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Ectomycorrhizal fungi in the Palaeotropics

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Summary. Field observations of suspected ectomycorrhizal fungi in Malaysian dipterocarp forests are discussed in the light of (1) the same taxa occurring in Philippine communities and (2) parallel taxa present in Central African Miombo woodland.

KEY WORDS: Kashmir, Peninsular Malaysia, Philippines, Zambia Copperbelt, Dipterocarpaceae, Pinaceae, Miombo woodland, Macromycetes including Boletales, Russulales, Cantharellaceae, Cortinariaceae *(Inocybe)*.

Introduction

Fassi & Moser (1991) in their contribution to the commemorative volume for B. Peyronel, celebrating his long work as a soil microbiologist, gave an excellent review of ectomycorrhizal systems then known in the neotropics and Africa. Fassi called on his experience in African communities whilst Moser brought into play his wide knowledge of ectomycorrhizal fungi in the Andean forests of S. America. Now it is time to commemorate Meinhard Moser's 70th birthday and commend him on his many contributions over and above the insight he gave to S. American fungi. The opportunity is therefore taken to offer a rather personal view and expand the ideas set out by Fassi and Moser to cover the dipterocarp and pine forests of the Philippines and more particularly the dipterocarp forests of Malaysia.

Study areas

Philippines

A short time has been spent in the dipterocarp forests of the Philippines dominated by *Anisoptera thurifera* (Blanco) Blume, *Shorea polysperma* (Blanco) Merr. etc. situated in the hills above Masinlos near Santa Cruz (West C. Luzon). However, much more time was spent in the same area examining *Pinus merkusii* Jungh. & De Vr., a pine of very limited distribution in the Philippines although known from Thailand to Borneo in suitable places; it is the most tropical of all the pines. The areas have been extensively burnt, a particular disastrous peri-

od being some 10–12 years ago, and are now dominated by a grass understorey. Even today some plots have been planted up for vegetables by local indigenous peoples.

In the vicinity of Baguio, a more northerly high mountain site, woodlands of *Pinus kesiya* Royle ex Gordon (= *P. insularis* Endl.) were visited both close to the city and the areas surrounding Bokod, 63 km from Baguio. The main distribution of this pine is in Burma. The forest had apparently been managed for generations and supports small herds of water buffalo which crop the grass; some fire damage was also apparent.

Central Africa

Several sites of miombo woodland in the Zambian Copperbelt dominated by *Brachystegia* spp. especially *B. longifolia* Benth. and *B. utilis* Burtt, Davy & Hutchison were examined including one (Ndola) from which fire, a feature of the management of these woodlands, had been suppressed. *Isoberlinia angolensis* (Benth.) Hoyle & Brenan and *Julbernardia paniculata* (Benth.) Troup, both caesalpinoid legumes, *Marquesia macroura* Gilg. (Dipterocarpaceae) and *Uapaca* spp. (Euphorbiaceae; Uapaceaceae Milne Redhead) are also present. Both the communities at Chati and Misaka, are open grassy woodlands maintained by regular burning; wood collection for charcoal production is also undertaken.

Malaysia

Lowland dipterocarp communities were selected for study, although two more montane areas were included in the survey, one dominated by *Shorea curtisii* Dyer ex King which prefers rather drier sites often on the tops of hill spurs and ridges. The main attention was paid to the Kepong forest belonging to the Forestry Research Institute Malaysia (FRIM), 16 km north-west of Kuala Lumpur, because within the policies there are many areas of dedicated arboreta within which individual tree-species are named and have been monitored. The area of 1319 hectares was established between 1925 and 1929 by the activities especially of Foxworthy but now the plantings have been invaded by secondary elements to create a lowland forest. Further details of this unique extensive 'experiment' are discussed in Watling & Lee (in press), where many of the suspected dipterocarp-fungal relationships are listed. The distribution of some of the major ectomycorrhizal components appear in a companion article (Watling, in press).

The fungi found in what is still an artificial habitat have been compared with these at (1) Awana, at 1000m a.s.l., a remnant lower montane forest developed on the sides of rather steep ravines with *Lithocarpus* (Fagaceae) prom-

inent, (2) Gombak, Selangor a lowland forest with many species of dipterocarp and some legumes including *Intsia palembica* Miq., and by the river *Tristania* (Myrtaceae), (3) Pasoh, Negri Sembilan an area which has been monitored for over thirty years, (4) Sungai Valley and Ula Langat lowland dipterocarp forests approximately 40km south-east of Kuala Lumpur, (5) Templer Park, adjacent to the Kepong forest and (6) Semangkok, Fraser's Hill a hill forest.

