KFS Journal, Vol. 19(6), 2008: 411-419

Some Physical Properties of 9-Year-Old *Xylia xylocarpa* Planted in Malaysia[1]

Mohd. Hamami Sahri[1], James Josue[2] and Su Kyoung Chun[†3]

ABSTRACT

Xylia xylocarpa is fast-growing trees that are currently planted on trial basis in Sabah, Malaysia. The wood quality of trees grown in Sabah may differ from those grown in other places due to the environmental factors. Five 9-year-old trees of each species were extracted from their respective plots at Luasong, Tawau. Wood specimens were prepared from three height levels; bottom, middle and top, at the inner and outer radial positions. The within-tree and between-tree variations of physical properties of these species were analyzed. The basic density, oven-dry density and green moisture content (MC) are 0.72 g/cm^3, 0.78 g/cm^3 and 49.8% respectively. The shrinkage from green to oven-dry conditions for the radial and tangential directions were 3.35% and 5.76%, respectively.

The trends of within-tree variations for most properties were more consistent in radial rather than vertical direction. This suggests diameter growth to be a more important factor contributing to the variations compared to height. Samples from the outer part of the stem were found to have higher density, shrinkage and mechanical strengths. The between-trees variations of some wood properties were found to be significantly different, probably due to genetic and micro-environmental factors. Significant correlation was recorded among the physical properties of the species. The true potential of *X. xylocarpa* for end-uses would be enhanced by further research such as the study on properties of wood from different sites and other properties like durability, seasoning, processing and machining characteristics. The characteristics of *X. xylocarpa* are comparable to a number of local popular hardwood species, indicating its suitability for heavy construction uses.

Key words: *Xylia xylocarpa*, physical properties, mechanical properties, durability.

INTRODUCTION

Sabah's major commercial timber resources are dwindling and the timber processing industry is desperately searching for additional raw material. In the near future, the supply will be less than 2 million m^3, as the sustainable log production from forest reserves will not exceed 1.5 million m^3 (Chai 1997). In the light of this development, forest plantation has been gaining importance not only for supplying forest products but also for enhancing existing timber resources.

The vibrant plantations of the fast-growing species have helped to provide the wood-based industry with new wood resources. However, these species are generally producing timbers of low density and consequently giving poor mechanical strength properties. Their utilization is restricted

Received for publication: April 12, 2008.
1) Faculty of Forestry, Universiti Putra Malaysia, 43400 Serdang Selangor Malaysia.
2) Forest Research Centre, Sabah Forest Department, Sepiluk Sandakan Sabah, Malaysia.
3) Department of Wood Science and Engineering, College of Forest and Environmental Sciences, Kangwon National University, Chunchon 200-701, Republic of Korea.
† Corresponding author: Su Kyoung Chun (Email: chun@kangwon.ac.kr).

to non-construction uses such as composite, pulp and paper, furniture or light structural which do not require high strength. At the same time, the traditionally used slow-growing tropical hardwoods such as selangan batu, resak, merbau and belian are fast depleting from natural forest. Therefore, it is about time to look for suitable species for replacement.

An early effort has been initiated with the introduction of *Xylia xylocarpa* into Sabah. A trial plot of this species was established in Luasong Forestry Centre, Tawau in 1990. This species belongs to the family of Leguminosae and occurs naturally in India, Myanmar, Indo-china and Thailand. It is reported to grow fairly fast and yields a hard and durable wood suitable for heavy construction in its country of origin. The tree seems to have adapted well with local environment and show high potential to be grown in Sabah. The nine-year-old plantation at Luasong gives a mean diameter at breast height of 26 cm and mean total height of 22 m. However, in selecting tree species for large plantation program, information about the survival and growth of trees alone is not sufficient. The suitability of the species for certain product is largely determined by its wood properties. An evaluation of the commercial potential of this timber in Sabah requires the examination of some of their wood properties.

This study intends to determine some of the wood physical properties of *X. xylocarpa* planted in Sabah namely, moisture content, density and shrinkage. The specific objectives of this study are to determine the wood initial moisture content and its variations between and within the tree and to evaluate wood density and the shrinkage values and its variations between and within the tree.

