PHYSICAL PROPERTIES OF *TECTONA GRANDIS* GROWN IN LAOS

PX Wanneng, B Ozarska & MS Daian

Department of Forest and Ecosystem Science, The University of Melbourne, Victoria 3010, Australia; phongxiong123@yahoo.com

Received April 2013

WANNENG PX, OZARSKA B & DAIAN MS. 2014. Physical properties of *Tectona grandis* grown in Laos. Teak is a valuable species planted in Laos, covering about 15,000 ha. The wood industries in Laos have been using teak wood harvested from different rotation ages ranging from 10 to 30 years. The optimal age of teak used for various high quality wood products is not known. The aim of this research was to assess selected physical properties, namely, density, specific gravity and shrinkage (tangential, radial and longitudinal) of plantation teak of different ages (10, 15, 20 and 25 years) grown in Laos. On average, similar values were observed between wood properties of plantation teak of different ages. The relationship between wood properties and age of trees was not apparent. This suggests that other factors may influence wood properties of plantation-grown teak trees. Wood properties of young teak (10 and 15 years) were not inferior to the ones from older plantation (20 and 25 years). Based on their physical wood properties, 10- and 15-year-old teak would be acceptable for a variety of wood products for both outdoor and indoor uses.

Keywords: Wood property, wood quality, wood science, age, plantation

INTRODUCTION

Plantation forest has been increasingly used for a wide range of wood conversion processes because timber sources from natural forests are deceasing (White et al. 1987). The Laos People's Democratic Republic (hereafter Laos) is a developing country where the demand for both natural and plantation wood is great (Department of Forestry 2007). Teak is grown in plantations in 36 tropical countries although it grows naturally in India, Laos, Myanmar and Thailand.

Teak is considered one of the highest value hardwood and has many uses. Currently, teak trees are cut at different ages. Growers have different opinions on the optimal age of teak for various wood products but little scientific data are available to support these views. In Laos, farmers have been harvesting teak from 10- to 30-year-old plantations. The optimal age of teak for high quality products to ensure maximum timber productivity as well as maximum yield from teak plantation is unknown (Midgley et al. 2007).

There is limited information on properties of teak at different ages of plantation. In India, Jha (1999) reported that teak rotation at 20 years gave the highest beneficial return as well as acceptable wood quality. However, these data have not been verified. Malaysia, Brazil and Costa Rica have been practising teak harvesting rotation at around 20 to 30 years (Perez 2008). Bhat and Priya (2004) reported that teak rotation age was prevalent at 35 years, while the traditional teak plantation rotation was previously 50 years or more. They reported that wood density, dimensional stability and strength properties of 35- and 50-year-old teak were not significantly different. However, there were no scientific figures supporting their statement.

Due to the limited number of studies on the optimal age of teak for various wood products, a study was undertaken to assess selected physical properties of plantation teak of different ages (10, 15, 20 and 25 years) grown in Luangprabang Province, Laos.

MATERIAL AND METHODS

Four ages of plantation teak were selected (10, 15, 20 and 25 years) from private teak plantations in Luangprabang Province, northern Laos. Luangprabang Province is a world heritage area in northern Laos, located between latitudes of 19° 15' N and 21° 10' N, longitudes of 101° 57' E and 103° 38' E and altitudes of 300 to 5000 m above sea level (Kham An 2010). The average rainfall is 1809 mm per annum. The average temperature is 24.8 °C (average minimum 20.36 °C and average maximum 28.65 °C) with average humidity of 80% (highest in August at 83% and lowest in March and April at 67%).

It would be ideal if trees of different ages could be taken from the same location but unfortunately it was not feasible as the majority of teak was planted by smallholders on private farms. Therefore, teak trees of various ages grew at different locations on small private farms. Teak trees for this study were selected from an area 100 ha around one village where soil conditions should be similar but there were differences in landscapes (slope area, flatland and mountainous area). The 10-year-old trees were sourced from mountainous areas while the 15-year-old trees, sloped areas. Twenty-year-old trees were found on flatlands near river banks. There was no 25-year-old teak in the forest plantation site. However, some trees of this age were grown around houses of local people. Accordingly, two of these trees were chosen for testing.

