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Wood variability in stems of *Parrotiopsis jacquemontiana* -(Decne.) Rehder. from temperate climate of Kashmir Himalaya, for its different end uses.

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Abstract

Background: *Parrotiopsis Jacquemontiana* -(Decne.) Rehder is regarded as an important natural resource almost throughout the world but relatively little is known about the within-tree variability of the anatomical characteristics of its wood.
Methods: For this purpose three sites were selected and from each site three trees were felled and five discs were extracted from base upto merchantable top of the each tree, equally spaced along vertical direction. The wood anatomical features viz. fiber length, fiber diameter, fiber wall thickness, varied significantly from different positions of trees.
Conclusion: Also the derived wood properties like Runkel ratio, Slenderness ratio, Luce's shape factor were evaluated from wood anatomical features as these parameters are directly related to industrial utility of wood especially, paper quality.

Key words: Anatomy, Fiber, *Paratiopsis jacquemontiana*, Wood.

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INTRODUCTION

Wood is unique among the world's important raw materials virtually used by every one in diverse ways. It is a remarkable material with a variability and flexibility that makes it useful for many kinds of products. Wood is known to have been used for various structural and other purposes since the dawn of history and has been serving mankind even in modern times with enormous technological know how. It is the fifth most important product of the world trade. The complex make up of wood (cellulose, hemicelluloses, lignin and pectin) makes it an ideal raw material for what could replace the petro-chemical industry, in providing not only plastic and all kinds of chemical products, but also food and textile products (Plomion et al. 2001). The durable properties of wood vary considerably from species to species often within the species, and selection of wood depends upon the conditions it is required to endure.

This variability arises from the dimensions of its anatomical structures like vessel elements, fibers, rays etc in both vertical i.e. from base up to the top of the tree and in radial direction from pith (inside) to the bark (peripheral) of tree respectively. The variability of wood anatomical features directly or indirectly has a bearing on the efficient use of wood for different end uses. Keeping in view the importance of wood anatomy in predicting the suitability of different woods for their varied utility purposes, the present work is an attempt to elucidate wood anatomical variation patterns within and among trees/shrubs of *Paratiopsis jacquemontiana.*

It is a large deciduous gregarious shrub/tree 6-20 feet high, found throughout Kashmir valley between 3800 to 8500 feet above sea level except on eastern slopes of Pirpanjal forest division from Gulmarg to Kulgam. It is an integral part in the living system of Kashmiries. Owing to the severe winter of Kashmir valley; the *Kangries* (made by weaving young twigs of *Parrotiopsis jacquemontiana* around earthen fire port), helps to Kashmiries, keep themselves and their children warm during prolonged winters from November to March. Charcoal made of *Parrotiopsis jacquemontiana* is considered of best grade. Its wood is used for making of tool handles were durability and strength is needed. Besides the wood is rich and best source of pulp for manufacturing of paper and plywood (Wani, 2010).

MATERIALS AND METHODS

Source of Material

The present study was carried out on *Parrotiopsis jacquemontiana,* a hardwood tree/ shrub with deciduous type of habit, belonging to family *Hammamaladiaceae* from natural provenances of Kashmir Himalaya for its anatomical characteristics. The sites which were surveyed are Khrew, Pampore, Ladhoo, Pulwama, Shopian, Ahrabal, Charsoo, Anantnag, Qaimoh, Budgam, Brenward Surasyar, Gowharpora, Shalimar, Darbagh, Naranag, Batpora, Habbak. Out of the sites, three were selected for the wood anatomical characteristics viz., Khrew (site-1), Surasyar (site-2), Shopian (Site -3).

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

A. Accessibility of sites

B. Availability of the material

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

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	30º 12′	34º 32′	33º 34′
East Longitude	75º 35′	74º 55′	75º 20′
Elevation (m)	2000	2400	2800
Soil	Sandy clay	Loamy soil	Sandy clay
Age in years	10- 13	10-13	10-13

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. These were named as DI, DII, DIII, DIV and DV from base up to the top respectively. From these discs, 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 wood element dimensions and variations within tree/ shrubs and among replicates at each site (Pande and Singh 2005).

