Introduction

Malaysia started forest plantation trials in the early 1900s with various indigenous and exotic species. Commercial forest plantations only started in the 1950s with the planting of teak in Kedah (Thai 2000). The importance of forest plantation lies in fulfilling the demand of the wood industries and conserving our natural forests (Haron et al. 1997, Thai 2000). According to Abdul Rasip et al. (2004), species selected for forest plantations must fulfill the criteria of high survival and successful growth after planting, good initial growth (height and girth) to reduce impact of weed competition, being tolerant of some shade and site competitions, natural self pruning with a good natural bole, being generally resistant to insect and fungal attacks, and ability to produce timber of good economic value and of general utility. Fast-growing exotic species like *Acacia mangium*, *Gmelina arborea* and *Paraserianthes falcataria* have been planted in the early 1980s. Among these species, *Acacia mangium* is one of the most widely planted with the objective to produce general utility timber (Abdul Rasip et al. 2004). According to Malaysia Timber Industrial Board (Anon 2007), eight species recommended for plantation in Malaysia are *Azadirachta excelsa* (sentang), *Khaya ivorensis* (African mahogany), *Tectona grandis* (teak), *Acacia* spp., *Hevea brasiliensis* (rubberwood), *Neolamarckia cadamba* (kelemayan/laran), *Paraserianthes falcataria* (batai) and *Octomeles sumatrana* (binuang).

*Khaya ivorensis* also known as African Mahogany is an exotic species to Malaysia; first introduced during the late 1950s (Lok & Ong 2002). This species belong to the family Meliaceae which in the same family with many other valuable timber trees such as *Toona* spp., *Azadirachta excelsa*, *Chukrasia tabularis*, *Swietenia macrophylla* and *Cedrela odorata* (Mabberly & Pannell 2007). The growth rates of these species are comparable to those of other fast growing species such as *Acacia mangium*, *Endospermum malaccense* and *Hopea odorata* (Lok & Ong 2002). Plantation of *K.ivorensis* has been established on about 0.3 ha site with the Rengam soil series in FRIM. In Kedah, about 0.04 and 0.02 ha respectively were established in Jeniang (Gajah Mati soil series) and Kulim (Rengam soil series). Other trial plots established were at Trolak, Perak, Gemencheh, Negeri Sembilan and Mata Ayer, Perlis (Lok & Ong 2002).

*Azadirachta excelsa* or locally known as sentang is a fast-growing tree and its characteristics are comparable with those of some popular timbers like meranti, keruing, nyatoh and ramin. This species has good potential as a resource for the furniture industry (Ahmad Zuhaidi & Mohd Noor 2002). Sentang has been planted in a 0.45 ha research plot of FRIM in 1953. Since then the Forestry Department of Peninsular Malaysia has established 400 ha of sentang plantation in Selangor, Kelantan and Perak. A few private companies such as Maju Aik Sdn Bhd in Perak, Farmer Organisation Authority, Negeri Sembilan, KETENGAH in...
Terengganu and SABAPURI Plantation Sdn Bhd, Tawau have shown keen interest in planting this species on a commercial basis (Ahmad Zuhaidi & Mohd Noor 2002). 

*Endospermum malaccense* (sesendok) belongs to the family Euphorbiaceae has been proposed for plantation in Peninsular Malaysia, a good alternative timber for furniture industry (Ahmad Zuhaidi et al. 2002, Khairul et al. 2010). According to Khairul et al. (2010) sesendok has been discovered as an alternative species to overcome the increasing price of rubberwood. This sesendok is extremely easy to be treated with chemicals (fire retardants or wood preservers); it has excellent working and nailing properties (Lim & Chung 2002). Trial plot of sesendok was established at FRIM Kepong. Other plantation plot of sesendok was established at Sungai Buloh Forest Reserve, Selangor (Ahmad Zuhaidi et al. 2002).

