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The Effect of Growth Rate on the Wood Quality of Fast Grown Hardwood Plantation Species in Sri Lanka

Hiran S. Amarasekera
Department of Forestry and Environmental Science, University of Sri Jayewardenepura, Sri Lanka

Introduction

In the past when most of the country was covered by natural forests, logs of various natural species flowed into the market. However, now that natural high canopy forest cover has reduced, and restrictions on felling and transport of timber, supplies from natural forests are limited. The domestic forest industries are dependent on the supply of wood from sources other than natural forests. Forest plantations play major role in supply of timber. State forest plantations established earlier and several private sector plantations, which are now being established, will produce main share of commercial timber in Sri Lanka in the future. Many private forest companies claims to produce fast-grown timber in very short rotations such as 15- 25 years. Foresters normally decide the age of felling based on the tree growth, (culminate point of MAI and CAI), but (Ruwanpathirana, 2002) suggested that maturation of different wood properties should also be considered in deciding the rotation age.

In this paper wood quality of fast grown plantation species are reviewed generally, with special reference to three key commercial hardwood species, which will make major share of future timber supplies in Sri Lanka: Eucalyptus (*Eucalyptus grandis*, Mahogany (*Swietenia macrophylla*) and Teak (*Tectona grandis*).

Key Commercial Timber Species in Sri Lanka

Wood supply studies (FSMP, 1995; Ariyadasa, 2002; Amarasena and Amarasekera, 2008) indicated that domestic forest industries are very much dependent on the supply of wood from sources other than natural forests. Home gardens, rubber plantations, coconut plantations, imports and forest plantations are the most important sources of sawlogs, although very small quantity is played by fellings in natural forest.

The common species producing log timber are from following

- Rubber uprooted from plantations
- Jak, Coconut, Mahogany, Teak, Del, Ginisapu, Alstonia, Lumumidella, Mango from homegardens
- Albizia, Grevillea, Eucalypts, Toona from Tea estates
- Teak, Mahogany, Pine, Eucalypts from Forest Department plantations

Wood Property Studies in Sri Lanka

Important wood property studies conducted in Sri Lanka are summarized in Table 1. Research on wood properties in Sri Lanka was started at the Forest department (FD) and most of the initial research on this area was conducted by the Timber Utilization division of the FD (Ranathunga, 1964; Aruchlvam, 1971; Seneviratna, 1971; Vivekanandan, 1978). Studies on the variation of wood properties radially and axially, and aspects of timber utilization had been investigated at that time. After the closure of the FD Timber Utilization branch, research on timber has been conducted by the research division of the state timber corporation (STC). University of Moratuwa has concentrated on research on structural aspects (Chandrakeerthy, 1985; Jayathilaka, 1985) and since 1983 University of Sri Jayewardenepura conducts research on timber properties and utilization (Singhakumara, 1985, Siriniwansa and Amarasekera, 1992, Amarasekeram 1996, Ruwanpathirana *et al*., 2002, Perera and Amaraeskera, 2003, Jayawardana and Amarasekera, 2008).

Table 1: Research conduced on studies on variation of wood properties in Sri Lanka

Species	Reference	Comments
Eucalypus grandis	Ranathunga 1964	Fiber and vessel element length increased from pith outwards, and thereafter reached a constant value
Eucalyptus robusta	Aruchelvam 1971	Core has low density and outside the core density increased
Six species of family Guttiferae	Seneviratna 1971	No distinct pattern of density variation from pith outwards and no difference in density between inner and outer wood.
Pinus caribaea	Vivekanandan and Chandraratna 1978	Basic density decreased with height
Eucalyptus camaldulensis	Vivekanandan 1978	Wood density decreased with height
Alstonia macrophylla	Singhakumara 1985	Lowest density at the pith thereafter it fluctuated with decrease in density close to bark. No density difference between sapwood and heartwood
Pinus caribaea	Siriniwansa, and Amarasekera 1992	Growth ring formation and some wood properties
Fifty timber species	Amarasekera and Denuwara 1995	Timber species were categorized according to Specific gravity and shrinkage
Eucalypus grandis and *E. microcorys*	Darshani and Amarasekera 1996	Density increased from pith outwards. Splitting varied between species (more splitting in *Eucalypus grandis)* height and diameter of logs
Several species	Amarasekera 1996	Review of literature on density and strength properties. Timbers classified as light, moderately heavy and heavy, based on density
Eucalyptus grandis and *Pinus caribaea*	Ruwanpathirana, 2002	Specific gravity, ring width, fiber length, fiber diamgter, vessel diameter, vessel area, modulus of rupture, modulus of elasticity were investigated axially and radial
Eucalypts grandis	Ruwanpathirana, Amarasekera and De Silva 2002	Radial and axial variation of specific gravity in three crown classes
Swietenia macrophylla, Khaya senegalensis, Paulownia fortunei	Perera and Amarasekera 2003	Radial variation of specific gravity and ring width
Tectona grandis	Jayewardenena and Amarasekera 2008	Radial variation of specific gravity and ring width in three crown classes