MATERIALS AND METHODS

Field sampling

Nine-year-old *X. xylocarpa* trees were obtained from Luasong Forestry Centre, Tawau, Malaysia. The area is located at 117° 23' E and 4° 36' N at an altitude of 132 m above sea level. The mean annual rainfall is 2575 mm. The seedlings were line-planted at original spacing of 3 m x 3 m and generally, the site drainage system is good.

Five (5) trees which had fairly straight bole, cylindrical with no sign of mechanical damage or attack by fungi or insects, and grew vertically on flat terrain were selected randomly from the site. Various measurements were conducted on each felled trees. The characteristics of these trees are summarized in Table 1.

Table 1. Characteristics of the sampled trees of *X. xylocarpa*

Tree No.	DBH (cm)	Clear Bole (m)	Total Height (m)
1	25.4	8.9	23.0
2	27.0	9.8	23.5
3	26.5	10.6	23.2
4	24.6	7.9	21.9
5	26.9	7.9	24.5
Average	26.1	9.0	23.2

Processing of test material

Logs

Boards of 30 mm thickness were cut out of the logs 1-3 (Fig. 1). The boards were cut in a way that the pith forms the centre of all boards (Fig. 2). The boards were quarter-sawn. The boards were labeled 1 to 5 representing the tree number, 1 to 3 for log number and 1 to 4 for the board number.

Sticks (30 x 30 mm) from two positions (inner: close to the pith and outer: near to the bark) were cut out of the boards. The sticks were labeled with the tree number, the log number, the board number and the position in tree (inner or outer).

A 15 cm long portion was cut out of each stick and sawn to a size of 30 x 30 mm. One 30 mm long sample and one 100 mm long sample were cut out of these portions. The samples were labeled in the same way as the sticks. These samples served for the determination of the shrinkage characteristics.

Discs

An approximately 3 cm wide strip of wood is cut out of the disc along its diameter. The strip was cut into two. One of the strips, which served for the determination of the oven-dry density, is immediately labeled with the tree and disc number and then oven-dried (103 °C).

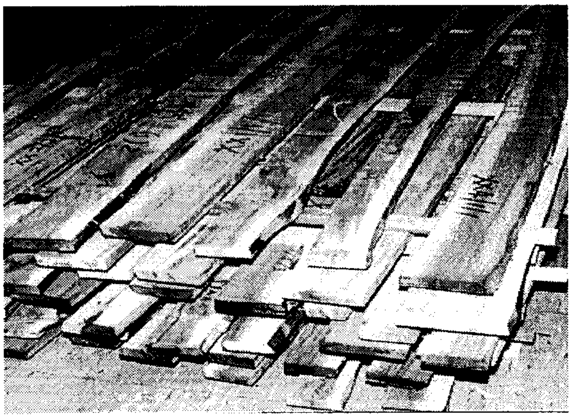

Fig.1. Boards of 30 mm thickness.

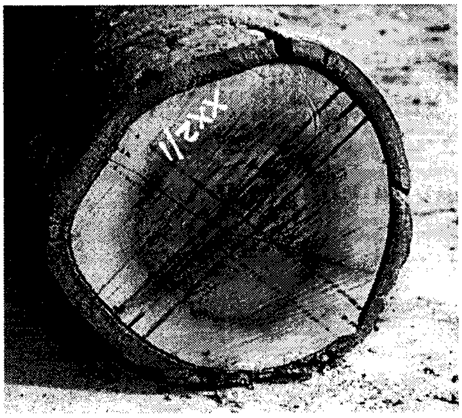

Fig.2. The pith forms the centre of all boards.

Testing physical properties

Most of physical property tests in this study were carried out in accordance with the International Standard Organization (ISO) standard: ISO 3129, ISO 3130 and ISO 3131 (1975) and International Standard Organization ISO 4469 (1981).

Analysis of results

Data obtained from each tree were pooled to compute the overall minimum, maximum, mean, standard deviation and coefficient of variation. Analysis of variance was computed using SPSS Software. The analysis of variance (ANOVA) was used to examine the effects of radial position and height level on various properties measured. Each wood property variable was evaluated independently to determine if variations among sampling height levels and between radial positions were significant. Tukey's Test was carried out to compare the samples to detect significant differences.

