

Variations in wood traits and specific gravity in male clone of *Populus deltoides* Bartr. Ex Marsh

Massarat Aziz (✉ massarataziz4@gmail.com)

Forest Research Institute

Research Article

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Abstract

*The present study deals with the variations of wood anatomical characters and specific gravity in male F₁ offspring of Populus deltoides. ANOVA indicated that within-ramet difference between the means at different heights of male offspring clone were significant for specific gravity only and non-significant for other wood traits studied. The specific gravity also increases from base to top of the ramet following an increasing trend. The variations for fiber length and vessel element length were significant for direction. The fiber length, fiber wall thickness and vessel element length significantly varied for different radial position. The interactions of height*direction and direction*position were non-significant for all wood traits except fiber outer diameter in height*direction interaction. The non-significant variations in different wood elements of single ramet of Populus deltoides due to peripheral and radial-direction may be related to the early maturity of clone raised tree. It seems non-significant variations in the wood element dimension's at different directions of Populus deltoides regulate the homogenous wood properties in the discs. The different types of ratios such as Runkel Ratio, shape factor, fiber length/diameter ratio and wall ratio were determined and are important particularly for determining the suitability of a particular material for pulping and paper making. The objectives of the study is to evaluate the wood quality on the basis of specific gravity, Vessel and fiber morphology and other wood anatomical parameters in the F₁ male clone of Populus deltoides.*

1. Introduction

The genus *Populus* belongs to the family Salicaceae that forms a part of the order *Salicales* of the group *Amentiflorae* which is widely distributed over the northern hemisphere and planted in many parts of the world. In India many species of *Populus* were introduced among which *Populus deltoides* did very well and has now occupied large chunk of forests, farmland, road and canal-sides in Haryana, Jammu and Kashmir, North Bengal, Punjab, Uttarakhand and Uttar Pradesh (Chaturvedi, 1982; Dalal and Trigotra, 1983; Jha and Gupta, 1991 and extended to Bihar.

Populus deltoides offers great scope in meeting the growing demand of wood based industries besides providing extra income to farmers. *Populus deltoides* is a medium density hardwood with an average standard specific gravity about 0.44. Its wood has high timber and fiber value for industrial applications. *Populus deltoides* is used in packing cases for fruits and other food stuffs, it also hold an excellent promise as a source of fiber for various grades of paper-fine paper, packing papers and news prints. *Populus deltoides* has been found to be one of the best ideal species for intercropping of integration with agriculture and horticulture crops (Tewari, 1993).

The variability in wood anatomical characteristics has profound influence on the properties of wood (Dadswell, 1957; Burley and Palmer, 1979). Features of interest in this connection include cell size, proportion and arrangements of different elements and specific gravity. The general pattern of variation in wood element dimensions is found not only within a species but also observed within a tree (Dinowoodie, 1961; Zobel, 1965; Rao and Rao, 1978; Pande et al. 1995; Aziz, 2012). Variability in wood

traits is mainly affected by genetic, environmental factors and silvicultural practices (Zobel and Sprague 1998; Zobel and van Buijtenen 1989; Lima et al. 2004). The variations in wood traits and specific gravity in male clone of *Populus deltoides* is to evaluate the wood quality on the basis of the studied parameters.

2. Materials And Methods

The Study site was situated at Rudrapur district (Udhamsingh Nagar), Uttarakhand, located at around 28° 53' N and 29° 23' N; 78°E and laterally extends between longitudes 78° 45' E and 80° 08 E at the altitude of 200 masl. The climate varies from Sub-tropical and sub-humid with three distinct seasons i.e summer, monsoon (rainy season) and winter. The annual rainfall was 1200 mm; of which 88% occurs during June–August. The average maximum summer temperature (April–June) was 36.7° and average minimum temperature (December– February) was 7.5°c (2005–2006). The soil of the site was sandy loam.

The planting material was collected from the F₁ male hybrid clone viz. (CC-01) with of *Populus deltoides* raised by WIMCO Plantations Ltd. at Rudrapur (Udhamsingh Nagar) India. The hybrid of F₁ generations (CC-01) was from the crosses namely G48*G3. The plantations were raised in Randomized Block Design. The spacing of ramets in plantations was 5x5m.

