# PATHOLOGY OF TROPICAL HARDWOOD PLANTATIONS IN SOUTH-EASTASIA*

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## ABSTRACT

*Acacia mangium* Willd., *Eucalyptus* spp., *Tectona grandis* L.f. (teak), *Hevea brasiliensis* (Willd. ex Adr. Juss.) Müll. Arg. (rubber), *Paraserianthes falcataria* (L.) I.C.Nielsen, and *Gmelina arborea* Roxb. (yemane) are the main tropical hardwood plantation species in South-east Asia. The occurrence of heart rot in acacias has received widespread attention but root rot is the most damaging disease of acacia plantations. Eucalypts face a different disease threat where outbreaks of leaf and shoot blights are most destructive. Teak, on the other hand, faces few disease threats although it has many insect pests. Since the 1980s, rubber has gained popularity as a source of timber (rubberwood or heveawood) and timber clones have recently been developed. The pathology of rubber is well understood and documented but the disease susceptibility of the new timber clones is currently unknown. In *P. falcataria* plantations gall rust appears to be an emerging threat. Yemane plantations in some parts of the world have failed due to disease problems, but no serious diseases threaten the South-east Asian plantations at present. Small plantations of other exotic and indigenous hardwood species have also been established throughout South-east Asia. Overall, comprehensive information on the pathology of many of the hardwood plantation species that have been planted in South-east Asia is lacking. Further co-operation, in particular from international agencies, needs to be continued and strengthened to ensure the success and continued productivity of hardwood plantations in South-east Asia for the betterment of local communities and economies.

**Keywords**: tropical plantation forests; heart rot; root rot; stem and foliage disease; *Acacia mangium*; *Tectona grandis*; *Eucalyptus pellita*; *Eucalyptus deglupta*; *Eucalyptus urophylla*; *Eucalyptus camaldulensis*; *Eucalyptus tereticornis*; *Hevea brasiliensis*; *Paraserianthes falcataria*; *Gmelina arborea*.

## INTRODUCTION

World wide, tropical hardwood species are estimated to occupy 31 million ha or approximately 57% of the tropical plantation forest area. *Eucalyptus* spp. are the most common tropical forest plantation species with 10 million ha planted, more than half of which are in Brazil and India (Brown & Ball 2000). Other popular species are acacias,

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which make up 12%, and teak, about 7%, of the world's hardwood plantations (FAO 1999). The main tropical hardwood plantation species planted in the countries of South-east Asia (namely Brunei, Indonesia, Malaysia, Singapore, Thailand, Vietnam, Cambodia, Myanmar, Laos, and the Philippines) are *A. mangium* and other *Acacia* spp., *Eucalyptus* spp., *Tectona grandis* (teak), *Hevea brasiliensis* (rubber), *Paraserianthes falcataria* (albizia), and *Gmelina arborea* (yemane). The history of tropical hardwood plantation establishment varies from country to country in South-east Asia. Countries such as Indonesia and Malaysia have a long history of and extensive tropical hardwood plantations, teak in the former and rubber in both; others, such as Singapore, do not have any tropical hardwood plantations at all. The main species planted also varies from country to country depending on historical and political reasons, local preferences, and industrial demand.

Species-wise plantation figures are not available for many countries in South-east Asia. Those with forest plantations exceeding 1 million ha are Indonesia and Vietnam. Indonesia has planted 3 million ha of predominantly industrial plantations, consisting mainly of *A. mangium*, teak, and *Pinus merkusii* Jungh. & De Vriese (Durst & Brown 2000). It has been estimated that over 14 million ha of land in Indonesia will be converted to forest plantations over a 10-year period (Effendy & Hardono 2000). Vietnam has established 1.05 million ha of forest plantations with a variety of species, dominated by *Pinus* and *Eucalyptus*, and the country's 5-million hectare reforestation programme to be carried out by 2010 includes plans to establish 3 million ha of intensively managed industrial plantations (Durst & Brown 2000). Smaller areas of exotic forest plantations have been established in other South-east Asian countries, with species of *Acacia* and *Eucalyptus* being the most popular.

Tropical regions may offer great potential for future plantation productivity gains. For example, *Eucalyptus* spp. rarely yield more than 25 $m^3$/ha per annum at present, but in Brazil hybrids of *E. grandis* W.Hill ex Maiden and *E. urophylla* S.T.Blake have on some sites attained growth rates of 70 $m^3$/ha per annum (Campinhos 1994). However, the extent to which such results can translate to other areas, and particularly whether problems such as poor wood quality, susceptibility to disease, or windthrow, may arise from focusing on growth and yield attributes, remain important questions (Brown & Ball 2000).