RESULTS AND DISCUSSION

The overall results of the physical properties of *X. xylocarpa* evaluated in this study are summarized in Table 2. The green or initial moisture content ranged from 28.47 to 93.54 % and the average was 49.72 %.

Table 2. Physical properties of 9-year-old planted *X. xylocarpa*

Property	Mean Value
Initial MC (%)	49.72
Basic density (g/cm^3)	1.15
Air-dry density (g/cm^3)	0.80
Oven-dry density (g/cm^3)	0.71
Green to Air-dry;	
Radial shrinkage (%)	1.17
Tangential shrinkage (%)	2.37
Volumetric shrinkage (%)	3.15
Air-dry to Oven-dry;	
Radial shrinkage (%)	2.52
Tangential shrinkage (%)	4.06
Volumetric shrinkage (%)	7.32
Green to Oven-dry;	
Axial shrinkage (%)	0.39

In an air-conditioned room (standard climate) the *X. xylocarpa* timber was dried to approximately 12% MC. The mean basic density, air-dry density and oven-dry density were 1.15, 0.80 and 0.71 g/cm^3 respectively. The density values obtained were very close to the reported density value (at 15% MC) in the PROSEA Handbook (Sosef et al. 1998) which ranged from 0.88 to 1.17 (-1.33) g/cm^3. It is a fairly common practice to relate the density to the durability of wood species. The greater the density, the greater the chance of the wood being durable or very durable (Rijsdijk and Laming 1994). The density of *X. xylocarpa* from this study was almost equivalent or within the densities range of most well-known hard durable timbers such as belian (0.84–1.19 g/cm^3), selangan batu (0.85–1.15 g/cm^3), resak (0.66–1.15 g/cm^3) and merbau (0.52–1.00 g/cm^3).

The overall mean radial, tangential and volumetric shrinkage from green to air-dry were 1.17, 2.37 and 6.74 % respectively. The average radial, tangential and volumetric shrinkage from air-dry to oven-dry were 2.52, 4.04 and 7.32% respectively. It is revealed that shrinkage was different in each of the tree principle directions. Tangential shrinkage was about twice as high as that in the radial shrinkage. Desch (1981) has mentioned that the value for tangential shrinkage is usually about twice as high as that in the radial shrinkage.

The ratio and difference of tangential to radial shrinkage from green to air-dry were 2.05% and 1.20 % respectively. These values were small and did not point to a high risk of deformation of wood occurring while drying. Ratios considered to be high were those over 2.2% and the differences to be high were those over 3.0% (Rijsdijk and Laming 1994).

Because the values for longitudinal shrinkage were generally very low, only the values for shrinkage of wood from green to oven-dry were calculated. As expected, the total shrinkage from green to oven-dry at axial (longitudinal) direction was small (0.39%).

Variations in physical properties

Data on the variability of the initial moisture content, density and shrinkage of *X. xylocarpa* is hardly available so far. Table 3 and Table 4 present a summary of the analysis of the overall means of wood physical properties and the variation between height levels respectively.

Table 3. Analysis of variance of physical properties of 9-year-old planted *X. xylocarpa*

Property	Sources of Variation	
	Height level	Radial position
Moisture Content	ns	*
Basic density	*	ns
Green to Air-dry; Radial shrinkage	ns	*
Tangential shrinkage	*	*
Air-dry to Oven-dry; Radial shrinkage	ns	ns
Tangential shrinkage	ns	ns
Green to Oven-dry; Axial shrinkage	ns	*

* - Significant difference ($P < 0.05$)
ns – Non-significant

Initial moisture content

The initial moisture content of *X. xylocarpa* varied between trees from 45.13 to 59.18 %. The moisture in the centre (inner) was significantly higher than that at the periphery (outer) of the stem (Fig. 3). A non-significant difference was observed for moisture content among the tree height levels.

