SULPHATE PULPING CHARACTERISTICS OF *ACACIA* HYBRID, *ACACIA MANGIUM* AND *ACACIA AURICULIFORMIS* FROM SABAH

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YAMADA, N., KHOO, K.C. & MOHD. NOR MOHD. YUSOFF. 1992. Sulphate pulping characteristics of *Acacia* hybrid, *Acacia mangium* and *Acacia auriculiformis* from Sabah. Various sulphate pulps were prepared from 9-year-old *Acacia* hybrid, a cross breed of *Acacia mangium* and *Acacia auriculiformis* and compared with those of *A. mangium* and *A. auriculiformis*. The trees were taken from the SAFODA plantations in Sabah. The *Acacia* hybrid gave very good pulp yields in excess of 55% and the properties of the pulps were generally superior to those of *A. mangium* and *A. auriculiformis*.

Key words: Sulphate pulps - *Acacia* hybrid - *Acacia mangium* - *Acacia auriculiformis*

Introduction

Malaysia places great emphasis on reafforestation with fast-growing trees as in the establishment of forest plantations. Prominent among the selected species is *Acacia mangium* of which in Sabah alone about 21,000 *ha* have been planted. These plantations are being intensively expanded to serve as a future wood resource of the country.

The adaptability of *Acacia auriculiformis* to Malaysian conditions has been noted since the early days of its introduction to this country. On account of its fast growth, low site selectivity and high resistance to disease and insect attack, it has been recommended as a useful reforestation species (Mitchell 1963).

A. mangium was introduced to Malaysia at a later date than *A. auriculiformis* and was first tried in Sabah in 1966. Its fast growth, good form and wide adaptability have put it in favour as a plantation species over many other established fast-growing species. Its growth is comparable to and even exceeds in some sites those of *Paraserianthes falcataria*, *Gmelina arborea*, *Eucalyptus deglupta* and *Anthocephalus chinensis* (Tham 1976, Sim 1987).

Spontaneous hybrids of *A. auriculiformis* and *A. mangium* have been reported from plantation grown trees in Sabah, especially when these two species are planted in close proximity to one another. Generally, they tend to grow vigorously and have

better form than *A. auriculiformis* and lighter branching, better self pruning ability and smoother bark than *A. mangium* (Tham 1979, Sim 1987).

The hybrids are extremely adaptable and regenerate naturally on disturbed sites. There is large potential in the establishment of hybrid plantations through the selection of high quality parents especially with characteristics favourable for some end products like lumber and pulp and fibre (Rufelds 1987, FAO 1982).

The pulping and papermaking properties of *A. auriculiformis* have been investigated by Guha and Pant (1966), Phillips and Logan (1976) and Mohd. Nor *et al.* (1986); those of *A. mangium* by a much larger group of workers such as Logan and Balodis (1982), Peh and Khoo (1982), Ku and Chen (1984), and Becker (1987). Generally, except for the yield, *A. mangium* has been found to be superior to *A. auriculiformis*. In 1988, the Sabah Forestry Development Authority (SAFODA) became the first agency in Malaysia to export chips from 7-y-old *A. mangium* logs for pulp and paper. No work has been reported of any pulping study on the *Acacia* hybrid. The present investigation examines the sulphate pulping of a hybrid grown in Sabah in comparison with that of the parent species.

Materials and methods

Wood samples of the two species and their hybrid were collected from the SAFODA plantations in Sabah. The locations and measurements of the sample trees are shown below:

Species	Age (y)	Height (m)	DBH (cm)	Location
A. mangium	9	17.5/19.4	15.4/17.4	Hobut, Kudut
A. auriculiformis	6	14.1	23.2	Timbang Menggaris,Kota Belud
A. hybrid	9	20.5	29.0	Hobut, Kudat

From each tree a 1 *m* long billet was sawn at one third of the stem height from the base. The logs were debarked manually and chipped. The chips of each wood sample were thoroughly mixed and sampled for measurements of density and fibre length, proximate chemical composition and pulping trials.