This paper discusses the pathology of the more important tropical hardwood plantation species planted in South-east Asia and highlights some of the associated factors that influence the development of diseases.

## Acacia spp. (Family: Leguminosae, Subfamily: Mimosoideae)

Acacias are popular industrial plantation species in South-east Asia, with *Acacia mangium* being the most popular and *A. crassicarpa* A.Cunn. ex Benth. and *A. auriculiformis* Benth. popular to a lesser extent. The natural distribution of *A. mangium* is 10°S to 19°S in Queensland, Australia, the western province of Papua New Guinea, the south-east district of Merauke, Irian Jaya, and the Indonesian islands of Sula, Ceram, and Aru (Pinyopusarerk *et al.* 1993). The species has a short history in plantations, having been first introduced into Sabah, Malaysia, in 1966 from seed of a very restricted genetic base (Pinyopusarerk *et al.* 1993). There are an estimated 1 million ha of *A. mangium* plantations in South-east Asia with more than 600 000 ha in Indonesia alone, mainly providing raw materials for the pulp and paper industry (Rimbawanto 2002). Increasingly, natural hybrids of *A. auriculiformis* and *A. mangium* are gaining popularity due to their finer branching, better growth characteristics, and wood properties.

Recent studies have shown that acacias are susceptible to a number of potentially destructive diseases in South-east Asia that may affect future productivity of the exotic plantations. A comprehensive discussion of diseases of tropical acacias, in particular of *A. mangium,* can be found in the CIFOR publication "A Manual of Diseases of Tropical Acacias in Australia, South-East Asia and India" (Old *et al*. 2000). In this paper, the most important diseases — namely, heart rot, root rot, pink disease, and phyllode rust — are highlighted.

*Heart rot*

Although *A. mangium* has been widely planted in South-east Asia, most of the information on *A. mangium* heart rot has come from Malaysia as few studies have been conducted elsewhere. A study presently under way in Indonesia under a joint Indonesian-Australian project should soon be contributing more information. Heart rot was first noted from *A. mangium* thinnings in young stands in Malaysia (Gibson 1981; Lee 1985) and has since been found in most countries where *A. mangium* plantations have been established (Lee 1999). In Malaysia it was found that although heart rot incidence can be very high ranging from about 50% to 98%, the volume of wood affected is usually rather small, not exceeding 10% (Ivory 1988; Zakaria *et al*. 1994). This level of degradation is unacceptable where the wood is used for construction and appearance grades, but it is of little significance where the crop is grown for pulp and paper or composites on a rotation of 7–10 years (Gregor 1993). Heart rot is also known to be present in *A. auriculiformis* but there is no comprehensive information. At present no data are available on the occurrence of heart rot in other tropical plantation acacias, such as *A. aulacocarpa* A.Cunn. ex Benth. and *A. crassicarpa*.

This stem defect is closely associated with fungal invasion of wounds. On *A. mangium* trees, branch stubs left after self-pruning or through singling (removal of multiple stems to leave a single leader) and artificial pruning operations and forking injuries, act as infection centres (Ivory 1988; Lee *et al*. 1988; Mahmud *et al*. 1993; Ito & Nanis 1997). It has been suggested that the self-pruning ability of *A. mangium* is reduced in parts of South-east Asia where a prolonged dry season is absent, thereby favouring the development of entry points (dying branches) for the decay fungi causing heart rot (Lee & Arentz 1997). Moreover, the wound response in *A. mangium* is reported to be slow (Schmitt *et al*. 1995).

A white fibrous rot is the most common type of rot found in *A. mangium* heartwood (Lee & Maziah 1993). The rot may occur as small pockets or throughout the length of the heartwood but is evident only when the tree is felled. *Phellinus noxius* (Corner) G.Cunn., *Tinctoporellus epimiltinus* (Berk. & Broome) Ryvarden, and *Rigidoporus hypobrunneus* (Petch.) Corner were found to be associated with *A. mangium* heart rot in Peninsular Malaysia and East Kalimantan, Indonesia (Lee & Noraini Sikin 1999). *Oxyporus* cf. *latemarginatus* (Durieu & Mont.) Donk was also found in samples from Peninsular Malaysia (Lee & Noraini Sikin 1999).