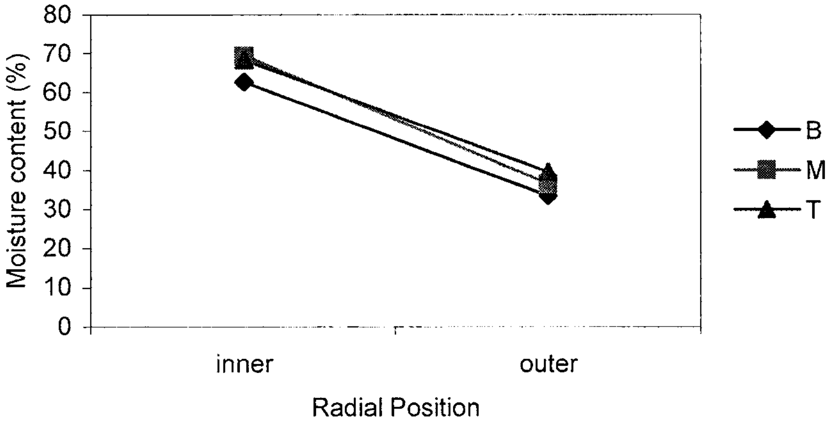

Fig.3. Moisture content at radial positions.

Basic density

The average basic density of different trees varied from 1.09 to 1.18 g/cm^3. A significant decrease of wood density with tree height was observed (Fig. 4). The 1.18 g/cm^3 (inner) and 1.15 g/cm^3 (outer) density at the bottom were dropped to 1.11g/cm^3 (inner) and 1.12 g/cm^3 (outer) at the top level respectively. These changes, however, were small and may not influence the possible utilization of the timber. An insignificant decrease of density from the centre to the periphery of the stem was also observed. This phenomenon is in contrast to many literature, which reported an increase in density from the pith to bark (e.g. Lathsamy 1998; Rita and Ong 1982; Trockenbrodt 1998; Wiemann and Williamson 1989). The low wood density near the pith was due to the formation of juvenile wood (Zobel and Van Buijtenen 1989). Larson (1969) stated that juvenile wood is formed in the early stage of the life of trees, and comprises growth rings that are formed close to the pith. Therefore, a non significant difference of density between the inner (close to pith) and the outer (close to bark) might suggest that this so called juvenile wood was less pronounced in the 9-year-old planted *X. xylocarpa*.

Table 4. Variation of the physical properties between height levels

Property	Height level		
	Bottom	Middle	Top
Moisture content	48.03a	53.02a	53.99a
Basic density	1.12a	1.13a	1.18b
Oven-dry density	0.84a	0.79ab	0.77b
Shrinkage (Green to Air-dry);			
Radial	1.25a	1.15a	1.11a
Tangential	2.05a	2.60b	2.49ab
Volumetric	2.72a	3.43a	3.35a
Shrinkage (Air-dry to Oven-dry);			
Radial	2.44a	2.62a	2.49a
Tangential	4.04a	4.19a	3.93a
Volumetric	7.13a	7.55a	7.27a
Shrinkage (Green to Oven-dry);			
Longitudinal	0.33a	0.41a	0.44a

Means followed by a different letter within a row are statistically different at $P < 0.05$ using Tukey's Test.

Oven-dry density

The density of the oven-dry samples ranged from 0.76 to 0.84 g/cm^3. As with the basic density, the oven-dry density also decreased with tree height level but only a slight change of density was observed in radial position.

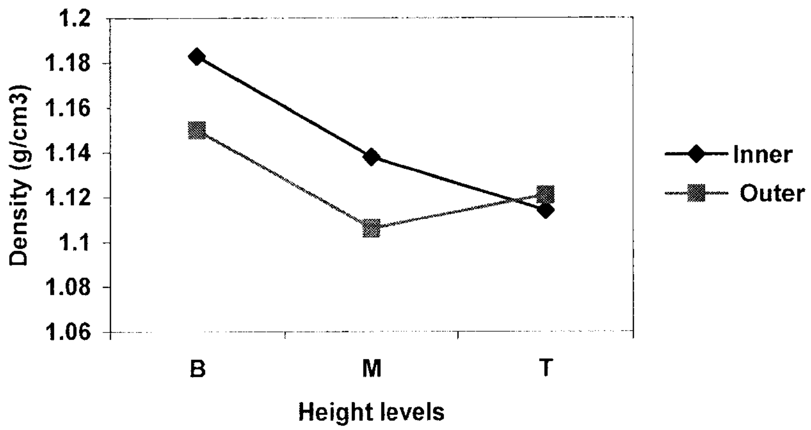

Fig.4. Density at tree height levels.

