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ECTOMYCORRHIZAL FUNGI ASSOCIATED WITH MEMBERS OF THE DIPTEROCARPACEAE IN PENINSULAR MALAYSIA - II

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WATLING, R. & LEE, S.S. 1998. Ectomycorrhizal fungi associated with members of the Dipterocarpaceae in Peninsular Malaysia - II. In the first publication of this series, over fifty agarics, boletes and their relatives were reported associated with dipterocarps in the locality of the Forest Research Institute Malaysia at Kepong in Peninsular Malaysia. In this present paper, 37 taxa are dealt with, 19 of which are new to the previously published list. Tables are provided indicating these records, including four species which may be called broad host range taxa; these are *Russula alboareolata, R. virescens, Boletus aureomycelinus* and a member of *Russula* sect. Ilicinae.

Key words: Ectomycorrhizas - fungi - dipterocarps - Malaysia

WATLING, R. & LEE, S.S. 1998. Cendawan ektomikoriza yang berasosiasi dengan pokok dipterokarpa di Semenanjung Malaysia - II. Artikel pertama dalam siri ini melaporkan lebih daripada lima puluh jenis cendawan 'agaric', 'bolete' dan ahli-ahli berkaitan yang berasosiasi dengan pokok dipterokarpa di kawasan Institut Penyelidikan Perhutanan Malaysia, Kepong, Semenanjung Malaysia. Dalam artikel ini, 37 taksa dibincangkan, di mana 19 adalah tambahan baru kepada senarai yang diterbitkan dahulu. Jadual-jadual yang menunjukkan rekod tersebut serta empat spesies iaitu *Russula alboareolata, R. virescens, Boletus aureomycelinus* dan satu ahli dari *Russula* sect. Ilicinae, yang boleh dianggap sebagai taksa yang mempunyai julat perumah yang luas disediakan.

Introduction

Since the compilation of a selection of suspected mycorrhizal associations with members of the Dipterocarpaceae (Watling & Lee 1995), many more observations have been made in and around the Forest Research Institute Malaysia (FRIM), Kepong. The preliminary conclusions made in the first paper of this series substantiate work by Singh (1966) and Hong (1979) and also indicate that the

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dipterocarp ectomycorrhizal flora of Peninsular Malaysia have greatest affinities with the flora of Japan (see Imazeki & Hongo 1987, 1989, Imazeki *et al.* 1988). This has been supported by a further two years of collection.

The present contribution is the second paper in a series making available our field data to mycologists, nature conservationists and foresters. Although several records from 1991 and 1992 are included, the bulk of the data reported here comes from collections made in 1993 and 1994.

Materials and methods

The methods used in this study exactly follow those outlined in the previous paper in this series (Watling & Lee 1995). In this paper, however, information from Gombak and Pasoh Forest Reserves has been omitted and further collections were not carried out around the Awana Golf and Country Club because of extensive damage to the forest. The materials therefore originated from the Bukit Lagong Forest Reserve in the extensive grounds of FRIM. The history of the property has been summarised in Watling and Lee (1995).

Interpretation of data

Unless the mycelium from the base of a basidiome can be traced to an ectomycorrhizal short root of an associated host plant, it is not possible to confirm whether a fungus is truly ectomycorrhizal or not by the examination of field material. Although evidence can be obtained by making isolates from fruit bodies and comparing synthesised mycorrhizas with field material, this was not carried out during the present study. Thus, it is only by inference from field associations and the long history of our knowledge that certain genera of basidiomycetes are generally (always?) ectomycorrhizal formers that a tree association can be suggested. In Indonesia, Smits (1994) recently found that some of these relationships in the field did in fact reflect definite associations of certain fungi with roots. However, we consider it prudent to continue using the term "putative" at all times until the physical links are observed. It must be realised that up to fifty per cent of the taxa we have dealt with in our surveys are new to science and that we are thus ignorant of the biology of many of the fungi involved although they belong to genera very familiar to western agaricologists (Hawksworth 1993).

The groups of *Shorea* adopted herein follow Symington (1974) while Ashton (1982) was referred to for further details and taxonomic characters.

Results and discussion

The data presented in this paper are arranged alphabetically according to host (Tables 1 and 2) and cover some new associations, these associations extending the results in the first paper of this series (Watling & Lee 1995). Some of the fungi which had not been identified to species before the publication of Part I are now included here.

