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Survey of Heart Rot on *Acacia magnum* in Sabah, Malaysia

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Abstract

Acacia mangium which appears to be one of the most promising species has been planted over wide areas in the humid tropics, because of its rapid growth rate, robustness and broad range of uses. Although *A. mangium* had been remarkably free from disease problems, recently it has been reported that several 44 months old thinnings were affected by heart rot. However detailed surveys have not been carried out. To clarify the extent and severity of heart rot in plantations and identify the causal agent, a survey on heart rot was conducted at SAFODA plantations in Sabah, Malaysia. The results of the survey indicated that the incidence of heart rot in *A. mangium* depended on the tree age. In 4 years old plantations, 10% of the trees were already affected by heart rot and the severity of the incidence increased with the age of trees. Fifty percent of 7 years old trees were affected by the rot. Causal fungi invaded mainly from dead branches and 5 fungal species were isolated from the decayed part of heartwood. It was found that *A. mangium* trees produced many branches from the age of 3 years and that dead branches remained attached to the stem for 3 to 5 years. Thus there are numerous potential infection courts for heart rot fungi on *A. mangium* trees. Because of the high incidence and severity of the rot, it appears that *A. mangium* is very susceptible to heart rot. It was also demonstrated that *A. auriculiformis* and the hybrid of *A. auriculiformis* and *A. mangium* did not exhibit heart rot. This fact suggests that heart rot on *A. mangium* could be controlled by breeding for disease resistance.

Discipline: Plant pathology
Additional key words: *A. auriculiformis*, dead branch, disease, pulplog, tropics

Introduction

Acacia mangium Willd. is a leguminous tree species in the subfamily Mimosoideae. The natural distribution of *A. mangium* is concentrated in the southern hemisphere and stretches from Aru Island in the Moluccas and Irian Jaya (the easternmost part of Indonesia), to the River Oriomo in the western division of Papua New Guinea and down to the northern part of Queensland.

A. mangium appears to be one of the most promising species for tree planting programs in the humid tropics. The success of *A. mangium* is primarily due to its rapid growth rate, robustness and wide range of uses. Now it is being planted over wide areas throughout tropical Asia, the Pacific Islands, West Africa, and the Americas.

A. mangium was introduced to plantation forestry in Sabah in 1966 by D. I. Nicholson[7]. In 1967, grown trees were planted as a fire break. Since the early 1980s, SAFODA (Sabah Forestry Development Authority) which was inaugurated in 1976 to establish forest plantations on land degraded by shifting cultivation and logging, introduced and planted *A. mangium* as forest plantation species. It was noticed that the species had a better stem form and was less site-specific, growing well on poor sites than *A. auriculiformis*. SAFODA operates *A. mangium* plantations over an area of 20,000 ha.

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A. mangium had been remarkably free from disease problems until recently. Preliminary studies, however, have shown that leaf diseases, root rot, pink disease and heart rot occurred in *A. mangium* plantations in Malaysia[3,6,10]. Of these diseases, heart rot is the most widespread and potentially most damaging one.

In 1981, heart rot in *A. mangium* was reported in Sabah by Gibson[2] from thinnings of a 44 months old seed stand where 12% of the thinnings showed heart rot. A similar observation was made in 4 years old thinnings at plantations in Peninsular Malaysia[3]. Lee[4] also conducted an extensive study on the disease in 4, 5 and 6 years old stands in the same plantation. In her study, it was found that discoloration and heart rot in *A. mangium* were caused by fungal invasion of poorly healed wounds, especially those left at branch stubs.

Generally, monoculture plantations are known to be very susceptible to diseases and pests. Heart rot may cause conspicuous losses in wood quantity and reduction in quality in terms of forest production. However, no detailed studies on heart rot in *A. mangium* plantations have been carried out

In this report, the results of a survey on heart rot on *A. mangium* conducted at SAFODA plantations in Sabah, Malaysia are described.

Materials and methods

The survey on heart rot was carried out in 14 *A. mangium* plantations in Sabah. The plantations were 2 to 7 years old and 9 years old. In each *A. mangium* plantation, 10 tree × 10 tree study plots (plots A–G) were laid out and then 10 trees were selected. Detailed description of each plot and tree is shown in Table 1.

The selected 10 trees were felled and total height (TH), height of each branch (DH, LBH) and diameter at breast height (DBH) were measured. After the measurements, each tree was cut with a chainsaw into logs approximately 1.0 m in length and then each log was sawed axially with a chainsaw again and the absence or presence, length and width of discoloration and decay were recorded. Disease severity of each tree was evaluated as shown in Table 2.

