

Physical And Mechanical Properties of *Acacia mangium* and *Acacia auriculiformis* from Different Provenances

MOHD HAMAMI SAHRI, ZAIDON ASHAARI,
RAZALI ABDUL KADER¹ and ABDUL LATIF MOHMOMD²

Department of Forest Production
Faculty of Forestry
Universiti Putra Malaysia
43400 Serdang, Selangor, Malaysia

¹Golden Hope Plantation Berhad
Oil Palm Research Station
42700 Banting, Selangor, Malaysia

²Forest Research Institute of Malaysia (FRIM)
Kepong, Kuala Lumpur, Malaysia

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ABSTRAK

Penilaian sifat-sifat fizikal dan mekanikal kayu *Acacia mangium* dan *Acacia auriculiformis* dari dua provenan berbeza ia itu Papua New Guinea dan Queensland, Australia telah dijalankan. Tiga sampel pokok yang sihat dari setiap provenan telah diambil dari Indonesia, Malaysia dan Thailand. Objektif utama kajian ini ialah untuk menentukan kesan tapak, spesies atau provenan keatas sifat-sifat kayu ini. Kajian telah dijalankan mengikut piawai BS 373. Keputusan menunjukkan ketumpatan bandingan dan sifat-sifat mekanikal kayu dipengaruhi oleh spesies dan provenan. Sampel dari Indonesia menunjukkan keputusan terbaik berbanding sampel dari Malaysia dan Thailand. *A. auriculiformis* mempunyai sifat-sifat yang lebih baik berbanding *A. mangium*. Kajian ini juga mengesahkan bahawa provenan PNG lebih baik dari Queensland.

ABSTRACT

An assessment of the physical and mechanical properties of *Acacia mangium* and *Acacia auriculiformis* from two different provenances, Papua New Guinea and Queensland, Australia were carried out. Three healthy trees of each species were sampled from Indonesia, Malaysia and Thailand. The main objective of the study was to determine the effect of site, species or provenance on the properties of these woods. The tests were carried out in accordance with British Standard BS 373 Standard. The results showed that the specific gravity and the mechanical properties of the samples were affected by the species and provenances. The Indonesian samples exhibited the best results in terms of both physical and mechanical properties compared to the Malaysian and Thailand samples. *A. auriculiformis* recorded better performance than *A. mangium*. The results also revealed that the Papua New Guinea provenance was superior for both species.

INTRODUCTION

Acacia mangium and *Acacia auriculiformis* are leguminous tree species of the sub-family Mimosoideae. Native to north Queensland, Australia, the trees are also found in Papua New Guinea and the Moluccas Islands of Indonesia. On account of their fast growth, good form and

utilization potential of the timber, these species have been chosen as plantation species in Malaysia.

The assessment of the timber quality may involve the consideration of a large number of anatomical, physical and mechanical properties of wood. Nevertheless, certain features are good

general indicators of timber properties and uses. Though the *A. mangium* has been studied extensively, little information is available about *A. auriculiformis*. Thus the study of wood structure and its relationship to its physical and mechanical properties of these species is important and very timely.

The density or specific gravity (SG) of *A. mangium* varies depending on the origin of the wood. It ranges from 420-483 kg/m³ based on green soaked volume; in dry condition it varies between 500-600 kg/m³ (Logan and Balodis 1982; Peh *et al.* 1982; Peh and Khoo 1984; Wang *et al.* 1989; Razali and Kuo 1991). National Research Council (NRC) (1983) reported that *A. mangium* wood has a specific gravity of 0.56 and the plantation-grown timber recorded slightly lower values (0.40 - 0.45). *A. mangium* wood from the natural stands is normally about 0.6. However Sining (1988) reported a slightly higher SG range from the plantation: 0.43 - 0.47 for 6-year-old *A. mangium* grown in Sabah. Keating and Bolza (1982) noted that *A. auriculiformis* from Indonesia recorded higher mean values for most strength properties than *A. mangium*, which falls under the light hardwood classification with low to moderate strength properties (Razali and Mohd. Hamami 1992).