The trees had been planted by seed generation with a spacing of 2 m × 2 m, where no thinning and pruning had been conducted. The trees were chosen for straightness and low incidence of knots, defects as well as insect and disease damages. In total, nine trees were selected and felled, comprising three trees of 10 years old and two trees each from the other age groups (15, 20 and 25 years). The selection of three trees from the 10-year-old plantation was due to the trees being smaller and more trees were needed to prepare specimens required for the tests. All sampled trees were measured and recorded for tree diameter, heartwood and sapwood proportions, boles and total height (Table 1). Small wood specimens were prepared according to the method outlined by Mack (1979). Two logs, each 2 m long, were cut from the bole of each tree, from a height of 1.3 m. Logs were sawn radially into timber boards from which the best samples were selected from random positions in the logs. After sawing, all timber boards were wrapped with plastic to prevent loss of moisture and transported to the University of Melbourne for testing. Wood moisture content (MC), density and specific gravity were determined according to AS/NZS 1080 standards (AS/NZS 2000, 2012). Density assessment was determined for wood at different wood MCs (initial, 17%, 12% and oven dry). Basic wood density is defined as pure wood density after water or moisture content in the wood structure has been removed while specific wood gravity is the ratio of the density of wood to the density of water at 4 °C.

Dimensional stability was tested according to ASTM D143 (ASTM 1994) and the method developed by Kingston et al. (1961). Percentage shrinkages in radial, tangential and longitudinal

Table 1 Details for sampled tress

Age (years)	Girth (cm)	Diameter (cm)	Bole length (m)	Total height (m)	Heartwood proportion (%)	Sapwood proportion (%)
10	46	15	8	13	70	30
	65	21	7	12	58	42
	56	18	8	14	65	35
Mean	55.66	18	7.66	13	64.3	35.7
15	64	20	10	16	78	22
	64	20	10	17	72	28
Mean	64	20	10	16.5	75	25
20	88	28	11	18	80	20
	77	24	11	17	74	26
Mean	82.5	26	11	17.5	77	23
25	98	31	15	20	85	15
	126	40	14	19	79	21
Mean	112	35.5	14.5	19.5	82	18

directions were determined from initial wood MC to 17%, 17 to 12%, 12% to oven dry (0%) MC and from initial MC to 12% MC.

RESULTS AND DISCUSSION

Wood moisture content

Average MC values of plantation teak of different ages at initial conditions (at the time of conducting experiments in Melbourne) were 42% for 10-year-old teak, 37% for 15-year-old teak, 44% for 20-year-old teak and 41% for 25-year-old teak (Table 2). The initial MC values were investigated for the purpose of comparing green MC of different teak ages. It was done to determine the initial MC of samples which were required for testing wood properties such as percentage shrinkage. It would not be possible to compare the green MC of various ages because the trees were felled and sawn at different times. The process of tree cutting, stacking and transporting from Laos to Australia took up till four weeks which resulted in a significant variation in MC even though the timber was wrapped in plastic.

Wood density

The wood densities of plantation teak of different ages were not significantly different. Generally, older trees would have higher wood density values but the results did not confirm this. The mean density at 12% MC of 10-year-old teak was 714 kg m^{-3} while 15-year-old 696 kg m^{-3}, 20-year-old 708 kg m^{-3} and 25-year-old 663 kg m^{-3} (Table 3). However, analysis of variance (ANOVA) (Table 4) showed that the wood density of plantation teak of different ages were significantly different at $\alpha = 0.05$ compared with the statistical probability value ($p = 0.00$). It should be noted that wood density depends not only on the growth rate of tree (age) but also on other factors such as the plantation site (soil), geographic location (plain or hill) and climate (wind and annual rainfall). Another factor affecting wood density is decay which occurs in some plantations. This study showed that teak at ages 10 and 15 years already had properties of a mature tree. This study showed that the wood densities of 10- and 15-year-old trees were slightly higher than the densities of 20- and 25-year-old trees and mature trees in other countries.

