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Research Article

# Evaluation of some wood quality measures of eight-year-old *Melia azedarach* trees

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**Abstract:** This study investigated the wood quality of 8-year-old *Melia azedarach* trees grown in Saudi Arabia. The wood quality of the trees was studied in terms of fibre length, specific gravity, and heartwood/sapwood area. The sampled trees were felled, their stem height and diameter were measured, and discs were cut from the stem base and breast height of each tree. Fibre length and specific gravity at breast height were determined, as well as the area and proportion of heartwood and sapwood at both base- and breast-height cross sections. The results showed that the fibre length of *Melia azedarach* wood varied between trees and ranged between 0.742 and 0.797 mm. It increased from pith to bark, ranging between 0.62 and 0.92 mm. Specific gravity did not vary among trees, but increased from pith to bark and ranged between 0.366 and 0.432. The proportion of heartwood accounted for about 70% at the base, but decreased to 63.32% at breast height. There was a significant variation in the proportion of sapwood between the base and breast height, as well as between trees. The area of sapwood in the breast-height cross section of *Melia azedarach* trees was 84.3 $cm^2$, compared with 102.3 $cm^2$ at the base; however, the proportion of sapwood was greater at breast height level.

**Key words:** *Melia azedarach* L., fibre length, specific gravity, heartwood/sapwood ratio

## Introduction

Fast-growing and high-yield tree species are being planted in different parts of the world to supply the growing demand for pulp and paper manufacturing and solid wood products (Espinoza 2004). In arid zones such as Saudi Arabia, the proper selection of planting species is very important for afforestation under the hot climate with low relative humidity and high evapotranspiration conditions (El-Juhany et al. 2001).

*Melia azedarach* is a deciduous tree native to the Himalayan region of Asia (Watkins and Sheehan 1975). This species has been widely cultivated as an ornamental and shade tree, as it is well adapted to warm climates, poor soils, and seasonally dry conditions (Harrison et al. 2003). *Melia azedarach* is of very high value and is found over a very wide range of habitats in Australia, including semiarid areas (Lowry and Seebeck 1997).

*Melia azedarach* is often planted for fuel supply in the Middle East and in Assam (India), where it is grown on tea estates for fuel. Its specific gravity is about 0.66 (calorific value: 5043-5176 kcal $kg^{-1}$) (National Academy of Sciences 1983). *Melia*

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*azedarach* wood, the "white cedar" of commerce, is used to manufacture agricultural implements, furniture, plywood, boxes, poles, and tool handles; it is used in cabinet-making and in construction because of its resistance to termites (World Agroforestry Centre 2006). Specific gravity is an important factor determining wood quality because most mechanical properties of wood are closely correlated to specific gravity (Haygreen and Bowyer 1996). For instance, the specific gravity of wood, because it is a measure of the relative amount of solid cell wall material, is the best index that exists for predicting the strength properties of wood (Panshin and de Zeeuw 1980). Wood density is one of the properties that differentiate the relative value of wood for fuel. The heavier the wood is (when dry), the greater is its calorific value (National Academy of Sciences 1981). The specific gravity of wood may vary in the stem cross section and along the stem length.

Heartwood and sapwood have varying properties, and their proportion within the stem has a significant effect on the rational utilisation of timber. In practice, the share of heartwood in tree stems has a positive effect for some branches of industry due to high stability or aesthetic value, while from the point of view of others, such as the plywood industry or pulp and paper industry, this effect is disadvantageous (Nawrot et al. 2008). Also, cross section and wood species were found to affect daily wood moisture content variation in some woody species (Üçüncü 2000). The present investigation aims at evaluation of some wood quality measures of *Melia azedarach* trees, as information about them is rather limited, if any, despite the importance of this species and the multiuse of its wood.