A comprehensive review of heart rot in Acacia was presented at a workshop held at CIFOR, Bogor, in 2001 (Lee 2002).

*Root rot*

This disease has been recognised as one of the most significant in tropical acacia plantations, especially in plantations established on logged-over forest sites (Arentz 1990, 1996; Lee 2000). Occurrence and spread of the disease are closely related to the presence of root disease inocula at the site, and mortality of trees generally increases with time in areas where the disease is already present before planting (Lee 2000). In a long-term root disease survey of *A. mangium* plantations carried out in Peninsular Malaysia, more than 40% mortality of trees aged between 10 and 14 years old was reported in severely infected areas (Lee 2000). Root rot is reported to be widespread and serious in *A. mangium* and *A. crassicarpa* plantations in Sumatra, Indonesia (Y.K.Chan pers. comm.). The disease is particularly serious in second-rotation *A. mangium* plantations in Sumatra, where trees as young as 6 months old have been killed by root disease (Old *et al*. 2000).

At least three, as yet unidentified, *Ganoderma* spp. are believed to be associated with the disease in Sumatra, Indonesia (Y.K.Chan pers. comm.). In Peninsular Malaysia *Ganoderma philippii* (Bres. & Henn. ex Sacc.) Bres. (= *G. pseudoferreum* (Wakef.) Overeem & B.A.Steinm.) and *Phellinus noxius* are known to be associated with root rot in *A. mangium* plantations (Lee 2000). *Ganoderma philippii* is rather common and is distributed from Burma (Myanmar) to the Solomon Islands, being found on dead stumps in the forest and in the open, and parasitic on roots of trees, especially rubber (Corner 1983). Similarly, *P. noxius* is widely distributed in tropical regions, causing a brown root-rot and decline of numerous orchard and forest tree species (Pegler & Waterston 1968; Singh *et al*. 1980; Hodges & Tenorio 1984; Neil 1986; Nandris *et al*. 1987). Root rot caused by *Fusarium* spp. is also reported to be problematical in acacia hedge orchards in Sumatra, Indonesia, (Y.K.Chan pers. comm.) but has not been observed elsewhere.

The basidiomycete root-rot fungi normally exist as endemic saprophytes in the natural forest. When land is cleared for plantation establishment, these fungi can survive in root remnants, tree stumps, and other woody debris in the soil. They depend on large food bases for their pathogenic activities and once established on dead wood they can become active and virulent parasites, infecting trees through their roots. The high disease incidence in acacia plantations in South-east Asia is most probably due to a combination of the large amount of woody debris left after harvest, the presence of root-rot pathogens in the natural forest or in the first-rotation planting, and the susceptibility of the tree species. Open burning for land conversion and replanting has been prohibited in both Malaysia and Indonesia in the aftermath of the 1997 regional haze. The resulting large amounts of woody residues after harvesting or forest conversion are likely to act as potential reservoirs and food resources for the facultative root-rot fungi which live in the soil. Control of root diseases is difficult and prevention would be preferable. This could be achieved through good cultural practices — in particular, proper land clearing, and removal of stumps and other woody debris. Much more study is needed in acacia plantations to review the incidence of root-rot diseases in relation to replanting method, factors promoting the occurrence and spread of the disease, and methods for prevention, management, and control of the disease.

*Pink disease*

This stem canker disease takes its name from the pink incrustation which develops on the stem of the tree and is caused by the fungus *Erythricium salmonicolor* (Berk. & Broome)

Burds. (*Corticium salmonicolor* Berk. & Broome). The pathogen infects and kills living bark tissue and is prevalent in areas of high rainfall and during the wet season. The disease is wind dispersed and spread by both basidiospores and conidia of the necator stage. Infected trees develop sunken stem and branch cankers, show wilting and dieback symptoms and, in severe cases, death may occur. *Erythricium salmonicolor* is widely distributed in the tropics, subtropics, and warmer parts of the temperate region and is a parasite of a wide range of woody plants. Although the disease is generally considered of little consequence in South-east Asian acacia plantations, recent surveys show that mortality rates can vary, probably depending on host susceptibility and local environmental conditions (Old *et al*. 1997).

The disease can be controlled with fungicides such as Bordeaux mixture and Calixin, but the cost of regular treatments would be economically prohibitive in forest plantations. Removal and disposal of infected branches would prevent inoculum build-up, and tree improvement programmes could be developed for selection of disease-resistant clones.

