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WITHIN TREE VARIATION IN ANTOMICAL PROPERTIES OF SOME CLONES OF EUCALYPTUS TERETICORNIS SM. FOUR AND HALF YEARS

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Abstract: The basic density and some of the anatomical properties of five clones of Eucalyptus tereticornis developed by ITC Bhadrachalam were reported. The five clones represented by four trees each of four and half years old were from Sarapaka, Andhra Pradesh. Within tree variation in anatomical properties of four and half years old grown Eucalyptus tereticornis clones have been investigated and correlated with basic density. Anatomical parameters studied were found to vary significantly from bottom to top with no definite trend. Significant variation exists in all the five clones of different parameters. Basic density was positively correlated with fibre length at middle, top and pooled positions. Fibre length was positively correlated with fibre diameter, fibre lumen diameter at bottom position, and with vessel diameter at middle position, and negatively correlated with vessel frequency at top position. The results obtained in this study have shown the suitability of raw material for paper and pulp where the required basic density is met with. Mainly these clone are primarily tried to meet the requirement of paper and pulp industry.

Key words: Basic density, fibre and vessel morphology, clones, paper and pulp.

I. INTRODUCTION

Eucalyptus tereticornis, known as Mysore gum in India and forest gum in Australia, is one of the most extensively planted eucalypt species in India. It is planted to meet the ever increasing demand for pulp wood and solid wood requirements of the Industry. ITC, Bhadrachalam Paper Boards Ltd., Andhra Pradesh, has come out successfully, after a number of trails, with some commercial clones of this species with improved productivity (Lal et al. 1993, 1997). There are only a few studies made on assessment of wood quality of Eucalyptus tereticornis from India belonging to different ages and localities of ordinary seed source (Purkayastha et al. 1979, Sharma & Bhandari 1983, Bhat & Bhat 1984, Bhat 1986, Bhat et al. 1987, Bhat 1990). Rao et al. (2002) initiated work on the assessment of the wood quality of Eucalyptus tereticornis clones. In this paper where studies made on basic density, fibre and vessel morphology of five commercial clones of ITC, Bhadrachalam which are about 4-5 years of age and grown in a clonal demonstration plot under rain fed conditions at Sarapaka, Andhra Pradesh are presented.

II. MATERIALS AND METHODS

Materials for this study were four trees from each of the five clones of ITC, Bhadrachalam numbered 3,4,6,7 and 10. These clones planted at an espacement of 1m x 1m except one clone (clone 10) where the espacement was 3m x 2m in red soil under rainfed conditions at Sarapaka, Andhra Pradesh, India. The trees were cut at 10 cm above ground level and 1m length billets up to the height of 3m were collected for Investigation. The average mid-girths of the billets of the different clones were 43.5 cm (clone 3), 31 cm (clone 4), 38 cm (clone 6), 33 cm (clone 7), 42 cm (clone 10). At the time of felling, the trees were four and half years old. From each billet a part (0.25 cm) of it was cut and set aside for paper and pulp studies and 5 cm thick discs were cut to study percentage of heartwood and sap wood, general features and gross structure. From the remaining part 2.5 cm wide radial strips were prepared. From these strips 1 cm on either side of the pith was removed and from the remaining lengthwise sticks were prepared. From these sticks 11 blocks were made and 10 blocks were used to find the basic density which was determined by using oven-dry weight/green volume of the sample. The eleventh block was used for anatomical studies. Only one side of the radius was used for the study as our earlier findings showed non-significant difference on both sides of the pith (Rao et al. 2002). Silvers taken from 1 cm3 blocks from billets of each clone and macerated with 30% nitric acid and a few crystals of potassium chlorate (Jane 1970). Fibre and vessel dimensions were measured from the macerated material. Thirty measurements per tree for each of the fibre and vessel characteristics were taken. Fibre wall thickness was calculated by deducting the fibre lumen diameter from the fibre diameter. For all the anatomical quantification a video Image analyzer was used. Fifty measurements were taken for each position. Nested ANOVA was performed to find variation within trees, within the clones and among the clones. A simple correlation coefficient was performed to examine the inter-relationships among the anatomical properties and density. Linear regression model was used to show the dependence of anatomical parameters on height position.