Determination of apparent density

The method employed was according to TAPPI T 258.

Fibre length measurement

The samples were cut into match-stick size and macerated in hot hydrogen peroxide and glacial acetic acid. The softened wood was broken up into fibres by shaking gently with glass beads in a bottle. The fibre length was determined by direct measurement of the magnified image of the mounted fibres.

Proximate chemical composition

(a)	Holocellulose	:	Determination of holocellulose from method of Wise *et al.* (1946)
(b)	Alpha-cellulose	:	Tappi T 203 os-74
(c)	Lignin	:	Tappi T 222 om-83
(d)	Alcohol/benzene solubles	:	Tappi T 204 os-76
(e)	One percent alkali	:	Tappi T 212 om-83
(f)	Hot water solubles	:	Tappi T 207 os-78
(g)	Pentosans	:	Tappi T 223 os-78
(h)	Ash	:	Tappi T 15 m-58

Pulping trials

The samples were pulped by the sulphate process in a 6-*l* MK digester, with a variable active alkali. The other fixed conditions of pulping were :

sulphidity = 25%; wood to liquor ratio = 1 : 3.5;
time to maximum temperature (170°*C*) = 90 *min*
time at maximum temperature (170°*C*) = 90 *min*

At the end of each cook, the softened chips were washed on a screen and disintegrated for 5 *min* in a Twing-Albert Lear Blend-A-Mill. The pulp obtained was thoroughly washed and screened by a Somerville fractionator.

The Kappa number of the screened pulp was determined according to Tappi T 236 os-76. Beating was carried out in a PFI mill.

Handsheets were conditioned and tested at temperature of 20±1°*C* and relative humidity of 65±2%.

Results and discussion

Apparent density and fibre length

The apparent density and fibre length of the three species are shown in Table 1. The *A. mangium* appears to be lighter in density and shorter in fibre length than samples of comparable age determined in earlier studies (Logan & Balodis 1982, Peh & Khoo 1982). The *A. auriculiformis* was more similar in density to that studied by Logan and Balodis (1982). However, its fibre length was closer to that of the 20-y-old sample measured by Mohd. Nor *et al.* (1986). Compared to the other two species, the density was very high in spite of its relatively younger age. The density and fibre length of the *Acacia* hybrid lay in between the values for the other two species. The three acacias were therefore characterised by a medium to low density and short fibred structure.

Table 1. Apparent density and fibre length

	A. mangium	*A. auriculiformis*	*Acacia* hybrid
Density ($kg\ m^3$)	403	471	436
Fibre length (*mm*)	0.78	0.84	0.82

Proximate chemical composition

The proximate chemical composition of the three species is given in Table 2. In the case of *A. mangium*, the results are close to those reported by Peh and Khoo (1982) except for the lower content of water solubles (about one third the value) and the higher lignin content (nearly by 8%). The hot water solubles, 1% alkali solubles, alcohol/benzene solubles and lignin content of *A. auriculiformis* were much higher than the values for the same species reported by Mohd. Nor *et al.* (1986). The holocellulose and alpha-cellulose contents were correspondingly lower. This species had the highest lignin content and lowest cellulose content among the three samples. With its high water and alkali solubilities, it would not be expected to be easily pulped and the pulp yield would not be high. The acacia hybrid is more similar in chemical composition to *A. mangium* than *A. auriculiformis*. It appears to have the highest cellulose content and the lowest lignin content and would most probably be the easiest to pulp to give the best pulp yield.

Table 2. Proximate chemical analysis (% based on oven dry wood)

Species	Hot water solubles	Alkali solubles	A/B solubles	Lignin	Holo-cellulose	Alpha-cellulose	Pen-tosans	Ash
A. mangium	3.3	13.4	3.8	27.3	77.7	46.5	14.2	0.20
A. auriculiformis	10.6	24.0	9.7	31.3	65.7	35.0	15.8	1.54
Acacia hybrid	2.5	13.9	3.8	26.6	79.3	47.3	13.4	0.59

Pulping

Table 3 presents the conditions and results of the sulphate pulping conducted on the three species. The samples were pulped to Kappa numbers of around 20 and 35-50 to produce bleachable and wrapping/packaging grades, respectively.

