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Wood Specific Gravity Variation among Five Important Hardwood Species of Kashmir Himalaya

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Abstract: Wood Specific Gravity (SG) is a measure of the amount of structural material a tree species allocates to support and strength. In the present study, specific gravity varied among the five different woods at three different sites from 0.40 in *Populus nigra* at site III (Shopian) to 0.80 in *Parrotiopsis jacquemontiana* at site II (Surasyar). Among the three different sites, specific gravity varied from 0.73 to 0.80 in *Parroptiosis 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 to 0.66. On the basis of the specific gravity variation patterns these woods were categorized as light (*Salix alba*, *Populus nigra*) moderately heavy (*Juglans regia*) and moderately heavy to heavy (*Robinia pseudoacacia*, *Parrotiopsis jacquemontiana*) which predicts their properties like strength, dimensional stability with moisture content change, ability to retain paint, fiber yield per unit volume, suitability for making particleboard and related wood composite materials and suitability as a raw material for making paper.

Key words: Specific gravity, wood, variation, tree

INTRODUCTION

Wood is unique among the world's important raw materials virtually used by everyone in diverse ways. It is basically secondary xylem produced by the meristematic activity of cambium and consists of cells or wood elements that have passed through various stages of development. All the phases i.e., cellular division, differentiation and maturation lead to wood formation. Variability and flexibility of wood makes it suitable for varied kinds of products. The variability of wood anatomical features directly or indirectly has a bearing on the efficient use of wood for different end uses. Tree to tree variability is especially large, with differences within species and variation often being strongly genetically influenced. The greater the uniformity of wood, the greater will be the efficiency of producing a specific product with much improved quality of the final product (Zobel and Van-Buijtenen, 1989). Although, variability and flexibility of wood makes it useful for many kinds of products giving it greater utility, this variability is also a major drawback for the wood to be used efficiently as a raw material (Zobel and Van-Buijtenen, 1989).

Many factors are responsible for the variability in wood and specific gravity is one of them. It is defined as the ratio of dry weight of wood substance to the weight of an equal volume of distilled water at 4°C. Some wood properties that are influenced by wood specific gravity are strength, dimensional stability with moisture content change, ability to retain paint, fiber yield per unit volume, suitability for making particleboard and related wood composite materials and suitability as a raw material for making paper (Bowyer and Smith, 1998). Hence, keeping in view the above importance, the present work was carried out *Salix alba*, *Populus nigra*, *Juglans regia*, *Robinia pseudoacacia* and *Parrotiopsis jacquemontiana* to reveal wood specific gravity variation patterns with and among these trees from Kashmir Himalaya.

MATERIALS AND METHODS

Source of material: The present study was carried out on five species of hardwood trees/shrub with deciduous type of habit, belonging to four families viz, Hammameliadaceae, Juglandaceae, Paplionaceae and Salicaceae from natural provenances of Kashmir Himalaya for their anatomical characteristics.

The species undertaken were *Salix alba* L., *Populas nigra* L., *Juglans regia* L., *Robinia pseudoaccacia* L. and *Parrotiopsis jacquemontiana* (Decne.) Rehder. Which were 10-13 years old. The sites which were surveyed are Khrew, Pampore, Ladhoo, Pulwama, Shopian, Ahrabal, Charsoo, Anantnag, Qaimoh, Budgam, Brenward Surasyar, Gowharpora, Shalimar, Darbagh, Naranag,

