A SURVEY OF HEART ROT IN SOME PLANTATIONS OF *ACACIA MANGIUM* IN SABAH

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MAHMUD SUDIN, LEE, S. S. & AHMAD HJ. HARUN. 1993. A survey of heart rot in some plantations of *Acacia mangium* in Sabah. The extent of heart rot in *Acacia mangium*, was determined by destructively sampling 100 trees from 3-y-old thinnings and 195 trees varying from six to nine years old in 20 selected plots. Only 4% of the thinnings had heart rot which appeared to originate from thinning wounds. In the older trees, the average incidence of heart rot was 35.5%. The volume of wood affected by heart rot and discoloration ranged between 0.3 and 24.0% while the volume of wood affected by heart rot alone ranged between 0.03 and 18.0%. The main infection courts were dead branches while cankers and less frequently, roots and branch stubs were supplementary infection courts. There was no significant difference ($p<0.05$) in diameter and height of heart rotted and non-heart rotted trees. However, there was a significantly higher incidence of heart rot in 8-y-old trees from Keningau (48.7%) than those from Kudat (10%) ($p<0.05$) and this was probably related to site factors. Only 4% of sampled trees were attacked by termites.

Keywords: *Acacia mangium* - heart rot - infection courts

MAHMUD SUDIN, LEE, S. S. & AHMAD HJ. HARUN. 1993. Bancian reput teras di beberapa ladang hutan *Acacia mangium* di Sabah. Pokok *Acacia mangium* ditebang untuk menentukan takat berlakunya reput teras. Sejumlah 100 pokok penjarangan berumur tiga tahun dan 195 pokok yang berusia di antara enam dengan sembilan tahun dari 20 plot terpilih telah disampel. Hanya 4% dari pokok penjarangan yang di sampel di serang reput teras yang mungkin berasal dari luka pemangkasan. Purata 35.5% dari pokok yang lebih tua ada reput teras. Isipadu kayu yang di serang reput teras dan mengalami pertukaran warna adalah dalam julat 0.3 hingga 24.0% manakala isipadu kayu yang diserang reput teras sahaja adalah dalam lingkungan 0.03 hingga 18.0%. Dahan mati merupakan sumber jangkitan utama reput teras sementara kanker dan kadang-kadang akar serta puntung dahan menjadi sumber jangkitan

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sampingan. Tidak terdapat perbezaan yang bererti ($p<0.05$) dalam garis pusat serta ketinggian pokok yang diserang atau bebas dari reput teras. Walaubagaimanapun, pokok berumur lapan tahun dari Keningau mempunyai takat reput bererti ($p<0.05$) yang lebih tinggi (48.7%) dari pokok yang sama umur dari Kudat (10%) dan ini mungkin di sebabkan oleh faktor-faktor tapak atau lokasi. Hanya 4% dari pokok yang di sampel diserang anai-anai.

Introduction

Acacia mangium was first introduced into Sabah from Queensland by D.I. Nicholson in 1966 and planted in the Ulu Kukut and Gum-Gum areas. During the mid-70s, its rapid growth rate, high yielding capacity and adaptability to degraded grasslands were noticed. This led to extensive planting of *A. mangium* in Sabah and subsequently in Peninsular Malaysia as well. In 1976, SAFODA (Sabah Forestry Development Authority) was established by the government of Sabah to undertake reforestation of grass lands and shifting cultivation areas, and the establishment of non-commercial forests with *A. mangium.* Since then, the Forestry Department, Sabah Softwoods Sdn. Bhd. (SSSB) and Sabah Forest Industries (SFI) have all established their own *A. mangium* plantations for the production of timber, chips and pulp. Presently, there are approximately 47,000 *ha* of hardwood plantations in Sabah, a large proportion of which consists of *A. mangium.*

Although the risk of disease outbreaks is inherently high in such monoculture plantations, little is known of the potentially damaging diseases of *A. mangium* and their control. Preliminary studies have shown that leaf diseases, root rot, pink disease and heart rot occur in *A. mangium* plantations in Malaysia (Gibson 1981, Khamis 1982, Lee 1985, Kugan 1987, Teng 1988). Of these diseases, heart rot is the most widespread and potentially most damaging.