III. RESULTS AND DISCUSSIONS

A. Basic density

Basic density differed significantly between the clones at 1% level (Table.1). The highest basic density was recorded for clone 4 (0.583 g cm-3) and the lowest for clone 3 (0.514g cm-3).

Grzeskowiak et al. (2000) also reported significant differences in basic density in two E. grandis x camaldulensis clones. Purkayastha et al. (1979) showed that basic density (0.538 g cm-3 to 0.640 g cm-3) of 8 to 9 year old Eucalyptus hybrid (probably E. tereticornis) varied significantly among five localities. However, Bhat and Bhat (1984) found that the mean basic density of 1-year-old trees of E. tereticornis from Kerala was 2.6% greater than the overall mean density of five different plantations of 8 to 9-year-old trees as reported by Purkayastha et al. (1979).

The present study, however, did not show higher value in any clone compared with the data provided by Bhat and Bhat (1984). Quilho and Pereira (2001) showed that the wood basic density in E. globulus differed depending on the sites where they were grown. Best and worst sites produced higher and lower densities respectively and density was independent of growth rate. From the above discussion, it becomes evident that basic density varies with age and locality. Since these clones are primarily tried to meet the requirements of the paper and pulp industry, it is worthwhile to consider the suggestion of Ikemori et al. (1986) who stated that basic density which was in the range of 480 to 570 kg m-3 was ideal for paper and pulp. The results obtained in this study have shown the suitability of raw material for paper and pulp where the required basic density is met with.

The results obtained on variation in basic density showed significant differences within trees, among clones and non-significant difference within clones (Table.2). Purkayastha et.al. (1979-80) who studied 8-9 year old plantation of E.tereticornis of unknown seed origin also reported bottom to top variation within rarrow limits in all the trees with no distint trend. Taylor (1968) reported a decrese in specific gravity (density) in yellow poplar trees with the increase in height. In contrast, Taylor (1973) found a decrease in specific gravity from 1.5 m to 4.6 m and then an increase with increased height in stems of E.grandis. Taylor (1979) could not find any correlation between sampling height and density in six of eight hardwood species in southern United States. Bouvet and Bailleres (1995) reported a similar type of observation in five year old urograndis eucalypt hybrids in line with Taylor (1968). Notwithstanding the above observations, Gohre (1960), Dargavel (1968) Skolman (1972) and Taylor (1973) reported an increase in specific gravity with height in some eucalypts and in some poplars.

Thus the trends as shown in the (Figure.1-5) (Table.1) is supporting different types of variations encountered by others with reference to individual trees, although the differences may be small. At clonal level the bottom to top variation in four clones (clone 3, clone 4, clone 7 and clone 10) with the exception of clone 6 showed mild increase in basic density from base upwards. As a population, the regression equation (Fig. 1) is suggestive of very small increase with a very low value of r2 = 0.0245. According to Panshin and de Zeeuw (1980) the confusion of such a little consistency with no overall dominance of single pattern of specific gravity variation is partly due to diversity in proportions of cell types in different parts of tree and also result of varying growth influences. The present study has also shown the existence of significant variation among the trees. A perusal of the data (Table.1 and 2) showed the potential for further exploitation within each clone if one is interested in higher or lower basic density. Bhat and Bhat (1984), however, found that specific gravity of one year old trees of E.tereticornis from Kerala was found to be more than 2.6% than 9 year old trees. The data of within clone variation and among clone variation in specific gravity however did not show any higher value in any clone compared to the data provided by Bhat and Bhat (1984) even though the material studied was older. The variation in specific gravity in any clone as seen in the present investigation is expected not to affect much in pulp yield. In fact a preliminary study made by Rao et al. (1999) and Sushma Mahajan et al. (2000) of clonal material of E. tereticornis showed pulp yields ranging from 46.47% (clone 6)-49.89 (clone 3) and 43% (clone 10) – 48% (clone 6) respectively.

B. Fibre Characteristics

Fibre length, fibre lumen diameter, significantly differed between clones at 5% level and wall thickness at 1% level whereas fibre diameter was non-significant (Table 1). Maximum fibre length found in clone 4 and minimum in clone 7. Clone 4 and 10 were significantly different from other three clones with regard to fibre length. Fibre lumen diameter was significantly higher in clone 3 and 4, wall thickness was significantly higher in clone 6, 7 and 10.