Chips (5 × 5 mm) were cut from discolored and decayed portions of heartwood. They were sterilized with 70% ethanol and sodium hypochlorite, then they were incubated in a culture medium at room temperature. PDA (potato dextrose agar) was used as culture medium in this study.

The survey was also conducted in 5 years old

Table 1. Description of study plots and trees

Plot	Tree age (year)	TH (m)	DH (m)	LBH (m)	FH (m)	DBH (cm)	Date of planting	Spacing (m)
A–1	2	8.1	0.8	1.3		9.6	Nov. 1988	5.0 × 2.0
A–2	2	8.3	0.5	1.2	4.0	7.1	Dec. 1988	2.1 × 2.1
B–1	3	13.1	1.7	6.7	5.7	11.1	Mar. 1987	3.0 × 3.0
B–2	3	11.5	1.5	3.1	4.9	12.9	Apr. 1987	3.0 × 3.0
C–1	4	14.7	2.2	7.7	5.5	13.0	Dec. 1986	3.0 × 3.0
C–2	4	14.2	0.8	8.3	2.4	11.2	Dec. 1986	2.5 × 2.5
D–1	5	11.6	1.8	4.2	6.7	12.4	1985	3.0 × 3.0
D–2	5	13.7	1.3	5.3	6.3	15.6	Apr. 1985	3.0 × 3.0
E–1*	6	18.9	2.7	9.6		13.5	1984	
F–1	7	19.6	2.3	10.8	7.0	16.6	1983	3.0 × 3.0
F–2	7	19.6	2.4	10.2	5.4	17.1	1983	3.0 × 3.0
G–1	9	16.0	3.2	6.3	3.4	14.6	1981	3.0 × 3.0
G–2	9	10.5	2.8	3.5	4.2	12.4	1981	3.0 × 3.0
G–3	9	22.1	2.9	11.8	8.4	18.5	1981	3.0 × 3.0

TH: Total tree height, DH: Height to the lowest dead branch, LBH: Height to the lowest living branch, FH: Height to forking part, DBH: Diameter at breast height.

* Natural regeneration after burned stand.

Table 2. Evaluation of discoloration and decay of heartwood in *A. mangium*

Disease index	Description of discoloration and decay in heartwood	Disease severity
R_0	Sound wood or less than 1 m of discolored part is observed.	0
R_1	Length of discolored part extends over more than 1 m.	1
R_2	Some parts of wood, less than 1 m, are decayed.	2
R_3	Length of decayed part extends over more than 1 m.	3
R_4	Decayed part is softened and can be easily removed.	4

plantations of *A. mangium, A. auriculiformis* and a hybrid of *A. auriculiformis* and *A. mangium*. Measuring methods were the same as those described above.

Results and discussion

In *A. mangium* trees, it was observed that sound sapwood was pale yellow to straw in color while sound heartwood was pale olive brown to gray brown. In contrast, discolored heartwood was purple to black in color and decayed heartwood showed a light yellow to bleached straw color. Initial decay was difficult to detect, but the wood color was intermediate between that of normal heartwood and wood with advanced decay. In some specimens, the zone of incipient decay was found to be surrounded by a circle of dark brown stain. This zone was significantly darker than normal heartwood. This survey enabled to confirm that the type of heart rot on *A. mangium* was white rot. Based on the disease progression, heartwood of *A. mangium* became white yellow (Plate 1, disease index R_3) and soft. Decayed portions exhibited a stringy appearance (Plate 2, disease index R_4) and were removed easily with a fingernail. Finally, heartwood became hollow (Plate 3).

As already shown in Table 2, 5 disease indices were used according to the progression of discoloration and decay in heartwood of *A. mangium*, and 5 degrees of disease severity based on the severity of wood decay were evaluated and were fitted to each disease index. As a result, disease severity corresponded to the disease index in this study. R_3 and R_4 (disease severity 3 and 4) in the 5 disease indices corresponded to heart rot, because the commercial value for sawlog and/or pulplog of these logs had decreased.

