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# Does stand thinning influence wood physical properties? An investigation in a tropical hardwood, *Acacia mangium* Willd

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**Abstract**

Wood properties are influenced by stand management practices like thinning, pruning, etc. The implication of stand management practices on softwoods is well documented. In the case of hardwoods, the response and variation in wood properties due to thinning are still not fully understood. Twenty year old *A. mangium* was subjected to stand thinning at 7th year and the effect of thinning was assessed after 13 years. The wood samples collected from felled trees were analysed based on IS standards. Lack of significant variation between wood physical properties due to thinning intensities was observed. However, enhanced basic wood density which ranged from 530.50 to 602.00 g cm$^{-3}$ for a 20-year-old tree was relatively higher compared to density values reported from younger aged plantations. Further, the increase in heartwood percentage (80.91%), lower moisture content and shrinkage values, all indicated that the prolonging the rotation age in fast growing species like *A. mangium* was more desirable from the utilisation point.

**Keywords:** *Acacia mangium,* Fast growing species, Rotation age, Thinning, Tropical trees, Wood properties.

## Introduction

Fast growing high yielding exotic tree species are being used to meet the wood supply and demand in tropical countries. Plantations are now major sources of wood supply, supplemented by imports in India following a ban on tree felling from natural forests in 1988. Selection of species for plantations are primarily based on productivity and site suitability but emphasis should also be given to the quality and utilisation potential for various end products. *Acacia mangium* is one of the fast growing species introduced in the 1980's and widely cultivated for various end uses. Rapid establishment of the species in humid tropical regions of Kerala occurred after its promotion by His Grace Benedict Mar Gregorius, the then Archbishop of Thiruvananthapuram (Dhamodaran and Chacko, 1999; Newaz et al., 2005; Shanavas and Kumar, 2003). Fast growth, ability to withstand adverse condition and amenability to integrate with other crops are the potential advantages that endear this species (Arisman and Hardiyanto, 2006; Kunhamu et al., 2009; Hegde et al., 2013).

*Acacia mangium* is mainly used for pulpwood production (Peh et al., 1982; Peh and Khoo, 1984; Griffin et al., 2011) with a small percentage used for the production of particle boards, medium density fibre boards (Tomimura et al., 1987) and plywood, as well as fuel wood and charcoal due to its high calorific value [calorific value (4800 kcal kg$^{-1}$ to 4900 kcal kg$^{-1}$)] (Dhamodaran and Chacko, 1999; Sein and Mitlöhner, 2011). *Acacia mangium* as a source of the sawn log has not been appreciated in Kerala due to the need for longer rotation which is usually avoided as it has better economic prospects in a shorter rotation. However, the wood has moderate density (450 - 690 kg m$^{-3}$) and can be seasoned without many defects. It is also amenable

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to preservation for enhanced utilisation (Awang and Taylor, 1993; Shanavas and Kumar, 2003; Krisnawati et al., 2011; Hegde et al., 2013). Fast growth and diverse utilization potential of exotic species can be exploited by better silvicultural practices including thinning. Implication of stand management practices in fast growing species like *Acacia mangium* has not been well understood.

Silviculturists play a critical role in stand management, especially when the goal is to produce large diameter trees for saw log production in the shortest time. This can be accomplished by appropriate stand management practices (Gerrand et al., 1997; Medhurst et al., 2001; West, 2006). One of the management practices used for short-rotation saw log production is to establish them at high density in the initial stages so that land resources are fully utilised (Forrester et al., 2010). Fast growing plantations tend to produce large number of small size stems with close spacing due to competition for resources between individuals (e.g. light, space and nutrients), which increase with tree age (Schönau and Coetzee, 1989; Neilsen and Gerrand 1999). Thinning treatments are necessary and can be carried out at an early age to get interim returns. The remaining trees will grow to better size and fetch higher price. This approach can be exploited for better economic returns from *Acacia mangium* plantations established at close spacing of around 2.5 m x 2.5 m (Awang and Taylor, 1993) and will also reduce defects such as forking of the leader stem and inherent fungal infection (heart rot). Simultaneously, thinning will also have major effects on the growth and wood properties as more space and nutrients are available to the remaining trees after thinning. Some conifers that do not responded to thinning, have been listed in the classic work of Zobel and van Buijtenen (1989). In hardwoods, changes in wood properties in response to thinning is more complex than in softwoods. Thinning can also lead to formation of epicormic branches in the hardwoods which can influence wood properties.

Estimation of wood physical properties like heartwood percentage may help in defining the differences in durability and wood characteristics of the species (Bhat et al., 1985). There are many studies on wood properties of *A. mangium* but no reports on the long term effect of thinning on wood properties.