Shrinkage

Radial shrinkage

The mean radial shrinkage from green to air-dry increased significantly from the centre (0.9 %) to the periphery of the stem (1.36 %) (Fig. 6). However, the increase trend from the centre to the periphery of the stem was not significant for shrinkage from air-dry to oven-dry. The differences in mean radial shrinkage both from green to air-dry and from air-dry to oven-dry were found to be not significant among the tree height levels (Fig. 5a and 5b).

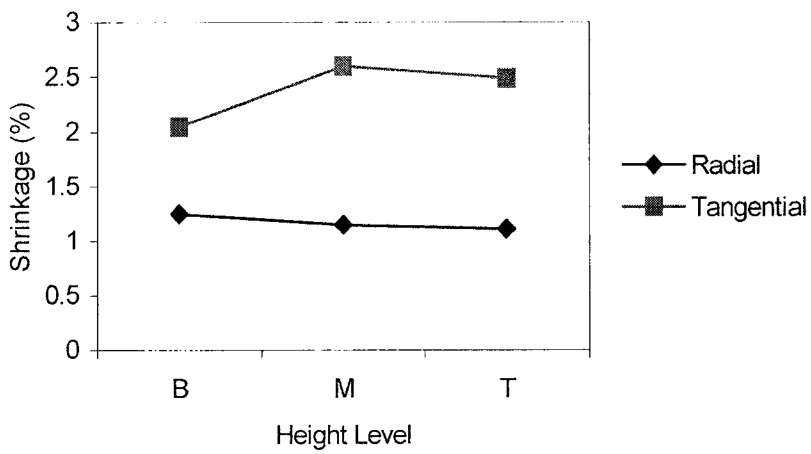

Fig.5a. Shrinkage (Green to Air dry) at tree height level.

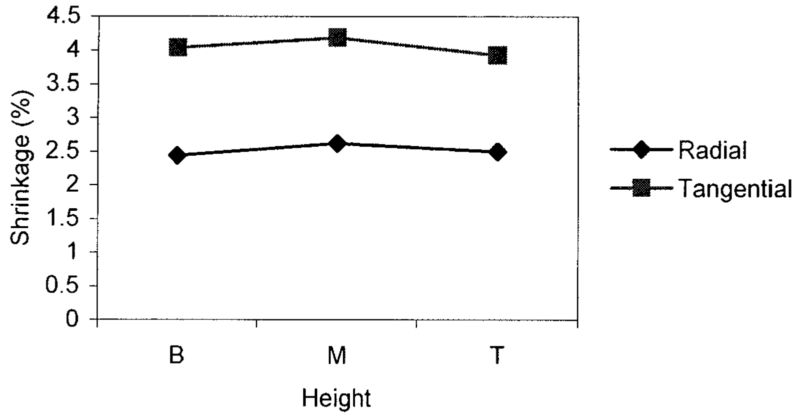

Fig.5b. Shrinkage (Air dry to Oven dry) at tree height level.

Tangential shrinkage

The mean tangential shrinkage from green to air-dry was significantly different among the tree height levels (Figure 5a). It increased from the bottom (2.05 %) to the middle (2.60 %), and then slightly decreased to the top (2.49 %). However, the difference in shrinkage from air-dry to oven-dry among the tree height levels was not significant (Figure 5b). In radial position, the mean shrinkage increased significantly from 1.80 % at the centre to 2.90 % at the periphery of the stem (Figure 6). In contrast, Peck (1933) and Tiemann (1951) reported that sapwood shrinks less than heartwood. However, shrinkage could also be affected by other factor, like bulking of certain extractive in wood (Stamm and Loughborough 1942).