The fibre lengths published so far for this species were 880 µm (Dadswell 1972; age not known), 742-804 µm (Purkayastha et al. 1979, 8-9 years), 750-820 µm (Laxmi Chauhan et al. 1983; 9 years), 660-790 µm (Sharma & Bhandari 1983; 8-10 years), 738 µm (Bhat 1986; 9-10 years).

A comparison of the values obtained in the present investigation with those above shows that the mean fibre length of any clone is longer than what has been reported for trees of higher age group of ordinary seed source.

The results obtained on fibre length, fibre diameter, fibre lumen diameter and fibre wall thickness have indicated that height having definite influence on the variation for the above characteristics (Fig.2-4),

While, fibre length decreased with the height in all the individual trees of any clone or in the clones themselves, the quantifiable change though significant is very low. It can also be seen that where the fibre length values are higher (Table.1) near the base (eg.clone.4) the subsequent values also remained higher when compared to other clones and their respective height positions (e.g. clone 4, clone 6, clone 7, clone 10). Thus, the trends of variation found in all the clones with respect to height position appears to be clone specific and are variable. The significant difference found may be due to positional effect from where the respective cambia produced these fibres. From the regression equation (Fig. 2) for the entire population of these clonal material produced, fibres which became shorter as one goes up from base. This is expected as the size of the cambial initials are comparatively more at the base than the cambial initials of the higher positions (Panshin & de Zeeuw 1980). Purkayastha et al. (1979-80) who studied 8-9 years old plantations of E. tereticornis found no consistent relationship between the whole tree fibre length either with the height or girth with the exception of Dehra Dun. Taylor (1973) however reported that sampling height having very little effect on fibre length in E. grandis. However, Bhat et al. (1990) found an initial increase from stump to breast height level then a gradual decrease towards the top in E. grandis. The average fibre length of one year old E. tereticornis was reported to be 610µm and positively correlated with height and diameter (Bhat & Bhat 1984), whereas the average fibre length for the same species, but 3 year old was 870 µm with no correlation to height or DBH (Bhat et al., 1987). In case of E. grandis (Bhat et al., 1990), the average fibre length increased both with the age and also with the height upto certain extent. The average fibre length varied from 812-1147µm in 3-9 year with a non- significant tree to tree variation. However, the present study indicated that the fibre length decreased from bottom to top and average fibre length reported for any clone is more than what has been reported by Purkayastha et al. (1979-80) and at par with the data of Bhat et al. (1987) of 3 year old trees. However, the present study gains support from Wendy Cheng and Bensend (1979) who found a decrease in fibre length with increase in height in the clones of Populus. According to Wendy Cheng and Bensend (1979) in juvenile wood, the variation in fibre length was mainly a result of physiological and environmental factor rather than a genetic factor.

The significant variation found within tree, within the clones and among clones is also suggestive of the juvenile nature of the tree and the conditions under which they were grown (Table 2). Grzeskowiak et al. (2000) also reported the existence of differences in fibre lengths among the clones of E. grandis they have studied. The present work is thus indicative of the importance of understanding the variation in fibre morphology particularly fibre length to envision potentials in the populations for better exploitations. The data if seen would suggests that wood material that could be obtained from these clonal plantations have not only provided improved fibre length but also more uniformity. The above observation thus confirms that when a clonal plantation is adapted, a uniform fibre length can be expected either at monoclonal level or at polyclonal level and percentage differences will be marginally very low. While the fibre length was found to vary significantly within the tree, within the clones and among the clones, the results obtained on fibre diameter, fibre lumen diameter, fibre wall thickness with reference to hierarchal sampling showed significant differences in relation to height for all the characteristics studied, a non-significant variation within the clones and a significant variation among the clones with exception of fibre diameter (Table 2). While the fibre diameter decreased from the bottom to top, (Fig.3)fibre lumen diameter increased, fibre wall thickness decreased. The interesting aspect in all these cases is the existence of non-significant variation among the trees. In other words a uniform characteristic could be obtained among the trees of any clone, thus eliminating larger variation. Fibre length, fibre diameter, fibre lumen diameter and fibre wall thickness have been shown to influence bulk, burst, tear, fold and tensile strength of the paper. Fibre characters were shown to have importance as coarse fibres were shown to have the same effect on paper as short fibres. Fibre diameter, fibre lumen diameter, fibre wall thickness are closely tied to specific gravity. The overall scenario that emerges out of this study is that height contributing to the major variations in cellular dimensions because of the post cambial activity of the respective cambia and the spatial adjustments required to perform the needed physiological function. However, from the point of view of utilization, where these variations are of less in nature, such variations will always produce a uniform wood quality and expected product. The present study of height related changes in fibre diameter is in conformity with the findings made by Taylor (1973).