As expected, there was a general reduction in total yield and a distinct decrease in Kappa number with increasing chemical concentration. The changes in yield with Kappa number are depicted in Figure 1.

An active alkali as low as 11% was sufficient to pulp *A. mangium* to produce a high yield of 51.0% at a Kappa number of 34.3. At an active alkali of 10% and less, however, the chips were largely undercooked. It was not necessary to pulp beyond 13% active alkali because at that level the Kappa number had dropped to 18.5 although the yield had improved to 52.0% The yields were not as good as those reported by Logan and Balodis (1982). They were, however, better than those reported by Peh and Khoo (1982) which can be accounted for by the higher holocellulose and alpha-cellulose contents of the present sample.

Table 3. Sulphate pulping conditions and unbleached yields

Species	Cook number	Active alkali (%)	Screened yield (%)	Total yield (%)	Kappa number	Notes
A. mangium	1	10	-	-	-	undercooked
	2	11	51.0	55.8	34.3	papermaking
	3	13	52.0	53.1	18.5	papermaking
A. auriculiformis	4	11	28.7	53.3	48.4	pulping only
	5	13	47.8	48.3	20.8	papermaking
	6	15	44.5	48.6	16.4	pulping only
Acacia hybrid	7	9	-	-	-	undercooked
	8	10	39.0	58.8	41.3	papermaking
	9	11	56.6	58.0	24.2	pulping only
	10	13	55.9	56.1	16.2	papermaking