*A. mangium* belongs to the family of Leguminosae and this species does not occur naturally in Malaysia. The timber of this species is commonly known as acacia (Lim & Chung 2002). This species was first introduced into Sabah in 1966 as a fire-break species. *A. mangium* has been planted in Peninsular Malaysia since the early 1980s to supplement the demand for timber in the industry. A total of 51 768 ha of *A. mangium* have been planted in Peninsular Malaysia, mainly in the states of Johore, Negeri Sembilan, Pahang and Selangor (Ho et al. 1999). *A. mangium* plantation established in Sabah is used as raw material for pulp and paper industry (Ahmad Zuhaidi 2002).

**Properties, durability and uses**

General characteristics, anatomical, physical, mechanical, wood working and seasoning properties, durability and the uses of the four plantation species viz *Khaya ivorensis* (African mahogany), *Azadirachta excelsa* (sentang), *E. malaccense* (sesendok) and *A. mangium* are presented in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th><em>Khaya ivorensis</em> (African mahogany)</th>
<th><em>Azadirachta excelsa</em> (sentang)</th>
<th><em>Endospermum malaccense</em> (sesendok)</th>
<th><em>Acacia mangium</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Colour of heartwood</td>
<td>Light pinkish brown turning reddish brown on exposure</td>
<td>Reddish brown</td>
<td>Bright yellow, often with a green tinge and darkens to light brown on exposure</td>
<td>Light brown to golden brown, darkening on exposure</td>
</tr>
<tr>
<td>2. Colour of sapwood</td>
<td>Whitish to yellowish</td>
<td>Yellowish white, grayish white or sometimes grey-pink</td>
<td>Sapwood is not differentiated from the heartwood</td>
<td>White</td>
</tr>
<tr>
<td>3. Porosity</td>
<td>Diffuse-porous</td>
<td>Usually a distinctly ring-porous structure, though this is not invariably present</td>
<td>Diffuse-porous</td>
<td>Diffuse-porous</td>
</tr>
<tr>
<td>4. Growth rings</td>
<td>Growth ring were delineated by several rows of tangential flattened fibers and with poorly defined band of boundary (terminal) parenchyma</td>
<td>No distinct or conspicuous growth rings</td>
<td>Growth rings are absent</td>
<td>Growth rings are absent or vaguely present</td>
</tr>
<tr>
<td>5. Grain</td>
<td>Straight or interlocked</td>
<td>Almost straight</td>
<td>Almost straight, shallowly interlocked or slightly wavy</td>
<td>Straight to shallowly interlocked</td>
</tr>
</tbody>
</table>

(continued)
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>6. Texture</td>
<td>Rather coarse</td>
<td>Slightly coarse and uneven</td>
<td>Rather coarse but even with spiral</td>
<td>Moderately fine</td>
</tr>
</tbody>
</table>

### Anatomical properties

1. Vessels
   
   i. Vessel grouping
      
      Occurred singly or in radial groups
      
      Solitary or in multiples of up to 5 or rarely more, clustering common, up to 4–5 vessels
      
      Solitary, predominantly in radial pairs and multiples of 2 to 7 in a series and occasional clusters
      
      Solitary and in radial multiples of 2–3, seldom more
   
   ii. Vessel arrangement
      
      Tendency to arrange in radial series, circular or slightly oval shaped
      
      Tendency to arrange in tangential and radial series of up to 4 vessels and round to oval shaped
      
      Arrange in radial series
      
      Diffuse, generally oval in shape sometimes round
   
   iii. Vessel contents
      
      Some vessels contained red or dark red-stained resin-like substances
      
      Filled with dark-coloured deposits of dried extractives are present in the heartwood
      
      Tyloses and deposit absent
      
      Tyloses generally absent, dark brown deposits present
   
2. Wood parenchyma
   
   Axial scanty paratracheal, axial parenchyma vasicentric, axial parenchyma in marginal or in seemingly marginal bands
   
   Apotracheal and paratracheal parenchyma. Apotracheal parenchyma showed 3–6 cells wide, sometimes more and paratracheal parenchyma occurs mainly as incomplete vasicentric
   
   Regularly spaced apotracheal bands
   
   Mainly as scanty paratracheal to very thinly vasicentric,

3. Rays
   
   Multiseriate rays with 3–5 cells, heterocellular
   
   Multiseriate rays mostly 2–3 cells wide, rarely 4, uniseriate present but rare, heterocellular
   