Several early studies concentrated on variation of wood properties within trees, variation from pith to bark, and from apex to base. Properties investigated at that time included basic density, fiber and vessel element length. Cell length measurements are not particularly important in Sri Lankan context, as timber is not used for pulp and paper industry. However those studies indicated the strong inherent radial and axial wood property trends.

Recent studies conducted by University of Sri Jayewardenepura concentrated on axial and radial variation of ring width (a measure of growth rate), cell dimensions (causal factor of specific gravity), specific gravity (measure of overall wood quality) and some mechanical properties (properties related to constructional aspects of timber).

Wood Quality of Fast Grown Plantations

The controversy over the effect of growth rate on wood was discussed in 1972 by Larson, who dealt with the concern that improved forest management practices may result in fast-grown wood of poor quality. It is evident that forestry is moving in the direction that wood is produced by harvesting fast growing trees at young age. As Zobel (1980) states "the proportion of trees from fast grown plantations will continue to increase and it will predominate in future. Therefore the industry must learn to use it effectively; just complaining about how different it is from what it has been using is not good enough. Wood from fast grown plantations is not necessarily 'bad wood' but certainly it is different."

Lasrson (1972) stated that ring width, ring structure and ring uniformity along with internal wood properties, determine the wood quality. Specific gravity largely determines the value and utility of wood (Zobel and van Buijtenen, 1989), and therefore can be taken as the major indicator of wood quality. Specific gravity or density is associated with the hardness of the wood, its shrinkage, and its capacity for becoming impregnated (Mottet, 1965).

Silvicultural manipulations such as fertilizing, felling and better site conditions will increase the growth rate. However as Larson (1962) stated, these environmental influences should not be directly related to wood quality, and the more logical approach would be to relate wood quality to growth and development of the crown. Amarasekera and Denne (2002) stated that it is important to distinguish wood characteristics that are influenced mainly by inherent trends (cambial ageing) from those that are affected by growth rate. Knowledge of this concept helps foresters to manipulate growth conditions to produce wood with desired properties. Environmentally induced aspects of wood formation may be regulated by management practices which control the size of the crown, whereas the inherent ageing processes are not affected by the same practices.

Specific Gravity and Growth Rate in Diffuse Porous Hardwoods

There are two different groups of hardwoods, namely ring-porous and diffuse-porous. Wood of these groups is affected differently by growth rate. Fukazawa (1983) stated that in the ring-porous hardwoods changes of basic density are influenced by the ring widths, while those of diffuse-porous hardwoods are almost independent of the ring width. The three species that are discussed mainly in this paper, teak, mahogany and eucalypts, are diffuse-porous hardwoods, although teak can sometimes be regarded as semi ring-porous.

Key findings related to effect of growth rate on the wood properties of diffuse-porous hardwoods are summarized in Table 2. Many researchers are in agreement with the fact that fast growth in ring-porous hardwoods results in dense wood (Zobel and van Buijtenen, 1989), while in diffuse-porous hardwoods, growth rate differences have little effect on specific gravity (Ferreira 1968; Skolman 1972; Perera and Amarasekera 2003; Jayewardenena and Amarasekera 2008). A lack of relationship was definitely indicated for the eucalypts by Hills and Brown (1978), who state "it appears that the mean wood density for a tree is not influenced by, or insignificantly correlated with, growth rate". However there are some exceptions to this generalization, and some studies indicated that growth rate results in slight increase in specific gravity (Scott and MacGregor 1952; Briscoe *et al*. 1963; Ruwanpathirana *et. al*. 2002). A negative relationship between growth rate and density was also found (Bhat and Bhat 1983).