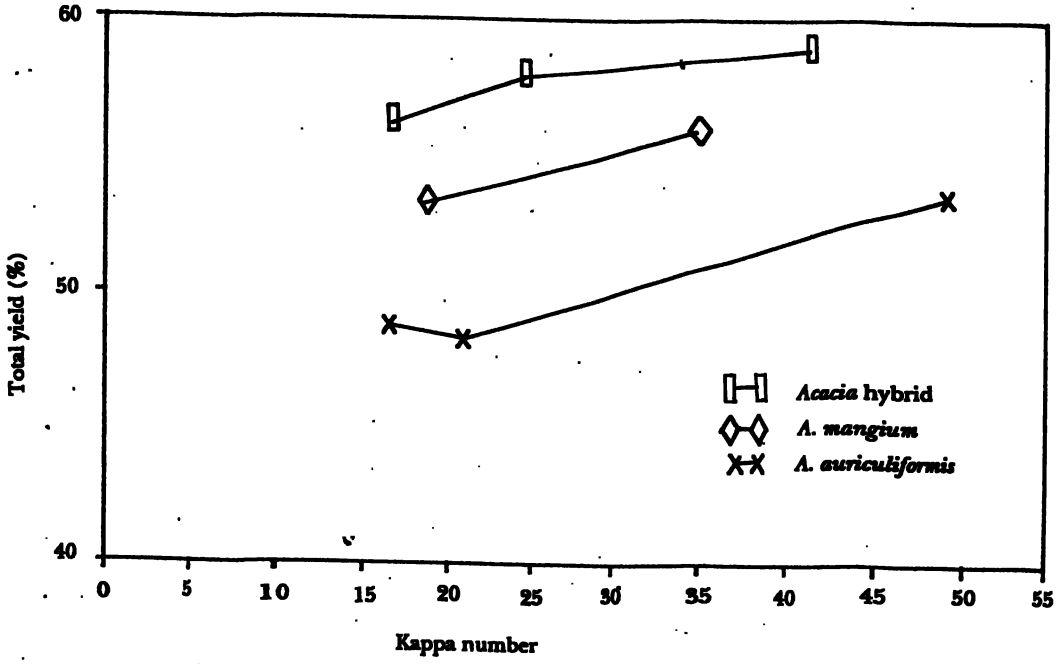

Figure 1. Total yield of sulphate pulps

The *A. auriculiformis* could not be so easily pulped. Although a pulp could be obtained at 11% active alkali, the screened yield at 28.7% was poor and the Kappa number of 48.4 too high. However, a slight increase of the active alkali to 13% gave an overall improvement of results. The screened yield shot up to 47.8% while a drastic drop of Kappa number to 20.8 was observed. It was obvious that increasing the active alkali above 13% was pointless as the pulp would probably be overcooked as shown by the drop in both the yield and Kappa number. In the study by Mohd. Nor *et al.* (1986), it was possible to cook the same species at 11 or 12% active alkali to produce pulps of acceptable yield and Kappa number but at around Kappa number of 20, the yield was not as good as that of the corresponding pulp in the present work.

In contrast to the other two species, the acacia hybrid generally gave better pulping results. It was possible to produce an acceptable pulp at active alkali of as low as 10%. At 11% active alkali the Kappa number had dropped to 24.2 while the yield had improved to 56.6 %. The pulp obtained at Kappa number of 16.2 when the active alkali was raised to 13% was perhaps overcooked but the yield showed only a slight decrease and was still good at 55.9% .

Of the two species and their hybrid, *A. auriculiformis* gave the poorest and the *Acacia* hybrid the best overall pulping results. This can be explained from their proximate chemical composition in which the former had the highest lignin content and the lowest cellulose content in addition to the highest hot water and alkali solubilities ; it was the reverse in the case of the latter which, in addition, also gave the best pulping yield (Figure 1).

Pulp evaluation

The properties of the handsheets made from the pulps of the three species are presented in Table 4 and some of the results are illustrated in Figures 2 to 4.

Table 4. Pulp evaluation

Cook number	Beating (revolution)	Freeness (*Csf*)	Basis weight ($g\ m^{-2}$)	Bulk ($cm^3 g^{-1}$)	Burst index ($kPa\ m^2\ g^{-1}$)	Tensile index ($Nm\ g^{-1}$)	Tear index ($mNm^2\ g^{-1}$)	Folds	Porosity ($s\ 100\ cm^{-3}$)
2	0	617	59.8	1.78	1.7	37	6.9	4	2
	1500	536	60.9	1.57	3.9	62	9.6	25	6
	3000	477	60.6	1.46	5.4	77	10.0	60	10
	6000	396	59.5	1.44	6.5	89	10.0	90	24
	10000	309	60.4	1.42	7.7	98	9.3	302	58
3	0	516	59.0	1.76	2.3	32	8.5	10	3
	1500	517	58.4	1.62	4.0	70	9.1	20	6
	3000	477	58.5	1.51	5.6	77	10.1	52	12
	6000	390	58.5	1.42	6.5	101	9.6	88	34
	12000	230	59.6	1.38	7.6	107	9.6	439	132
5	0	572	60.3	1.89	2.2	39	7.8	8	2
	1500	470	61.3	1.70	3.9	66	9.5	39	8
	3000	421	59.8	1.64	4.9	76	10.0	40	11
	6000	345	59.9	1.55	5.8	88	9.9	115	23
	10000	261	60.8	1.49	6.8	91	10.4	128	63
8	0	637	59.1	1.95	1.6	42	8.2	9	2
	3000	551	58.1	1.65	5.1	81	12.1	79	5
	6000	489	59.4	1.52	6.4	100	11.2	154	10
	9000	393	58.4	1.51	7.7	115	11.6	282	25
	14000	289	59.1	1.44	8.8	135	11.3	612	98
10	0	509	59.7	1.78	1.9	79	11.4	16	6
	3000	417	60.4	1.50	6.2	90	11.0	111	23
	6000	346	60.2	1.47	7.1	100	10.5	196	31
	10000	263	61.3	1.39	8.2	106	9.9	267	89