2.1 Sampling

Wooden samples were collected from the F₁ hybrid of male clone. The F₁ male hybrid was then bisected at various heights. The wooden discs were collected at the base and at regular intervals of 2.5 m at three different heights from each ramet to study base to top (vertical) variations. The discs were referred as DI, DII, DIII and DIV from the base. Small radial chips from the samples were macerated to determine fiber length, fiber diameter, lumen diameter and wall thickness, vessel element length and vessel element diameter as per Schultz's method (50% HNO₃ and a pinch of KClO₃). The macerated wood elements were thoroughly mixed and were spread on a glass slide and observations were taken under a compound microscope. The study was conducted to study the within-ramet vertical and horizontal variations.

The present study is an attempt to study the within ramet variations in F₁ generation of male clone for wood anatomical properties and specific gravity of *Populus deltoides* at the harvesting age (6 years) raised by WIMCO Seedlings Ltd.

Within-ramet horizontal variations were studied by dividing the each disc into three peripheral directions (North, South-East and South-West) for directional variations. Each direction was further divided into three positions (pith to periphery) viz. inner, middle and outer for radial variation. Nine wooden sample blocks discarded pith were selected from each disc. Thirty six sample blocks (36) were taken out from the ramet and were considered for the study.

Specific gravity of each sample (block) was determined by the gravimetric method using single pan balance. The green volume of the blocks was measured by water displacement after blocks were fully

soaked in water. Thereafter, samples were kept for drying in hot air oven at $103 \pm 2^\circ\text{C}$ till the constant weight and oven dry weight was recorded (Purkayastha *et al.* 1979-80). Basic density of wood samples was calculated as the ratio of oven dry weight and volume of saturated wood sample. Specific gravity was determined by using the following formula:

Specific gravity = Basic density of wood sample / Density of water

2.2 Pulp and paper ratios

Anatomical data obtained was used to determine Runkel Ratio ($2 \times \text{cell wall thickness} / \text{lumen diameter}$), shape factor ($(\text{outer fiber diameter}^2 - \text{lumen diameter}^2) / (\text{outer fiber diameter}^2 + \text{lumen diameter}^2)$) and fiber-length: diameter ratio (Singh *et al.*, 1991).

2.3 Statistical Analysis

The data obtained were statistically analyzed using SPSS (version 10.0). Multivariate analysis was carried out to test the differences in the mean for within- (both vertical and horizontal) variations. In the analysis, ramet, vertical position, peripheral direction and radial position were fixed factors while wood traits namely fiber length, fiber diameter, lumen diameter, wall thickness, vessel element length, vessel element diameter and specific gravity were dependent variables.

3. Results And Discussion

3.1 Within ramet variations in F1 male hybrid clone (CC-01)

Variance ratio (F) test showed that within-ramet difference between the means in male offspring clone were significant for specific gravity only. The variations for fiber length and vessel element length were significant for direction. The fiber length, fiber wall thickness and vessel element length significantly varied for different radial position. The interactions of height*direction and direction*position were non-significant for all wood traits except fiber outer diameter in height*direction interaction (Table 1). Most agree with that fibers are shorter and specific gravity is less near the center of the tree (Zobel and Buijtenen 1989). This pattern was also reported for *Populus* (Jayme *et al.* 1943; Boyce and Kaiser 1961) and *Eucalyptus* (Bisset and Dadswell 1949). Other genera including *Fagus*, *Quercus*, and *Fraxinus* have continuous increase in fiber length for 40 to 100 years in seed raised trees, depending on the species (Zobel and Buijtenen 1989). In some clonal plantations such as *Dalbergia sissoo* and *Eucalyptus tereticornis*, centre to outwards and bottom to top within ramet variations in wood elements and specific gravity were not reported, and the variations were not related to the early maturity of the wood in clone raised trees due to carrying over the physiological age of the tree for the wood traits. Wood element dimensions also varied non-significantly in L-34 clones of *Populus deltoides* from bottom to top and pith to periphery (Gautam 2010). There was no impact of age on wood elements and wood properties were generally homogenous within the ramet (Pande 2005; Pande and Singh 2009; Veenin *et al.* 2005). Inheritance pattern of wood anatomical characters and specific gravity from parents to the F₁ offspring