   Uniseriate and multiseriate rays of 2–3 cells wide, heterocellular
   
   Uniseriate and multiseriate mostly 2 cells wide rarely 3, homocellular

### Physical properties

1. Timber classification
   
   Light hardwood
   
   Light hardwood
   
   Light hardwood
   
   Light hardwood

2. Density (kg/m³)
   
   i. Commercially supply timber
      
      580 to 690
      
      550 to 780
      
      305 to 655
      
      290 to 580
   
   ii. Younger timber
      
      (8-year-old)
      
      416 to 512
      
      (8-year-old)
      
      438 to 547
      
      (12-year-old)
      
      313 to 525
      
      (8-year-old)
      
      350 to 580

3. Shrinkage from green to air dry (%)
   
   i. Commercially supply timber
      
      Tangential - 4.5
      
      Tangential - 1.2
      
      Tangential - 1.3
      
      Tangential - 6.4
      
      Radial - 2.5
      
      Radial - 0.5
      
      Radial - 1.2
      
      Radial - 2.7

(continued)
Table 1 (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
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</tr>
</thead>
<tbody>
<tr>
<td>ii. Younger timber</td>
<td>(8-year-old) (^b) Tangential - 3.1 Radial - 2.0</td>
<td>(8-year-old) (^b) Tangential - 2.7 Radial - 1.8</td>
<td>(12-year-old) (^e) Tangential - 2.5 Radial - 1.8</td>
<td>(9-years-old) (^d) Tangential - 4.4 Radial - 2.6</td>
</tr>
</tbody>
</table>

**Mechanical properties**

1. Commercially supply timber

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Modulus of rupture (MOR) (N/mm(^2))</td>
<td>71−126 (^c)</td>
<td>60 (^f)</td>
<td>81 (^g)</td>
<td>111 (^b)</td>
</tr>
<tr>
<td>Modulus of elasticity (MOE) (N/mm(^2))</td>
<td>8700−10 800 (^c)</td>
<td>6770 (^f)</td>
<td>10678 (^e)</td>
<td>10 764 (^b)</td>
</tr>
<tr>
<td>Compression (N/mm(^2))</td>
<td>37−48 (^c)</td>
<td>31 (^f)</td>
<td>10 (^g)</td>
<td>53 (^h)</td>
</tr>
<tr>
<td>Shear (N/mm(^2))</td>
<td>8−12 (^c)</td>
<td>23 (^f)</td>
<td>6 (^g)</td>
<td>16 (^b)</td>
</tr>
</tbody>
</table>

2. Younger timber

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Modulus of rupture (MOR) (N/mm(^2))</td>
<td>77 (^b)</td>
<td>81 (^b)</td>
<td>48 (^e)</td>
<td>97 (^h)</td>
</tr>
<tr>
<td>Modulus of elasticity (MOE) (N/mm(^2))</td>
<td>7667 (^b)</td>
<td>7099 (^h)</td>
<td>5618 (^e)</td>
<td>10 347 (^b)</td>
</tr>
<tr>
<td>Compression (N/mm(^2))</td>
<td>37 (^b)</td>
<td>38 (^b)</td>
<td>24 (^e)</td>
<td>46 (^h)</td>
</tr>
<tr>
<td>Shear (N/mm(^2))</td>
<td>11 (^b)</td>
<td>13 (^b)</td>
<td>6 (^e)</td>
<td>12 (^b)</td>
</tr>
</tbody>
</table>

**Wood working properties**

- Easy to saw and work, turning, boring, and sanding are all reported to be satisfactory, wood holds nails and screws well and glues satisfactorily \(^i\)
- Generally easy to work, taking a good finish, nailing property is satisfactory, the boring properties are rated as good and planing and shaping as moderately good, glues rather satisfactorily \(^i\)
- Easy to saw and plane and produces a smooth surface, nailing property is excellent \(^d\)
- Easy to work, plain, easy to sand as the surface quality was consistently graded as good to excellent, easy to turn and bore \(^m\)