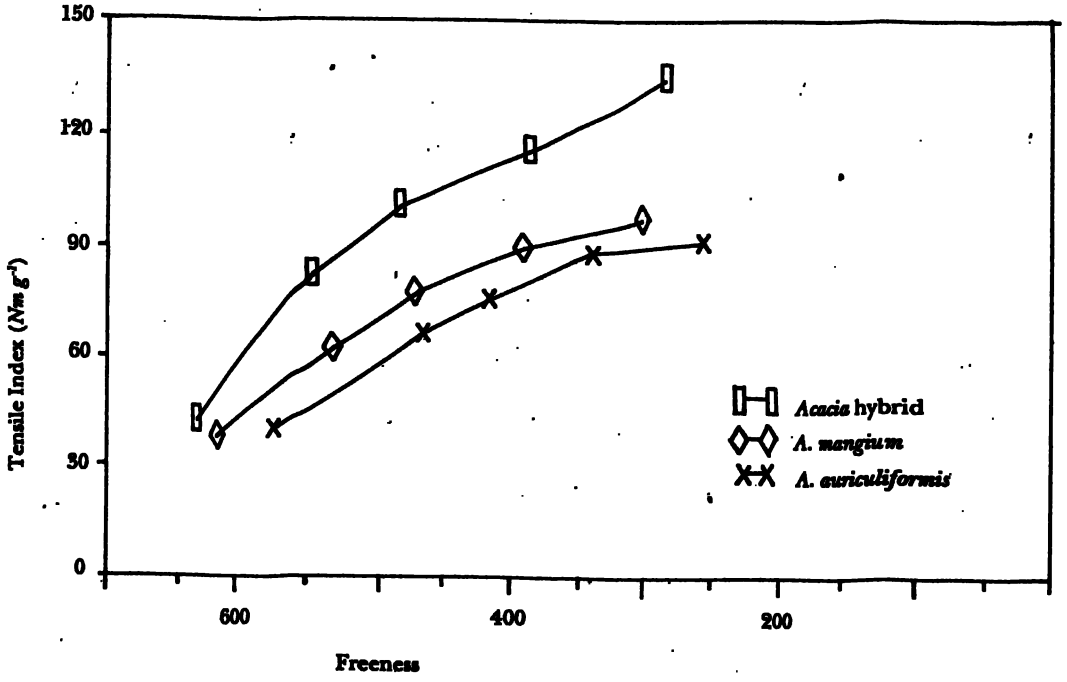

Figure 2. Pulp property (Tensile Index)