Table 1. Suspected ectomycorrhizal fungi found associated with dipterocarp dominated plant communities at FRIM, Kepong, Malaysia including additional putative associations to those listed in Watling and Lee (1995)

Host species	Suspected ectomycorrhizal fungi
Dipterocarpus costulatus	Amanitaceae: *Amanita tjibodensis*
Dipterocarpus verrucosus	Boletaceae: *Austroboletus rubiicolor* Cortinariaceae: *Inocybe fuscospinosa*
Dryobalanops aromatica	Amanitaceae: *Amanita angustilamellata, A. cinctipes, A. mira* Boletaceae: *Boletus catervatus, Rubinoboletus ballouii* Cortinariaceae: *Inocybe corneri, I. palaeotropica* Russulaceae: *Russula alboareolata*
Dryobalanops oblongifolia	Amanitaceae: *Amanita hemibapha* subsp. *similis, A. ovalispora, A. xanthogala* Boletaceae: *Boletus aureomycelinus, B. maculatus* [erroneously named *B. maculosus* in Watling & Lee (1995)]
Hopea odorata	Amanitaceae: *Amanita angustilamellata, A. fritillaria* f. *malayensis, A. gymnopus, A. sychnopyramis* Boletaceae: *Boletus aureomycelinus* Russulaceae: *Russula chloroides* var. *parvispora* Sclerodermataceae: *Scleroderma sinnamariense**
Neobalanocarpus heimii	Boletaceae: *Strobilomyces velutipes* Cortinariaceae: *Inocybe aequalis*
Shorea bracteolata	Cortinariaceae: *Inocybe aequalis*
Shorea leprosula	Amanitaceae: *Amanita fritillaria* f. *malayensis, Amanita* sp. 6 (Corner & Bas 1962) Boletaceae: *Boletus aureomycelinus*
Shorea macrophylla	Boletaceae: *Boletus aureomycelinus*
Shorea maxwelliana	Cortinariaceae: *Inocybe sphaerospora*
Shorea parvifolia	Boletaceae: *Boletellus emodensis, Boletus aureomycelinus* Cortinariaceae: *Inocybe lutea*
Shorea parvifolia/ Shorea longisperma (midway between specimen trees)	Boletaceae: *Boletus aureomycelinus*
Shorea sumatrana	Amanitaceae: *Amanita perpasta, Amanita* sp. 6 (Corner & Bas 1962) Boletaceae: *Boletus aureomycelinus, Strobilomyces polypyramis* Cortinariaceae: *Inocybe asterospora, I. aequalis* Sclerodermataceae: *Scleroderma dictyosporum, S. verrucosum*
Shorea sp.	Sclerodermataceae: *Scleroderma dictyosporum*

**Scleroderma sinnamariense* occurs in mixed dipterocarp communities, in *Shorea-Dryobalanops, Hopea odorata*-mixed dipterocarps and *Neobalanocarpus heimii-Dryobalanops aromatica* associations.

Species of putative dipterocarp ectomycorrhizal fungi additional to those already listed in Table 1 of Part I (Watling & Lee 1995) are shown in Table 1 while those associated with dipterocarp species not previously reported are shown in Table 2. Forty-seven new associations involving 33 different fungi and 15 host species are reported in Table 1. Of these 33 fungal species, there were 12 species of *Amanita*, 8 members of the Boletaceae, 7 species of *Inocybe*, 3 species of *Russula* and 3 species of *Scleroderma*. Members of the Boletaceae were associated with 11 host species, *Inocybe* spp. with 7 host species, *Amanita* spp. with 6 host species, and *Russula* spp. and *Scleroderma* spp. with 3 host species each.

Table 2. Suspected ectomycorrhizal fungi found associated with dipterocarp dominated plant communities at FRIM, Kepong, Malaysia - new associations in addition to Watling and Lee (1995)