Table 2: Relationship of growth rate to wood properties in diffuse-porous hardwoods

Species	Reference	Comments
Tectona grandis	Scott and MacGregor 1952	Faster growing trees had a slightly higher specific gravity
Swietenia macrophylla	Briscoe *et al*. 1963	Specific gravity increased with growth rate
Eucalyptus alba	Ferreira 1968	Tree basic density does not bear any relationship to rate of growth
Eucalyptus robusta	Skolman 1972	There is no relationship between growth rate and specific gravity among stands
Swietenia macrophylla	Chudnoff and Geary 1973	No relationship was found between tree size and wood density
Eucalyptus grandis	Taylor 1973	Radial growth rate in South Africa does not have a significant effect on specific gravity; however trees with fast height growth have a lower specific gravity
Eucalyptus grandis	Brasil *et al*. 1979	In Brazil, there was no relationship between specific gravity and diameter class
Eucalyptus grandis	Ferreira *et al*. 1979	There is no correlation between wood volume increment and wood specific gravity
Eucalyptus saligna	King 1980	In coppice, the largest shoot had the highest specific gravity
Eucalyptus tereticornis	Bhat and Bhat 1983	Fast growth is slightly related to lower basic density and higher moisture content. Height and diameter growth rate explain only 9% of the variation in basic density and 31% in fiber length
Eucalyptus spp.	Kininmonth *et al*. 1983	Internal growth stresses in the eucalypts are usually less serious in fast grown than in slow grown sawlogs of the same age
Eucalyptus spp.	Wilkes and Abbott 1983	Fast grown trees have a larger vessel volume
Tectona grandis	Keiding *et al.* 1984	Evaluation of a series of provenance trials showed a strong effect of the diameter on wood density
Eucalyptus spp.	Delwatta 1985	In the Congo, some clones that are the fastest growing have the densest wood, while others have less dense wood
Eucalyptus grandis	Ruwanpathirana *et. al*. 2002	Fast growth site had the highest specific gravity
Swietenia macrophylla	Perera and Amarasekera 2003	In Sri Lanka, no relationship exist between growth rate, as measured by ring width and specific gravity

Khaya senegalensis	Perera and Amarasekera 2003	In Sri Lanka, no relationship exist between growth rate, as measured by ring width and specific gravity
Tectona grandis	Bhat *et al.* 2004	Density of short rotation plantation was not inferior to slow grown timber
Eucalyptus grandis and *Pinus caribaea*	Ruwanpathirana *et. al*. 2005	Fast grown *Eucalyptus grandis* had higher mechanical properties but fast grown *Pinus caribaea* had lower mechanical properties
Tectona grandis	Jayawardana and Amarasekera 2008	In Sri Lanka, there is no relationship between growth rate, as indicated by crown classes of trees, and specific gravity

Fast-growing wood harvested from plantations of young ages, contains a higher proportion of juvenile wood. As stated by Amarasekera (1992) juvenile wood is usually defined as that formed near the pith of the tree produced by juvenile cambium. In softwoods, juvenile wood is known to be inferior to that of outer mature wood. However, several studies on teak concluded that although fast grown plantations contain higher percentage of juvenile wood, quality in terms of specific gravity may not be inferior to that of slow grown plantations (Jayawardana, 2008), and juvenile wood is not inferior to mature wood (Sanwo, 1986, Bhat *et al.* 2001).

Ruwanpathirana (2002) stated that in eucalypts, specific gravity, Modulus of Rupture and Modulus of Elasticity can be enhanced by growth rate. However it should be noted that wood properties such as specific gravity show an inherent radial patterns which can be attributed to cambial aging. These inherent patterns are independent of growth rate. Percentage heartwood was found to be more related to age rather than diameter at breast height (Jayawardana and Amarasekera, 2008), hence fast grown trees harvested at short rotations contain large proportion of sapwood.

Conclusion

When conducting experiments on growth rate of wood quality, it is important to compare trees of the same age. Despite the conflicting results, several studies conducted in Sri Lanka and in other courtiers suggest that growth rate differences have very little effect on specific gravity of diffuse porous hardwoods. This suggests that foresters can manipulate growth conditions to enhance the timber production with shorter rotations without detrimental effect on the specific gravity of the species. However these young fast grown trees may contain higher proportion of sapwood.

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