Table 2 Initial moisture content (MC) of teak of different ages

Age (years)	No. specimens	Minimum MC (%)	Maximum MC (%)	Mean MC (%)	Standard deviation
10	32	35	47	41.59	3.78
15	28	31	45	36.96	3.98
20	22	37	49	44.34	3.50
25	20	33	47	41.45	4.04

Table 3 Wood densities at different moisture contents and basic teak wood densities

Age (years)	No. of specimens	Initial MC density (kg m^{-3})		12% MC density (kg m^{-3})		Oven dry MC density (kg m^{-3})		Basic density (kg m^{-3})	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
10	56	928.08	87.59	714.42	37.98	675.56	37.27	532.30	30.85
15	42	840.58	106.74	696.89	46.97	664.97	47.61	520.82	38.43
20	50	964.25	76.11	708.54	57.40	676.66	55.80	527.83	42.73
25	56	849.20	100.12	663.98	37.20	633.65	36.33	496.63	30.31

MC = moisture content

Table 4 Analysis of variance for teak of different ages (10, 15, 20 and 25 years)

Property	Interaction	Sum of squares	Df	Mean square	F value	Significant p value
Density (12% MC)	Between group	84238.69	3	28079.56	13.78	0.00 *
	Within group	407461.59	200	2037.30		
	Total	491700.28	203			
Basic density	Between group	41968.20	3	13989.40	11.06	0.00 *
	Within group	252961.85	200	1264.80		
	Total	294930.05	203			
Specific gravity (12% MC)	Between group	0.06	3	0.02	12.18	0.00 *
	Within group	0.33	200	0.00		
	Total	0.39	203			
%Longitudinal shrinkage (initial–12% MC)	Between group	0.09	3	0.03	1.60	0.18 ns
	Within group	3.73	200	0.01		
	Total	3.82	203			
%Radial shrinkage (initial–12% MC)	Between group	0.06	3	0.02	0.91	0.43 ns
	Within group	4.93	200	0.02		
	Total	5.00	203			
%Tangential shrinkage (initial–12% MC)	Between group	0.11	3	0.03	1.24	0.29 ns
	Within group	5.97	200	0.03		
	Total	6.08	203			

*Significant (α = 0.05), ns = not significant

Bhat and Prya (2004) also found that the wood density of plantation teak of ages 13, 21, 55 and 65 years were not significantly different (Figure 1).

Wood specific gravity

Results of wood specific gravity are shown in Table 5 and Figure 2. This study showed that wood specific gravity of 10-, 15-, 20- and 25-year-old teak had similar values. The results were unexpected because normally older trees would have higher values of wood specific gravity. However, as previously mentioned, wood properties depended not only on the growth rate of the tree but also other external environmental factors. A study by Kim et al. (2011) found that site and clone could significantly influence fibre length and wood specific gravity.

Moya and Perez (2008) investigated effects of physical and chemical soil properties on physical wood characteristics of teak plantations in Costa Rica. The study revealed that normal tangential shrinkage and normal radial shrinkage were the most correlated variables with soil characteristics, while the less correlated variables were specific gravity and normal volumetric shrinkage. Soil characteristics (physical and chemical) had no influence on wood properties.

ANOVA showed that the values of wood specific gravity of plantation teak were significantly different at significant value (α = 0.05) compared with the statistic of probability value (p = 0.00) (Table 4). Comparison was made between the specific gravity obtained in this study and the data from Castro (2000) and Negi et al. (2004). The values from plantation teak grown in Laos were not much different from previous studies (Figure 2). The specific gravity of 10-year-old teak was similar to 22-year-old teak. This shows that 10-year-old plantation teak has specific gravity equivalent to mature trees and may be suitable for similar uses.

Dimensional stability

The percentage shrinkage between teak of different ages in the radial, tangential and longitudinal directions were similar (Tables 6 and 7). ANOVA (Table 4) indicated that shrinkage values of teak of different ages were not significantly different at α = 0.05. On average, the tangential section showed the highest shrinkage, nearly double those of the radial section for each age. The longitudinal section had the lowest shrinkage compared with the other two directions.