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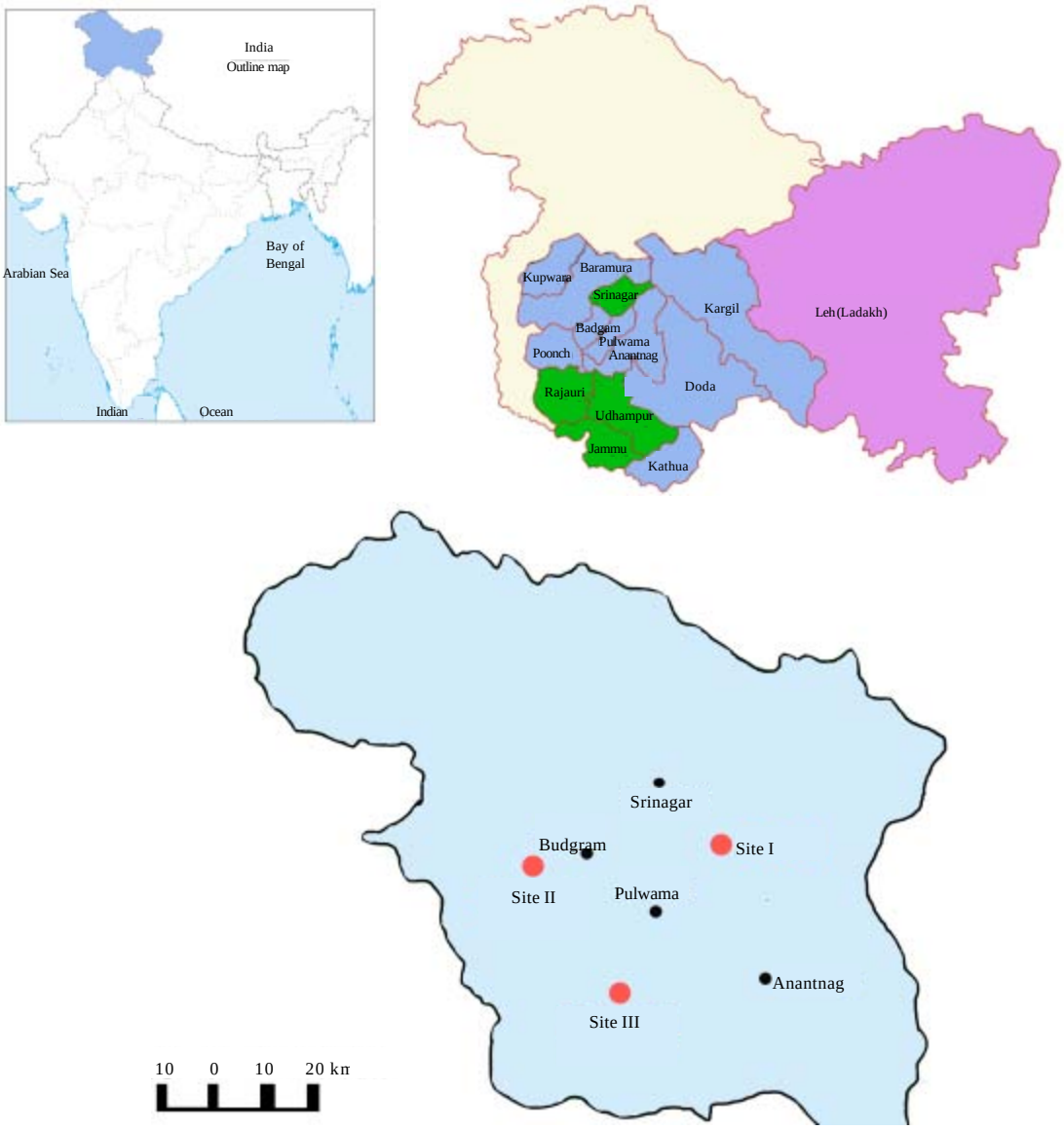

Fig. 1: Map of the study sites

Batpora, Habbak. Out of the sites, three were selected for the wood anatomical characteristics viz., Khrew (site-1), Surasyar (site-2), Shopian (site-3) (Fig. 1).

These sites were selected on the basis of the following criterions:

- Accessibility of sites
- Availability of the material
- Collectiveness of the selected species

The geographical locations along with other characteristics of the selected sites are summarised in the Table 1.

Three trees of each species were felled and 10 cm thick discs were cut at five positions equally spaced along the vertical directions from base up to the merchantable top of tree/shrub. These were named as DI, DII, DIII, DIV and DV from base up to the top, respectively. in order to study a vertical variation, a disc wedge was removed at any cardinal directions (Chauhan *et al*., 2001). The wedge was further divided into three parts as per locations viz., inner (Pith), middle and outer (peripheral). All samples were studied for variation within tree and among replicates at each site (Pande and Singh, 2005).