Heart rot in *A. mangium* was first reported in Sabah by Gibson (1981) who noticed a white fibrous decay with a peripheral brownstain in 44-*mth*-old thinnings. This was followed by an intensive survey throughout *A. mangium* plantations in Sabah by a team of Australian-Canadian volunteers in 1985 whose results, however, were never reported or published.

In Peninsular Malaysia, Lee *et al.* (1988) reported a volume loss of 2.7 - 17.5% of the merchantable volume of *A. mangium* due to heart rot. They found that cankers associated with decayed branch stubs and poorly healed basal pruning wounds were good indicators of discoloration and decay in the heartwood of those trees. Chan (1984) in his study on sawn timber recovery from 12-*y*-old *A. mangium* planted as a firebreak avenue in Ulu Kukut, reported that 16.5% of the logs had heart rot and that no sawn timber could be recovered from 73% of the heart rotted logs.

Gibson (1981) and Thomas and Kent (1986) suggested that an unknown Basidiomycete was associated with *A. mangium* heart rot in Sabah. In Peninsular Malaysia, Lee *et al.* (1988) isolated 17 species of fungi from the discolored and decayed heartwood of *A. mangium,* one of which was a sterile brown Hymenomycete member of the Basidiomycetes suspected to be the heart rot fungus.

In view of the large area of *A. mangium* plantations in Sabah and the lack of comprehensive data on the extent and severity of heart rot, this study was undertaken in Sabah in 1990 with the following objectives: (i) to determine the per cent incidence of heart rot in selected stands and thinnings of various ages; (ii) to measure the volume of wood affected by heart rot; and (iii) to investigate the relationship between heart rot incidence and various site factors. It was not our intention at this stage to isolate and identify the fungi associated with the heart rot.

This study was divided into two parts; the first part entailed a survey of heart rot incidence in *A. mangium* thinnings while the second part concentrated on an intensive survey of the incidence and volume of heart rot in selected samples of *A. mangium* from plots located in different parts of Sabah.

Our original intention was to obtain samples from all age classes planted in Sabah for the second part of the study. However, in the time available, samples could only be obtained from six, eight and nine-y-old trees. Trees of other ages will be sampled at a later stage to obtain a more complete picture of the relationship of heart rot with age in *A. mangium*.