*Phyllode rust*

A phyllode rust caused by *Atelocauda digitata* (G.Winter) Cummins & Y.Hirats. has been widely found in *A. mangium* plantations in Sumatra and Kalimantan, Indonesia (Hadi & Nuhamara 1997; Lee 1998; Old 1998). This phyllode rust is also present on *A. aulacocarpa*, *A. auriculiformis*, *A. crassicarpa,* and *A. mangium* in their indigenous habitat in northern Queensland. Heavy infestation results in foliage deformation, defoliation, stunted form, and reduced growth. The impact of the disease on tree productivity has not yet been assessed. There appear to be large differences in susceptibility to the rust at species, provenance, and family levels suggesting that the inclusion of resistant traits in acacia improvement programmes would be an achievable aim for control of the disease (Old & Ivory 1999).

*Other diseases*

A range of fungal leaf spots, blotches, and tip necrosis occur on the phyllodes of tropical acacias. Associated pathogens include species of *Cercospora*, *Colletotrichum*, *Cylindrocladium*, *Pestalotiopsis*, *Phomopsis*, *Phaeotrichoconis*, *Phyllosticta,* and *Pseudocercospora* (Old *et al*. 2000). Their impact on tree growth is generally uncertain. Powdery mildew caused by species of *Oidium* can be found in most nurseries where tropical acacias are grown and this sometimes causes serious losses — for example, 75% mortality of *A. auriculiformis* seedlings was reported in Thailand (Tanaka & Chalermpongse 1990). In well-managed nurseries with good hygiene, the disease is generally not considered of great importance. Under humid conditions, powdery mildew can occasionally be found on phyllodes of lower branches or coppice shoots under canopies of established plantations.

## Eucalyptus spp. (Myrtaceae)

*Eucalyptus* spp. are the most widely planted exotics in the tropics. Most of the more than 600 species of eucalypts are indigenous to Australia but a few are native to the tropics outside Australia. For example, *E. pellita* F.Muell. occurs in Australia, Papua New Guinea, and Irian Jaya (Indonesia); *E. deglupta* Blume in Papua New Guinea, eastern Indonesia (Sulawesi, Moluccas, and Irian Jaya), and Mindanao in the Philippines; and *E. urophylla* is limited to Timor and some nearby islands (CABI 2000). Species of eucalypts which are widely planted in the tropics outside Australia are *E. camaldulensis* Dehnh. which has the widest geographical range of any eucalypt, and *E. tereticornis* Sm., which has the most extensive latitudinal range (9°S to 38°S) of any species in the genus. There are an estimated 1.6 million ha of eucalypts in South-east Asia, mostly of *E. camaldulensis*, *E. tereticornis,* and *E. urophylla* planted mainly in Vietnam, Thailand, and Indonesia, ranging from woodlots of a few hectares to industrial plantations of several hundred hectares (Old & Ivory 1999). The popularity of these three species in South-east Asia can be attributed to their versatility, adaptability, tolerance of harsh conditions, fast growth, and variety of uses. In addition, they are generally relatively free from disease problems when well adapted to the site. However, diseases become common when they are planted off-site or when inappropriate provenances are used. In areas of high rainfall and humidity, stem cankers and shoot blights are serious disease problems causing heavy losses. The main diseases affecting plantation eucalypts in South-east Asia are foliar diseases and stem cankers.

### *Foliar disease*

In Vietnam, the leaf pathogens *Cylindrocladium quinqueseptatum* Boedijn & Reitsma, *Cryptosporiopsis eucalypti* Sankaran & B.Sutton, and a fungus tentatively identified as *Pseudocercospora eucalyptorum* Crous, M.J.Wingfield & Marasas have caused severe defoliation of *E. camaldulensis* (Old & Ivory 1999). In Thailand where climatic conditions generally do not favour epidemics of *Cylindrocladium quinqueseptatum*, *Cryptosporiopsis eucalypti* is the more damaging leaf and shoot blight pathogen (Pongpanich, cited by Old & Ivory 1999). A hazard mapping programme based on climate modelling, and on temperature and rainfall patterns conducive for epidemic leaf blight of *E. camaldulensis* caused by *Cylindrocladium quinqueseptatum,* has been developed for regions of Vietnam, Cambodia, Laos, and Thailand (Booth *et al*. 1999). In Sumatra, Indonesia, the pathogens *Cylindrocladium colhounii* Peerally var. *colhounii*, *C. quinqueseptatum*, *C. intermedium* Matsush., and *Phaeophleospora* (*Kirramyces*) *destructans* (M.J.Wingf. & Crous.) Crous., F.A.Ferreira & B.Sutton are reported to cause serious leaf and shoot blight on vigorously growing *E. grandis*, *E. urophylla,* and *E. grandis* x *E. urophylla* hybrids (Y.K.Chan pers. comm.). An outbreak of *Cylindrocladium* leaf and shoot blight occurred in late 1996 but there has been no widespread recurrence of the disease since and *P. destructans* is currently more dominant (Y.K.Chan pers. comm.). In 2000 *P. destructans* was reported as a new pathogen causing severe defoliation of *E. camaldulensis* in eastern Thailand and it has since been reported from various parts of Vietnam on *E. camaldulensis*, *E. urophylla,* and hybrid clones (K.M.Old pers. comm.). This pathogen is viewed as a serious threat to eucalypts in South-east Asia. Selection of *Cylindrocladium*-tolerant clones is being conducted in both Vietnam and Indonesia.