Specific gravity: Specific gravity of wood is the ratio, between oven dry weight of the wood and the weight of an equal volume of water:

$$\text{Specific gravity of Wood} = \frac{\text{Weight of wood (Oven dry)}}{\text{Weight of like volume of water}}$$

The dry weight of wood was determined by oven drying the wood samples at 103±2°C until they ceases to lose weight and the like volume of water was calculated by displacement method (Brown *et al*., 1949), in which a graduate of sufficient size was taken and increase in the volume of water immersing wood samples was taken as weight of like volume of water.

Chowdhury and Ghosh (1958) classified the woods on the basis of specific gravity as:

- **Very light (Papita class):** Specific gravity less than 0.35 (below 350 kg m^{-3})
- **Light (Semul class):** Specific gravity greater than 0.35-and less than 0.55 (350-550 kg m^{-3})
- **Moderately heavy (Teak class):** Specific gravity greater than 0.55-and less than 0.75 (550-750 kg m^{-3})
- **Heavy (Sal class):** Specific gravity greater than 0.75-and less than 0.95 (750-950 kg m^{-3})
- **Very heavy (Sundri Class):** Specific gravity equal to 0.95 or above than 0.95 (950 kg m^{-3})

RESULTS

***Parrotiopsis jacquemontiana* (Decne.) Rehder:** In *Parrotiopsis jacquemontiana*, the mean specific gravity varied significantly among the sites from 0.73 in site I to 0.80 in site II (Table 2). In site I (Khrew), it varied from 0.73 in disc V to 0.78 in disc II, having the maximum values in disc III followed by disc II , disc I, disc IV and disc V (outer), respectively (Table 2).

In site II (Surasyar) specific gravity varied from 0.73 in disc V to 0.78 in disc II, having the maximum values in disc III followed by disc II, disc IV, disc I and disc V respectively (Table 2). In site III (Shopian), specific gravity ratio varied from 0.73 in disc V to 0.79 in disc II, having the maximum values in disc III, followed by disc II, disc I, disc IV and disc V respectively (Table 2). All the discs within these site and also their locations in radial direction i.e., inner, middle and outer are statistically significant (Table 3).

***Robinia pseudoacacia*:** In *Robinia pseudoacacia*, the mean specific gravity varied significantly among the sites from 0.71 in site II to 0.79 in site I (Table 2). In site I (Khrew), it varied from 0.73 in disc V to 0.79 in disc III, having the maximum values in disc III followed by disc IV, disc II, disc I and disc V, respectively (Table 2).

In site II (Surasyar), specific gravity ratio varied from 0.71 in disc V to 0.78 in disc III, having the maximum values in disc III followed by disc II, disc I, disc IV and disc V, respectively (Table 2).

In site III (Shopian) specific gravity varied from 0.71 in disc V to 0.77 in disc II, having the maximum values in disc II followed by disc III, disc I, disc IV and disc V respectively (Table 2). All the discs within these site and also their locations in radial direction i.e. inner, middle and outer are statistically significant (Table 4).

***Salix alba* Linn.:** In *Salix alba*, the Specific gravity varied significantly among the sites from 0.42 in site II to 0.48 in site III (Table 2). In site I (Khrew), it varied from 0.43 in disc V to 0.48 in disc II, having the maximum values in disc II followed by disc III, disc IV, disc I and disc V, respectively (Table 2).

In site II (Surasyar), specific gravity ratio varied from 0.42 in disc V to 0.47 in disc II, having the maximum values in disc II followed by disc III, disc IV, disc I and disc V, respectively (Table 2).

In site III (Shopian), specific gravity, varied from 0.42 in disc V to 0.48 in disc II, having the maximum values in disc II followed by disc I, disc III, disc IV and disc V, respectively (Table 2). All the discs within these site and also their locations in radial direction i.e., inner, middle and outer are statistically significant (Table 5).

***Populus nigra* Linn.:** In *Populus nigra*, the mean specific gravity varied significantly among the sites from 0.40 in site III to 0.48 in site I (Table 2). In site I (Khrew), it varied from 0.41 in disc V to 0.48 in disc III, having the maximum values in disc III followed by disc II, disc IV, disc Iand disc V, respectively (Table 2).

In site II (Surasyar), specific gravity ratio varied from 0.41 in disc V to 0.47 in disc III, having the maximum values in disc III followed by disc II, disc IV, disc I and disc V, respectively (Table 2).