Maceration

Maceration was done as per Jeffery's method (Johansen 1940) for all the samples studied. In this method, small slivers of wood were taken from the samples collected into the test tube and then filled with 10% chromium trioxide and 10% nitric acid and left for one to several days at room temperature and the process was hastened by heating up to approximately 60^0C for few minutes. After that, the material was thoroughly washed with distilled water till traces of the acid were removed. The mixture was teased/shaken thoroughly to separate the wood elements and stained with 1% Safranin and mounted in glycerine on microscopic slides.

Wood Element Measurements

The measurements/dimensions of fibers were done with the help of ocular-stage micrometry. Twenty-five measurements were made from unbroken fibers for diameter, wall thickness and length.

The derived wood properties of Runkel ratio, Luce's shape factor, and Slenderness ratio were calculated from measurements of the fiber morphology as per (Ohshima et al. 2005).

$$\text{Runkel ratio} = \frac{\text{fiber wall thickness x2}}{\text{fiber lumen diameter}}$$

$$\text{Slenderness ratio} = \frac{\text{fiber length}}{\text{fiber diameter}}$$

$$\text{Luce's shape factor} = (\text{fiber diameter}^2 - \text{fiber lumen diameter}^2) / (\text{fiber diameter}^2 + \text{fiber lumen diameter}^2)$$

Statistical analysis

The data collected for present study was statistically analyzed by using Sigma Plot 12.0 statistical software (SPSS. Chicago. IL.USA) and Minitab 11.0 for windows.

RESULTS

(a) Fiber length

In *Parrotiopsis jacquemontiana*, the fiber length varied significantly among the sites. The average fiber length ranged from 923.36 µm in site III (Shopian) to 1169.33 µm in site II (Surasyar) (**Table 2a**). The fiber length variation within disc i.e., from inner to outer (inner, middle and outer); within tree i.e., from base upto merchantable top of tree (DI, DII, DIII, DIV and DV) and among sites (site I, site II, site III) is statistically significant. But, the interaction of site, disc and location i.e. site × disc, site × location, disc × location and site × disc × location does not show any statistical significance (**Table 2b**).

Table 2a: Fiber Length in µm at different sites and locations of *Parrotiopsis jacquemontiana.*

Position	Location	Site I	Site II	Site III
Disc I	Inner	956.43	1132.33	975.23
	Middle	986.58	1150	1011
	Outer	1002.86	1161.33	967.93
Disc II	Inner	975.1	1132.66	987.00
	Middle	996.2	1146.66	1028.66
	Outer	1016.33	1169.33	1031
Disc III	Inner	965.03	1105.66	951.20
	Middle	971	1114.33	983
	Outer	1009.1	1135	1012.66
Disc IV	Inner	950.63	1097	934.36
	Middle	956.2	1102.66	955.20
	Outer	966.13	1124.33	995.20
Disc V	Inner	930.76	1073.33	923.36
	Middle	952.93	1085.33	951.80
	Outer	958.60	1096.33	954.26

(b) Fiber diameter

In *Parrotiopsis jacquemontiana*, the mean fiber diameter varied significantly among the sites. The mean fiber diameter ranged from 14 µm in site III (Shopian) to 17.18 µm in site I (Khrew) (**Table 3a**). The interaction of site, disc and location i.e. site * disc, disc * location and site * disc * location does not show any statistical significance except site * location interaction which is statistically significant (**Table 3b).**

(c) Fiber wall thickness

The fiber wall thickness in *Parrotiopsis jacquemontiana* varied significantly among the sites. The average fiber wall thickness ranged from 4.14 µm in site III (Shopian) to 5.87 µm in site I (Khrew) (**Table 4a**). Besides these, the interaction of site, disc and location i.e. site * disc, site * location, disc * location and site * disc * location does not show any statistical significance (**Table 4b**). Hence statistically there is no effect of these interactions on the dimensions of fiber wall thickness.

Table 2b: ANOVA for fiber length of *Parrotiopsis jacquemontiana.*

Source	Sum of Squares	df	Mean Square	F	Sig.
Model	142322601.78	45	3162724.484	6617.171	.000
Site	644814.915	2	322407.457	674.553	.000
Disc	63451.020	4	15862.755	33.189	.000
Location	26304.834	2	13152.417	27.518	.000
Site * Disc	4393.040	8	549.130	1.149	.339
Site * Location	1721.096	4	430.274	.900	.467
Disc * Location	3898.622	8	487.328	1.020	.427
Site * Disc * Location	5799.007	16	362.438	.758	.727
Error	43016.148	90	477.957		
Total	142365617.93	135			

Derived wood properties of *Parrotiopsis jacquemontiana*.