### *Stem cankers*

*Cryphonectria cubensis* (Bruner) Hodges, the stem canker pathogen, is a widespread and important pathogen of plantation eucalypts in the tropics and subtropics. In Sumatra, Indonesia, it is reported to occur on trees over 3 years old but its occurrence is not extensive (Y.K.Chan pers. comm.). In Vietnam, stem cankers associated with a related *Cryphonectria* species, *C. gyrosa* (Berk. & Broome) Sacc., have been recorded but are of relatively minor importance (Old *et al*. 1999). Stem cankers associated with *Erythricium salmonicolor* cause what is more familiarly known as pink disease, one of the most important diseases of eucalypts (Ciesla *et al*. 1996). It is known to occur in areas of high rainfall in Vietnam (Old *et al*. 1999) and on stressed trees in Sumatra, Indonesia (Y.K.Chan pers. comm.). The disease is reported to be serious in eucalypt plantations in India (Seth *et al*. 1978) but has not caused serious losses in South-east Asian plantations. Other minor stem canker pathogens are *Cytospora eucalypti* J.K.Sharma, C.N.Mohanan & Florence and *Botryosphaeria* sp. in Vietnam (Old *et al*. 1999) and *B. rhodina* (Berk. & M.A.Curtis) Arx in Indonesia (Y.K.Chan pers. comm.).

*Other diseases*

In areas of high rainfall in Vietnam, bacterial wilt caused by *Ralstonia solanacearum* (Smith 1896) Yabuuchi et al. 1996 (=*Pseudomonas solanacearum*) is viewed as a potential disease threat (Old *et al*. 1999). This soil-borne pathogen causes the wilt and death of young eucalypt trees and is known to occur in several countries in Africa, in China, Australia, and Brazil. At present there is no known treatment for the disease.

## Tectona grandis (Verbenaceae)

*Tectona grandis*, commonly known as teak, is the most important timber tree of peninsular India, Indonesia, Thailand, and Myanmar. It is naturally distributed between 9°N and 25°30'N latitude, and 73°E and 104°E longitude, in most of peninsular India, large areas of Myanmar, and parts of Laos and Thailand (White 1991). Teak has been widely planted both within and beyond its natural range; it can be found in Africa, and is widespread in Central and South America and in the Pacific. It is estimated that there are about 2.25 million ha of teak worldwide, of which 94% are in the Asian tropics with 1 million ha in Indonesia (Ball *et al*. cited by Nair 2001). Other countries in South-east Asia where teak has been planted as an exotic are Cambodia, Laos, Malaysia, the Philippines, and Vietnam. Teak is a well-known multi-purpose timber and there is great demand for teakwood, particularly for furniture. As a timber for ship-building, it is in a class by itself (CABI 2000).

Teak is known to have many insect pests, several of which are very damaging. In contrast, diseases are generally not recognised as major problems in teak although there are some pathogens of importance. In nurseries, bacterial wilt, leaf spots, and leaf rust can sometimes cause serious problems.

*Bacterial wilt*

*Ralstonia solanacearum* causes typical vascular wilt in Indonesia, Malaysia, and Myanmar, and *Pseudomonas tectonae* Roldan & Andres is prominent in the Philippines (Gibson 1975; Sharma *et al*. 1985). Lack of or poor soil drainage, and root injury, are predisposing factors of bacterial wilt. The disease is usually more severe in young seedlings than in older ones. It has also been reported from young plantations in Malaysia and Indonesia (Maziah & Lee 1999; Nair & Sumardi 2000).