In site III (Shopian), specific gravity, varied from 0.40 in disc V to 0.48 in disc III, having the maximum

Table 1: Salient features of the sites and age of trees selected for the present study

Factor	Site I (Khrew)	Site II (Surasyar)	Site III (Shopian)
North latitude	30°12′	34°32′	33°34′
East longitude	75°35′	74°55′	75°20′
Elevation (m)	2000	2400	2800
Soil	Sandy clay	Loamy soil	Sandy clay
Age in years	10- 13	10-13	10-13

Table 2: Specific gravity of five different species of hardwoods in both vertical and horizontal direction

	Specific gravity														
	Salix alba			*Populus nigra*			*Parrotiopsis Jacquemontiana*			*Robinia pseudoacacia*			*Juglans regia*		
Position	Site I	Site II	Site III	Site I	Site II	Site III	Site I	Site II	Site III	Site I	Site II	Site III	Site I	Site II	Site III
Disc I															
Inner	0.43	0.42	0.44	0.43	0.41	0.43	0.74	0.73	0.76	0.74	0.72	0.73	0.61	0.60	0.61
Middle	0.45	0.44	0.46	0.44	0.43	0.44	0.75	0.74	0.77	0.75	0.73	0.74	0.62	0.60	0.62
Outer	0.46	0.45	0.47	0.45	0.44	0.46	0.77	0.76	0.79	0.77	0.75	0.76	0.64	0.62	0.64
Disc II															
Inner	0.46	0.45	0.45	0.44	0.43	0.44	0.75	0.75	0.77	0.74	0.74	0.74	0.63	0.61	0.63
Middle	0.47	0.46	0.47	0.45	0.45	0.45	0.76	0.76	0.78	0.76	0.75	0.75	0.64	0.62	0.64
Outer	0.48	0.47	0.48	0.46	0.46	0.47	0.78	0.78	0.79	0.77	0.77	0.77	0.66	0.64	0.66
Disc III															
Inner	0.46	0.45	0.44	0.46	0.44	0.45	0.76	0.77	0.78	0.77	0.75	0.74	0.64	0.62	0.63
Middle	0.47	0.46	0.45	0.47	0.45	0.46	0.77	0.78	0.79	0.78	0.76	0.75	0.66	0.64	0.64
Outer	0.48	0.47	0.46	0.48	0.47	0.48	0.78	0.8	0.8	0.79	0.78	0.77	0.63	0.65	0.66
Disc IV															
Inner	0.45	0.43	0.42	0.44	0.42	0.41	0.74	0.75	0.74	0.75	0.72	0.72	0.61	0.6	0.61
Middle	0.46	0.45	0.44	0.45	0.44	0.43	0.75	0.75	0.75	0.76	0.73	0.73	0.62	0.61	0.62
Outer	0.47	0.46	0.45	0.46	0.45	0.44	0.77	0.77	0.77	0.78	0.75	0.75	0.64	0.63	0.64
Disc V															
Inner	0.43	0.42	0.42	0.41	0.41	0.4	0.73	0.73	0.73	0.73	0.71	0.71	0.6	0.59	0.6
Middle	0.44	0.43	0.44	0.43	0.42	0.42	0.74	0.74	0.75	0.74	0.72	0.72	0.61	0.6	0.61
Outer	0.45	0.45	0.45	0.44	0.44	0.43	0.76	0.76	0.76	0.76	0.74	0.74	0.63	0.62	0.63

Table 3: Analysis of variance for *Parrotiopsis jacquemontiana* specific gravity

Source	DF	SS	MS	f	p-value
Site	2	0.0036576	0.0018288	20.36	0.000
Disc	4	0.0194599	0.0048650	54.17	0.000
Location	2	0.0187266	0.0093633	104.26	0.000
Error	126	0.0113155	0.0000898		
Total	134	0.0531597			

Table 4: Analysis of variance for *Robinia pseudoacacia* specific gravity

Source	DF	SS	MS	f	p-value
Site	2	0.0098123	0.0049061	37.20	0.000
Disc	4	0.0220277	0.0055069	41.75	0.000
Location	2	0.0196486	0.0098243	74.49	0.000
Error	126	0.0166189	0.0001319		
Total	134	0.0681075			