## Materials and methods

Thinning treatments were taken up during 2002 in a seven-year-old *Acacia mangium* stand planted in August 1995 in an area of about 2 ha at LRS (Livestock Research Station), Thiruvazhamkunnu, [$11^0$ 21’ 30" N, $76^0$ 21’ 50" E; 60m AMSL] in Palakkad district, Kerala, India and the impact of treatments on wood properties was evaluated during 2016-17. The study site has a warm humid tropical climate with a mean annual rainfall of 2600 mm $year^{-1}$ to 3200 mm $year^{-1}$. Mean maximum temperature ranged from 27.3°C to 37.7°C and mean minimum temperature from 17.5°C to 24.3°C. Most of the rainfall was received during the south-west monsoon, i.e., June to August, with an ancillary peak in September to October. Ultimo (very deep, clayey, mixed Ustic Palehumults) type of soil is found at the study site, with pH and bulk density of 5.4 and 0.86 g $cm^{-3}$ respectively. The site has an undulating terrain and general slope in North - South direction. Three thinning treatments of varying intensity were applied along with an unthinned control in plots of size 17.5 x 17.5 m (306 $m^2$) in a randomised block design with four replications.

Thinning treatments:

i) Treatment 1: Thin every third row to retain one-third growing stock (1066 trees $ha^{-1}$)
ii) Treatment 2: Thin alternate diagonal row to retain half the growing stock (800 trees $ha^{-1}$)
iii) Treatment 3: Thin alternate rows and alternate trees in every other diagonal row to remove two-third growing stock (533 trees $ha^{-1}$)
iv) Treatment 4: No thinning (Control) (Retaining 1600 trees $ha^{-1}$)

Morphometric parameters like height, dbh, and crown spread were estimated for the standing trees in all experimental plots, and based on the dbh measurement, two trees per treatment plot were selected randomly (Shujauddin and Kumar, 2003). A total of 32 trees were felled and stem cross-sectional samples were collected at 0.15m, breast height level (1.37 m from ground level), at 50% commercial bole height and at bole height for all trees. Firstly the heartwood area and sapwood area ($m^2$) were estimated using the digimizer software (Version 4.6.1) using a digital photograph of each sample taken along with a calibrated ruler (± 0.5 mm). After the heartwood area and sapwood area estimation, the samples were used for assessing the physical properties i.e., basic density, moisture content, shrinkage (LS and RS) and volumetric shrinkage in accordance with IS: 1708 standards of BIS (1986). Analysis of variance (ANOVA) was carried out using SPSS V.22.0. Duncan's Multiple Range Test was used to test the differences among treatment means. Heartwood percentage, sapwood percentage and heartwood to sapwood ratio along different axial positions were subject to two-way ANOVA and other parameters were subjected to one-way ANOVA.

## Results and discussion

*Wood physical properties*

Basic wood physical properties such as basic density, moisture content, volumetric shrinkage, radial, tangential and longitudinal shrinkage were assessed and data are presented in Table1.

The basic density value ranged from 530 kg $m^{-3}$ (two-third thinned plot) to 600 kg $m^{-3}$(unthinned plot). Analysis of variance conducted revealed that there was no significant difference in basic density between thinning treatments. The mean basic density for 20-year-old *Acacia mangium* was 570.50 kg $m^{-3}$. No effect of treatments on the wood moisture content was observed even though the values ranged from 40.05 % (two-third thinned plot) to 32.99 % (one-third thinned plot) with a mean value of 37.51%. The volumetric shrinkage values ranged from 7.32 % (unthinned plot) to 11.82 % (half thinned plot). Analysis of variance did not indicate any significant difference in volumetric shrinkage (VS) between treatments. Neither did the other measurements of shrinkage i.e., tangential, radial and longitudinal shrinkage show any statistically significant difference between the treatments. The mean values of tangential, radial and longitudinal shrinkage for 20-year-old *Acacia mangium* were 6.75 %, 4.30 % and 1.15% respectively.