The timber seasons fairly rapidly without developing serious defects, and responds satisfactorily to preservative treatment. It is fairly easily impregnated with preservatives using standard techniques such as the full-cell pressure method (NRC 1983). The timber planes well and sands easily, producing a lustrous, smooth surface without torn fibres. It also drills satisfactorily and turns well, requiring only low to moderate pressure (NRC 1983). Research has been carried out on the utilization of *A. mangium* timber. Tan (1979), Peh and Khoo (1984), Ong (1987) and Mohd. Zin *et al.* (1991) have studied some of its mechanical and physical properties.

Yong (1984) summarized the mechanical and working properties of *A. mangium* timber in comparison to Light Red Meranti which is in great demand. The specific gravity, modulus of elasticity (MOE) and the hardness value are similar to those of black walnut (*Juglan nigra*), but the modulus of rupture (MOR) and the compression values are somewhat higher than those of walnut. Glue joint strength of *A. mangium* timber was found to be satisfactory (Mohd. Hamami *et al.* 1991b).

Potential Uses of *A. mangium* and *A. auriculiformis*

A. mangium timber makes attractive furniture and cabinets, door frames, window parts, mouldings, and sliced veneers. It is also employed as a light-duty building timber for uses such as framing and weathering board (NRC 1983). In 1983, sawing, plywood manufacture and slicing testings were carried out on 12-year-old avenue-grown acacia trees. The tests showed that there were no physical difficulties in carrying out these various operations. Chan (1983) reported low sawing recovery rate (37 - 40%) for sawn timber production. The low rate could be attributed to four factors: small diameter logs, flutings, knots and heart rot.

Peh *et al.* (1982) reported that pulping of timber from a 9-year-old plantation is easy, giving high yields and good strength properties. Pulping with bark was readily done by a neutral sulphite semi-chemical process and the pulp exhibited very good paper-making properties (Logan and Balodis 1982). The pulp is comparable to that obtained from commercial *Eucalyptus* and is suitable for the manufacture of products such as liner boards, bags, wrapping papers and multiwall sacks.

Because of its density and calorific value (4,800 - 4,900 Kcal/kg), the wood makes good fuel (Mohd. Hamami *et al.* 1991a). Although the species has not been planted on a large scale for firewood, it appears well suited for this purpose. It produces reasonably good charcoal, and it is suitable for the manufacture of wood pellets and activated carbon.

Objectives of the Study

The objectives of this study were:

- i) To investigate the effect of site, species and provenance variation on the physical and mechanical properties of *A. mangium* and *A. auriculiformis* timbers.
- ii) To describe the relationship between the physical and mechanical properties of these timbers.

MATERIALS AND METHODS

Selection of Trees

Three trees of 6-year-old *A. mangium* and *A. auriculiformis* were selected from three different sites namely Serdang, Malaysia (MP01); Bogor, Indonesia (IF01); and a site in Thailand (TS01). The selection was done based on criteria such as bole straightness, absence of excessive defects and good cylindrical form. Their basic mensuration data are shown in Table 1.

TABLE 1
Mensurational data of the sampled trees

Tree	Total height (m)	DBHOB (cm)	Total height (m)	DBHOB (cm)
Site/Provenance	Species			
	<i>A. mangium</i>		<i>A. auriculiformis</i>	
A1: Indonesia/PNG				
1.T1	20.7	23.5	21.5	16.0
2.T2	23.0	20.0	18.4	20.0
3.T3	15.2	16.0	17.3	14.0
A2: Indonesia/Queensland				
1.T1	17.3	17.0	24.0	16.0
2.T2	14.6	17.0	20.3	16.0
3.T3	15.4	18.0	18.2	15.5
B1: Malaysia/PNG				
1.T1	11.4	17.4	4.4	20.8
2.T2	10.1	15.0	11.9	20.0
3.T3	9.0	14.7	-	-
B2: Malaysia/Queensland				
1.T1	-	-	4.1	18.6
2.T2	-	-	3.1	13.3
C1: Thailand/PNG				
1.T1	12.9	15.3	12.5	12.2
2.T2	13.1	14.7	11.4	11.5
3.T3	10.4	12.8	10.4	13.0
C2: Thailand/Queensland.				
1.T1	13.1	15.0	12.9	12.1
2.T2	11.0	14.5	11.6	11.9
3.T3	12.09	13.0	12.5	14.9