Host species	Suspected ectomycorrhizal fungi
Dipterocarpus chartaceus Rather rare. Distributed from Thailand through Johor in the Malay peninsula.	Boletaceae: *Boletus aureomycelinus*
Dipterocarpus rigidus Eastern coastal hills of Malay peninsula. Also in Sumatra, Borneo and Anambas Islands.	Russulaceae: *Russula eburneoareolata*
Hopea latifolia Rare. Malay peninsula and Borneo (Sarawak and Brunei).	See also *Shorea laevis* and *S. longisperma* below. Amanitaceae: *Amanita tjibodensis* Boletaceae: *Boletus aureomycelinus*
Hopea wightiana Concan, western peninsular India.	Amanitaceae: *Amanita xanthogala* Boletaceae: *Leccinum intusrubens**
Shorea acuminata Malay peninsula, Sumatra and Lingga.	Amanitaceae: *Amanita* sp. 6 (Corner & Bas 1962) Boletaceae: *Boletus aureomycelinus* Cortinariaceae: *Inocybe sphaerospora* Russulaceae: *Russula eburneoareolata*
Shorea curtisii (see Watling & Lee 1995)	Boletaceae: *Boletus aureomycelinus*
Shorea dasyphylla Well drained areas in the Malay peninsula, Sarawak and Sumatra.	Boletaceae: *Boletus aureomycelinus*
Shorea foxworthyii Malay peninsula, Sumatra and Borneo.	Boletaceae: *Boletus aureomycelinus* Russulaceae: *Russula alboareolata*
Shorea hemsleyana Low lying areas in Perak, peninsular Thailand and eastern Sumatra.	Amanitaceae: *Amanita xanthogala* Boletaceae: *Boletus aureomycelinus* Russulaceae: *Russula* sect. Ilicinae

(Continued)

Table 2 (continued)

Shorea laevis Common on inland ranges of the Malay peninsula, Borneo, peninsular Burma and Thailand, north Sumatra.	(Between *S. laevis* and *H. latifolia*) Boletaceae: *Boletus aureomycelinus*
Shorea longisperma Peninsular Malaysia except seasonal areas, eastern Sumatra and Borneo.	(Between *S. longisperma* and *H. latifolia*) Amanitaceae: *Amanita sychnopyramis, Amanita* sp. 6 (Corner & Bas 1962) Boletaceae: *Boletus aureomycelinus* Cortinariaceae: *Inocybe lutea*
Shorea maxima Peninsular Malaysia, south from Perak and Pahang although rare.	Amanitaceae: *Amanita hemibapha* subsp. *similis*
Shorea multiflora Peninsular Malaysia, Sumatra and Borneo.	Amanitaceae: *Amanita angustilamellata* Russulaceae: *Russula virescens*
Shorea ovalis Malay peninsula, Sumatra, adjacent islands and Borneo.	Russulaceae: *Russula alboareolata, R. singaporensis* Sclerodermataceae: *Scleroderma dictyosporum*
Shorea resinosa Malay peninsula from Perak to Johor, central Sumatra and Borneo.	Russulaceae: *Russula alboareolata*
Shorea singkawang Lowland forests of the Malay peninsula, also Sumatra and Lingga.	Boletaceae: *Boletus aureomycelinus*
Vatica nitens Peninsular Malaysia from Perak to Johor, Borneo.	Russulaceae: *Russula alboareolata*
Vatica odorata Indochina to Tennasserim, south China and Borneo, Thailand southwards to Negri Sembilan and Pahang in the Malay peninsula.	Boletaceae: *Boletus aureomycelinus* Russulaceae: *Russula virescens*
Non-dipterocarp associates	
Eugenia sp. (Myrtaceae)	Amanitaceae: *Amanita* sp. 6 (Corner & Bas 1962)
Fagraea elliptica (Loganiaceae)	Amanitaceae: *Amanita* sp. 6 (Corner & Bas 1962)
Scorodocarpus borneensis (Olacaceae)	Amanitaceae: *Amanita ?elata, A. fritillaria* f. *malayensis, A. sychnopyramis* Boletaceae: *Boletus aureomycelinus* Russulaceae: *Russula alboareolata*

*Fomerly *Boletus intusrubens* Corner, transferred to *Leccinum* by Høiland and Schumacher (1982), based on a Thai collection. The microstructures, however, do not agree with temperate members of this genus.

Of the new associations reported in Table 2, 18 putative ectomycorrhizal species were associated with 21 host species, 3 of which were non-dipterocarps. Of the 18 fungal species, there were 8 species of *Amanita*, 5 species of *Russula*, 2 each of the Boletaceae and *Inocybe* and 1 of *Scleroderma*.

Overall, *Amanita* spp. were most numerous, 13 species being found in association with 16 host species. Members of the Boletaceae accounted for the highest number of fungal-host associations, 9 species being associated with 23 host plant species. However, 83 % of these associations were credited to one species, *Boletus aureomycelinus*.