*Foliar diseases*

Apart from the leaf rust caused by *Olivea tectonae* (T.S.Ramakr. & K.Ramakr.) Thirum, there are few reports of foliar diseases on teak in South-east Asia. Leaf spots caused by

*Phomopsis tectonae* D.P.Tiwari, R.C.Rajak & Nikhra and *Colletotrichum gloeosporioides* (Penz.) Penz. & Saccardo have been reported from Malaysia (Maziah & Lee 1999) and when occurring in combination they have been reported to result in defoliation and death of teak seedlings in India (Sharma *et al*. 1985). Teak rust is a widespread obligate parasite in teak-growing areas in Asia and, as in teak nurseries and plantations elsewhere, it has been reported to cause premature defoliation in Malaysia, Myanmar, Indonesia, Thailand, and the Philippines (Gibson 1975; De Guzman *et al*. 1990; Maziah & Lee 1999). In nurseries, the rust can be controlled by foliar sprays of sulphur-based fungicides and in young plantations by reducing crown humidity through pruning and thinning.

*Other diseases*

Pink disease has been reported to cause stem canker and the death of terminal shoots of young trees in Indonesia (Gibson 1975; Sumardi & Widyastuti 2000) but the disease is not widespread and has not been reported from elsewhere in South-east Asia.

Root rot has also been observed in several small teak plantations in Peninsular Malaysia and in Thailand (Maziah & Lee 1999) but its impact has not been particularly serious. Several fungi have been reported to cause root rot and decay of standing teak trees in India, Tanzania, Dahomey, Nigeria, and Papua New Guinea, but they are of local and minor importance (CABI 2000). However, it would not be surprising to see increased tree mortality rates and concomitant decreased productivity in subsequent rotations of teak in South-east Asia in view of the short rotation lengths (15 years) and the ban on open burning by regional governments.

Heart rot has been reported from teak plantations in India (Harsh & Tewari 1996) but it is not known how serious or widespread this defect is in other teak-growing countries of South-east Asia.

## Hevea brasiliensis (Euphorbiaceae)

The rubber tree, *Hevea brasiliensis*, is indigenous to South America and occurs between latitudes 12°N and 35°S (CABI 2000). Since the early 1900s, rubber has been planted as an exotic in large-scale commercial plantations in South-east Asia for the production of latex and it has long been an important commercial agricultural crop. However, since the late 1980s, it has become an important source of timber in South-east Asia, especially in Malaysia, Indonesia, and Thailand. In 2000 rubberwood was second of the top five species of sawlogs consumed by the sawmill, plywood, and veneer industries in Peninsular Malaysia (Forestry Department Peninsular Malaysia 2000). The wood is used mainly for furniture; it is also suitable for the manufacture of composite boards and plywood. The importance of rubberwood has led to the development of clones aimed at production of timber instead of latex. Currently, it is estimated that there are 9 million ha of rubber plantations worldwide, with 80% located in South-east Asia (CABI 2000).

With its long history of cultivation as an exotic, the pests and diseases of rubber have been well studied and many articles, publications, and manuals have been produced (e.g., Sharples 1936; Hilton 1959; Abu Bakar & Samsudin 1985). Methods for management and control of the various diseases of rubber are well known and have been successfully practised in South-east Asian plantations for many decades. The challenge facing rubber plantation managers at present is how to harmonise plant protection with the environment using integrated pest management techniques while keeping costs and manpower requirements low. However, it is worthwhile here to highlight a few important diseases that are still prevalent in rubber plantations and which also have an impact on plantations of other hardwood species. The susceptibility of the new "timber clones" to these diseases is as yet unknown.

*Root diseases*

Rubber trees suffer from three main root diseases, namely white root, red root, and brown root diseases caused by *Rigidoporus lignosus* (Klotzsch) Imazeki, *Ganoderma philippii*, and *Phellinus noxius*, respectively. These facultative parasites spread mainly by root contact, and methods for their control are well established and documented (Abu Bakar & Samsudin 1985).

*Foliar diseases*

The main fungal leaf diseases of rubber in South-east Asia are caused by *Glomerella cingulata* (Stoneman) Spauld. & H.Schrenk, *Corynespora* spp., and *Phytophthora* spp. These leaf diseases generally cause leaf spots and may result in premature and/or heavy defoliation, thereby affecting the growth and yield of the trees. Various chemical control methods have been effectively applied for the management of these diseases (Abu Bakar & Samsudin 1985). South American leaf blight (*Microcyclus ulei* (Henn.) Arx) is a major disease problem of rubber trees in South and Central America but has so far not been recorded in South-east Asia. Stringent quarantine measures are in place in South-east Asian rubber-growing countries to prevent the entry of this very destructive pathogen.

