimenté avec les Badjoué l'exploitation, dans un cadre actuel des « forêts communautaires », de produits tels que bois sciés et fruits à des fins monétaires. D'autres, enfin, ont étudié les interactions du système traditionnel de gestion des ressources de la forêt avec la politique forestière actuelle du gouvernement camerounais.
Les conclusions provisoires concernent au premier chef le Cameroun, mais, à travers ce cas particulier, c'est toute la problématique du développement des communautés villageoises en forêt tropicale qui est abordée.
Résumé adapté d'après l'annonce de l'éditeur.