Table 5: Analysis of variance for *Salix alba* specific gravity

Source	DF	SS	MS	f	p-value
Site	2	0.0023534	0.0011767	12.37	0.000
Disc	4	0.0144228	0.0036057	37.89	0.000
Location	2	0.0147076	0.0073538	77.28	0.000
Error	126	0.0119894	0.0000952		
Total	134	0.0434732			

Table 6: Analysis of variance for *Populus nigra* specific gravity

Source	DF	SS	MS	f	p-value
Site	2	0.0015126	0.0007563	6.87	0.001
Disc	4	0.0246400	0.0061600	55.93	0.000
Location	2	0.0134681	0.0067341	61.14	0.000
Error	126	0.0138785	0.0001101		
Total	134	0.0534993			

Table 7: Analysis of variance for *Juglans regia* specific gravity

Source	DF	SS	MS	f	P
Site	2	0.0059229	0.0029615	13.79	0.000
Disc	4	0.0187775	0.0046944	21.85	0.000
Location	2	0.0171467	0.0085734	39.91	0.000
Error	126	0.0270665	0.0002148		
Total	134	0.0689137			

values in disc III followed by disc II, disc I, disc IV and disc V, respectively (Table 2). All the discs within these site and also their locations in radial direction i.e., inner, middle and outer are statistically significant (Table 6).

***Juglans regia*:** In *Juglans regia*, the mean specific gravity varied significantly among the sites from 0.59 in site II to 0.66 in site I (Table 2). In site I (Khrew), it varied from 0.60 in disc V to 0.66 in disc II, having the maximum values in disc II followed by disc III, disc I, disc IV and disc V, respectively (Table 2).

In site II (Surasyar), specific gravity, varied from 0.59 in disc V to 0.65 in disc III, having the maximum values in disc III followed by disc II, disc IV, disc I and disc V, respectively (Table 2).

In site III (Shopian), specific gravity ratio varied from 0.6 in disc V to 0.66 in disc II, having the maximum values in disc II followed by disc III, disc I, disc IV and disc V, respectively (Table 2). All the discs within these site and also their locations in radial direction i.e., inner, middle and outer are statistically significant (Table 7).

As per Chowdhury and Ghosh (1958) for classifying woods on the basis of specific gravity the presently investigated species belongs to following classes:

- Light class *Salix alba*, *Populus nigra*
- Moderately heavy *Juglans regia*
- Moderately heavy to heavy *Robinia pseudoacacia*, *Parrotiopsis jacquemontiana*

DISCUSSION

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 (Zobel and Talbert, 1984; Bowyer and Smith, 1998). Some wood properties that are closely related to wood specific gravity are strength, dimensional stability with moisture content change, ability to retain paint, fiber yield per unit volume, suitability for making particleboard and related wood composite materials and suitability as a raw material for making paper (Bowyer and Smith, 1998).

During the present study the specific gravity varied among the sites significantly from 0.73 to 0.80 in *Parrotiopsis jacquemontiana*, 0.42 to 0.48 in *Salix alba*, 0.40 to 0.48 in *Populus nigra*, 0.59 to 0.66 in *Julans regia* and 0.71 to 0.79 in *Robinia pseudoacacia*. The highest values of specific gravity among the sites in these species were present in site III (Shopian) followed by site I (Khrew) and site II (Surasyar).