*Heartwood and sapwood percentage*

The heartwood proportion ($cm^2$) at breast height (1.37m) of 20-year-old *A. mangium* ranged from 229.95 to 961.44 $cm^2$ (mean of 488.31$cm^2$) i.e., 80.91±1.11 %. The trend line representing the

*Table 1*. Effect of stand thinning on wood physical properties of 20-year-old *Acacia mangium* trees at Thiruvazhamkunnu, Kerala

| Treatments | Basic density (kg $m^{-3}$) | VS (%) | LS (%) | RS (%) | TS (%) | MC (%) |
|---|---|---|---|---|---|---|
| Unthinned | 602.00 | 7.32 | 1.44 | 3.89 | 6.48 | 40.05 |
| | (89.45) | (1.21) | (0.69) | (1.19) | (1.63) | (10.43) |
| One-third thinning | 572.25 | 10.10 | 0.90 | 4.82 | 7.87 | 32.99 |
| | (53.13) | (2.71) | (0.44) | (1.35) | (1.96) | (7.23) |
| Half thinning | 577.25 | 11.82 | 0.40 | 3.98 | 6.14 | 38.38 |
| | (34.86) | (3.43) | (0.34) | (0.88) | (1.53) | (4.04) |
| Two-third thinning | 530.50 | 10.33 | 1.88 | 4.53 | 6.51 | 38.62 |
| | (47.06) | (1.11) | (2.28) | (1.05) | (2.89) | (7.79) |
| Mean | 570.50 | 9.89 | 1.15 | 4.30 | 6.75 | 37.51 |
| | (25.67) | (1.63) | (0.56) | (0.44) | (0.66) | (3.10) |
| p-value | ns | ns | ns | ns | ns | ns |

VS-Volumetric shrinkage; LS-Longitudinal shrinkage; RS-Radial shrinkage; TS-Tangential shrinkage; MC- Moisture content
(Values in parentheses are standard deviation) (Values with the same superscripts do not differ significantly within a column)

proportion of heartwood area increased slightly with an increase in thinning intensity, with the same trend followed in the case of the sapwood too (Figs. 1a and 1b). Plotting the heartwood and sapwood area ($cm^2$) against DBH (cm) showed that the increment in sapwood area with reference to DBH was not similar to that of heartwood area increment (Fig. 2). Even though,there was an increase in heartwood area with thinning intensity, the analysis of variance (two-way ANOVA) did not show any statistically significant difference between treatments in both heartwood and sapwood percentage (Tables 2 and 3). However, with reference to axial position, the heartwood percentage significantly increased from the bottom to the top of the stem and vice-versa in the case of sapwood percentage (Fig. 3).

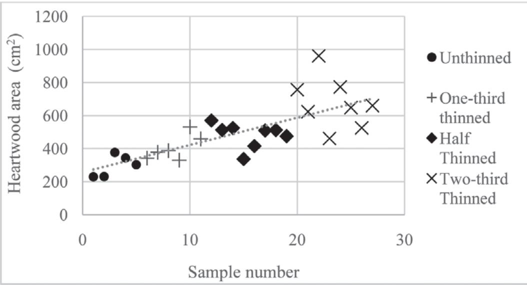


Figure 1a. Variation in heartwood content across thinning intensity

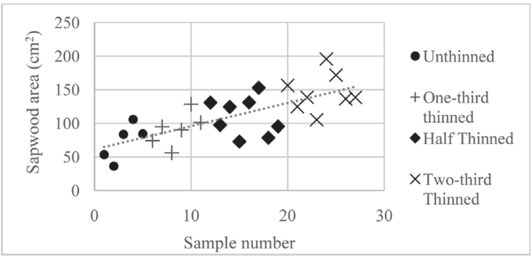


Figure 1b. Variation in sapwood content across thinning intensity

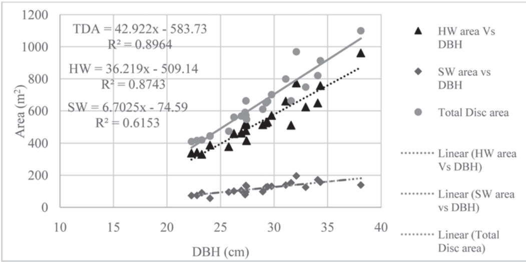


Figure 2. Total, heartwood, and sapwood area with DBH of 20-year-old *Acacia mangium* subjected to stand thinning

*Heartwood to sapwood ratio*

The heartwood to sapwood ratio was estimated at the different axial positions for the four different thinning treatments (Table 4). Analysis of variance (two- way ANOVA) revealed that across thinning treatment, there was no statistically significant variation. Similarly, in reference to the axial positions, the heartwood to sapwood ratio was statistically different in all thinning treatments ($p < 0.000$).