Table 3. Disease severity and incidence of heart rot in *A. mangium* plantations

Plot	Tree age (year)	Disease severity					Average disease severity	Incidence of heart rot (%)
		0	1	2	3	4		
A-1	2	9	1	0	0	0	0.1	0
A-2	2	10	0	0	0	0	0	0
B-1	3	5	5	0	0	0	0.5	0
B-2	3	7	3	0	0	0	0.3	0
C-1	4	7	1	1	1	0	0.6	10
C-2	4	4	0	2	3	1	1.7	40
D-1	5	5	2	1	1	1	1.1	20
D-2	5	0	4	2	4	0	2.0	40
E-1	6	1	3	2	3	1	2.0	40
F-1	7	1	1	3	3	2	2.4	50
F-2	7	2	1	3	3	1	2.0	40
G-1	9	1	1	3	2	3	2.5	50
G-2	9	3	2	0	3	2	1.9	50
G-3	9	1	2	2	3	2	2.3	50

$$\text{Average disease severity} = \frac{0 \cdot N1 + 1 \cdot N2 + 2 \cdot N3 + 3 \cdot N4 + 4 \cdot N5}{N1 + N2 + N3 + N4 + N5}$$

$N1 + N2 + N3 + N4 + N5 = 10$

N: tree number.

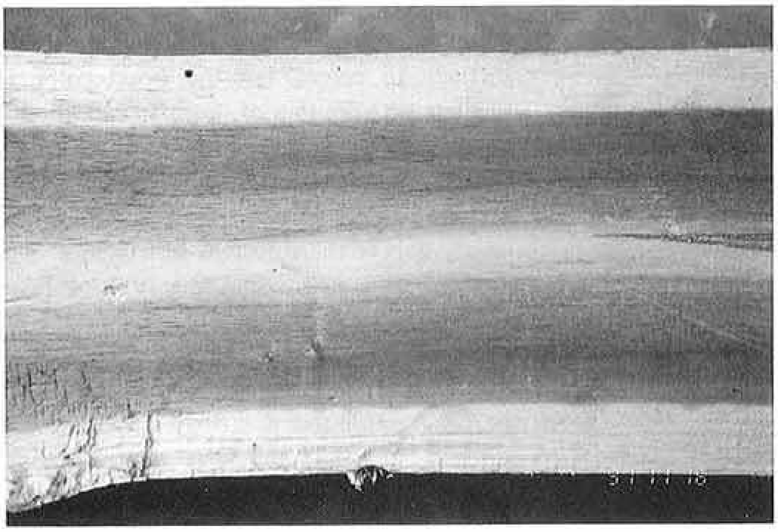

Plate 1. Decay (disease index R_3)

Plate 2. Advanced decay (disease index R_4)

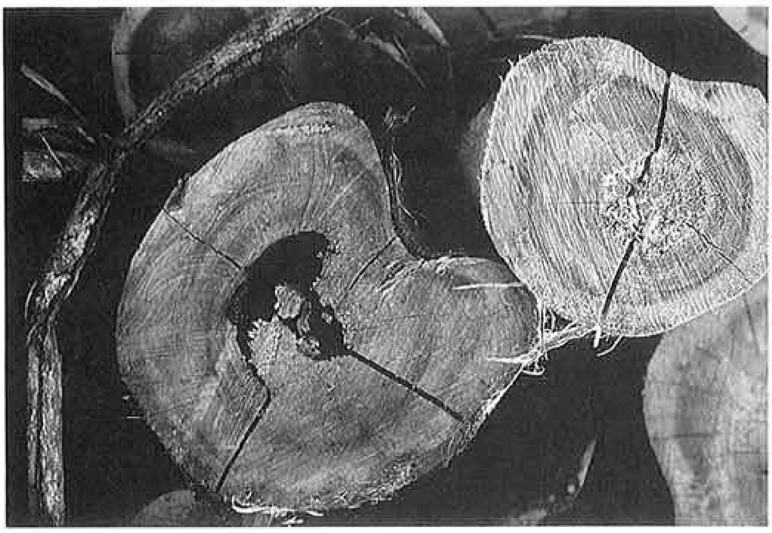

Plate 3. Hollow in heartwood due to heart rot

Percentage of incidence of heart rot and disease severity in each plot are summarized and shown in Table 3. It was evident that the incidence of heart rot and the disease severity depended on the tree age. In 4 years old plantations, 10% of the trees were affected by heart rot, and the incidence of heart rot increased with the age of the trees.

Disease severity also increased with age. Disease severity of trees less than 3 years old ranged from 0 to 1, suggesting that their heartwood had not yet decayed. In 4 and 5 years old trees heartwood had decayed and 10 to 40% of them already showed heart rot, while the average disease severity ranged between 1 and 2. In 6, 7 and 9 years old plantations, more than 40% of the trees showed disease indexes of 3 and 4 and the average disease severity exceeded 2. Furthermore, 20% of the trees in the 7 and 9 years old plantations showed a disease index of R_4.

Infection courts of heart-rot trees were examined in detail. Results are summarized in Table 4. Infection courts of heart rot in *A. mangium* included dead branches or dead branch stubs (Plate 4-A), unhealed wounds (Plate 4-B), forking injuries and wounds by animals (Plate 4-C).