The variation found among the clones in fibre wall thickness may be the resultant of availability of carbohydrates and hormonal activity as exemplified by Richardson (1959, 1964) on the physiology of xylem development who found that the major determinant of wall thickness is the availability of carbohydrate and hormonal activity. He further concluded that increase in cell lengths are directly related to temperature but only indirectly to increased carbohydrate formation caused by increased light intensity. Depending upon what sort of correlation it gives, necessary improvements can be made for the selection of clones which show suitable influence.

C. Vessel Characteristics

Vessel frequency, vessel diameter showed significant differences at 1% level between the clones (Table 1). Whereas vessel element length was non-significant. The mean vessel frequency ranged from 14 mm-2 (Clone 10) to 19 mm-2 (Clone 3). The mean vessel diameter ranged from 111 µm (clone 3) to 135 µm (clone 6). Clone 3 and 7 had significantly higher vessel frequency than the other three clones. However, the higher values obtained for vessel frequency in the present study compared to what has been reported by Purkayastha (1982) and Agarwal and Laxmi Chauhan (1988).

The vessel frequency, vessel diameter and vessel element length have shown significant within tree variation with no definite trend between any two trees in any clone with respect to height. The trend of bottom to top variation for each clone also is not consistent Since the dimensions of the vessels of any clone affect the paper sheet properties those clones with lower values would be preferred. Thus, clone 10, 4 and 6 have lower vessel frequency,whereas clone 3 has higher frequency. Similarly clone 3 has less vessel diameter compared to clone 6. In case of vessel element length the differences are non-significant. The interesting aspect of the present study is that within the clone there are no significant variation for any other characteristics and also for vessel element length among the clones (Table.2). Thus, the vessel frequency and vessel diameter will play a vital role for segregation of the clones as an index for wood quality assessment. Grzeskowiak et al. (2000) also reported significant clonal variation in vessel diameter and vessel frequency in certain clones of Eucalyptus.

The variation in average vessel diameter as found in the present study among the clones is within the range (112 µm-194 µm (147µm)) of what has been reported by Dadswell (1972) for E. tereticornis. So also for the vessel element length [(310µm-460µm (380µm)]. However, the higher values obtained for vessel frequency in the present study compared to what has been reported by Purkayastha (1983) and Agrawal and Luxmi Chauhan (1988), may be due to the juvenile nature of wood material in the former.

Generally vessels which are characteristic features of hardwoods are an important cellular constituents designated to perform the function of conduction of water and mineral nutrients in the living trees (Panshin & de Zeeuw 1980, Carlquist 1988). In timber utilization, vessels can be important in impregnation of chemical preservatives, drying, gluing, painting, cutting and other processes (Hillis & Brown 1984). While its role in timber utilization for solid wood purpose is yet to be ascertained for the clonal material, however, their role for conduction of water and mineral nutrients and also their adaptability to ecological conditions can be ascertained by looking at their vulnerability and mesomorphic nature.

There is an experimental evidence which has shown that a single genetic stalk grown in two places have greater vessel grouping in the drier habitat (Bissing, 1982). Vessel density (Vessel frequency) is an extremely sensitive measure of mesomorphy and xeromorphy.

Inter-relationship between Basic density and Anatomical properties:

A. Correlations at bottom position

Specific gravity was found to be positively correlated with vessel diameter, Fibre length was positively correlated with fibre diameter, fibre lumen diameter and fibre diameter was positively correlated with lumen diameter, fibre wall thickness, fibre lumen diameter was negatively correlated with vessel element length.

B. Correlations at middle position

The significant correlation coefficient observed for heartwood percentage was fibre lumen dimeter. Specific gravity was found to be correlated positively with fibre length, vessel diameter and negatively with vessel frequency. In case of fibre length a positive correlations was found with vessel diameter, fibre lumen diameter was positively correlated with vessel frequency, negatively with fibre wall thickness.