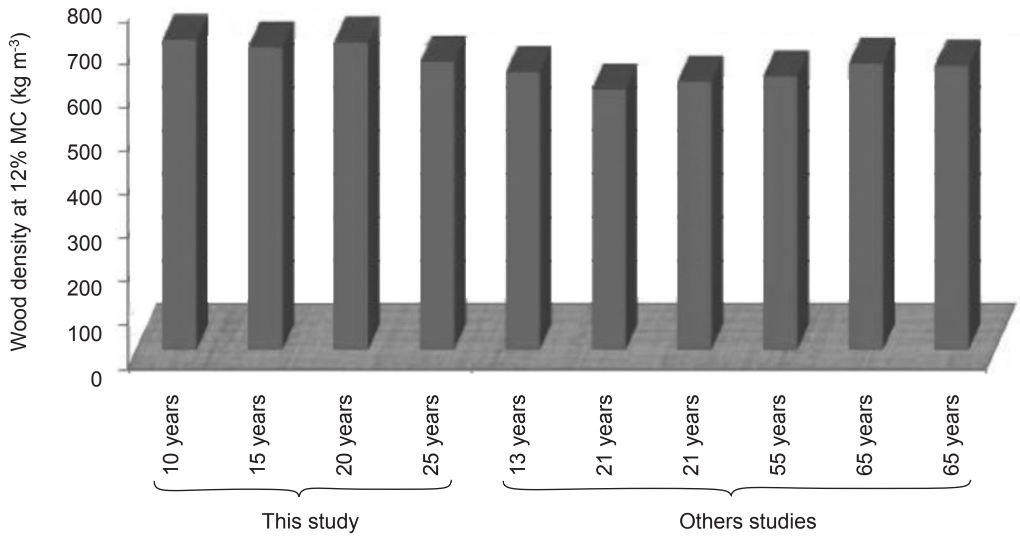

Figure 1 Wood density of plantation teak of different ages obtained in this study compared with densities from other studies (Bhat 1998, Bhat & Priya 2004)

Table 5 Wood specific gravity

Age (years)	No. of specimens	Initial MC		12% MC		Oven dry MC	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
10	56	0.53	0.03	0.64	0.03	0.68	0.03
15	42	0.52	0.03	0.62	0.04	0.67	0.04
20	50	0.53	0.04	0.63	0.05	0.68	0.05
25	56	0.50	0.02	0.59	0.03	0.63	0.03

MC = moisture content

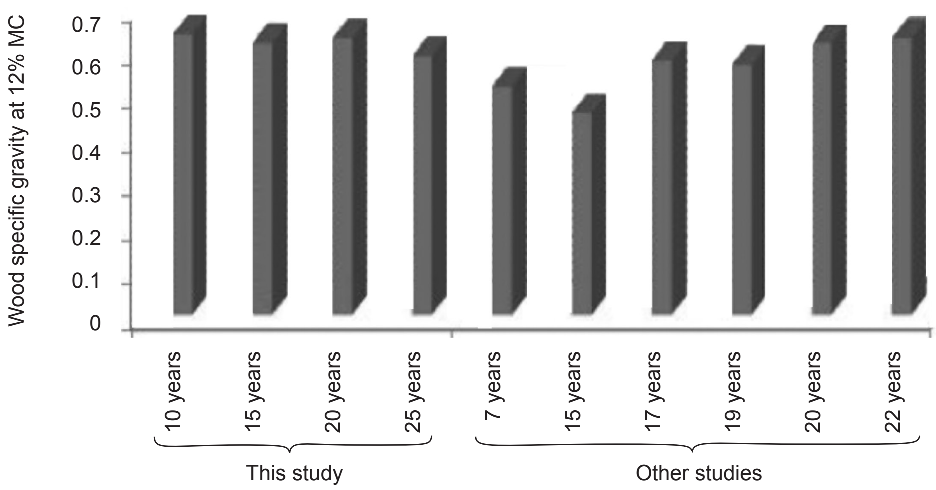

Figure 2 Specific gravity of plantation teak of different ages obtained in this study compared with other studies (Castro 2000, Negi et al. 2004); MC = moisture content