of *Populus deltoides* was reported by Aziz et al. (2008,2009). Results indicated that within ramet variations were significant for fiber length, vessel element length and diameter, specific gravity and Runkel Ratio and non-significant for fiber diameter. Fiber length was highest in female offspring (Bahar) followed by male offspring, female parent (G48) and male parent (G3). The variations were significant for wall thickness and were found to be highest in offspring than parents. Characters like fiber length, wall thickness and vessel element length were higher in offspring's followed by parents whereas fiber diameter, vessel element diameter, specific gravity and Runkel ratio were higher in parents followed by offspring. Vessel element diameter and specific gravity were higher in male group followed by female group.

Table 1
Within ramet variations in CC-01.

Treatments/variables	F (P) values							
	df	FL	FD	FLD	WT	VEL	VED	SG
Height	3	0.15 (0.923)	0.69 (0.566)	0.86 (0.473)	1.22 (0.323)	3.75 (0.024)	3.28 (0.038)	8.80 (0.000)
Direction	2	13.44 (0.000)	2.64 (0.092)	0.88 (0.425)	2.92 (0.073)	9.32 (0.001)	2.63 (0.092)	1.57 (0.228)
Position	2	76.85 (0.000)	2.09 (0.145)	0.19 (0.821)	11.94 (0.000)	60.40 (0.000)	2.52 (0.101)	0.48 (0.624)
Ht.* Dir.	6	0.41 (0.861)	4.43 (0.006)	3.07 (0.030)	0.58 (0.740)	1.38 (0.275)	1.44 (0.252)	3.45 (0.019)
Dir.* Pos.	4	0.76 (0.561)	1.14 (0.360)	0.47 (0.753)	1.76 (0.169)	0.74 (0.571)	0.14 (0.964)	0.77 (0.550)
FL = fiber length, FD = fiber diameter, FLD = fiber lumen diameter, FWT = fiber wall thickness, VEL = Vessel element length, VED = vessel element diameter								

The fiber length was maximum at DIII of the ramet and minimum at DI of the ramet thus follow an irregular trend. The fiber diameter was maximum at DI (bottom of the ramet) and minimum at DII of the single ramet. The fiber lumen diameter was maximum at DI (lower disc) and minimum at DIII while the fiber wall thickness was maximum at DIII (top of the ramet) and minimum at DII (lower disc) thus follows an increasing trend from base to top the ramet. The vessel element length is minimum at DI and maximum at DII. The vessel element diameter is minimum at DIII and maximum at DI base thus follows an irregular trend. The specific gravity is maximum at DIV (top of the ramet) and minimum at DI thus follows increasing trend from base to top of the ramet (Table 2)

Table 2
Wood traits at different heights in female offspring clone (CC-01).

Para- meters	DI Mean ± SEM	DII Mean ± SEM	DIII Mean ± SEM	DIV Mean ± SEM	Mean ± SEM
FL	1243.28 ± 40.20	1243.26 ± 45.25	1256.40 ± 43.32	1252.70 ± 40.83	1248.91 ± 42.40
FD	24.00 ± 1.06	23.36 ± 0.99	23.42 ± 0.90	23.43 ± 0.90	23.55 ± 0.96
FLD	16.71 ± 0.02	16.28 ± 0.02	15.93 ± 0.14	16.00 ± 0.15	16.23 ± 0.08
FWT	3.64 ± 0.25	3.54 ± 0.24	3.74 ± 0.27	3.71 ± 0.27	3.66 ± 0.26
VEL	593.76 ± 25.60	620.86 ± 28.80	608.12 ± 24.56	636.71 ± 25.50	614.86 ± 26.12
VED	133.94 ± 6.32	124.72 ± 4.92	119.97 ± 4.67	126.25 ± 4.75	126.22 ± 5.16
SG	0.36 ± 0.12	0.38 ± 0.13	0.44 ± 0.15	0.45 ± 0.15	0.41 ± 0.14
FL = fiber length, FD = fiber diameter, FLD = fiber lumen diameter, FWT = fiber wall thickness, VEL = Vessel element length, VED = vessel element diameter					