Associations covering species which we now might consider of broad host range are reported in Table 3. This table is offered in response to the conclusion in Part I that some species of basidiomycetes can be found with a range of dipterocarps (Watling & Lee 1995). These fungal species are believed to be adapted to a wide range of host tree species and/or those with a broad host spectrum. It is suggested that *Boletus aureomycelinus* Pat. & Baker, *Russula virescens* (Schaeff.) Fr., *Russula alboareolata* Hongo and a member of *Russula* section Ilicinae are broad host range species. *Boletus aureomycelinus* is by far the most common, being associated with 21 host species followed by *Russula* sect. Ilicinae which is associated with 11 host species, *R. virescens* with 10 host species and *R. alboareolata* with 9 host species. *Russula* sect. Iilicinae was previously indicated as *Russula* cf. *castanopsidis* (Watling & Lee 1995), but although superficially similar macroscopically, the microscopic characters place this species in the recently erected group Ilicinae. Fruiting of this fungus was monitored over a 2-week period between 21 February and 4 March 1991 when a single basidiome remained; there was no earlier fruiting and no later fruitings were observed. The year 1991 was a bumper year for the fructification of both *Russula virescens* and *Russula* sect. Ilicinae while 1993 was best for *Boletus aureomycelinus*. *Boletus aureomycelinus* was also found in mixed *Shorea bracteolata* and *Dryobalanops aromatica* stands, whereas *R. virescens* occurred in *D. aromatica-Hopea* communities. The solitary growing *B. aureomycelinus* was considered uncommon by Corner (1972), but is obviously quite widely occurring in Peninsular Malaysia. It is also known to occur in Guangdong province of China, other parts of Asia and North America (Bi *et al.* 1993). The edible *R. virescens* is found throughout Europe, Asia and North America while *R. alboareolata* is known from Japan (Hongo 1979).

Table 4 lists all the putative ectomycorrhizal fungi reported in this paper, the authorities and the herbarium numbers of the voucher specimens. Material has been lodged in the herbarium of the Royal Botanic Garden, Edinburgh (E) with some duplicates in FRIM. Specimens collected by the second author and her colleagues are all lodged at FRIM. Of the 37 fungi reported in this paper, 18 are new additions to the list in Part I (Watling & Lee 1995), 7 of which are species of *Amanita*, 5 species of the Boletaceae, 5 species of *Inocybe* and 1 species of *Russula*.

Table 3. Suspected broad host range basidiomycete species associated with dipterocarps planted at Kepong

Host	*Russula alboareolata*	*Russula* sect. Ilicinae*	*Russula virescens*	*Boletus aureomycelinus*
Dipterocarpus baudii	-	-	+	-
Dipterocarpus chartaceus	-	-	-	+
Dipterocarpus costulatus	-	-	+	-
Dipterocarpus kerrii	-	-	-	+
Dipterocarpus verrucosus	-	-	+	-
Dryobalanops aromatica	+	-	+	+
Dryobalanops oblongifolia	+	+	+	+
Hopea dryobalanoides	-	+	-	-
Hopea latifolia	-	-	-	+
Hopea mengarawan	-	+	-	-
Hopea odorata	-	+	+	+
Hopea sangal	-	+	-	-
Shorea acuminata	-	-	-	+
Shorea bracteolata	+	-	-	+
Shorea curtisii	-	-	-	+
Shorea dasyphylla	-	-	-	+
Shorea foxworthyii	+	-	-	+
Shorea hemsleyana	-	+	-	+
Shorea laevis	-	-	-	+
Shorea leprosula	-	+	+	+
Shorea longisperma	-	-	-	+
Shorea macrantha	-	+	-	-
Shorea macrophylla	-	-	-	+
Shorea materialis	-	+	-	-
Shorea multiflora	-	-	+	-
Shorea ovalis	+	-	-	-
Shorea parvifolia	-	-	-	+
Shorea platyclados	-	+	-	-
Shorea resinosa	+	-	-	-
Shorea singkawang	-	-	-	+
Shorea stenoptera	-	+	+	-
Shorea sumatrana	+	-	-	+
Vatica nitens	+	-	-	-
Vatica odorata	-	-	+	+
Scorodocarpus borneensis	+	-	-	+

Notes:
* Indicated as *Russula* cf. *castanopsidis* by Watling and Lee (1995).
+ = present, - = absent

It should be noted that the new *Pisolithus aurantioscabrosus* Watling recorded from Pasoh Forest Reserve and reported in Part I (Watling & Lee 1995) has now been published as a new species (Watling *et al.* 1995).