## Materials and methods

### Plantation history and site characteristics

The plantation was established in 1998 with initial spacing of 5 × 5 m as a field trial at the Agricultural Research and Experiments Station of King Saud University, 50 km south of the city of Riyadh, Saudi Arabia. The location at which the *Melia azedarach* L. trees were grown has the following characteristics: 24°6′N, 46°5′E; 650 m above sea level with average temperatures ranging between 0 °C in winter and 37 °C in summer, and 50 mm of annual rainfall. The soil is sandy loam with an average of 61%, 23%, and 15% sand, silt, and clay, respectively.

### Tree felling

At random, 3 *Melia azedarach* L. trees were chosen from an 8-year-old plantation and felled in December 2005. The trees were felled through cutting their stems at 30 cm above the soil level. Diameters at the base and breast height, as well as total stem height for each tree, were measured just before felling (Table 1).

### Sampling method

Along the grain, 2 discs, 5 cm in thickness, were cut from both base and breast heights of each felled tree. As the boundaries of sapwood/heartwood were very clear due to their distinct colour, the areas of both were measured manually using a planimeter. A diametric strip, 3 cm wide, was cut from each breast-height disc. Strips were then cut systematically into a number of specimens.

#### *Preparation of wood specimens*

Each strip was machine-sawn into specimens, 2 cm wide, from both sides of the pith, and then each specimen was split into 2 parts. One part was used for fibre length determination and the other was used for specific gravity determination.

#### *Fibre length determination*

The part of each specimen assigned for fibre length determination was cut into small sticks and then subjected to a maceration process. The sticks of each specimen were placed in a test tube and immersed with a mixture of 1:1 glacial acetic acid and 30% hydrogen peroxide (v/v). The tubes and their contents

Table 1. Stem diameter at base, stem diameter at breast height, and total stem height of 8-year-old *Melia azedarach* trees.

| Tree no. | Diameter at base (cm) | Diameter at breast height (cm) | Total height (m) |
|---|---|---|---|
| 1 | 24.3 | 19 | 10.20 |
| 2 | 21.5 | 18 | 10.30 |
| 3 | 21.0 | 19 | 11.00 |

were placed in an oven at 60 °C for 48 h. The macerated fibres within each tube were washed several times with distilled water and then subjected to shaking, using small glass balls to ensure the obtaining of more individual fibres. The macerated fibres of each specimen were stained using safranin dye diluted with ethanol alcohol (1:1, v/v). A wet sample of the stained fibres was taken on a slide to determine the length of both fibre tracheids and libriform fibres using projection fibre images on a screen. The length of the fibres was measured to the nearest 0.01 mm. The required number of fibres to be measured was determined with some samples of the prepared fibres according to the equation suggested by Avery (1967), as follows.

$$n \geq t^2 S^2/E^2$$

where:

n = number of fibres required,

t = tabulated "t" value from "t" distribution at P = 0.05 with n - 1 degrees of freedom,

S = standard deviation of the sample, and

E = the desired half-width of the confidence interval (0.1 of the mean).

The result of applying this equation indicated that 35 fibres per sample point were required to be measured.

***Specific gravity determination***

The part of each specimen assigned for specific gravity determination was immersed in water and subjected to a vacuum until saturation, then oven-dried at 103 ± 2 °C until a constant weight. The maximum moisture content of each specimen was calculated, and its specific gravity was determined accordingly, using the equation developed by Smith (1954), as follows.

$$G = 1/ M_{max} + (1/1.53)$$

where:

G = specific gravity of the wood specimen,

1.53 = specific gravity of the wood substance, and

$M_{max}$ = maximum moisture content in gram of water per gram of oven-dried wood.

Maximum moisture content (MMC) is recommended for common use on account of its accuracy (Usta 2010).

***Statistical analysis***

The obtained data from determination of both fibre length and specific gravity were analysed through the analysis of variance procedure using the SAS computer program (SAS 2001). The means of treatment were compared using the least significant difference test (LSD) (Steel and Torrie 1986).