C. Correlation at top position

Specific gravity was found to be positively correlated with fibre length and negatively with vessel frequency. Fibre length was negatively correlated with vessel frequency and Fibre diameter has shown positive correlation with fibre wall thickness, Fibre lumen diameter was found to have negative correlation with fibre wall thickness.

From the foregoing account it can be seen that the correlations between any two characteristic was not consistent, when height is taken into consideration. The exception being fibre diameter and fibre wall thickness. This indicates that the relationships may change from significant to non-significant and also from positive to negative depending up on the height position.

D. Correlation for pooled up positions

The position wise data was merged for each tree and correlation coefficients were derived combining all the clones. Thus the influence of height position was nullified and the possible correlations among the properties for the combined clonal material was arrived at. From the Table.6 it can be seen that the existence of non-significant correlation between girth and specific gravity, fibre morphology including heartwood content is an indication of girth having no influence on the above properties. Percentage of heartwood was negatively correlated with vessel diameter. A significant positive correlation was found between specific gravity and fibre length, vessel diameter and a negative correlation with vessel frequency. The fibre diameter was positively correlated with fibre wall thickness. From this study it can be seen that the correlation coefficients which are significant, found to vary with respect to the height position and suggestive of the variation in the dimension, of wood anatomical characteristics from which these factors have been derived and one of the important factors being variation in girth.

Notable correlation for the pooled up data showed that all these factors are independent of specific gravity except fibre length, vessel frequency and vessel diameter. The positive and negative correlations found among the anatomical characteristics excluding a few which were found to be artificial in nature, is an indicative of the complex spatial adjustments of various cell dimensions with respect to post cambial activity. The variation in specific gravity in the clonal plantation along with fibre morphology is not influenced by girth. The various correlations, as found in the present study, were suggestive of complex inter-relationship existing between anatomical characteristics in these newly introduced clonal materials.

IV. CONCLUSIONS

Significant variations in Anatomical properties and basic density were observed in five clones of four and half years old trees except for fibre diameter and vessel element length. Basic density was positively influenced by fibre length, vessel diameter and negatively influenced by vessel frequency. Significant within tree variation was found in respect of basic density, vessel frequency, vessel diameter, vessel element length, fibre length, fibre diameter, fibre lumen diameter, fibre wall thickness. Basic density was positively correlated with fibre length at middle, top and pooled positions. Fibre length was positively correlated with fibre diameter, fibre lumen diameter at bottom position, and with vessel diameter at middle position, and negatively correlated with vessel frequency at top position. The variation in respect of height was more and also responsible for the variation among the clones. Relationships varied between anatomical characteristics, specific gravity and growth rate depending upon height position.

V. ACKNOWLEDGEMENTS

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Property	Clone number					Significance
	3	4	6	7	10	
Basic density (g cm-3)	0.514 a	0.583 b	0.550 c	0.529 d	0.541 e	* *
Fibre length (4 m)	907 b	948 a	925 c	886 d	946 a	*
Fibre diameter (4 m)	12.54	12.73	13.01	13.08	13.06	NS
Fibre lumen diameter (4 m)	7.89 a	7.74 a	7.33 b	7.49 b	7.33 b	*
Wall thickness (4m)	4.64 b	4.98 c	5.67 a	5.59 a	5.72 a	* *
Vessel frequency	19 a	15 b	15 b	18 a	14 b	* *
Vessel diameter (4m)	111 a	127 b	135 c	115 d	121 e	* *
Vessel element length (4m)	393	392	399	379	389	NS

Table 1. Basic density and Anatomical properties of Eucalyptus tereticornis clones.

NS= not significant
*Significant at 5% level
**Significant at 1% level

The values sharing common alphabet do not differ significantly at 0.05 probability level.