Many unidentified agarics which are suspected to be ectomycorrhizal have been found during the present and earlier studies. They can, in some cases, be assigned to subgenera or sectional taxa, but have not been added to the lists until further critical work is undertaken. Many new records require further study and the genus *Russula* contributes greatly to this category of material.

Table 4. Summary of the putative ectomycorrhizal fungi reported in this paper and their herbarium numbers as deposited: Watling and Turnbull in Edinburgh, S-S in FRIM, Kepong

Families and species of fungi	Herbarium numbers
Amanitaceae	
Amanita angustilamellata Boedijn	S-S 786, 802, 810, 817
A. cinctipes Corner & Bas	Wat. 25806, 26429
A. ?elata (Mass.) Corner & Bas	S-S 723
A. fritillaria f. *malayensis* Corner & Bas	S-S 780
A. gymnopus Corner & Bas	S-S 612, Wat. 25858
A. hemibapha subsp. *similis* Corner & Bas	S-S 779
A. mira Corner & Bas	S-S 1108, 1246, 1275, 1448
A. ovalispora Boedijn	S-S 193
A. perpasta Corner & Bas	S-S 1416
A. sychnopyramis Corner & Bas	S-S 746, Wat. 25854
A. tjibodensis Boedijn	S-S- 191, Wat. 26417
A. xanthogala Bas	S-S 623, Wat. 25864, 25865
Amanita sp. 6 (Corner & Bas 1962)	S-S 145, 149, 773, 825, Wat. 26423 - 26428
Boletaceae	
Boletellus emodensis (Berk.) Singer	Wat. 24475
Boletus aureomycelinus Pat. & Baker	S-S 583, 585, Wat. 25704, 25779, 26430, 26440
Boletus (Tylopilus) maculatus Corner	Wat. 25793
Boletus (Austroboletus) rubiicolor Corner	Wat. 24475
Leccinum intusrubens (Corner) Høil.	Wat. 25721
Rubinoboletus ballouii (Peck) Heinem & Rammeloo	S-S 1295
Strobilomyces polypyramis Hook. f. apend Berk.	Wat. 25770
S. velutipes Cooke & Massee	S-S 580, 619, Wat. 25719, 25795
Cortinariaceae	
Inocybe aequalis (Horak) Watling & Turnbull	S-S 846, Wat. 25734
I. asterospora Quél.	Turnbull 27
I. corneri Horak	S-S 828
I. fuscospinosa Horak	S-S 570
I. lutea Koby. & Hongo	S-S 866, Wat. 25735, Turnbull 37
I. paleotropica Watling & Turnbull	S-S 575, 726, Wat. 25736
I. sphaerospora Kobayasi	Wat. 24563, 24565-24567
Russulaceae	
Russula alboareolata Hongo	S-S 735, 766, 783, 789, 815, 824, 827
R. chloroides var. *parvispora* Romagn.	S-S 758
R. eburneoareolata Hongo	Wat. 24474
R. singaporensis Singer	S-S 807
R. violeipes Quél.	S-S 794
R. virescens (Schaeff.) Fr.	S-S 729, 732, 739
Sclerodermataceae	
Scleroderma dictyosporum Pat.	Wat. 26482, Turnbull 55
S. sinnamariense Mont.	S-S 618, Wat. 25188, Turnbull 1, 61
S. verrucosum Pers.	Wat. 24872, Turnbull 26

Conclusion

The ectomycorrhizal flora of the Bukit Lagong Forest Reserve is confirmed to be very rich in species. In one 14-day period, 256 collections were made and we believe that this only scratches the surface. However, our knowledge of the mycota of Bukit Lagong and Malaysia in general is increasing by leaps and bounds. As the tables again show, the Amanitaceae, Russulaceae and Boletaceae are important components of the flora with *Inocybe* playing a minor but nonetheless distinctive role. Our conviction that Japanese and eastern North American studies are important in deciphering the mycota is substantiated. It has been estimated that in excess of 1840 non-lichenised fungi will be found in the small area of the state of Selangor (Watling & Turnbull 1994) of which nearly 300 are expected to be ectomycorrhizal.

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