Pasoh is the site of a FRIM field station and is one of the few remaining untouched lowland dipterocarp forests in south-east Peninsular Malaysia. Although the dipterocarps there have been the subject of extensive study over many years the fungi are only now being studied. The Sungai Lallang and Ula Langat Forest Reserves were selectively logged almost 30 to 40 years ago but good specimens of *Shorea leprosula* Miq. still remain. The forest along the old Gombak-Bentong road also contain fine specimen trees but this lowland dipterocarp forest is highly disturbed. The Templar Park site is of natural and historic interest in that it is dominated by *Dryobalanops aromatica* Gaertn., a tree not normally associated with closed communities in western areas of Peninsular Malaysia. No knowledge of planting, however, is available.

N. India

Reference will be made in the text to some of the areas visited in Kashmir by the author in 1978, and all have been discussed in Watling & Gregory (1980). The main areas were in montane communities of *Abies pindrow* (Royle) Spath. with *Picea smithiana* (Wall.) Boiss. and *Pinus wallachiana* Jackson (Gulmarg, Pahlgam and Tangmang), or *Betula utilis* D. Don (Sonamang). However, lower altitude communities with more deciduous elements are described from the Dachigam Reserve. Watling & Abraham (1992a, 1992b) have discussed the fungi found during a wider survey.

Results

In the Philippine dipterocarp forest familiar taxa from Peninsular Malaysia were found e. g. *Amanita gymnopus* Corner & Bas amongst a rich flora of *Russula* (Russulaceae), *Amanita* (Amanitaceae) and *Phylloporus* (Paxillaceae, including a blackening taxa resembling *P. bogoriensis* Hoehn.); a single *Boletus* and *Inocybe* were seen. This community contrasted markedly with the Baguio pinewoods where *Boletellus emodensis* (Berk.) Singer and *Strobilomyces velutipes* Cke. & Mass. and several *Suillus* spp. and *Phylloporus* spp. were found. They surprisingly included *Suillus bovinus* (L.: Fr.) O. Kuntze, along with its frequent companion *Gomphidius roseus* (Fr.: Karst). This is the first time *Gomphidius* has been recorded for this part of S. E. Asia. The genera *Boletus* and *Amanita* are

well represented both by sect. Edules and Luridi in the former and by *Amanita hemibapha* (Berk. & Br.) Sacc.; and *A. pantherina* (DC.: Fr.) Secr. etc. in the latter. It is interesting to note that *A. hemibapha* is represented here by var. *hemibapha* whereas in the lowland dipterocarp forests of Malaysia it is represented by var. *similis* (Boed.) Corner & Bas. Both *Boletellus emodensis* and *Strobilomyces velutipes* are also known from Malaysian forests, but both have wide distributions from India to Australia. The pine-woods are rich in Russulaceae both *Russula* e.g. *R. virescens* (Schaeff.) Fr. and *Lactarius*, the latter particularly represented by numbers of sect. Diapetes Fr., and at least one hypogeous taxon *(Rhizopogon)* has been collected; Sclerodermataceae is an important component of both dipterocarp and pine forests. These forests parallel the *Nothofagus/Alnus* forests outlined by Moser in Fassi & Moser (1991), indeed in the species of *Suillus* present there appeared to be a distinct north-west N. American element, a phenomenon which must be explored further. The *Pinus merkusii* forests were also dominated by *Suillus* spp. (Hadi 1980) but in addition the genus *Inocybe* is prominent. These forests were on mineral soils with a more open aspect. The conifer woods therefore of the Philippines resembled those typical of the boreal regions or those found in the Himalayas, Japan etc., and contrasted markedly with the conifer forests of lowland S. America dominated there by endomycorrhizal relationships, except where exotics have been planted (Singer 1964). Thus although for example some boletes and Russulaceae are found in Paraná State in Brazil they are few in number and a large proportion are associated with introduced hosts (Watling & Meijer, ined.).

The C. African Miombo woodland is equally as rich as the Baguio forests but the components are very different. Although they are rich in *Amanita* and Russulaceae (both *Russula* and *Lactarius*) the individual taxa are different and they are joined by a whole group of tylopiloid boletes, e.g. *Tylopilus niger* (Heinemann & Goos.) Wolfe and *Gyroporus* spp., e.g. *Gyroporus microsporus* var. *congolensis* (Heinem.) Heinem. & Rammeloo; *Tubosaeta brunneosetosa* var. *retipes* Heinem. & Rammeloo is also characteristic. The last genus is not known in S. E. Asia. Boletes assigned to the genus *Rubinoboletus* by Heinemann & Rammeloo (1983) are common to both vegetational areas although there is a complex of species around *R. balloui* (Peck) Heinem. & Rammeloo. *Strobilomyces* would appear to be replaced in Zambia by *Afroboletus* (Watling 1994), although the former genus is represented in Zaire (Heinemann 1954, 1960). *Pulveroboletus* represented by a complex around *P. ravenelii* (Berk. & Curt.) Murrill is found in Africa and S.E. Asia, and in Malaysia there are several additional taxa; the most widespread is *P. icterinus* (Pat. & Baker) Watling.