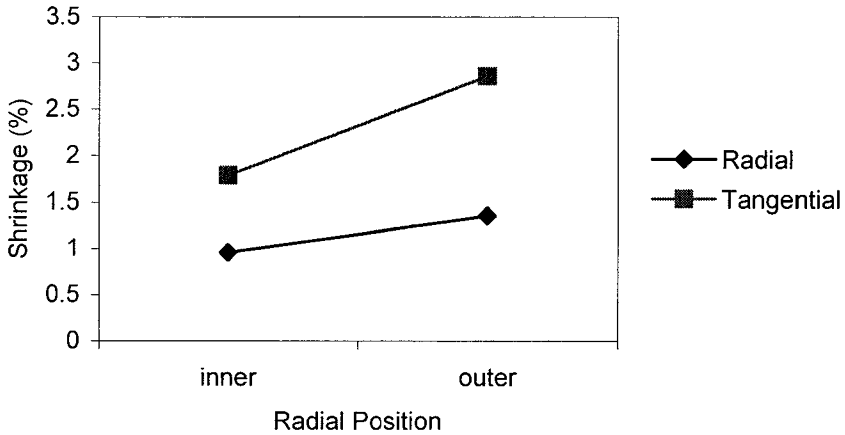

Fig.6. Shrinkage (Green to Air dry) at radial position of the stem.

Axial (longitudinal) shrinkage

The axial mean shrinkage from green to oven-dry was not significant in height levels. In radial position, the mean shrinkage was increased significantly from 0.35 % at the centre to 0.43 % at the periphery of the stem. However, the axial shrinkage was so small that it could be neglected.

CONCLUSION

It is obvious from the present study that young planted *X. xylocarpa* from Sabah is able to produced high density wood which is comparable to the other well- known hard and durable timbers used for heavy construction.

The density variation within the tree was small. Uniformity of wood density is important as large variation can have marked effect on the utilization of the wood.

The shrinkage value did not vary greatly within the tree, and a high risk of deformation of wood during drying was not observed.

However, for more comprehensive discussion on physical properties and their variations, the preliminary findings of this study have to be verified by additional studies on other properties of planted *X. xylocarpa* from Sabah like anatomical properties and mechanical properties.

REFERENCES

Chai, D. N. P. 1997. Implementing sustainable forest management: problems, strategies and implications: In Kugan, F. and W. Kollert (Eds.) Forest Sector Coordination Towards Sustainable Development. Proc. of The Seminar, 4 Sept. 1996, Kota Kinabalu, Forestry Department, Sabah.

Desch, H. E. 1981. Timber: Its Structure, Properties and Utilization. Sixth Edition. MacMillan. London.

International Standard Organisation. 1975. ISO 3129, ISO 3130, and ISO 3131.

International Standard Organisation. 1981. ISO 4469.

Larson, P. R. 1963. Microscopic wood characteristics and their variations with tree growth. Proc. IUFRO, Section 41, Madison. Wis.

Lathsamy, B. 1998. Wood quality of plantation grown *Azadiractha excelsa* (Jack) Jacobs from Malaysia. Phd. Thesis. Faculty of Forestry, Universiti Putra Malaysia, Serdang, Selangor.

Peck, E. C. 1933. Specific gravity and related properties of softwood lumber. US. Dept. Agriculture, Bull. 343 pp.

Rijsdijk, J. F. and P. B. Laming. 1994. Physical and Related Properties of 145 Timbers. Information for Practice. Kluwer Academic Publishers, Netherlands. 380 pp.

Rita, T. and S. H. Ong. 1982. Wood density of *Gmelina arborea* in Sabah. Malaysian Forester. 45(4)

Sosef, M. S. M., L. T. Hong and S. Prawirohatmodjo. 1998. Plant Resources of South- East Asia No. 5(3) Timber Trees: Lesser Known Timbers. Backhuys Publisher, Leiden.

Stamm, A. J. and W. K. Loughborough. 1942. Variation in shrinkaging and swelling of wood A. S. M. E. Trans. Wood Industries (Division). 64: 379-386.

Tiemann, H. D. 1951. Wood Technology. 3rd Edition. Pithman Publishing, New York.

Trockenbrodt, M. 1998. Density variation in Bayur (*Pterospermum* sp.), Randagong (*Trema orientalis*) and Magas (*Duabanga moluccana*) From Sabah, Malaysia. Holz als Roh- und Werkstoff 56: 221-222.

Wiemann, M. C. and G. B. Williamson. 1989. Radial gradients in the specific gravity of wood in some tropical and temperate trees. For. Science. 35: 197-210.

Zobel, B. J. and J. P. Buijtenen. 1989. Wood Variation- Its Causes and Control (Springer Series in Wood Science) Springer, Berlin Heildberg, New York.