Table 6 Percentage shrinkage in the radial and tangential directions

Age (years)	No. of samples	Radial direction (% reduction)										Tangential direction (% reduction)									
		Initial–17% MC		17–12% MC		12–0% MC		Initial–12% MC		Initial–0% MC		Initial–17% MC		17–12% MC		12–0% MC		Initial–12% MC		Initial–0% MC	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
10	56	1.35	0.11	0.16	0.09	0.61	0.12	1.52	0.15	2.13	0.26	2.46	0.17	0.26	0.11	0.71	0.13	2.72	0.21	3.43	0.26
15	42	1.30	0.10	0.18	0.11	0.67	0.20	1.48	0.18	2.15	0.30	2.42	0.09	0.26	0.12	0.83	0.20	2.68	0.15	3.50	0.26
20	50	1.36	0.10	0.17	0.07	0.70	0.12	1.54	0.11	2.24	0.20	2.49	0.10	0.25	0.07	0.79	0.18	2.75	0.11	3.54	0.22
25	56	1.32	0.12	0.19	0.09	0.65	0.11	1.51	0.17	2.16	0.25	2.46	0.14	0.25	0.10	0.79	0.12	2.71	0.17	3.50	0.22

MC = moisture content; SD = standard deviation

Table 7 Percentage shrinkage in the longitudinal direction

Age (years)	No. of samples	Longitudinal direction (% reduction)									
		Initial–17% MC		17–12% MC		12–0% MC		Initial–12% MC		Initial–0% MC	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
10	56	0.10	0.07	0.08	0.05	0.28	0.09	0.18	0.09	0.46	0.17
15	42	0.14	0.23	0.06	0.06	0.23	0.09	0.20	0.23	0.43	0.25
20	50	0.10	0.06	0.06	0.03	0.22	0.07	0.16	0.06	0.38	0.11
25	56	0.09	0.11	0.06	0.04	0.23	0.06	0.14	0.11	0.38	0.13

MC = moisture content

The most important value in wood shrinkage studies is the shrinkage from initial MC to 12% MC. This value indicates how much a timber will shrink. The data are essential in timber product design processes in order to accommodate potential movement of timber in various service conditions.

The literature revealed that only limited data were available on wood percentage shrinkage of teak of different ages. The results of this study were compared with general (no age was specified) data available on teak wood percentage shrinkages (FAO 1995, Castro 2000, Kham An 2010, Miranda et al. 2011) (Table 8). The comparison showed that the shrinkage values of 10-, 15-, 20- and 25-year-old had similar values to teak studied in other countries.

The results obtained from this study were unexpected as they were not consistent with the common understanding that values of wood properties increased with tree age. This research revealed that there were no significant differences in physical wood properties of teak of different ages.

CONCLUSIONS

Teak of different ages had similar values for the tested properties. The mean values did not show relationship between wood properties and the age of tree. However, ANOVA indicated that the properties of teak were significantly different at the significant value (α = 0.05) except for the wood percentage shrinkage (radial, tangential and longitudinal directions). This suggests that other factors may influence the properties of plantation-grown teak. Therefore, it is highly recommended that future research should determine not only the relationship between wood properties and the growth rate of tree but also external factors such as site (soil, altitude), tree genetics, wind and methods of tree management (thinning and space of planting).

It could be concluded that 10- and 15-year-old teak would be acceptable for a variety of wood products for both outdoor and indoor service conditions for domestic and international markets. However, it is critical that proper processing and manufacturing procedures are applied to allow the products meet international quality requirements, product standards and specifications. Based on the wood property results, rotation age between 10 and 15 years would be suitable for timber harvesting.

REFERENCES

ASTM. 1994. *ASTM D143–94. Standard Test for Testing Small Clear Specimens of Timber.* American Society for Testing and Materials International, West Conshohocken.

AS/NZS. 2012. *AZ/NZS 1080.1 Timber—Methods of Test—Moisture Content.* Standards Australia and Standards New Zealand, Home Bush.