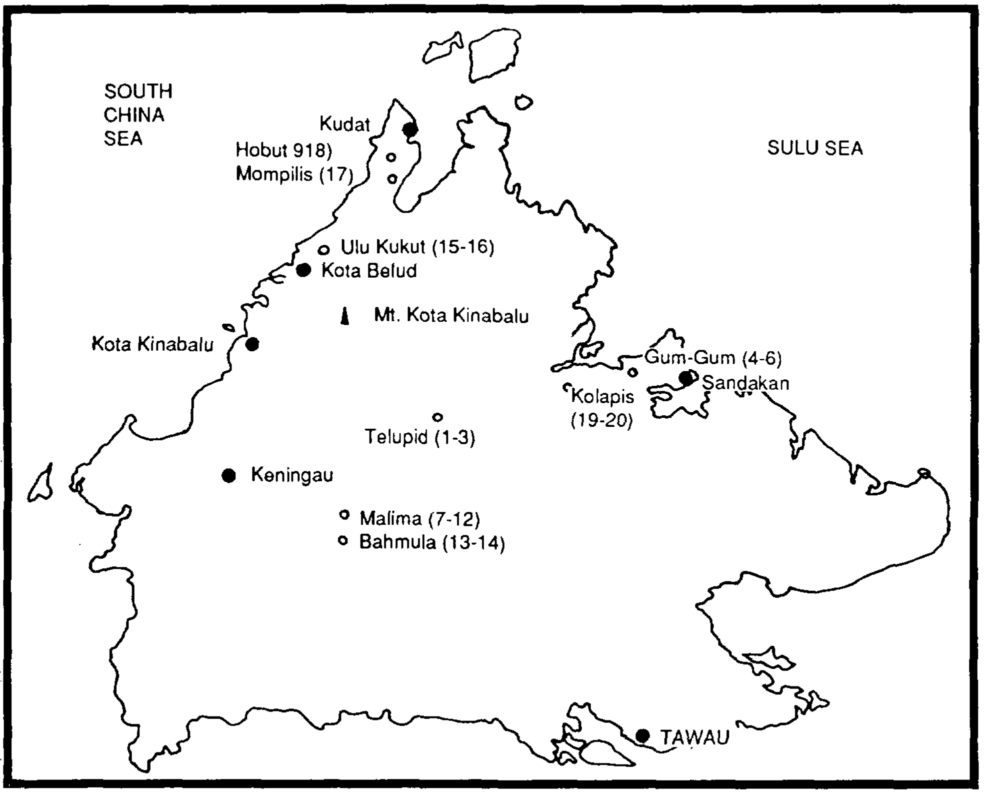

Figure 1. Location of plots established throughout Sabah. The numbers in parentheses are the sample plot numbers

Table 1. Location and ages of *A. mangium* plots established and sampled

Location	Plots	No. of plots	Age at sampling (no. of years)	Owner Agency
Ulu Kukut	Sarang	1	9	SAFODA
	Timbang	1	8	
Kudat	Mompilis	1	8	SAFODA
	Hobut	1	8	
Keningau	Malima	6	8	SAFODA
	Bahmula	2	8	
Gum-Gum	Gum-Gum	3	8	Forest Dept.
Telupid	Telupid	3	6	Forest Dept.
Kolapis	Kolapis A	2	6	Forest Dept.

Materials and methods

Thinnings

During this study, thinnings were only available from one thinning operation at Bengkoka. One hundred trees representing a 10% sample of 1000 thinned tress were randomly chosen from a 3-y-old *A. mangium* plantation that was being thinned by the SAFODA authorities at the Alasu plot, Bongkol, Bengkoka. The diameter at breast height (DBH), presence of external indicators of heart rot, such as decayed branch stubs, cankers, wounds and broken branches (see Lee *et al.* 1988), occurrence of heart rot and termite attack were recorded for each tree.

Intensive survey

Twenty sample plots (Plot 1 - Plot 20), each measuring 30 x 30 *m* and consisting of about 100 trees, were established in *A. mangium* plantations at various locations in Sabah (Figure 1 and Table 1). The background information for the various plots is given in Table 2.

Ten trees were randomly chosen in each plot. The DBH, presence of external indicators of heart rot, vigour and degree of forking of each tree were recorded before the tree was felled. The merchantable height (MHT) up to 10 *cm* diameter top of the felled tree was measured before it was bucked into 1 *m* lengths and split longitudinally for the determination of volume of decayed and discolored wood (Lee *et al.*, 1988). The point of heart rot invasion and presence of termite attack were also recorded.

A code system was devised for evaluating discolored and heart rotted wood (Table 3). Trees given codes 0 to 2 were considered sound while those given code 3 were considered discolored and probably in the incipient stage of decay. Trees

Table 2. Background information for plots of *A. mangium* established at various locations in Sabah