Average whole ramet Runkel Ratio ranged for selected heights from 0.45 to 0.49 (mean = 0.51 ± 0.00). Shape factor ranged from 0.35 to 0.37 (mean = $0.38 \pm .00$); fiber-length/outer fiber diameter ranged from 48.12 to 49.66 (mean = 46.78 ± 0.26); flexible co-efficient ranged from 4.23 to 4.32 (mean = 4.22 ± 0.04); wall ratio ranged from 30.80 to 32.54 (mean = 31.48 ± 0.40) (Table 3).

Table 3
Mean ± SEM at different heights for male clone.

Para- meters	DI Mean ± SEM	DII Mean ± SEM	DIII Mean ± SEM	DIV Mean ± SEM	Mean ± SEM
RR	0.45 ± 0.00	0.47 ± 0.00	0.47 ± 0.00	0.49 ± 0.00	0.47 ± 0.00
SF	0.35 ± 0.00	0.36 ± 0.00	0.36 ± 0.00	0.37 ± 0.00	0.36 ± 0.00
FL/FD	48.12 ± 0.35	49.66 ± 0.14	48.82 ± 0.12	49.15 ± 0.43	48.78 ± 0.26
FC	4.23 ± 0.038	4.24 ± 0.031	4.23 ± 0.048	4.32 ± 0.046	4.22 ± 0.04
WR	30.80 ± 0.35	31.49 ± 0.18	31.49 ± 0.88	32.54 ± 0.17	31.48 ± 0.40
Runkel Ratio, Shape Factor, Fiber length / Fiber diameter, Flexibility Co-efficient, Wall Ratio					

In Fig. 1 the increasing trend was followed by Runkel Ratio, Shape Factor and for wall Ratio from base to top of the ramet and other pulp and paper ratios like Fiber length/Fiber diameter, Flexibility Co-efficient,

Wall Ratio follow an irregular trend for male hybrid (Fig. 1)

Different types of ratios such as Runkel Ratio, shape factor, fiber length/diameter ratio and wall ratio were determined and are important particularly for determining the suitability of a particular material for pulping and paper making. 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 one which can produce pulp of reasonable quality, which is same as that of our results and is in the range of 0.45 to 0.49 from base to top of the male clone and hence can produce pulp of reasonable quality. The highest values of Runkel Ratio obtained was (0.49) for *Acacia aulacocarpa* followed by *A.auriculiformis* (0.48) among four species of *Acacia*. The fiber length/fiber diameter ratio, as significant differences were observed between provenances *Acacia auriculiformis* and species of *Acacia*. Higher the ratios, greater will be the expected fiber flexibility that will give better tensile and tear property to the paper. The fact that the provenances of *A. auriculiformis* (49.42) and *Acacia crassicarpa* (44.93) were superior in terms of this ratio and also offers opportunity to exploit these provenances for pulp and paper making Anoop, (2004). This supports the present study where the values range from (48.12 to 49.66) from base to top of the ramet. Aziz, (2012), Shashikala and Rao (2005) reported variation in clonal wood quality of *Populus deltoides* and *Eucalyptus tereticornis* respectively and its role in pulp and paper production. Runkel Ratio and shape factor were studied in 6–7 year- old trees to gain insight into the range of variations which are important industrial quality parameters for their suitability in paper and pulp industry. It showed that all the clones (1, 8, 99, and 158) were useful except clone 158 for having lower basic density and clone 8 for having higher Runkel Ratio. Lim and Gan (2000) reported some physical properties and anatomical features of two trees of 14-year-old *Acacia mangium*. The average Runkel Ratio of two trees was 1.38, FL/FD was 47.97 and shape factor was 0.47. This value of Runkel Ratio was greater than the values obtained in the present study while values of FL/FD were found almost same and shape factor were found in lower side as compared to the present study. This value of Runkel Ratio (1.38) reported by Lim and Gan (2000) was greater than the values of the present study.

4. Conclusion

The present problem is focused on within-ramet variations in wood traits and specific gravity in male ramet F1 offsprings of *Populus deltoides* the objectives of the study is to evaluate wood quality on the basis of specific gravity, vessel and fiber morphology and other anatomical parameters in the male offspring.