**Seasoning properties**

- Air dries and kiln dries easily with little degrade, but some warping may occur due to the presence of interlocked grain. Once dry, the wood is fairly stable in service \(^c\)
- The timber seasons fairly rapidly, with only slight twisting and end checking as the main sources of degrade. Boards of 13 mm take approximately two months to air dry, while 38 mm boards take four months \(^j,d\)
- The timber seasons fairly rapidly without serious degrade except for some insect attacks, 13 mm boards take 2 months to air dry, while 38 mm boards take 3 months \(^d\)
- Air drying of 30 mm boards took about 150 days from green to air dry moisture content of about 16.5% and could achieve uniform moisture content throughout the board \(^n\)

**Durability**

- Rated as durable to moderately durable \(^a\)
- Rated as durable to moderately durable \(^d\)
- Non-durable but is extremely easy to treat with preservative \(^d\)
- Non-durable \(^l\)

(continued)
Table 1 (continued)

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</tr>
</thead>
<tbody>
<tr>
<td>Uses</td>
<td>Used for high quality furniture, paneling, cabinet making, superior joinery, turnery, canoes and other decorative works. Suitable for light construction, light flooring, ship building, vehicle bodies, handles, ladders, sporting goods, musical instruments, toys, novelties, precision equipment, carving, turnery and pulpwod.</td>
<td>Suitable for high-class joinery works, furniture manufacture, interior finishing for shops, houses and boat, paneling, partitioning, sliced veneers and plywood, particleboard, medium density fibreboard, flooring, carving, fancy articles and turneries. Suitable for pulp and particleboard.</td>
<td>Is a favoured species for manufacture of match splints and boxes and also suitable for trays, plywood and wooden clogs. Recently, this species has been used as raw material for furniture as an alternative species to overcome the increasing price of rubberwood.</td>
<td>Suitable for light construction work, flooring, linings, mouldings, agricultural tool handles, veneer, plywood, furniture, cabinets, joinery, turning, walking sticks and other light utility purposes.</td>
</tr>
</tbody>
</table>

Source: 
- a. Lok & Ong 2002
- b. Ani & Nordahlia 2009
- c. Lemmens 2008
- d. Lim & Chung 2002
- e. Khairul et al. 2010
- f. Noraini 1997
- g. Lee 1979
- h. Mohammad Omar & Mohd Jamil 2011
- j. Lim et al. 2006
- k. Mohd Nor & Koh 1997
- l. Salmiah et al. 2011
- m. Khairul et al. 2011
- n. Gan & Zairul 2011
- o. Lee 1979
- p. Mohammad Omar & Mohd Jamil 2011
- r. Lim et al. 2006
- s. Mohd Nor & Koh 1997
- t. Salmiah et al. 2011

**Khaya ivorensis** wood disc
Source: Nordahlia (2009)

**A. excelsa** wood disc
Source: Nordahlia (2009)

**E. malaccense** wood disc
Source: Khairul (2010)

**A. mangium** wood disc
Source: Lim & Gan (2011)
Figure 1  Anatomical structure of *K. ivorensis*: (a) transverse section, (b) tangential section, (c) radial section

Figure 2  Anatomical structure of *A. excelsa* (sentang): (a) transverse section, (b) tangential section, (c) radial section

Figure 3  Anatomical structure of *E. malaccense* (sesendok): (a) transverse section, (b) tangential section, (c) radial section

Figure 4  Anatomical structure of *A. mangium*: (a) transverse section, (b) tangential section, (c) radial section
Potential uses of younger plantation species

Based on the density, the 8-year-old K. ivorensis, A. excelsa, A. mangium and 12-year-old E. malaccense could be classified as light hardwood. These timbers are suitable for light duty purposes such as furniture component, joinery works, souvenir items and plywood.

References


MOHAMAD OMAR K & MOHD JAMIL AW. 2011. Mechanical properties. Pp 23–45 in Lim et al. (eds) Properties of Acacia Mangium Planted in Peninsular Malaysia. ITTO Project on Improving Utilisation and Value adding of Plantation Timbers from Sustainable Sources in Malaysia Project No. PD 306/04 (1).