Table 4 indicates that in about 50% of the cases, the infection courts consisted of dead branches and dead branch stubs. Therefore it is evident that the dead branches are the most common point of entry for the heart rot fungus of *A. mangium*. It was reported that the heart rot fungus also invaded the trees from wounds caused, for example, by irregular pruning, animal attacks and fire scars[4].

It is widely known that *A. mangium* has many thick branches that do not fall easily. The results mentioned above suggest that dead branches are essential for heart rot infection in *A. mangium*. When *A. mangium* trees grew older, LBH (height to the lowest living branch) increased rapidly, while DH (height to the lowest dead branch) increased gradually. For example, DHs of 3 and 9 years old trees were 1.7 and 2.9 m and LBHs of the trees of the same age were 6.7 and 11.8 m, respectively. It is evident that the difference between the former 2 values is very small, while there is an appreciable difference between the latter 2 values, suggesting that dead branches of *A. mangium* remained on the stem for many years. It was also found that *A. mangium* trees bore many branches already when they became about 3 years old.

Table 4. Infection courts in heart rot of *A. mangium*

Infection courts	Percentage (%)
Dead branch stubs	38.2
Dead branches	20.6
Unhealed wounds	19.1
Forking injuries	7.4
Squirrel damage	5.9
Unknown	8.8

In the studies on the isolation of the fungi, 8 species of fungi were mainly isolated from discolored and decayed portions of heart rot. Among these species, *Phialophora* spp., *Macrophoma* sp. and an unknown one were isolated from discolored heartwood, especially *Phialophora* spp. were isolated most frequently. It is well known that *Phialophora* spp. cause a discoloration of woods in many living trees[9]. From decayed heartwood, 5 white sterile fungi, members of the Basidiomycetes group which could be distinguished from one another by their color and colony type on the culture medium were isolated. Fruiting bodies that seemed to cause heart rot in *A. mangium* were not found in this study. In Peninsular Malaysia, 25 fungi, differing from each other based on cultural characteristics, were isolated from the rotted part of heartwood[5]. These findings suggest that several fungi may invade the heartwood and cause heart rot of *A. mangium*. More extensive studies should be carried out to identify the causal agent of this heart rot.

Based on the results described above, it was inferred that heart rot occurrence and progression in *Acacia mangium* trees were as follows. While 1 and 2 years old *A. mangium* trees have few dead branches, in 3 years old ones the number of dead branches tends to increase. From these branches, some microorganisms, for example bacteria and fungi referred to as the pioneer wound invading fungi[8] that do not cause decay, invade, become active and cause a discoloration of the wood in trees about 3 or 4 years old. Thereafter, heart rot fungi invade from the same dead branches and cause the decay of heartwood in trees about 5 or 6 years old. In trees more than 7 years old, the decay progresses and extends axially and heartwood becomes soft.

From this study, it is concluded that since *Acacia mangium* trees are very susceptible to heart rot, losses in wood quantity and reduction of wood quality of *A. mangium* due to heart rot are very high. To produce good quality sawlogs, it is essential that artificial pruning of *A. mangium* should be conducted at an early stage while the diameter of the branches is still small. The resulting wound will be small and can heal over rapidly.

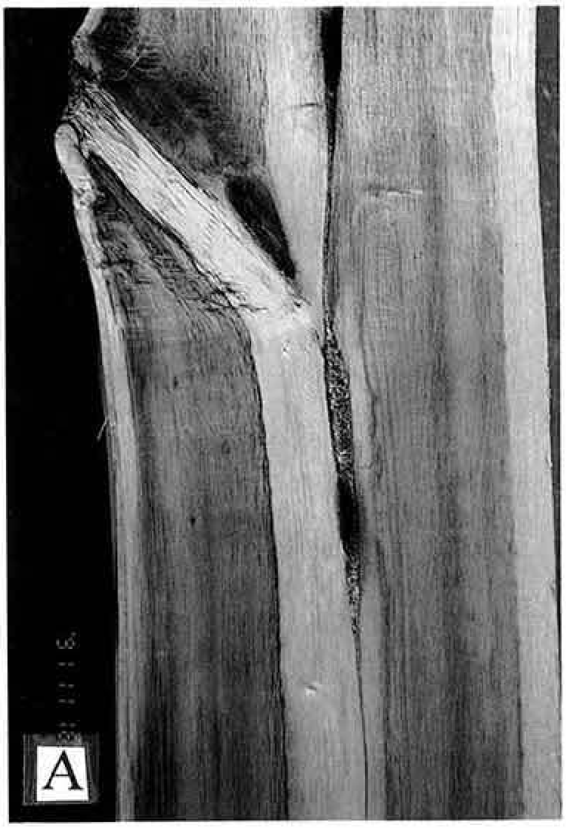

Plate 4. Infection courts of heart rot in *A. mangium*
A: Dead branch stub,
B: Unhealed wound,
C: Squirrel damage.