Runkel ratio

In *Parrotiopsis jacquemontiana*, the Runkel ratio varied significantly among the sites (Table 5a) from 1.51 in site I to 2.28 in site III (**Table 5**). In all the discs, among the sites three locations i.e. inner, middle and outer are statistically significant with one another within the discs **(Table 5a**).

Table 3a: Fiber diameter in µm at different sites and locations of *Parrotiopsis jacquemontiana.*

Position	Location	Site I	Site II	Site III
Disc I	Inner	16.83	16.04	15.28
	Middle	16.41	16.18	15.99
	Outer	16.41	16.42	16.28
Disc II	Inner	17.18	16.18	15.71
	Middle	16.70	16.37	16.04
	Outer	16.56	16.66	16.56
Disc III	Inner	16.85	15.94	15.04
	Middle	16.56	16.18	15.61
	Outer	16.47	16.27	15.80
Disc IV	Inner	16.70	15.61	14.76
	Middle	16.13	15.85	15.09
	Outer	15.9	16.04	15.47
Disc V	Inner	15.94	15.33	14.00
	Middle	15.9	15.57	14.48
	Outer	15.72	15.75	14.86

Luce's shape factor

In *Parrotiopsis jacquemontiana*, the Luce's shape factor varied significantly among the sites from 0.70 in site III to 0.84 in site I (Table 5b). In all the discs, among the sites, three locations i.e. inner, middle and outer are statistically significant with one another within the disc (**Table 5b**).

Slenderness ratio

In *Parrotiopsis jacquemontiana*, the Slenderness ratio varied significantly among the sites from 56.76 in site I to 71.09 in site II (**Table 5c**).

DISCUSSION

Fiber morphology

Fiber length varied significantly among the sites in presently studied species of *Parrotiopsis jacquemontiana* (923.36 µm to 1169.33 µm), Previous reports on the variation of fiber length among sites were reported by many authors (Murphy et al.1979; Phelps et al. 1982; Chauhan et al. 1999, 2001; Jorge et al. 2000; Rao et al. 2002; Yanez-Espinosa et al. 2004; Monteoliva et al. 2005; Pande and Singh 2005). Thus the present results are in agreement with the above said authors. (Cheng and Bensend 1979; Einspahar et al. 1963; Peszlen 1994) reported that fiber length is under genetic control. On the contrary in the present study, the pattern of fiber length and the dimensions of anatomical characters varied with site for the same

Table 3b ANOVA for fiber diameter of *Parrotiopsis jacquemontiana.*

Source	Sum of Squares	df	Mean Square	F	Sig.
Model	34402.986	45	764.511	5029.921	.000
Site	23.803	2	11.902	78.304	.000
Disc	22.012	4	5.503	36.206	.000
Location	1.406	2	.703	4.626	.012
Site * Disc	2.444	8	.305	2.010	.054
Site * Location	7.051	4	1.763	11.597	.000
Disc * Location	.262	8	.033	.216	.987
Site * Disc * Location	.394	16	.025	.162	1.000
Error	13.679	90	.152		
Total	34416.665	135			

Table 4a: Fiber wall thickness in µm at different sites and locations of *Parrotiopsis jacquemontiana.*

Position	Location	Site I	Site II	Site III
Disc I	Inner	5.19	5.17	4.52
	Middle	5.40	5.34	4.64
	Outer	5.61	5.59	4.76
Disc II	Inner	5.40	5.28	4.66
	Middle	5.67	5.53	4.72
	Outer	5.87	5.70	5.04
Disc III	Inner	5.06	5.15	4.44
	Middle	5.39	5.40	4.58
	Outer	5.49	5.58	4.72
Disc IV	Inner	5.02	5.01	4.22
	Middle	5.28	5.29	4.44
	Outer	5.37	5.45	4.61
Disc V	Inner	4.99	4.95	4.14
	Middle	4.97	5.14	4.32
	Outer	5.16	5.26	4.46

clone, which is indicative of overshadowing of genetic control by environmental factors on fiber dimensions.