## Results

The analysis of variance procedure showed significant variations between trees in fibre length, which ranged between 0.742 and 0.797 mm ($P < 0.0001$) (Table 2). Fibre length at breast height showed

Table 2. Between trees, and means of fibre length and specific gravity of 8-year-old *Melia azedarach* wood at breast height.

| Source of variation | Fibre length (mm) | Specific gravity |
|---|---|---|
| Trees | | |
| 1 | *0.80 a | 0.413 |
| 2 | 0.76 b | 0.410 |
| 3 | 0.74 c | 0.404 |
| Distance from pith outward | | |
| 1 | 0.62 c | 0.366 b |
| 2 | 0.74 b | 0.429 a |
| 3 | 0.92 a | 0.432 a |

*Means followed by the same superscript lower case letter within each 3 consecutive vertical cells are not significantly different according to LSD test at P < 0.05.

an increase from the pith to bark (P < 0.0001) (Table 2). There were no significant differences between trees in wood specific gravity, but it increased from the pith to bark at breast height of *Melia azedarach* trees (Table 2).

The specific gravity values of *Melia azedarach* wood found in the present study ranged between 0.404 and 0.413 at the breast-height level (Table 2).

Determining the cross-sectional area of heartwood showed a significant variation in this trait between the base and breast height of trees (P = 0.0022). The proportion of heartwood accounted for about 70% at the base, but decreased to 63.32% at breast height (Table 3). On the other hand, there was a significant variation in the proportion of sapwood between the base and breast height (P ≤ 0.05), as well as between trees (P < 0.05) (Table 3). The ratio of sapwood to heartwood differed significantly between the base and breast height levels of *Melia azedarach* trees, at 43.44 and 58.42, respectively.

## Discussion

The significant variation between trees in fibre length in the present study concurs with that reported by Abo Hasan and El-Osta (1982) for *Casuarina glauca* and Aday et al. (1984) for Caribbean pine. However, other researchers found variation in fibre length between trees rather small, or higher within trees compared to between trees (Salang and Fujii 2000; Leal et al. 2006; Rautiainen and Alén 2009). Tree-to-tree variation in fibre length could be attributed to the inherent potential of individual trees to produce longer or shorter fibres than their neighbours (El-Osta 1982).

The length of fibres in the present study is more or less close to that found in other studies. For instance, Richter and Dallwitz (2000) reported an average fibre length of 0.8-1.65 mm, considered medium-to-long. Abdul Wasim (2007) reported a 0.78-1.3 mm length for *Melia azedarach* fibres. Increasing fibre length from the pith to bark in the present study is in accordance with other previous results for different tree species (e.g. Butterfield et al. 1993, for *Hyeronima alchorneoides* and *Vochysia guatemalensis*; Doosthoseini and Parsapajouh 1997, for *Carpinus betulus*; Gartner et al. 1997, for *Alnus rubra* Bong.; Salang and Fujii 2000, for *Acacia mangium* Willd.; Miranda and Pereira 2002, for *Eucalyptus globules*; Leal et al. 2006, for *Quercus suber* L.; Rautiainen and Alén 2009, for *Pinus sylvestris*). On the other hand, some researchers found a slight increase of fibre length as the diameter from the pith increased (Yang 2006), or no significant radial variation (Brasil and Ferreira 1979; Aday et al. 1984). Within individual trees, wood density often varies vertically along the main axis of the stem and/or radially from the pith to the bark (Panshin and de Zeeuw 1980; Grabner and Wimmer 2006).

In the present study, there was no significant difference between trees in wood specific gravity. However, others have reported significant variation in specific gravity among trees (e.g. Butterfield et al. 1993; Matekere 1999; Roque and Fo 2007). The specific gravity values of *Melia azedarach* wood found in the present study ranged between 0.404 and 0.413 at breast-height level. Others reported different values for wood density of *Melia azedarach* wood. For instance, Matekere (1999) and Richter and Dallwitz (2000) reported a wood density of 0.436 and 0.5-0.65

Table 3. Means of area, and proportion of cross-sectional surface of heartwood and sapwood at base and breast height in 8-year-old *Melia azedarach* trees.