DBHOB = Diameter at breast height over bark

Vertical Sampling

Sampling along the length of the trees was done on a fixed percentage basis: at breast height (DBH), at the middle and the top of the clear bole height. The percentages were measured from the stumps, which were kept as uniform as possible.

At each sampling position, two cross-sectional discs, of about 5 cm thick were removed, avoiding obvious knots and other defects. Six discs were removed from each tree (Fig. 1). The upper discs of each section were

used for the anatomical studies, the lower discs for the SG determination. The billets between the sampling points were cut into two-metre bolts and numbered in accordance with the tree number and the position within the tree. These bolts were reserved as physical and mechanical test specimens.

Sample Preparation

The lower, 5-cm thick discs from each height level of every tree were used for the determination of specific gravity (SG), moisture

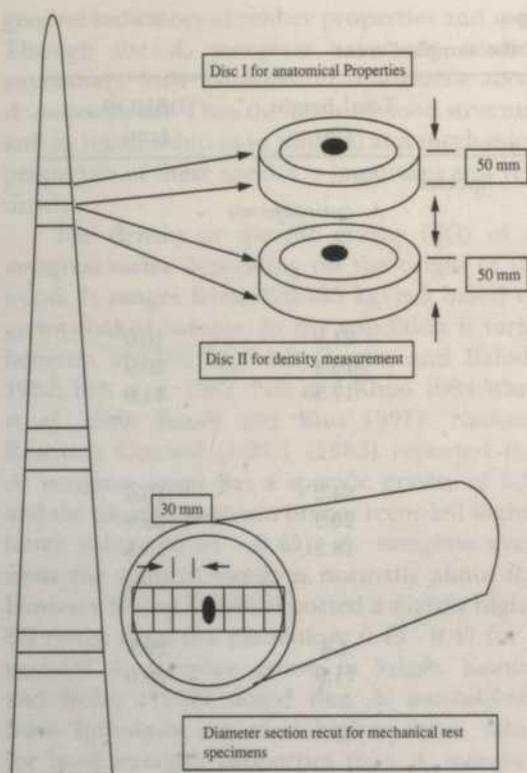


Fig 1. Location of vertical sampling points within a selected tree

content and shrinkage. Three specimen blocks measuring 25 mm in cross section and 13 mm thick were cut from the strips and labelled. Loose fibres in the specimen blocks were removed by rubbing with sand paper; spoilt or defective specimens were rejected. The wood properties determined from each block were SG, moisture content, green to oven-dry radial, and tangential shrinkage.

Specific Gravity Determination

Specific gravity (SG) was determined on a green volume, oven-dry weight basis. The green volume was obtained by the water immersion or displacement method. The saturated blocks were submerged in a beaker placed on an electric balance which recorded the weight of the water displaced. The formula used to calculate the specific gravity was

$$SG = \frac{\text{oven-dry weight}}{\text{weight of the displaced volume of water}}$$

Moisture Content (MC) Determination

The moisture content of the same block was determined by the standard oven-dry method. The green weight was obtained by weighing the saturated blocks after soaking them in the water. The formula to calculate MC, expressed as a percentage, was

$$MC = \frac{\text{Weight of wood} - \text{oven-dry weight}}{\text{oven-dry weight}} \times 100$$