Purkayastha *et al*. (1980), Grzeskowiak *et al*. (2000) and Rao *et al*. (2002, 2003) reported that sites had a significant impact on wood specific gravity. Pande and Singh (2005) reported same results in *Salix nigra* and *Dalbergia sissso* Roxb, respectively. Monteoliva *et al*. (2005), while studying wood density of *Salix* clones in Argentina at different sites came to same conclusion. The parameter under discussion also varied in *Populus* spp. (Einspahr and Benson, 1967; Posey *et al*., 1969; Blankenhorn *et al*., 1992). Same results were reported by Kellison (1967) in *Liridendron tulipifera* L.; (Chudnoff, 1970) in *Swetianai macrophylla* King.; Karnik *et al*. (1970) in *Terminalia paniculata* Roth. and *Terminalia tomentosa* Willd. (Shukla and Rajput, 1981) in *Eucalyptus*. Significant clonal variations in wood specific gravity have been demonstrated for *Salix* spp. by Flower-Ellis and Olsson (1981) and Sennerby-Forsse (1983, 1985, 1986). The forgoing discussion depicts that the sites had a significant effect on wood specific gravity which may be due to the different edaphic and climatic factors. Wood specific gravity is directly related to the yield of pulp produced from the wood. The denser is the wood, the higher is the yield (Kennedy, 1968). So among the five different species, *Parrotiopsis jacquemontiana* with highest value of specific gravity will yield more pulp, followed by *Robinia pseudoacacia*, *Juglans regia*, *Salix alba* and *Populus nigra*, respectively. Within sites the highest yield of Pulp would come from site III (Shopian), followed by site I (Khrew) and site II (Surasyar) Table 2.

Radial variation in specific gravity of the species under investigation viz *Parrotiopsis jacquemontiana*, *Salix alba*, *Populus nigra*, *Juglans regia and* in *Robinia pseudoacacia* showed general trend of increase of specific gravity from pith to Periphery as is evident from the Table 2. While studying the Specific gravity, Briscoe *et al*. (1963), Hunter and Goggans (1963), Van Eck and Woessner (1964), Webb (1964), Herpka (1965), Sluder (1970), Einspahr and Benson (1967) Einspahr *et al*. (1972), Skolman (1972), Hills and Brown (1978), Land and Lee (1981), Yanchuk *et al*. (1983), Rueda and Williamson (1992) and Chauhan *et al*. (2001) reported it increased from pith to outwards in species of *Swietenia macrophylla* King., *Liquidambar stryaciflua* L., *Liriodendron tulipifera* L., *Salix alba*, *Populus tremuloides*, *Eucalyptus robusta* Sm., *Eucalyptus* spp., *Eucalyptus grandis* Hill ex Maiden., *Plantanus occidentials* L., *Ochroma pyramidale* (Cav. Ex Lam.), *Populus deltoides*.

The occurrence of low specific gravity near the pith and high specific gravity towards the bark in this study indicates that the presence of juvenile wood in the stem center of trees of sites. Sulaiman and Lim (1993) stated that wood with low specific gravity reduces its utilization potential. In this context, it is worthwhile to quote De Villiers (1973) who stated that "the problems experienced with the utilization of species are due in the first place to the presence of radial density gradient in the stem". The almost distinct pattern of wood specific gravity decline, as observed in all sites of the five different species would be helpful in understanding the presence of juvenile wood within the trees and therefore, in utilizing these sites carefully, especially for structural uses.

In contrast to radial variation, bottom to top changes in the wood specific gravity within trees of the five different species among sites generally showed decline in specific gravity for disc II-III (50% from base) upto merchantable top of tree. The pattern of variation of specific gravity along the stems agrees well with that in other reports on hard woods (Taylor, 1968; Hakkila, 1970; Manwiller, 1979). Similar results were noticed in trees of *Populus deltoides* by Chauhan *et al*. (2001) and in *Salix* species by Sennerby-Forse (1989).

CONCLUSION

During the present study the specific gravity varied among the sites significantly from 0.73 to 0.80 in *Parrotiopsis jacquemontiana*, 0.42 to 0.48 in *Salix alba*, 0.40 to 0.48 in *Populus nigra*, 0.59 to 0.66 in *Julans regia* and 0.71 to 0.79 in *Robinia pseudoacacia*. The highest

values of specific gravity among the sites in these species were present in site III (Shopian) followed by site I (Khrew) and site II (Surasyar) So among the five different species, *Parrotiopsis jacquemontiana* with highest value of specific gravity will yield more pulp, followed by *Robinia pseudoacacia*, *Juglans regia*, *Salix alba* and *Populus nigra*, respectively. Within sites the highest yield of Pulp would come from site III (Shopian), followed by site I (Khrew) and site II (Surasyar). Also radial variation in specific gravity of these species showed general trend of increase from pith to Periphery. The almost distinct pattern of wood specific gravity decline, as observed in all sites of the five different species would be helpful in understanding the presence of juvenile wood within the trees and therefore in utilizing these sites carefully, especially for structural uses.

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