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Figures

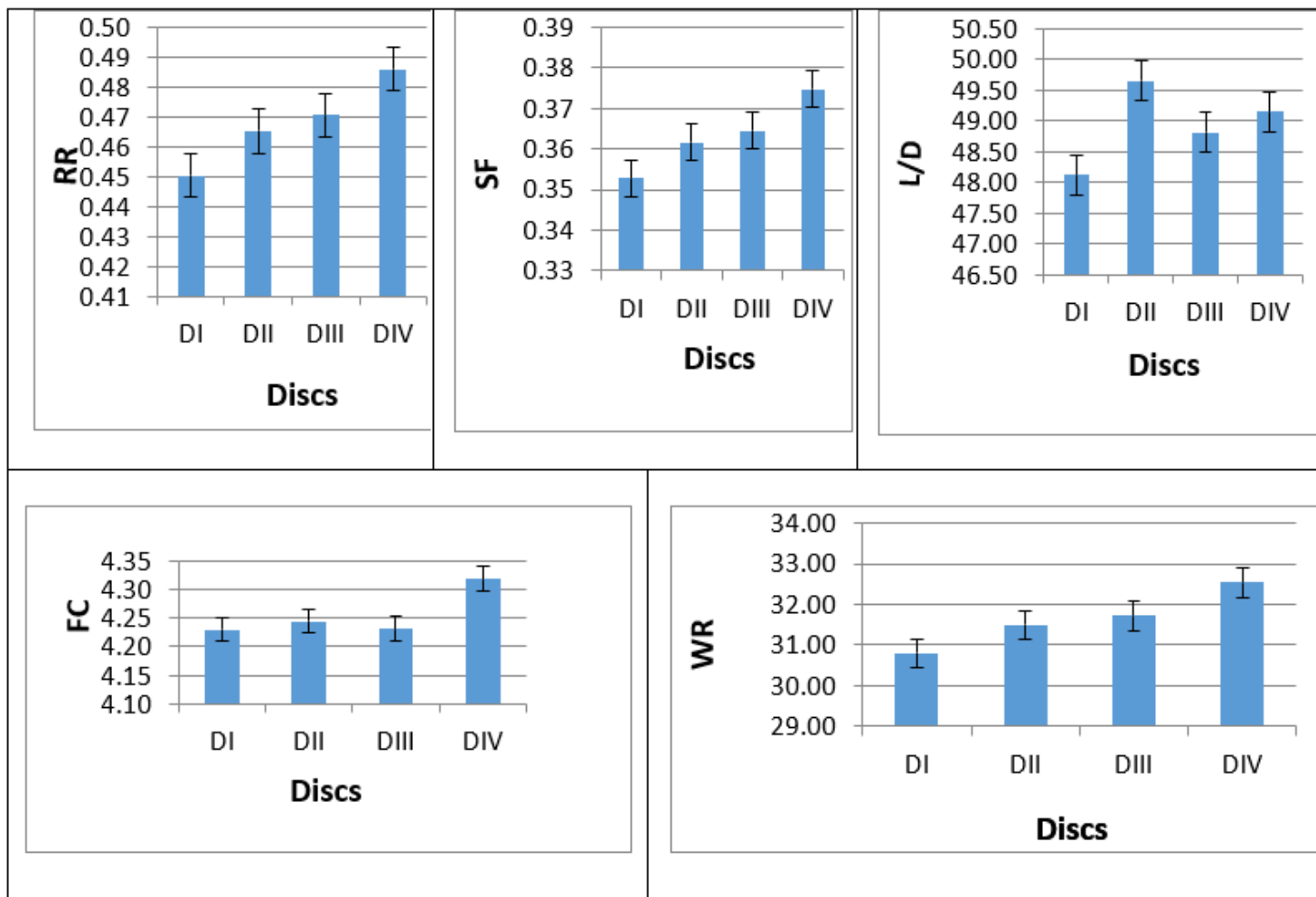


Figure 1

Mean $\pm$ SEM of pulp and paper ratios for male hybrids