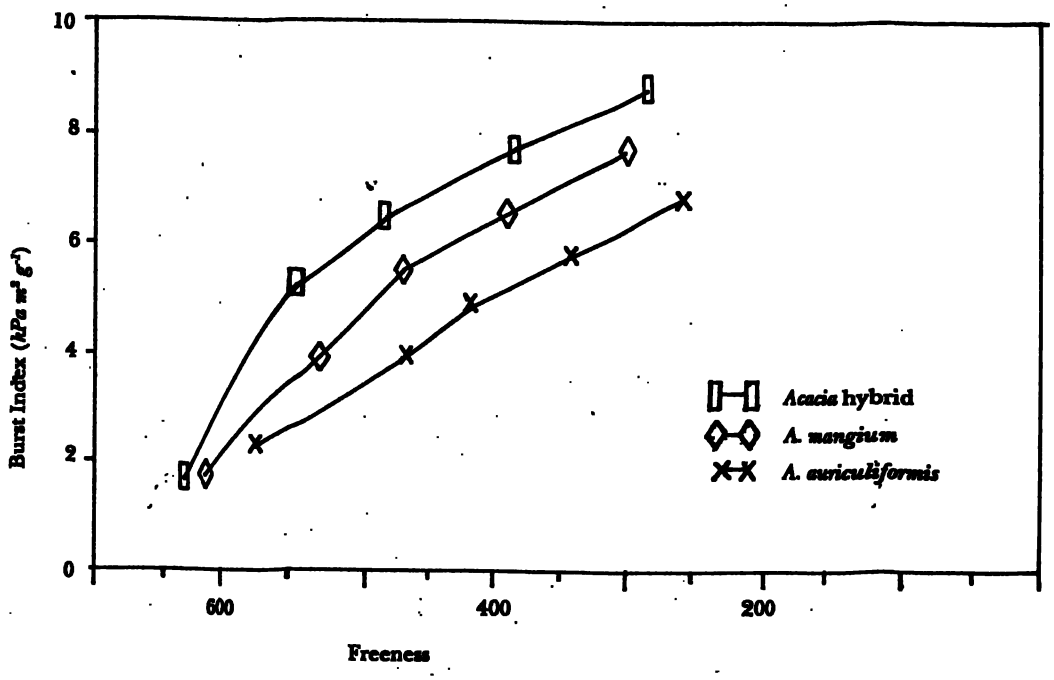

Figure 3. Pulp property (Burst Index)

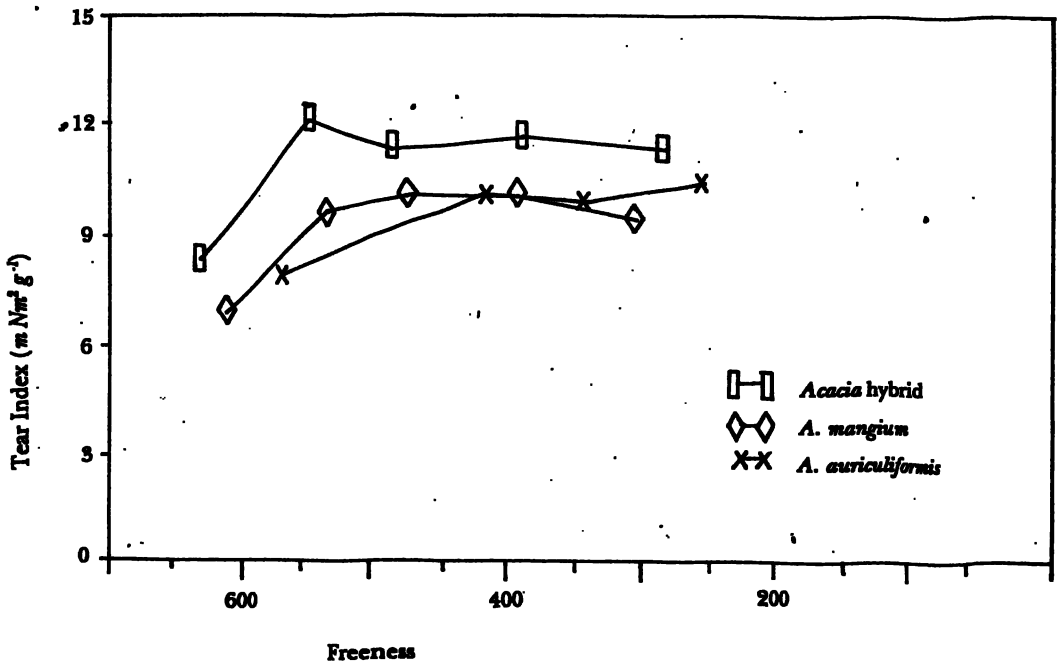

Figure 4. Pulp property (Tear Index)

There are no vast differences in the properties between the two *A. mangium* pulps. Generally, the pulps are similar to those prepared by Peh and Khoo (1982).

Only one pulp from the *A. auriculiformis*, that with Kappa number of 20.8, was evaluated. Compared to the *A. mangium* pulp of equivalent Kappa number, it is generally weaker although differences are not great. However, compared to the *A. auriculiformis* pulps prepared by Mohd. Nor *et al.* (1986), it is very similar to the pulps from the 7-y-old samples except for slightly poorer double folds, but stronger than the pulps from the 20-y-old trees.