Age group (year)	Location (plots)	Soil type	Drainage	Pruning & thinning	Fire history	Provenance	DBH (*cm*)			MHT (*cm*)		
							Min	Max	Mean	Min	Max	Mean
9	Ulu Kukut (Sarang)	Sandy & stony	Excessively drained	None	1987	unknown	21.0	35.0	27.7	12.2	15.0	13.7
8	Gum-Gum (Gum-Gum)	Mudstone & sand-stone	Well drained	None	None	Ex-Oriono River , PNG	10.6	38.2	19.4	5.9	26.8	18.1
8	Keningau (Malima & Bahmula)	Terraces shallow soil	Poorly drained	None	1987	Unknown	10.9	25.0	16.8	3.2	15.8	9.7
8	Kudat (Mompilis & Hobut)	Mudstone & sandstone	Excessively drained	None	None	Unknown	11.0	22.2	16.4	6.8	15.6	10.7
8	Ulu Kukut (Timbang)	Sandy & stony	Excessively drained	None	1987	Unknown	11.5	25.0	17.1	9.6	13.5	11.5
6	Telupid (Telupid)	Mudstone & sandstone	Well drained	At year 2	1983	Ex-Oriono River, PNG	12.0	35.0	22.6	10.1	22.1	16.3
6	Kolapis (Kolapis A)	Mudstone, sandstone, misc. rock	Poorly drained	None	Unknown	Unknown	13.2	28.3	19.3	4.22	1.4	12.5

Note: DBH = diameter at breast height; MHT = merchantable height.

with codes 4 and 5 were considered rotted.The data were statistically analysed using Analysis of Variance for differences in heart rot incidence and volume of wood affected in relation to DBH, merchantable height and localities.

Table 3. Evaluation of discoloration and decay in *A. mangium*

class	Description
0	Normal sound wood, no discoloration or decay
1	Heartwood reddish brown but sound
2	Heartwood unusually dark brown but sound
3	Heartwood dark brown, a little fibrous
4	Heartwood pale yellow, cut end fibrous and porous
5	Heartwood bleached, corky in texture, easily removed with fingernail, core often hollow or filled with debris

Results and discussion

The decayed heartwood of *A. mangium* was a light yellow to bleached straw colour in contrast to the light brown of sound heartwood. In severe rot the wood was bleached almost white and was fibrous to corky in texture, being easily removed with the fingernail. Some trees were so severely rotted that the core was hollow. Discolored wood was always found adjacent to, or bordering, rotted heartwood. The characteristics of discolored wood were similar to those reported by Lee *et al.* (1988), that is discolored sapwood was usually light to dark greenish yellow while discolored heartwood was purplish to almost black in colour. Incipient decay was probably indicated by wood of intermediate colour between sound and decayed wood, usually of darker colour than normal heartwood. The decay fungi involved were probably Hymenomycetes of the white rot group which utilise both cellulose and lignin since the resulting decayed wood was typical of white rotted wood.

Thinnings

Only 4% of the thinnings had heart rot while another 6% had discolored heartwood. The heart rot and discoloration appeared to originate from wounds which had been left from artificial pruning carried out when the trees were one year old. In all samples, the rot was confined to a small central core. The heartwood of another 13% of the thinnings was discolored with the point of initiation appearing to originate from the roots. No termite damage was found in sample trees.

The DBH of the thinnings ranged between 10.2 and 19.5 *cm* with a mean of 14.0 *cm* while the mean DBH of trees with heart rot was 14.2 *cm*.

It would appear that heart rot was not a serious problem in the three-year-old *A. mangium* in Bongkol even though the trees were generally of poor form and vigour. From a survey of 140 *A. mangium* trees ranging between two and nine years of age in Sabah, Ito (1991) reported that *A. mangium* trees had many dead branches from the age of three years old and that heart rot only became evident in trees four years old and older.

Intensive survey

In the 6-y-old stands, 36.7% of the trees sampled at Telupid and 28% of those sampled at Kolapis had heart rot. The total volume of merchantable timber affected by discoloration and heart rot ranged from 0.04 to 23.93% (in one tree only). However, the volume of timber lost to heart rot was small and in most samples affected less than 5% of the merchantable timber. The mean volume lost was approximately 1% only (Table 4).

In 8-y-old *A. mangium* stands, the incidence of heart rot ranged from 10% in the Kudat and Ulu Kukut areas to 48.7% in the Keningau area. However, although the incidence of heart rot was high, the volume of wood affected in each tree was generally small; in most samples less than 3% of the merchantable volume was affected. The maximum loss of volume was 18.1% in one tree while the maximum mean volume loss was 5.5% (Table 4). There was no significant difference ($p = 0.05$) in the diameter of trees with and without heart rot.