Wood physical properties did not vary significantly with thinning. However, the decline in basic density

*Table 2.* Effect of stand thinning on heartwood percentage of 20-year-old *Acacia mangium* trees at Thiruvazhamkunnu, Kerala

| Treatments | Heartwood percentage (%) | | | | | |
|---|---|---|---|---|---|---|
| | One-third thinning | Half Thinning | Two-third thinning | Unthinned | Mean | p-value |
| Axial positions | | | | | | |
| At stump (0.15m) | 82.42 | 83.37 | 81.11 | 81.90 | 82.20[a] | |
| | (1.76) | (4.20) | (1.34) | (3.09) | (2.67) | |
| At DBH (1.37m) | 79.84 | 81.37 | 82.27 | 80.18 | 80.92[a] | |
| | (2.77) | (3.58) | (2.53) | (3.03) | (2.87) | 0.000 |
| At 50 % of commercial bole height | 78.32 | 79.73 | 77.73 | 74.25 | 77.51[b] | |
| | (2.51) | (3.92) | (1.67) | (4.53) | (3.65) | |
| At commercial bole height | 70.90 | 74.35 | 72.67 | 70.25 | 72.04[b] | |
| | (5.07) | (4.87) | (3.84) | (4.29) | (4.39) | |
| p-value | | | 0.111 | | | |

(Values in parentheses are standard error of means)(Values with the same superscripts do not differ significantly within a column)

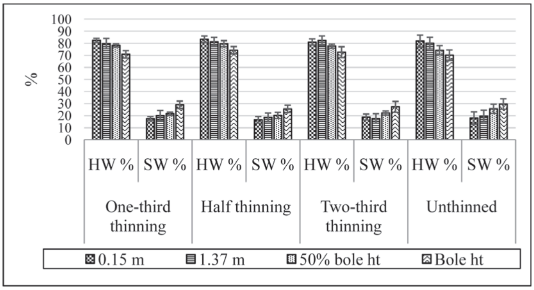


Figure 3. Heartwood and sapwood percentage across different thinning treatments and different axial positions

value in the thinned plots compared to that of the unthinned plot could be attributed to opening up tree canopy which increased the rate of growth, but it was not statistically significant (Evans and Turnbull, 2004; Wistara et al., 2016). Wood density in a heavily thinned *Acacia salicana* stand was reported to be 3.8% less than that of unthinned plot (Hegazy et al., 2014). However, the effect of thinning is presumed to be of temporary nature and many studies have indicated that wood basic density is not significantly influenced by thinning. Wood density did not vary in a 22- year old *Eucalyptus nitens* stand which was thinned six years after planting (Medhurst et al., 2012). In another work, Lin et al. (2012) concluded that row thinning in 24-years old *Cryptomeria japonica* did not significantly influence wood physical and mechanical properties. However, wood properties of *Cupressus lusitanica* in Tanzania did respond to different thinnings (Malende and Ringo, 1987).

In India, thinning schedules in teak did not bring in any influence on wood properties including

*Table* 3. Effect of stand thinning on sapwood percentage of 20-year-old *Acacia mangium* trees at Thiruvazhamkunnu, Kerala

| Treatments | Sapwood percentage (%) | | | | | |
|---|---|---|---|---|---|---|
| | One-third thinning | Half Thinning | Two-third thinning | Unthinned | Mean | p-value |
| Axial positions | | | | | | |
| At stump (0.15m) | 17.59 | 16.63 | 18.89 | 18.11 | 17.80[c] | |
| | (1.76) | (4.20) | (1.34) | (3.09) | (2.67) | |
| At DBH (1.37m) | 20.16 | 18.63 | 17.73 | 19.82 | 19.08[c] | |
| | (2.77) | (3.58) | (2.53) | (3.03) | (2.87) | 0.000 |
| At 50 % of commercial bole height | 21.68 | 20.27 | 22.27 | 25.76 | 22.49[b] | |
| | (2.51) | (3.92) | (1.67) | (4.53) | (3.65) | |
| At commercial bole height | 29.10 | 25.66 | 27.33 | 29.75 | 27.96[a] | |
| | (5.07) | (4.87) | (3.84) | (4.29) | (4.39) | |
| p-value | | | 0.078 | | | |

(Values in parentheses are standard error of means)(Values with the same superscripts do not differ significantly within a column)

*Table 4*. Effect of stand thinning on heartwood to sapwood ratio of 20-year-old *Acacia mangium* trees at Thiruvazhamkunnu, Kerala

| Treatments | Heartwood to Sapwood ratio | | | | | |
|---|---|---|---|---|---|---|
| | One-third thinning | Half thinning | Two-third thinning | Unthinned | Mean | p-value |
| Axial positions | | | | | | |
| At stump (0.15m) | 4.735 | 5.300 | 4.315 | 4.750 | 4.75[a] | |
| | (0.624) | (1.528) | (0.397) | (0.950) | (0.95) | |
| At DBH (1.37m) | 4.038 | 4.513 | 4.730 | 4.355 | 4.36[a] | |
| | (0.744) | (1.001) | (0.848) | (0.819) | (0.82) | 0.000 |
| At 50 % of commercial bole height | 3.665 | 4.068 | 3.513 | 3.553 | 3.55[b] | |
| | (0.605) | (0.916) | (0.354) | (0.720) | (0.72) | |
| At commercial bole height | 2.530 | 3.018 | 2.713 | 2.668 | 2.67[c] | |
| | (0.703) | (0.858) | (0.500) | (0.632) | (0.63) | |
| p-value | | | 0.120 | | | |