*Pink disease*

Certain rubber clones such as RRIM 527, 600, 612, 628, 701, 703, and PB217 are very susceptible to pink disease which affects the bark and stem of the trees. However, the disease can be effectively controlled through fungicide treatments (*see above*) and by the use of resistant clones such as GT1, PB5/51, PR107, PR255, or PR261.

## Paraserianthus falcataria (Leguminosae, Mimosoideae)

*Paraserianthes falcataria* was previously known as *Adenanthera falcataria*, *Albizia falcata*, *A. falcataria,* and *A. moluccana*. The currently preferred name is *Falcataria moluccana* (Miq.) Barneby & J.W.Grimes but the widely used *P. falcataria* is used here for familiarity. This fast-growing tree is a native of the Moluccas, Papua New Guinea, the Bismarck archipelago, and the Solomon Islands from 10°S to 30°S but has been widely planted in the humid tropics (CABI 2000). In South-east Asia, *P. falcataria* plantations are found in Indonesia, Malaysia, and the Philippines. It is planted for reforestation and afforestation of denuded and eroded lands, fuelwood, charcoal, paper pulp, manufacture of viscose rayon, general utility purposes such as construction and furniture components, lightweight veneer and plywood, composite products, and as an ornamental tree (Rojo 1997; CABI 2000). It is also commonly used in agroforestry systems throughout its range.

Seedlings in nurseries are prone to damping-off caused by *Sclerotium*, *Rhizoctonia*, *Fusarium*, *Phytophthora,* and *Pythium* spp. and to root disease caused by *Botryodiplodia* sp. but these diseases can be easily controlled by soil sterilisation and application of fungicides to the seeds and soil. The more serious diseases in the plantations are pink disease, root rot, and gall rust.

*Pink disease*

*Erythricium salmonicolor*, the causal pathogen of pink disease, has seriously damaged plantations in the Philippines (Eusebio *et al.* 1980). As on other tree species, the disease causes wilting, dieback, and death of trees when severe. There are currently no reports of pink disease from *P. falcataria* plantations elsewhere.

*Root rot*

Red root disease caused by *G. philippii* is known to occur in *P. falcataria* plantations (Soerianegara & Lemmens 1993). *Botryodiplodia* sp. has also been reported causing root disease in plantations in Kalimantan, Indonesia (Anggraeni & Suharti 1997) but this may not be the primary pathogen. There are, however, no data on the impact and severity of root disease in *P. falcataria* plantations.

*Gall rust*

In 1988 and 1989, gall rust caused by *Uromycladium tepperianum* (Sacc.) McAlpine produced heavy damage in *P. falcataria* plantations in Bukidnon province, Mindanao, the Philippines, resulting in a Government ban on the transport of logs in and out of the province, and a suspension of planting (Eusebio *et al.* 1990). More recent information is unavailable. In late 1992, an outbreak of gall rust was reported from plantations in Sipitang, on the west coast of Sabah, Malaysia. The disease spread through the entire plantation of 450 ha within 1 year, causing wilting of gall-bearing branches, severe dieback, stunting, and, in severe cases, death of trees (Anonymous 1993). This disease was caused by an unidentified species of *Uromycladium* (Lee unpubl. data). Plantings after 1993 were also affected and the plantations did not recover, nor was the disease eradicated (E.Gan pers. comm.). At that time the disease was not reported from another large plantation on the east coast of Sabah but 6 years later, in 1999, it was found to be widespread on 3- to 4-year-old trees (Lee unpubl. data). The disease is controlled in the nursery by application of oxycarboxin, but control in the field has not been possible and the disease is reported to be spreading (Mohd. Hatta Jaafar pers. comm.). More recently, an outbreak of *Uromycladium* gall rust was observed on *P. falcataria* planted as shade trees over coffee in East Timor (Ken Old pers. comm.).

At present there is no control known for gall rust. To ensure the success of *P. falcataria* plantations, it is important that a tree improvement programme be developed for resistance to the disease. From experience with rust diseases of other tree genera elsewhere, there are indications that there may be major differences in resistance at the species, provenance, and family levels.