Only five trees were sampled in the 9-y-old stand at Sarang in Ulu Kukut because most of the trees were of smaller DBH than the 10 *cm* merchantable height diameter. The poor growth of these trees was probably a reflection of the poor sandy, stony soil and the steep and hilly terrain at Sarang. Three of the trees had heart rot affecting between 0.36 and 1.71% of the merchantable volume. The total amount of wood affected by heart rot and discoloration ranged between 0.69 and 2.82% of the merchantable volume (Table 4).

The volume loss figures were not very different from results reported by Lee *et al.* (1988) who found between 2.7 and 17.5% volume loss in tree ranging between four and six years of age in Peninsular Malaysia.

The overall average incidence of heart rot in the *A. mangium* stands sampled was 35.5%. Ito (1991) reported an average of 39% incidence of heart rot in *A. mangium* ranging from four to nine years of age in similar areas in Sabah. No trends of increasing heart rot incidence with age could be observed in this study due to the limited range of ages sampled. However, Ito (1991) found that heart rot incidence generally increased with age; 25% incidence in 4-y-old trees increasing to about 50% incidence in 7-y-old and 9-y-old trees.

Within the 8-y-old stands at the different locations, an analysis of variance showed that the incidence of heart rot was significantly lower in Kudat (10%) than at Keningau (48.7%) ($p<0.05$). This was probably due to site factors. The soil in the Kudat plots was sandy and stony and generally very well drained while the plots at Keningau had shallow soil with a high clay content that was poorly drained. Thomas and Kent (1986) considered the latter sites of low quality. Climatic data was not available and thus was not considered in the relationship between incidence and locality. The 1987 fire in Keningau which left many fire scars and dead branches on the trees could also have facilitated entry of the heart rot fungi into trees at Keningau thus resulting in a higher incidence of rot.

Table 4. Heart rot incidence, volume of wood affected by heart rot and discoloration and incidence of termite attack

Age group (year)	Location (Plots)	Number of trees sampled	Heart rot incidence %	Rotted volume (% merchantable volume)		Discolored and rotted volume (%)	Termite attack %
				Range	Mean		
9	Ulu Kukut (Sarang)	5	60.0	0.36-1.71	0.96	0.69-2.82	Nil
8	Gum-Gum (Gum-Gum)	30	30.0	0.02-2.78	0.77	0.32-2.78	Nil
8	Keningau (Malima & Bahmula)	80	48.7	0.05-18.10	2.59	0.30-18.10	Nil
8	Kudat (Mompilis & Hobut)	20	10.0	0.03-10.82	5.51	0.29-12.63	Nil
8	Ulu Kukut (Timbang)	10	10.0	0.03	0.03	0.29	Nil
6	Telupid (Telupid)	30	36.7	0.07-6.19	1.37	0.76-23.93	23
6	Kolapis (Kolapis A)	20	28.0	0.03-3.21	1.13	0.04-5.80	5

Termite damage

Termite damage was only found in samples from Telupid and Kolapis (Table 4). At Telupid seven trees were attacked by termites. Four of these trees also had heartwood severely damaged by heart rot while one showed early stages of heart rot (Table 5). Of the remaining two trees, one had rotted sapwood colonised by *Auricularia* sp. while the other had no symptoms of fungal decay. At Kolapis only one tree was attacked by termites and this tree was severely affected by heart rot.