(Values in parentheses are standard deviation)(Values with the same superscripts do not differ significantly within a column) heartwood percentage, specific gravity and density (Tewari, 1999). Pérez and Kanninen (2005) concluded that impact of thinning on the wood properties such as heartwood percentage and density tended to be temporary in nature and in the long run, the effect got nullified, based on their work on different thinning schedules in teak plantations of Costa Rica. So, the effect of thinning after a long period got subdued. In the present study, thinning was carried out about 10 years earlier which was the reason for lack of effect on wood properties. The other physical properties followed the same trend of basic density. This was further supported by the findings of Zhang (1995), who aimed to understand the effect of growth rate on wood specific gravity and mechanical properties in softwood, diffuse porous wood and porous wood. The study revealed that the diffuse porous wood was very little influenced by an enhancement in growth rate while the porous wood was least influenced. Similar sort of findings has also been reported in *Swietenia macrophylla, Khaya senegalensis* and *Paulownia fortunei,* where increased growth rate did not influence wood properties (Perera et al., 2012). *A. mangium* being a diffuse porous wood (Anoop et al., 2012), the enhancement in the growth rate had very little influence on the wood properties.

On the whole, the mean basic wood density for 20-year-old *Acacia mangium* was 575.50 kg $m^{-3}$which was higher than the value reported for a 14-year-old stand in similar site condition to that of the present study (Jago, 2015). The basic density value showed an increasing trend with an increase in age following a similar trend to the results of Chowdhury et al. (2005). Many other studies in other species have reported an increase in density with increase in age (Young, 2000; Lim and Gan, 2011). The pioneering work on wood properties of *Acacia mangium* in Kerala was by Dhamodaran and Chacko (1999). They have stated that lack of mature trees for wood property estimation was the shortcoming in their study. The present study has sorted out this shortcoming.

Wood density parameter can vitally shed some light on the other wood features including mechanical properties as it has a direct relationship (Hegazy et al., 2014). For instance, Yang and Evans (2003) predicted the MOE of Eucalyptus using the density and microfibril angle as parameters. Hence the increase in the density of 20-year-old *Acacia mangium* wood should significantly enhance the structural utilisation of the wood.

The higher moisture content compared to other Acacia species has been one of the curtailments in the utilisation of *A. mangium.* This has been commented as wet-heartwood (Yamamoto et al., 2003) or as soft core (Dhamodaran and Chacko, 1999), which may fall apart and cause hollow holes in the heartwood. This is a negative trait with regard to utilisation. However, all these reports are from a young *Acacia mangium* stand of age around 8 to 14 years. In the present study, the mean moisture content (37.51±3.1) was relatively very low compared to the values reported from the previous studies. Further, there was relatively less incidence of the soft core in the disc that was dried. The shrinkage values were also lower compared to the results published from humid tropics as well as other parts of the globe.

*Heartwood and sapwood percentage*

The increase in heartwood across treatments as shown in Fig. 1a was an implication of the diameter increment due to thinning, revealed in Fig. 2. Even though the gradual increase in DBH due to thinning treatment has directly impacted the heartwood area, the heartwood percentage and heartwood to sapwood ratio was not influenced by thinning treatment. Hence, it was clear that the thinning had no implication on the heartwood production. The heartwood percentage decreased on moving up, with increase in the axial position. This was an expected usual trend. A study by Lim and Gan (2011) in 16 and 20-year-old *A. mangium* plantations in Malaysia also concluded that the sapwood percentage increased with an increase in height. This indicated that sapwood-heartwood percentage followed a particular pattern (Fig. 1b).

The results from the present study indicates that there is scope for using Mangium wood for structural timber purpose. The wood of *Acacia mangium* has so far been only focused as raw material for pulp and paper. However, there are several issues in the utilisation of *Acacia mangium* for structural purposes. A better suited silvicultural management regime has to be designed so that the thinned materials from *Acacia mangium* plantation can be used for pulpwood purpose and the remaining trees can be used for the structural purpose.

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