S.no	Property	F calculated	Significant at test
1	Within tree Basic density Within clone Among clones	0.594 0.205 13.38	** Ns **
2	Within tree FL Within clone Among clones	6.39 4.59 3.37	** ** *
3	Within tree FD Within clone Among clones	18.39 0.29 2.21	** Ns ns
4	Within tree FLD Within clone Among clones	19.83 0.36 4.18	** Ns *
5	Within tree FWT Within clone Among clones	91.77 0.068 17.21	** Ns **
6	Within tree VD Within clone Among clones	18.36 0.977 13.25	** Ns **
7	Within tree VEL Within clone Among clones	12.59 1.05 0.285	** Ns ns
8	Within tree VF Within clone Among clones	6.52 0.74 11.17	** Ns **

Table 2. Nested Analysis of Variance showing variation among, within clones and within trees of Basic density and anatomical parameters

Legends: Basic density; FL-fibre length; FD-fibre diameter; FLD-Fibre lumen diameter; FWT-fibre wall thickness; VF-vessel frequency; VD-vessel diameter; VEL- vessel element length

	Girth	**HW%**	Basic density	**FL**	**FD**	**FLD**	**FWT**	**VF**	**VD**	**VEL**
Girth	1.000									
HW%	0.092	1.000								
Basic density	-0.252	-0.236	1.000							
FL	-0.038	-0.178	0.328	1.000						
FD	**-0.529***	-0.321	0.144	**0.455***	1.000					
FLD	-0.027	-0.393	0.146	**0.521***	**0.560****	1.000				
FWT	**-0.614****	-0.085	0.060	0.148	**0.768****	-0.100	1.000			
VF	-0.241	0.263	-0.325	-0.150	0.108	-0.096	0.200	1.000		
VD	-0.244	**-0.602****	**0.642****	0.251	0.230	0.336	0.015	-0.377	1.000	
VEL	-0.254	0.220	-0.011	-0.205	-0.290	**-0.536****	0.068	0.369	-0.170	1.000

Table 3. Correlation coefficients for the interrelationships between girth, heartwood percentage, specific gravity and selected pairs of anatomical characteristics for the bottom position

n=20
* Significant at 0.05 level
** Significant at 0.01 level
Legends: HW%- heartwood percentage; FL-fibre length; FD-fibre diameter; FLD-Fibre lumen diameter; FWT-fibre wall thickness; VF-vessel frequency; VD-vessel diameter; VEL- vessel element length

	Girth	**HW%**	Basic density	**FL**	**FD**	**FLD**	**FWT**	**VF**	**VD**	**VEL**
Girth	1.000									
HW%	-0.217	1.000								
Basic density	-0.257	0.149	1.000							
FL	-0.018	0.067	**0.587****	1.000						
FD	0.219	-0.015	0.013	0.161	1.000					
FLD	-0.295	**0.512***	-0.023	0.122	0.040	1.000				
FWT	0.373	-0.389	0.024	0.023	**0.671****	**-0.703****	1.000			
VF	-0.360	0.237	**-0.471***	-0.385	0.063	**0.508***	-0.333	1.000		
VD	0.027	-0.239	**0.512***	**0.437***	-0.301	-0.265	-0.015	**-0.809****	1.000	
VEL	-0.011	-0.030	0.246	0.035	-0.392	-0.205	-0.123	-0.237	0.245	1.000

Table 4. Correlation coefficients for the interrelationships between girth, heartwood percentage, specific gravity and selected pairs of anatomical characteristics for the middle position

n=20
* Significant at 0.05 level
** Significant at 0.01 level

	Girth	**HW%**	Basic density	**FL**	**FD**	**FLD**	**FWT**	**VF**	**VD**	**VEL**
Girth	1.000									
HW%	-0.171	1.000								
Basic density	-0.256	-0.001	1.000							
FL	0.124	0.023	**0.519***	1.000						
FD	0.386	-0.383	0.015	0.081	1.000					
FLD	**-0.458***	**0.589****	0.144	0.026	-0.295	1.000				
FWT	**0.529***	**-0.619****	-0.094	0.023	**0.739****	**-0.861****	1.000			
VF	-0.099	0.191	**-0.62****	**-0.451***	-0.350	0.010	-0.194	1.000		
VD	0.062	-0.390	0.324	0.319	0.345	-0.267	0.372	**-0.503***	1.000	
VEL	0.227	0.131	0.048	0.322	0.173	0.034	0.066	-0.084	0.016	1.000