Shrinkage Determination

Specimen blocks were placed in water for four days to attain full green volume. In this water-saturated condition, the radial and tangential dimensions were marked and measured to the nearest 0.02 mm using a dial calliper. The blocks were then air dried for a week and oven-dried at 105°C for 36 hours. The oven-dried blocks were then weighed and the dimensions were measured again along the points marked earlier using the same dial calliper. The green-to-oven-dry shrinkage in radial and tangential directions of the same blocks was determined, expressed as a percentage of the saturated dimension to its oven-dry dimension. The formula used was

$$\text{Shrinkage} = \frac{\text{Change in dimension from saturated size}}{\text{Saturated dimension}} \times 100$$

Mechanical Properties Determination

Each of the 2-m bolts were first sawn in half centred at the pith following the north-south direction. From each half a 35-mm thick plank was sawn from the pith. Each plank was cut into test specimens of 30 x 30 cm in cross-section and 45 cm in length at three different sections along the north-south direction to represent three wood types. The innerwood was cut one centimetre from pith, middlewood was cut at the middle section of pith to bark and the outerwood was cut near the bark.

The test specimens were kiln-dried to 12% MC at 60 ± 5% relative humidity and 25 ± 2°C. The moisture content of the samples was tested every day until it reached 12% when kiln-drying was stopped. It took seven days to obtain the required moisture content.

TABLE 3
Mean values of physical and mechanical properties of two plantation species from different sites

Sites	Physical Properties				Mechanical Properties	
	MC (%)	SG	ST (%)	SR (%)	MOE (MPa)	MOR (MPa)
	Mean Values					
Indonesia	15.54a	0.47ab	4.08a	2.09a	6728a	75.02a
Malaysia	7.79c	0.42b	1.99b	1.27b	6286a	68.15a
Thailand	13.53b	0.55a	3.71a	2.19a	6168a	80.54a

Means within the same column for each property followed by the same letter are not significantly different at $p = 0.05$

Legend:

MC = moisture content (%)

ST = shrinkage (tangential) (%)

MOE = modulus of elasticity (MPa)

SG = specific gravity

SR = shrinkage (radial) (%)

MOR = modulus of rupture (MPa)

In general, the specific gravity values obtained from Malaysia and Indonesia are lower when compared to the value obtained from Thailand. These values were significantly different. The sites also have a significant effect on the mean moisture content and shrinkage values. Being the driest, Malaysian samples recorded the lowest shrinkage values compared to Thailand and Indonesia counterparts.

Statistical analysis (Table 2) showed that site differences in specific gravity are highly significant. The variation may be due to the genetic differences that are inherited in the individual tree. In addition to the genetically controlled effects, differences were also due to the site micro-environment of the growing trees. According to Panshin and de Zeeuw (1980), environmental factors affect the growth of the trees in particular site. The mean temperature and mean annual rainfall may also have some effect on growth and finally to the amount of wood material produced by the tree.

Site Variation: Mechanical Properties

The effect of site on the mechanical properties of these woods are tabulated in Table 3. In contrast to the physical properties, the mean values of MOE and MOR were not affected by the site, and not significantly different at 95% level of confidence. This indicates that these species will show similar strength properties regardless where they are planted. Mohd. Zin *et*

al. (1991) reported that the age and the site have little or no effect on the major strength properties of the *A. mangium*.

Species Variation: Physical Properties

The effect of species on the physical properties of wood is given in Table 4. Variations in wood physical properties especially specific gravity (SG) were greatly influenced by the species. The results revealed that the mean SG of *A. mangium* and *A. auriculiformis* showed significant different at 95% level of confidence. The SG of *A. auriculiformis* in this study was higher than *A. mangium*. The same results were also noted by Keating and Bolza (1982).

However, the moisture content and shrinkage values were not affected by the species. Results from this study showed that mean values of these properties were not significantly different at 95% confidence level.