Table 5. Description of sampled trees

Plot	Tree age (year)	TH (m)	DH (m)	LBH (m)	FH (m)	DBH (cm)	Date of planting	Spacing (m)
H-1	5	17.8	2.4	7.7	9.8	15.5	Oct. 1988	2.5 × 2.5
H-2	5	14.4	1.2	5.8	1.7	12.5	Oct. 1988	2.5 × 2.5
H-3	5	17.5	1.0	7.9	5.7	13.8	Oct. 1988	2.5 × 2.5

H-1: *A. mangium* plantation.
H-2: *A. auriculiformis* plantation.
H-3: Hybrid of *A. auriculiformis* and *A. mangium*.

Table 6. Incidence and severity of heart rot in *A. mangium*, *A. auriculiformis* and *Acacia* hybrids

Plot	Tree age (year)	Disease severity					Average disease severity	Incidence of heart rot (%)
		0	1	2	3	4		
H-1	5	1	2	2	4	1	2.2	50
H-2	5	4	6	0	0	0	0.6	0
H-3	5	4	2	4	0	0	1.0	0

Other species of *Acacia* are known to be affected by heart rot caused by various fungi. In India, heart rot in *A. catechu* is caused by *Fomes badius*. In Australia and New Zealand, heart rot in *A. dealbata* is caused by *Ganoderma applanatum*[1].

It is generally recognized that *A. auriculiformis* trees display a less incidence of heart rot, because they have thin branches compared to *A. mangium*. However, no survey on heart rot has ever been conducted in *A. auriculiformis* and the *Acacia* hybrid. To determine the incidence of discoloration and heart rot in these trees, a survey was carried out in 5 years old plantations of *A. mangium, A. auriculiformis* and the hybrid of *A. auriculiformis* vs. *A. mangium* (Table 5). The incidence of heart rot and disease severity in *A. mangium* were 50% and 2.2 (Table 6). These results were in agreement with those obtained in previous surveys. On the other hand, the disease severity in *A. auriculiformis* and the hybrid plantation trees was 0.8 and 1.0, respectively, and the trees did not suffer from heart rot disease. The disease severity was remarkably different from that in the former plantation. This survey suggested that *A. auriculiformis* is resistant to heart rot.

The optimum method of prevention of heart rot occurrence would be to breed trees that have fewer and thin branches and in which wounds heal rapidly.

References

1) Bakshi, B. K. (1957): Fungal diseases of Khair (*Acacia catechu* Willd.) and their prevention. *Indian Forester*, **85**, 41-46.
2) Gibson, I. A. S. (1981): Seed source establishment and tree improvement — Sabah, Malaysia. Forest Mycology. *In* Consultant's report No. 3 FAO/UNDP-MAL/7B1009, Rome, pp.45.
3) Lee, S. S. (1985): Tree diseases and wood deterioration problems in Peninsular Malaysia. *In* Occasional paper No. 5, Faculty of Forestry, Agriculture University of Malaysia, pp.15.
4) Lee, S. S. et al. (1988): Discoloration and heart rot of *Acacia mangium* Willd. — Some preliminary results. *J. Trop. Forest Sci.*, **1**, 170-177.
5) Lee, S. S. & Maziah Zakaria (1993): Fungi associated with heart rot of *Acacia mangium* in Peninsular Malaysia. *J. Trop. Forest Sci.*, **5**, 479-484.
6) Liu, P. S. W. (1977): Supplement to a host list of plant diseases in Sabah, Malaysia. *In* CMI phytopathological paper No.21.
7) Logan, A. F. & Balodis, V. (1982): Pulping and papermaking characteristics of plantation-grown *Acacia mangium* from Sabah. *Malaysian Forester*, **45**, 217-230.
8) Rayner, A. D. M. & Boddy, L. (1988): Fungal decomposition of wood. *In* It's biology and ecology. John Wiley & Sons, New York, pp.587.
9) Shortle, W. C. & Cowling, E. B. (1978): Development of discoloration, decay and microorganisms following wounding of sweet gum and yellow poplar trees. *Phytopathology*, **68**, 609-616.
10) Williams, T. H. & Liu, P. S. W. (1976): A host list of plant diseaes in Sabah, Malaysia. *In* CMI phytopathological paper, No.19, pp.67.

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