The Cortinariaceae is represented in the Miombo woodland by the genus *Inocybe* of which there are a few widely distributed and often common taxa; in this way it resembles the lowland rainforest. *Cortinarius* is not represented, un-

like the Cantharellaceae which is represented by several taxa all of which are collected avidly by local people and if not consumed by them are sold on the roadside, species include *Cantharellus densifolius* Heinem. and *C. longisporus* Heinem. Hypogeous fungi have been found in the Miombo woodland e. g. *Dendrogaster congolense* Dissing & M. Lange, and one species apparently associated with *Marquesia* (Alexander & Högberg 1986). Sclerodermataceae are also well represented and *Pisolithus arhizus* Raus. found in native pine woods at Baguio (Philippines) was again found with introduced *Pinus* spp. in Zambia.

The lowland dipterocarp forests of Malaysia are undoubtedly rich and the few fleshy fungi noted by Chipp (1921) do not give a correct impression. Indeed in *Russula* alone the two species listed can be increased many-fold; a hint of this can be gained by examining a selection of Corner's publications, e. g. *Boletus* in Malaysia (1972).

Singh (1966) although not identifying the fungi concerned first recorded mycorrhizal associations between Dipterocarpaceae and Fagaceae and larger fungi in Malaysia. Hong (1979) listed the main genera of agarics associated with sixteen selected dipterocarp hosts and six fungal genera but only three determinations *Amanita angustilamellata* (Hoehn.) Boed., *A. hemibapha* (see above) and *A. princeps* Corner & Bas. Since these field observations Lee (1989, 1992) has expanded the study to laboratory and experimental field aspects. It was, however, not until the spring of 1992 that the present author with help from Dr Lee and colleagues tackled the taxonomic problem, involving Dr A. Taylor who painstakingly traced basidiomes to short roots of the trees.

The boletes are very well represented in the Malaysian flora as exemplified by Corner (1972) and the present study has been able to extend the distribution of species described therein e. g. *Boletus rufoaureus* Mass. (collected under *Drybalanops aromatica*), and *B. maculatus* Corner. At least forty taxa have been documented including several new taxa, especially with filamentous detersile veil viz. *Pulveroboletus.* The fairly widespread species *Heimiella retispora* (Pat. & Baker) Boejidn which has been collected from montane forests with *Shorea curtisii* Dyer ex King to lowland communities at Pasoh etc. may need more careful study. Basidiospore size in the Malaysian collections is extremely variable as is the ornamentation of the stipe. *Boletus peltatus* Corner & Watling occurred in several score basidiomes in several populations at Pasoh, in 1992; steps have now been taken to validate the name (Watling 1993). *B. pernanus* Pat. & Baker (= *B. nanus* Mass. ss. Corner 1972) is widespread in all localities growing on mossy logs.

Russulaceae is also a dominant group: eighty six species of *Russula* have been recognised in 175 collections, some familiar e. g. *R. virescens, R. compacta* Peck and some closely connected to the Flora of Japan, e. g. *R. alboareolata* Hongo and possibly *R. castanopsidis* Hongo. Some, such as the last, can be found

with a range of dipterocarps whilst others are at the moment only found with a single taxon (Watling & Lee 1994). *Lactarius* spp. number ten of which the sect. Plinthogali Singer is a very important element; *L. gerardii* Peck, or a species very close, is common. Other new taxa await description, as found in *Cantharellus* despite the monograph by Corner (1966). A small clutch of Laccaria spp. has been tabulated of which *L. vinaceoavellanea* Hongo is the most widespread. *Inocybe* is represented by a few distinctive taxa (5) especially *Inocybe sphaerospora* which has been found growing with *Dryobalanops aromatica* and *D. oblongifolia* Dyer and in mixed *Neobalanocarpus heimii* (King) Ashton – *Shorea maxwelliana* King communities. Other species have been listed by Watling & Lee (ined.); *Cortinarius* is absent.