Table 5. Association of termite attack with occurrence of heart rot in *A. mangium*

	Telupid	Kolapis A
Total number of trees	30	20
Number of trees with heart rot	10	5
Number of trees with termites & heart rot	5	1
Number of trees with termites only	1	0
Number of trees with termites & other decay	1	0

Invasion courts

Dead branch stubs, knots, and dead branches were the most common points of heart rot invasion in all the trees regardless of age (Tables 6a & 6b). Dead branch stubs remaining on the main trunk after self-pruning accounted for 37.7% of the invasion points and dead branches resulting from other factors another 34.8% (Table 6a). Ito (1991) also reported similar results, about 50% of infection was through dead branch stubs and dead branches. Cankers associated with wounds caused by fire or unknown agents were associated with invasion points in 21.7% of the heart rotted trees. In 2.9% of the trees invasion of the heartwood occurred via the roots. It appeared that the heart rot fungi could also invade the tree through forks, especially where the bark had split exposing the wood at the point of forking. Unhealed pruning wounds were not common points of invasion because all the trees with the exception of those in Telupid and Kolapis had not been pruned.

Table 6a. Relationship between occurrence of heart rot in *A. mangium* and types of infection courts

Type of infection court	Present in heart rotted trees %
Dead branch stubs and knots	37.7
Dead branches	34.8
Stem cankers	21.7
Butt and root	2.9
Unhealed pruning wounds	1.4
Forking injury	1.4

There was some variation in the occurrence of invasion points at the different sites (Table 6b). At Sarang, Ulu Kukut, heart rot invasion points in all the three heart rotted trees were cankers on the trunk located between 0.4 and 1.5 *m* above the ground. The cause of the cankers could not be determined but there is a possibility that they could have been caused by fire judging from the damage on the bark and wood of the trees. Cankers were also the only points of invasion in trees at Timbang, Ulu Kukut. At Telupid the most common invasion points were dead or broken branches (Table 6b). This was not surprising since about 57% of the trees there had dead or broken branches probably caused by winds.

Ito (1991) found that *A. mangium* trees produced many branches from the age of three years and that dead branches remained attached to the stem for many years. Thus, there are numerous potential infection courts for heart rot fungi on *A. mangium* trees. From the high incidence and severity of the rot it appears that *A.mangium* heartwood is very susceptible to rot. It would be interesting to investigate whether this is due to the rapid growth of the species, or other endogeneous factors.

Conclusion

Although the variable and small diameter of the logs and the high incidence of the heart rot would affect the recovery of *A. mangium* (Chan 1984), this does not preclude its use for purposes where the core could be avoided and the bole converted into smaller dimensions for manufacture of a variety of products. The percentage of wood loss as a result of heart rot is generally small.

Table 6b. Frequency of types of infection courts on heart rotted trees at the various sites

Types of infection courts	Location						
	Ulu Kukut (Sarang)	Gum-Gum (Gum-Gum)	Keningau (Malima & Bahmula)	Kudat (Mompilis & Hobut)	Ulu Kukut (Timbang)	Telupid (Telupid)	Kolapis (Kolapis A)
Number of trees	5	30	80	20	10	30	20
Dead branch stubs and knots		44.4%	43.6%	100%		30.0%	20.0%
Dead branches		33.3%	46.2%			30.0%	
Stem cankers	100%	22.3%	7.7%		100%	20.0%	60.0%
Butt and root						20.0%	
Unhealed pruning sounds							20.0%
Forking injury			2.5%				

Evidently, *A. mangium* is highly susceptible to heart rot once the tree is damaged or wounded whether on the root, stem or branches.

Thus, special care should be taken to avoid damage to *A. mangium* trees during silvicultural operations. Where pruning or singling operations are to be conducted, they should be carried out when the branches are of small diameter so that the resulting wound can rapidly heal. The use of wound dressings has generally lost popularity in forestry as research has indicated that such treatments have little or no effect on the prevention of decay (James 1990) and even the best treatments are not effective after about 110 days (Mercer *et al.* 1983).

Control and prevention of heart rot in *A. mangium* is obviously very difficult. From the viewpoint of forest pathology we support Ito's suggestion (1990) that this species should be harvested on a seven or eight-year rotation until some control or prevention system can be formulated for heart rot. In the long term, the best strategy would appear to be selecting and breeding trees that produce few branches, have rapid wound healing abilities, and are resistant to heart rot. Alternatively, if it can be shown that climate plays a major role in disease incidence (and severity), *A. mangium* could be restricted to low-risk sites.

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