Cell size and relating dimensions of fibers have a major influence on the quality of paper and pulp products as well as solid products (Clark 1962; Monteoliva et al. 2005). For pulp and paper production, species with higher lengths are preferred since a better fiber net is achieved, resulting in higher resistance of the paper. The existence of significant variation between sites for the fiber morphological traits indicates good opportunities for exploitation of these sites and superior trees among them for specific end uses.

Fiber morphological parameters, such as fiber length, diameter, and wall thickness were found to be significantly influenced by their radial positions within tree. Fibers in the pith region were shorter, thin walled and less wide in diameter as compared to those at periphery, there being a gradual increase radially from centre.

Table 4b: ANOVA for fiber wall thickness of *Parrotiopsis jacquemontiana.*

Source	Sum of Squares	df	Mean Square	F	Sig.
Model	3489.999	45	77.556	2064.030	.000
Site	17.818	2	8.909	237.098	.000
Disc	3.778	4	.945	25.139	.000
Location	2.982	2	1.491	39.682	.000
Site * Disc	.160	8	.020	.532	.829
Site * Location	.040	4	.010	.266	.899
Disc * Location	.100	8	.012	.331	.952
Site * Disc * Location	.129	16	.008	.215	.999
Error	3.382	90	.038		
Total	3493.381	135			

Table 5: Derived wood properties of *Parrotiopsis jacquemontiana*.

Parrotiopsis jacquemontiana		**Runkel ratio**			**Luce's shape factor**			**Slenderness ratio**		
Position	**Location**	**Site I**	**Site II**	**Site III**	**Site I**	**Site II**	**Site III**	**Site I**	**Site II**	**Site III**
Disc I	Inner	1.53	1.61	1.75	0.74	0.78	0.71	56.83	70.60	63.87
	Middle	1.73	1.70	1.85	0.79	0.79	0.70	60.16	71.09	63.22
	Outer	1.85	1.86	2.05	0.82	0.82	0.70	61.13	70.77	59.50
Disc II	Inner	1.68	1.66	1.70	0.76	0.78	0.72	56.76	70.01	62.89
	Middle	1.92	1.73	2.01	0.81	0.81	0.71	59.66	70.07	64.15
	Outer	2.04	1.91	2.28	0.84	0.82	0.73	61.39	70.22	62.25
Disc III	Inner	1.59	1.58	1.61	0.73	0.78	0.71	57.26	69.35	63.25
	Middle	1.90	1.69	1.77	0.78	0.80	0.71	58.83	68.87	62.98
	Outer	1.84	1.85	1.99	0.80	0.82	0.72	61.27	69.74	64.10
Disc IV	Inner	1.51	1.59	1.54	0.72	0.77	0.69	56.91	70.28	63.30
	Middle	1.76	1.85	1.73	0.79	0.80	0.71	59.30	69.56	63.28
	Outer	1.96	1.77	1.98	0.81	0.81	0.72	60.79	70.10	64.33
Disc V	Inner	1.62	1.69	1.65	0.75	0.78	0.71	58.40	70.04	65.93
	Middle	1.78	1.65	1.69	0.75	0.79	0.72	60.01	69.72	65.73
	Outer	1.89	1.73	1.82	0.79	0.80	0.72	61.00	69.60	64.26

Most reports on radial pattern of variation in hardwoods dealing with fiber dimensions agrees that fibers near the centre of the tree are shorter, thin walled and narrow in diameter as compared to periphery fibers. To quote some authors in favour are (Hejnowicz and Hejnowicz 1959; Carvalho 1962; Denne 1971; Bhat and Karkkanian 1981; Furukawa et al. 1983; Tomazello-Filho 1987; Stringer and Olson 1987; Sennerby-Forse 1989; Bhat et al. 1990; Peszlen 1994; Kauba et al. 1998; Adamopoulos and Voulgaridis 2002; Marsoem et al. 2002).

The increase of fiber length from pith to periphery could be explained on the basis of the increase in length of cambial initials with increasing cambial age from pith to periphery (Ghouse and Siddiqui 1976; Jorge et al. 2000).

Table 5a: ANOVA for Runkel ratio of *Parrotiopsis jacquemontiana*.