The sulphate pulp of the acacia hybrid having the higher Kappa number of 41.3 is clearly superior to the better cooked pulp of Kappa number 16.2 which was possibly a little overcooked. While the latter pulp developed its optimum strength at around 300 *Csf*, the former could still be further beaten for more strength development. On the whole, both pulps are stronger than the corresponding pulps from the other two samples. At high Kappa number, the hybrid pulp is clearly stronger than that of *A. mangium*. At Kappa number of around 20, the hybrid pulp is better than that of *A. auriculiformis* in all respects but almost similar to that of *A. mangium* except for a better tear (Figures 2,3 and 4).

Conclusion

The hybrid of *Acacia auriculiformis* and *A. mangium* has distinct advantage as a pulping material over the parent species. It gives the best yield in the production

of sulphate pulp and surpasses *Acacia mangium* in some strength properties, especially in the tear. It would be worthwhile examining this hybrid further to recommend its wider establishment in pulpwood plantations.

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References

BECKER, E.S. 1987. Evaluation of Samples of *Acacia mangium*, *Eucalyptus deglupta* and *Gmelina arborea* for Kraft Pulping, Bleaching and Paper Strength Properties. *Report to the North Borneo Timbers Bhd.* ECONOTECH Services Ltd. 10 pp.

FAO. 1982. Variation in *Acacia mangium* Willd. Seed Sources Establishment and Tree Improvement Project, Sabah, Malaysia. *FAO/UNDP-MAL/78/009 Consultants Report No. 8.* 41 pp.

GUHA, S.R. & PANT, P.C. 1966. Pulping of *Acacia auriculiformis* A.Cunn. *Indian Forester* 92 (1) : 51 - 55.

KU, Y.C. & CHEN, H.T. 1984. Study on the pulping of fast-growing *Acacia* species. *Taiwan Forestry Research Institute Bulletin* 416 : 1 - 9.

LOGAN, A.F. & BALODIS V. 1982. Pulping and papermaking characteristics of plantation-grown *Acacia mangium* from Sabah. *Malaysian Forester* 45 (2) : 217 - 236.

MITCHELL, B.A. 1963. Forestry and tanah bris. *Malaysian Forester* 26 (3) : 160 - 170.

MOHD. NOR MOHD. YUSOFF, KHOO, K.C., LEE, T.W. & PEH, T.B. 1986. Sulphate pulping of *Acacia auriculiformis* from Peninsular Malaysia. *Malaysian Forester* 49 (1) : 23 - 34.

PEH, T.B. & KHOO, K.C. 1982. Sulphate pulping of *Acacia mangium* and *Cleistopholis glauca* from Sabah. *Malaysian Forester* 45 (3) : 404 - 418.

PHILLIPS, F.H. & LOGAN, A.F. 1976. Papua New Guinea hardwoods : future source of raw material for pulping and papermaking. *Appita* 30 (1) : 29 - 40.

RUFELDS, C.W. 1987. Quantitative comparison of *Acacia mangium* Willd. *versus* hybrid *A. auriculiformis*. Forest Research Centre, Sabah. *FRC Publication No. 40*. 22 pp.

SIM, B. L. 1987. Research on *Acacia mangium* in Sabah : a review. International Workshop, Forestry Training Centre, Queensland, Australia, 4-7 August 1986. *ACIAR Proceedings* 16: 164-166.

THAM, C.K. 1976. Introduction to a plantation species - *Acacia mangium* Willd. Pp. 153-158 in Proceedings of the *6th Malaysian Forestry Conference*, Vol. II Oct. 11-17, 1976. Kuching, Sarawak.

THAM, C.K. 1979. Trial of *Acacia mangium* Willd. as a plantation species in Sabah. *FAO Forest Genetic Resources Information* 9 : 32 - 35.

WISE, L.E. & D'ADDIECO, A.A. 1946. Chlorite holocellulose, its fractionation and bearing on summative wood analysis and on studies on the hemicelluloses. *Paper Trade Journal* 122 (2) : 35.