Wood Specific Gravity Variations Within and Among Trees

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Abstract
Wood specific gravity, which is a way of expressing how much wood substance is present per unit volume, is the most important within species wood characteristic because knowledge about it allows the prediction of a greater number of properties than any other trait. Some wood properties that are closely related to wood specific gravity are: strength, dimensional stability with moisture content change, ability to retain paint, fibre yield per unit volume, suitability for making particleboard and related wood composite materials and suitability as a raw material for making paper. This work throws light on the variation of wood specific gravity within and among trees.
Keywords: Wood, specific gravity, variation, trees.

Introduction
Wood is highly variable material derived by the activity of cambium. In order to produce and use wood efficiently, the variation patterns within trees, among trees of the same species and also among different provenances must be understood well. Wood anatomical features directly and indirectly have a bearing on wood properties which in turn reflect their utility for different purposes and therefore different woods have different characteristics. Of the various wood quality parameters specific gravity is the most widely studied? This property is of great importance in forest products as it has major effects on both yield and quality of fibrous and solid wood products (Davis, 1961; Barefoot *et al.*, 1970; Lewark, 1979). It is the ratio of the weight of a given volume of wood to the weight of equal volume of water at 4^0C (grams of wood/grams of cubic centimetre of water) and is therefore a unit less measure (Zobel and van-Buijtenen, 1989).

Specific gravity increases from pith to bark and such increment extend over the entire radius of the tree and are more extreme than any radial variation found in temperate trees. Wood specific gravity is extremely variable among species, ranging from 0.05 to 1.08 (Kanehira, 1933). Differences in specific gravity among species are more pronounced in the tropics than in temperate zone (Howe, 1974; Williamson, 1984; Wiemann and Williamson, 1989). Moreover, due to environmental and genetic influences, wood specific gravity varies among trees of the same species; however temperate tree species have sufficiently consistent specific gravities that each is characterised by a narrow range of values (Panshin and DeZeeuw, 1980).

Importance of wood specific gravity

Specific gravity of wood is the best indicator of strength and associated mechanical properties which reflect important life history attributes of arboreal species. Trees with low specific gravity usually grow rapidly, require full sunlight, reproduce at early age and are subjected to snapping of bole (Williamson, 1975; Putz *et al.*, 1983; Wiemann and Williamson, 1988). Species in succession are often ranked in order of their increasing wood specific gravity which is related to wood attributes such as cutting forces required in machining, dimensional stability, mechanical strength, paper-forming properties, shrinkage, treat ability with preservatives, value as fuel as well as acoustical, electrical and thermal insulating properties (Chundoff, 1984).

Wood specif gravity variations

Different patterns for the variation of specific gravity from pith to bark are found in hardwoods. Some species such as *Swietenia macrophylla, Liquidambar styraciflua L. , Liriodendron tulipifera ,Gmelina arborea* and other have an increase in specific gravity from the pith to outward (Briscoe *et al.*, 1963; van Eck and Woessner, 1964; Herpka, 1965; Lamb, 1968; Sluder, 1970). Of particular importance are the eucalyptus, which generally show a small increase from the tree centre outward (Ferreira, 1972*;* Hans *et al*., 1972).

Purkayastha *et al.* (1982) studied variation in specific gravity, heartwood proposition and fiber length in plantation grown *Eucalyptus tereticornis* trees and reported that there was no significant effect of height on specific gravity, but there were significant difference in heartwood proportion. Sennerby-Forsse *et al*. (1983) carried out a case study on performance of 21 Salix clones (One year old shoots) during 1978 and found that wood specific gravity without bark varied between 0.26 to 0.43g cm^3. Yanchuk *et al.* (1983) worked out with four trees from each of the three putative clones of trembling aspen (*Populus tremuloides*) and determined the pattern of wood density variation. They reported that in the radial direction, wood density was higher near the pith, decreased for some distance and then again increased in the mature wood zone (after 15-20 + years). Average density values within the stems varied from 0.348g/cm^3 to 0.402g/cm^3. Sennerby-Forsse (1985) studied one year shoots of 20 clones of Salix (*S.viminalis* 14, *S.dasyclados* 4 and one each of *S. caprea* x *viminalis* and *S. fragilis*) for wood specific gravity, moisture content and stem bark percentage. It was observed that the specific gravity of wood without bark varied between 0.26 and 0.43 g cm^{-3} in the clones. Although a high intraclonal variation occurred, the statistical analysis indicated considerable differences among the clones. Mosseler *et al*. (1988) studied the variation in biomass production, moisture content and specific gravity on one year coppice shoot of 4 north American willows viz., *S. eriocephala, S. exigua, S. lucida and S. almygdaloides* in full-sib test and found that 65 to 77 per cent of the variation in plant biomass was due to species, while less than 5 per cent was due to families. Approximately 39 per cent of the variation on moisture content and 37 per cent of the variation in specific gravity was due to species differences. *S eriocephala* produced the highest yield and had lowest moisture contest and higher moisture content and highest specific gravity (0.457) where as the specific gravity for three species *S. exigua, S. lucida* and *S. almygdaloides* were recorded to be 0.430, 0.394 and 0.421 respectively.