| Height level | Heartwood area area ($cm^2$) | Sapwood ($cm^2$) | Heartwood (%) | Sapwood (%) | Sapwood to heartwood ratio |
|---|---|---|---|---|---|
| Base | 235.3 a | 102.3 a | 69.99 a | 30.01 b | 43.44 b |
| Breast height | 146.0 b | 84.3 b | 63.32 b | 36.68 a | 58.42 a |

*Means followed by the same superscript lower case letter within each 2 consecutive vertical cells are not significantly different according to LSD test at P < 0.05.

g $cm^3$, respectively. The variation between different reports of specific gravity of the same species may be attributed to age factor (e.g. Chowdhury et al. 1994; Kabir et al. 1996) and to effects of geographic variation such as latitude, temperature, and precipitation (Wiemann and Williamson 2002).

Specific gravity at breast height in *Melia azedarach* trees increased from pith to bark. Similar results were obtained for other tree species (e.g. Butterfield et al. 1993; Sulaiman and Lim 1993; Nogueira et al. 1997; Gonzalez and Fisher 1998; Nock et al. 2009). On the other hand, Junaji et al. (2006) found that the specific gravity of *Melia azedarach* increased slightly from the pith outward, while Gartner et al. (1997) asserted that the specific gravity of *Alnus rubra* wood was constant radially. The majority of researchers reported that within individual trees, wood density often varies vertically along the main axis of the stem and/or radially from the pith to the bark (e.g. Panshin and de Zeeuw 1980; Grabner and Wimmer 2006). On the contrary, Doosthoseini and Parsapajouh (1997) found that the specific gravity of *Carpinus betulus* wood decreased from pith to bark. A similar trend was found in *Populus euramericana* (Kord et al. 2010). It is thought that radial increases in wood density result from a shift in allocation from low density wood and rapid height growth early on in tree development, to denser wood and structural reinforcement as trees increase in size, age, and height within the forest (Wiemann and Williamson 1989).

The cross-sectional area of heartwood in the present study showed a significant variation between the base and breast height of trees. The proportion of heartwood accounted for about 70% at the base, but decreased to 63.32% at breast height. This result concurs with that reported by Morais and Pereira (2007), in which the heartwood proportion in the stem cross section of *Eucalyptus globulus* Labill. trees at 12-15 years decreased from the base upwards. Nawrot et al. (2008) found decreased heartwood formation in stems of European larch from the butt end towards the tree top. Recently, Miranda et al. (2009) found that 18-year-old *Eucalyptus globulus* trees possessed a large proportion of heartwood, on average 60% of the wood's cross-sectional surface. On the other hand, there was a significant variation in the proportion of sapwood between the base and breast height, as well as between trees. The decrease in the proportion of heartwood from the base upwards followed the growth nature of the tree. Typically, there is less sapwood than heartwood in any given stem. Although the area of sapwood at breast height in *Melia azedarach* trees was 84.3 $cm^2$, compared with 102.3 $cm^2$ at the base, the proportion of sapwood was greater at the breast-height level. This concurs with the fact that sapwood is thicker in the upper portion of the trunk of a tree than near the base, because the age and the diameter of the upper sections are less. The ratio of sapwood to heartwood differed significantly between the base- and breast-height levels of *Melia azedarach* trees, at 43.44 and 58.42, respectively. The quantitative ratio of heartwood to sapwood in tree stems depends first of all on the age of trees, climatic and soil conditions, the height at which the analyzed stem cross section is located, and the crown size (Duda and Pazdrowski 1975; Nawrot et al. 2008).

## Conclusion

The results of the present investigation showed significant variation between *Melia azedarach* trees in fibre length, ranging between 0.74 and 0.80 mm. The specific gravity of *Melia azedarach* wood ranged between 0.404 and 0.413. Both fibre length and specific gravity increased from the pith to bark.

The cross-sectional area of heartwood showed a significant variation between the base and breast height of trees, as well as between trees. The proportion of heartwood accounted for about 70% at the base, but decreased to 63.32% at breast height.

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