AS/NZS. 2000. *AS/NZS 1080.3 Timber—Methods of Test—Density.* Standards Australia and Standards New Zealand, Home Bush.

Bhat KM. 1998. Properties of fast-grown teak wood: impact on end-use. *Journal of Tropical Forest Product* 4: 1–10.

Bhat KM & Priya PB. 2004. Influence of provenance variation on wood properties of teak from the Western Ghats region in India. *Wood Science* 25: 273–282.

Castro F. 2000. Growth and physical–mechanical properties of 17 year old teak (*Tectona grandis*) growing in Costa Rica. *Agronomia Costarricense* 24: 7–23.

Department of Forestry. 2007. *Forestry Sector Development Report for 2006–2007.* Department of Forestry, Vientiane.

FAO. 1995. Teak for the future. Pp 1–55 in Kashio M & White K (eds) *Proceedings of the Second Regional Seminar on Teak.* 29 May–03 June 1995, Yangon.

Jha KK. 1999. *Teak (Tectona grandis) Farming.* International Book Distributing Co, Charbagh.

Kham An K. 2010. Teak quality in 15 years of age grown at the Forest Research Center (NFEC), Luangprabang Province, Laos. MSc thesis, National University of Laos, Vientianne.

Kingston RST, June C & Risdon E. 1961. *Shrinkage and Density of Australian and Other South-West Pacific Woods.* Commonwealth Scientific and Industrial Research Organization, Melbourne.

Kim NT, Matsumura J & Oda K. 2011. Effect of growing site on the fundamental wood properties of natural hybrid clones of *Acacia* in Vietnam. *Wood Science* 57: 87–93.

Mack JJ. 1979. *Australian Methods for Mechanically Testing Small Clear Specimens of Timber.* Commonwealth Scientific and Industrial Research Organization, Melbourne.

Miranda I, Sousa V & Pereira H. 2011. Wood properties of teak (*Tectona grandis*) from a mature unmanaged stand in East Timor. *Japan Wood Research Society* 57: 171–178.

Midgley SJ, Blyth M, Mounlamai K, Midgley D & Brown A. 2007. *Towards Improving Profitability of Teak in Integrated Smallholder Farming Systems in Northern Laos.* ACIAR Technical Reports No. 64. Australian Centre for International Agricultural Research, Canberra.

Moya R & Perez D. 2008. Effects of physical and chemical soil properties on physical wood characteristics of *Tectona grandis* plantations in Costa Rica. *Journal of Tropical Forest Science* 20: 248–257.

Negi YS, Lal M & Jain VK. 2004. Strength properties variation of plantation teak with age, tree height and locality. *Academy of Wood Science* 1: 40–48.

Perez D. 2008. Growth and volume equations developed from stem analysis for *Tectona grandis* in Costa Rica. *Journal of Tropical Forest Science* 20: 66–75.

White PC, Passauer RW, Porter RD & Keating WG. 1987. *Timber Technology: Wood Properties.* Australian Government Publishing Service, Canberra.

Table 8 Comparison of the results of this study with other studies

Age (years)	Results of our study: Radial direction (% reduction)		Results of our study: Tangential direction (% reduction)		Previous data (age of the plantation teak was not specified): Country	Radial direction (% reduction)		Tangential direction (% reduction)		Reference
	Initial–12% MC	Initial–0% MC	Initial–12% MC	Initial–0% MC		Initial–12% MC	Initial–0% MC	Initial–12% MC	Initial–0% MC	
10	1.52	2.13	2.72	3.43	Costa Rica	2.20	–	3.9	–	Castro (2000)
15	1.48	2.15	2.68	3.50	Thailand	–	2.50	–	5	FAO (1995)
20	1.54	2.24	2.75	3.54	India	–	2.20	–	4	FAO (1995)
25	1.51	2.16	2.71	3.50	Philippines	–	2.20	–	4	FAO (1995)
					Laos	1.45	1.80	4.30	5.44	Kham An (2010)
					East Timor	–	3.50	–	5.17	Miranda et al. (2011)

MC = moisture content