## Gmelina arborea (Labiateae)

*Gmelina arborea*, commonly known as yemane, is native from Pakistan south to Sri Lanka and east to Myanmar (Soerianegara & Lemmens 1993). It is a fairly fast-growing tree producing a light-weight hardwood suitable for general utility purposes, general carpentry, packaging, carving, furniture, decorative veneers, musical instruments, particleboard, and good quality pulp. It has been widely planted in South-east Asia, tropical Africa, and Brazil. In South-east Asia, it has been planted in Brunei, Cambodia, Indonesia, Malaysia, Myanmar, the Philippines, and Vietnam with large-scale plantations in Sumatra, Kalimantan, and the Moluccas in Indonesia.

Severe pest and disease problems are frequent in plantations within the natural distribution of yemane and in some places have led to the failure of plantations — for example, the JARI project in Brazil. In Africa and South America, serious losses have been reported due to root diseases caused by *Armillaria mellea* (Vahl) P.Kumm., *Ganoderma colossus* (Fr.) C.F.Baker, and *Poria rhizomorpha* Bagchee, and a wilt caused by *Ceratocystis fimbriata* (Ellis & Halst.) Sacc.(Soerianegara & Lemmens 1993; CABI 2000). Thus far, no serious losses of yemane due to diseases have yet been reported from South-east Asia. In Indonesia and Malaysia, damping-off caused by *Pythium*, *Phytophthora,* and *Rhizoctonia* spp. is common in nurseries (Maziah & Noraini 1998; Nair & Sumardi 2000) while anthracnose caused by *Colletotrichum gloeosporioides* is common on seedlings (Kobayashi & Zinno 1984; Lee & Goh 1989). *Botryodiplodia* sp. has been reported causing root rot in young plantations in Indonesia (Anggraeni & Suharti 1997). However, there is no information about its impact or severity.

### Other Species

Many hardwood species, both indigenous and exotic, have been planted in South-east Asia, mostly in small plantations or in small-holdings. Among the more popular species are *Azadirachta excelsa* (Jack) Jacobs (Meliaceae), several members of the Dipterocarpaceae, *Maesopsis eminii* Engl. (Rhamnaceae), *Neolamarckia cadamba* (Roxb.) J.Bosser (= *Anthocephalus cadamba* Miq., Rubiaceae), *Octomeles sumatrana* Miq. (Datiscaceae), *Peronema canescens* Jack (Verbenaceae), and *Swietenia macrophylla* King (Meliaceae). Some information on the pathology of these species is available but overall there is a lack of comprehensive data.

## CONCLUSION

There has been much debate over the merits of plantations of exotics *versus* plantations of indigenous species. On the one hand, it is noted that there are many documented instances of insects and disease causing extensive damage to natural forests, as well as an increasing number of examples of plantations that have been grown over many cutting cycles with few problems. An example of the latter is the more than 100-year history of exotic rubber plantations in Malaysia. On the other hand, a strong case is presented to support the contention that plantations, and particularly single species plantations, are at a much greater risk of catastrophic insect and disease losses than are natural forests (e.g., Perry & Maghembe 1989; Schultz 1999). In a recent study seeking to answer the question "Is there a greater risk of pest outbreaks in exotic forest plantations?", Nair (2001) concluded that case studies vindicated both views as some are at greater risk while others at lesser risk. His overall conclusion from the study was that, while plantations are at greater risk of pest outbreaks than natural forests, plantations of exotics are at no greater risk than plantations of indigenous tree species.

However, it is still widely recognised that there is very limited information available on the pathology of the various hardwood plantation species in South-east Asia. This lack of information is often not an indication of the absence of any disease but more often because little or no research has been conducted. The problem is due largely to the low number of suitably trained personnel, reduced emphasis on such basic science topics in the curricula of local universities, lack of funding for fundamental research, and, to some extent, the restricted flow of information from some of the large privately owned plantations. Despite this, forest pathologists in South-east Asia have obtained some very significant results, showing that some of the exotic hardwood plantation species are susceptible to indigenous fungal pathogens whereas some pathogens appear to have extended their range or significance. It is important that plantation managers and administrators recognise the importance of forest pathology studies and that forest pathologists need to be involved in the many stages of plantation development, from species-site matching and tree improvement studies to the choice of land preparation techniques, nursery hygiene, and silvicultural operations.

The commitment and high level of international co-operation which have been a feature of forest pathology research in South-east Asia over the last decade, should also be acknowledged. This commitment and co-operation need to be continued and strengthened to ensure the success and continued productivity of hardwood plantations in South-east Asia for the betterment of local communities and economies.

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