Species Variation: Mechanical Properties

The effect of species on the physical properties of wood is given in Table 4. The modulus of elasticity (MOE) of *A. mangium* was found to be significantly lower than *A. auriculiformis*. However, the mean values of modulus of rupture (MOR) of these species were not significantly different at 95% confidence level. The strength properties of wood are closely associated with specific gravity. This was also recorded in the results of this study. *A. auriculiformis* recorded

TABLE 4
Mean values of physical and mechanical properties of two different plantation species

Species	Physical Properties				Mechanical Properties	
	MC (%)	SG	ST (%)	SR (%)	MOE (MPa)	MOR (MPa)
Mean Values						
<i>A. auriculiformis</i>	12.94a	0.56a	3.26a	1.91a	6960a	86.90a
<i>A. mangium</i>	11.63a	0.40b	3.26a	1.79a	5828b	62.23a

Means within the same column for each property followed by the same letter are not significantly different at $p = 0.05$

Legend:

MC = moisture content (%)

ST = shrinkage (tangential) (%)

MOE = modulus of elasticity (MPa)

SG = specific gravity

SR = shrinkage (radial) (%)

MOR = modulus of rupture (Mpa)

higher SG values, which were reflected in the MOE and MOR or strength values. From the preceding discussion, it was clear that *A. auriculiformis* has the edge and performed better than *A. mangium*. It has higher specific gravity and strength values.

Provenance Variation: Physical Properties

The effect of genotype or provenance on the physical properties of *A. mangium* and *A. auriculiformis* was also studied. The results are tabulated in Table 5. The mean values show that different properties behave differently. Three

TABLE 5
Mean values of physical and mechanical properties of two plantation species from different provenances

Genotype	Physical Properties				Mechanical Properties	
	MC	SG (%)	ST	SR	MOE (%) (MPa)	MOR (%) (MPa)
Mean Values						
AAPNG	13.68a	0.61a	3.67a	2.29a	7921a	95.23a
AAQ	12.21a	0.52a	2.86b	1.53b	5999b	78.58a
AMPNG	13.56a	0.50a	3.89a	2.23a	7963a	81.30a
AMQ	9.71b	0.31b	2.63b	1.36b	3694c	43.16b

Means within the same column for each property followed by the same letter are not significantly different at $p = 0.05$

Legend:

AAPNG = *A. auriculiformis* from Papua New Guinea

AMPNG = *A. mangium* from Papua New Guinea

AAQ = *A. auriculiformis* from Queensland

AMQ = *Acacia mangium* from Queensland

MC = moisture content (%)

SG = specific gravity

ST = shrinkage (tangential) (%)

MOE = modulus of elasticity (MPa)

MOR = modulus of rupture (MPa)

SR = shrinkage (radial) (%)

provenances (AAPNG, AAQ and AMPNG) recorded no significant differences in the mean values of physical properties, except for radial shrinkage. The only provenance which showed significant difference in mean values of physical properties was AMQ. The mean values from this provenance were significantly lower than the other three provenances.

Provenance Variation: Mechanical Properties

The effects of provenance on the mechanical properties of the wood are tabulated in Table 5. Similar effects were also observed for MOE and MOR of these three provenances. The mean values of MOE and MOR of AAPNG, AAQ and AMPNG provenances were not significantly different at 95% confidence level. The only provenance which showed a significant difference in mean values of mechanical properties was AMQ. The MOE and MOR values from this provenance were much lower than the other three provenances though the moisture content was lower.

CONCLUSION

Few general conclusions could be derived from this study: The specific gravity and the mechanical properties of these timbers were affected by site, species and provenance. Indonesian samples were superior in terms of growth, physical and mechanical properties.

From all sites, *A. auriculiformis* recorded higher physical and mechanical properties and performed better than *A. mangium*. From the results it is clear that Papua New Guinea (PNG) provenances for both species showed better performances in terms of the physical and mechanical properties. On the other hand, provenances from Queensland, Australia did not perform well for both *A. mangium* and *A. auriculiformis*.

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