Source	**DF**	**SS**	**MS**	**F**	**P**
Site	2	7.0546	3.5273	83.47	0.000
Disc	4	0.4082	0.1021	2.42	0.052
Location	2	2.0042	1.0021	23.71	0.000
Error	126	5.3248	0.0423		
Total	134	14.7918			

There is an increase in fiber dimensions upto certain height and thereafter decrease in it. Same pattern was also observed by Bisset and Dadswell 1949; Carvalho 1962; Sardinha and Huges 1978; Wilkes 1998; Bhat et al. 1990; Jorge 1994; Jorge et al. 2000 in hardwood species. The decrease of wood fiber dimensions towards the top was also described by Stringer and Olson 1987 for *Robinia pseudoacacia* L. (Ridoutt and Sands 1993) for *Eucalyptus globulus* Labill. and (Chauhan et al. 2001) for *Populus deltoides* Bartram. ex Marsh. This increase in fiber dimensions from base up to certain height and there after decreasing upto top of tree in vertical direction is due to the differential proportion of juvenile wood in trees (Zobel and Talbert 1984).

Derived wood properties (Ratios and Factors)

Different types of ratios such as Runkel ratio, Luce's shape factor and Slenderness ratio were determined from the respective basic data related to fiber morphology. These ratios are important particularly for determining the suitability of a particular material for pulping and

Table 5b: ANOVA for Luce's shape factor of *Parrotiopsis jacquemontiana.*

Source	DF	SS	MS	F	P
Site	2	0.175418	0.087709	99.94	0.000
Disc	4	0.006019	0.001505	1.71	0.151
Loca-tion	2	0.035047	0.017524	19.97	0.000
Error	126	0.110576	0.000878		
Total	134	0.327060			

paper making.

Runkel ratio is obtained by dividing double wall thickness by fiber lumen diameter. The approximate limits of Runkel ratio appears to be from 0.25 to 1.5 (Singh et al. 1991) for a species. (Dadswell and Wardrop 1959) suggested Runkel ratio to be less than 1 which can produce pulp of reasonable quality, while (Ona et al. 2001) suggested that Runkel ratio is significantly related to pulp yield. The values obtained in this investigation shows significant variation between sites for Runkel. Among the three sites site II (Surasyar) can produce reasonable quality of pulp with good conformability and fiber to fiber contact followed by Site I (Khrew) and Site III (Shopian).

Slenderness ratio (fiber length/fiber diameter) showed significant differences among the sites in *Parrotiopsis jacquemontiana,* higher the ratios, greater will be the expected fiber flexibility that will give better tensile and tear property to the paper. In present study the highest values of slenderness ratio are present in site II (Surasyar) followed by site III (Shopian) and site I (Khrew). Hence among the sites, site II (Surasyar) with highest values of Slenderness ratio, the wood from this site would be suitable for paper having higher flexibility, hence better tensile and tear property, followed by site III and site I respectively

Table 5c: ANOVA for Slenderness ratio of *Parrotiopsis jacquemontiana*

Source	DF	SS	MS	F	P
Site	2	2607.90	1303.95	263.72	0.000
Disc	4	16.69	4.17	0.84	0.500
Location	2	23.45	11.73	2.37	0.097
Error	126	622.99	4.94		
Total	134	3271.03			

Luce's shape factor an important derived wood property obtained by equation (fiber diameter^2- fiber lumen diameter^2)/(fiber diameter^2 + fiber lumen diameter^2) (Oshima et al. 2005) and is directly related to the paper sheet density (Ona et al. 2001). In the present study the highest values of Luce's shape factor are found in site II (Surasyar) followed by site I (Khrew) and site III (Shopian). Hence among the sites; site II (Surasyar) with highest values of Luce's shape factor, possess the highest values of paper sheet density by, followed by site I and site III respectively.

CONCLUSION

In the present study fiber length varied significantly among the sites, which is indicative of overshadowing of genetic control by environmental factors on fiber dimensions. The existences of significant variation among sites for the fiber morphological traits indicate good opportunities for exploitation of these sites and superior trees among them for specific end uses. For pulp and paper production, species with higher lengths are preferred since a better fiber net is achieved, resulting in higher resistance of the paper. Also the derived properties of wood like Runkel ratio, Slenderness ratio and Luce's shapes factor varied among the sites as these ratios are important particularly for determining the suitability of a particular material for making pulp and paper.

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