Reuda and Williamson (1992) studied radial and vertical wood specific gravity in *Ochroma pyramidale* and reported specific gravity increased linearly with radial distance at any given height. McDonald *et al*. (1995) reported a large increase of specific gravity with increase in a distance from pith to the outside and attributed it to the increase of fiber wall thickness, decrease in fiber diameter and decrease in fiber lumen diameter. Rajput *et al*. (1997) recorded specific gravity for 20 clones of *Populus deltoides* growing at 5 x 5 m spacing .Plantations were 7 years old .Specific gravity showed large differences between clones with radial position. The central portion of log was significantly weaker than outer portion. Two of the clones (St 63 and s7- C3) had much greater average specific gravity than rest and also exhibited superior growth. The two best clones (G-3 and G-48) had poorer specific gravity than St-63 and S7-C3.

Ticku (1977) reported that weight of green wood was about 700 kg/m^3 and of air dry wood was about 450 kg/m^3 (i.e. 0.450 specific gravity) in willow (*S. alba var. culva*). He further emphasized that wood density and weight vary with site as trees raised in swampy area gives denser (heavier) wood than the acceptable quality for cricket bats

Chauhan *et al. (2001*) reported that in *Populus deltoides* specific gravity gradually increased from pith to periphery following a rapid increase up to seventh ring.

Pande and Singh (2005) studied in detail, inter-clonal, intra-clonal, and single tree variations of wood anatomical properties and specific gravity of clonal ramets of *Dalbergia sissoo Roxb*. and reported that radial and location wise intra-clonal variations were nonsignificant for wood anatomical properties and specific gravity , however inter-clonal variations were significantly different.

Wani *et al.* (2014) studied wood specific gravity variation among five different hardwood species and reported that specific gravity varied from 0.73 to 0.80 in *Parrotiopsis jacquemontiana*; in *Robinia pseudoacacia* it varied from 0.71 to 0.79; In *salix alba* it varied from 0.42 to 0.48; In *Populus nigra* it varied from 0.40 to 0.48 and in *Juglans regia* it varied from 0.59 to0.66. On the basis of the specific gravity variation patterns, they classified these woods as light (*Salix alba, Populus nigra*), moderately heavy (*Juglans regia*) and moderately heavy to heavy (*Robinia pseudoacacia, Parrotiopsis jacquemontians*)

Wiemann and Williamson (2014) studied the wood specific gravity variation with height and its implications for biomass estimation in five tropical trees and reported that there is no consistent specific gravity pattern across the five species. At all heights, the four fast-growing pioneer species (*Cecropia obtusifolia Bertolini, Cecropia peltata* L. *Ochroma pyramidale (Cav. ex Lam.), Trema micrantha* L. *Blume*) showed the shift from lower specific gravity (SG) wood near the pith to higher SG wood adjacent to the bark that characterize these species, although the magnitude of the shift varied with height.

Gupta *et al.* (2017) determined wood specific gravity of stem and branches of 21 tree species in the hot semi-arid region of Western India. Three individual trees from each species were randomly selected and sampled for determination of wood specific gravity(WSG) of stem, primary and secondary branch. They reported that the WSG varied significantly among the species ($F = 42.83$, $P < 0.001$) and sampling locations (stem and branches) ($F = 29.43$, $P < 0.001$). In stem (at DBH), it ranged from 0.42 ± 0.04 to 0.74 ± 0.03 among the species while within an individual tree it varied in order of stem > primary branch > secondary branch in most species. WSG of stem and branches showed linear relationship and branches were found a good predictor of stem WSG ($R 2 > 0.83$).

Conclusion

Specific gravity is the best indicator of strength and associated mechanical properties of wood. In woody trees it increases from pith to the bark and also increases from merchantable top of tree down to base of tree trunk. This increase in wood specific gravity is mainly associated with anatomical changes i.e. increase in fiber wall thickness, decrease in fiber lumen diameter and increase in fiber frequency.

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