Sclerodermataceae are present. Thus *Scleroderma dictyosporum* Pat., from Kepong, *S. echinatum* (Petri) Guzmán from Pasoh, *S. sinnamariense* Mont., widespread in all communities, and *S. verrucosum* Pers. from Ula Langat are all recorded. A new species of *Pisolithus* with orange "cockatoo"-like scales from Pasoh is to be described. From the same area *Sarcodon thwaitesii* Maas. Geest. and a hypogeous fungus close to *Chamonixia* (ss. Corner & Hawker 1953) were found. *Galiella celebica* (Henn.) Nannf., whose role in the community is unknown, was collected both at Kepong and at Subico Bay, Olongapo City, Philippines thus extending its distribution considerably.

Conclusions

The dipterocarp forests of Malaysia have been shown to have a wide range of ectomycorrhizal associations, supporting and expanding earlier studies. The accounts of fungi and fungal associations documented or hinted at from Thailand (e.g. Chalarempongse 1987), Indonesia (e.g. Smits 1987, Jülich 1988) and Philippines (this account) parallel the information from Malaysia, but because of the extensive taxonomic studies conducted over many years in the last country (Corner 1993) much more is now known of the fungi involved there. Thus the dipterocarp forests of S. E. Asia as a whole can now be considered an additional great ectomycorrhizal community equalling the conifer forests of the boreal countries, the myrtaceous forests of Australia, the *Nothofagus* forests of the Southern Hemisphere and the extensive caesalpinoid communities extending in a wide belt across the centre of Africa.

The pine forest communities of the Philippines are also ectomycorrhizal and parallel their more northerly counterparts and differ markedly in their constituent ectomycorrhizal taxa from adjacent dipterocarp forests.

The lowland dipterocarp forest mycota of Malaysia have many connections it would appear with fungal floras of Japan and China. In a way this may be a result of bias because we know less of the diversity to be found in Burma, Thai-

land, Vietnam etc.; even much of China is still to be explored but initial observations show similarities (Li Tai Hui, pers. comm.). It would appear that whilst some taxa have a wide host-range it must be hypothesised that some switching of host trees has taken place in certain circumstances in much the same way as with willows in Europe (Watling 1991) and *Uapaca* in W. Africa (Watling 1994). It might also be hypothesised that in any migration the host plants have moved with their appropriate ectomycorrhizal fungi as a unit (Watling 1988), and if this were the case the appearance of boreal fungi, not apparently introduced by man, in the dipterocarp forest might be explained by Ashton's suggestion that the dipterocarps evolved in the north and moved into Malaysia (Ashton 1982). Certainly the ancestors of the remnants, if this is what they are, in Central Africa e. g. *Marquesia* support a rich and parallel ectomycorrhizal flora about their roots. Tracing connections between basidiomes and tree are now required in parallel to those carried out in Malaysia. The Miombo woodland, dominated as it is by caesalpinoid legumes, possesses a rich mycota with many similar or parallel species to those in Malaysia, and might even share common taxa (Watling & Turnbull 1993).

Some so-called Indo-Malaysian flora enters the eastern parts of Australia and some comparisons have already been made with Malaysia (Watling 1994). Certainly taxa such as *Pulveroboletus* recently recorded for Australia (Watling & Gregory 1988), are a major feature of the lowland dipterocarp forests of Malaysia (Corner 1972, Watling & Hollands 1990).

It emphasises the fact that as in other aspects of the modern world Australasia should be looking to the countries within its own area than to Europe, even though the classical macrofungi were described from there.

The forests of Luzon in the Philippines have been highly degraded and it is not really possible to make meaningful comparisons with the dipterocarp forests of Malaysia, except to indicate that ectomycorrhizal studies in the latter may be of assistance in understanding, coming to terms with, and possible rehabilitation of the Philippine situations.

The species data from the *Pinus kesiya* forests in the Philippines have parallels with forests in Kashmir and Simla and whereas the N. W. India, certainly the alpine meadows, might have links with Europe (Watling & Gregory 1980). The Baguio area at least has similarities with northwest North America; some European elements and unique components are also present.

Further work is now required to substantiate some of these hypotheses based on only a small window of information. Certainly work needs to be focused, specificity experiments conducted and further transplant trials conducted as demonstrated by Lee (1988). Already laboratory work with members of the Sclerodermataceae are in hand, and it is intended to extend this to other groups now that a base-line has been produced.

The tropical floras of Africa and Malaysia etc. are exceedingly rich in fleshy fungi so reinforcing the views of Corner (1940), and subsequently others, refuting the claims of the rarity of such life-forms there (Masefield 1940).

Support should also be given to Fassi & Moser (1991) when they proposed that a closer multidisciplinary examination of phytogeography including its ectomycorrhizal components, coupled with supporting experimental studies were necessary for a fuller understanding of the role and distribution of fungi in tropical forest communities.

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