Table 5. Correlation coefficients for the interrelationships between girth, heartwood percentage, specific gravity and selected pairs of anatomical characteristics for the top position

n=20
* Significant at 0.05 level
** Significant at 0.01 level

	Girth	**HW%**	Basic density	**FL**	**FD**	**FLD**	**FWT**	**VF**	**VD**	**VEL**
Girth	1.000									
HW%	-0.150	1.000								
Basic density	-0.262	0.006	1.000							
FL	0.016	-0.27	**0.495***	1.000						
FD	-0.051	-0.238	0.070	0.297	1.000					
FLD	-0.371	**0.472***	0.057	0.265	0.228	1.000				
FWT	0.255	**-0.568****	0.007	0.030	**0.627****	**-0.615****	1.000			
MFA	**-0.675****	**0.500***	0.067	0.027	0.109	**0.534***	-0.340			
VF	-0.302	0.309	**-0.639****	-0.399	-0.123	0.403	-0.420	1.000		
VD	0.028	**-0.457***	**0.620****	0.371	0.076	-0.362	0.347	**-0.716****	1.000	
VEL	0.034	0.132	0.186	0.123	-0.254	0.053	-0.250	-0.031	-0.011	1.000

Table 6. Correlation coefficients for the interrelationships between girth, heartwood percentage, specific gravity and selected pairs of anatomical characteristics for the pooled position.

n=20
* Significant at 0.05 level
** Significant at 0.01 level

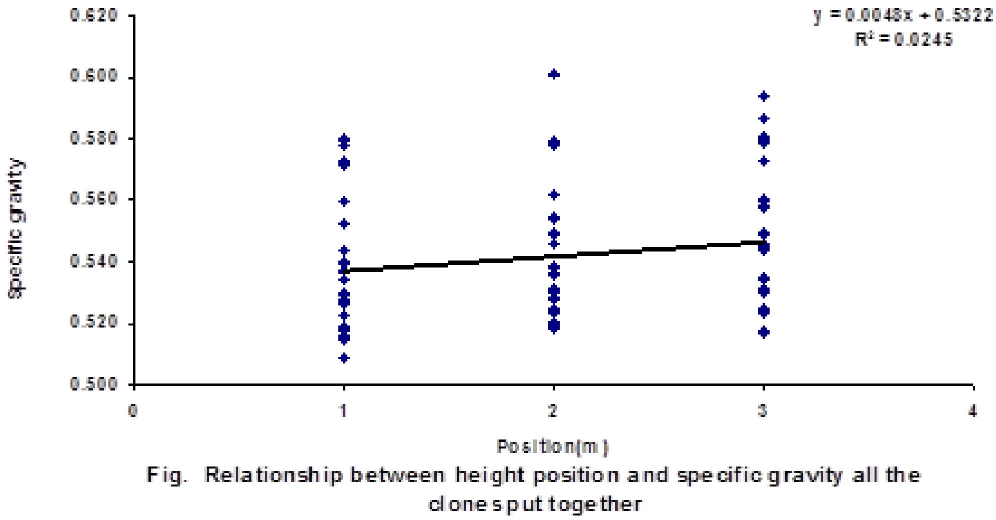

Fig.1

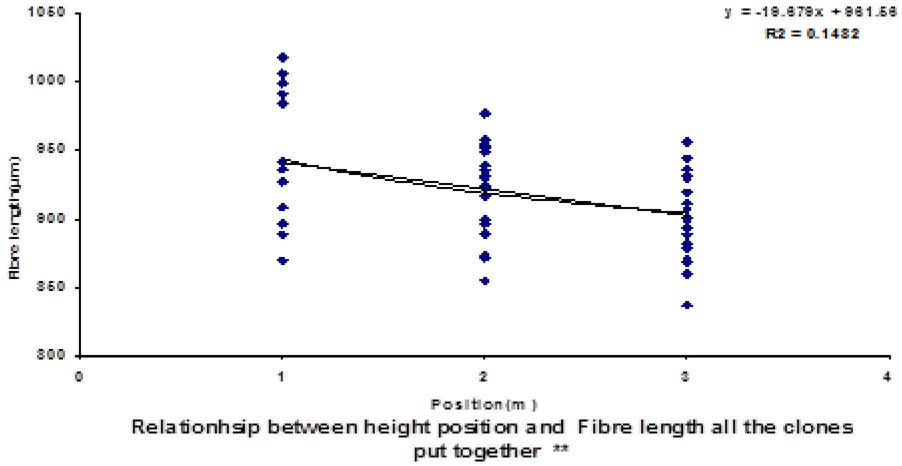

Fig.2

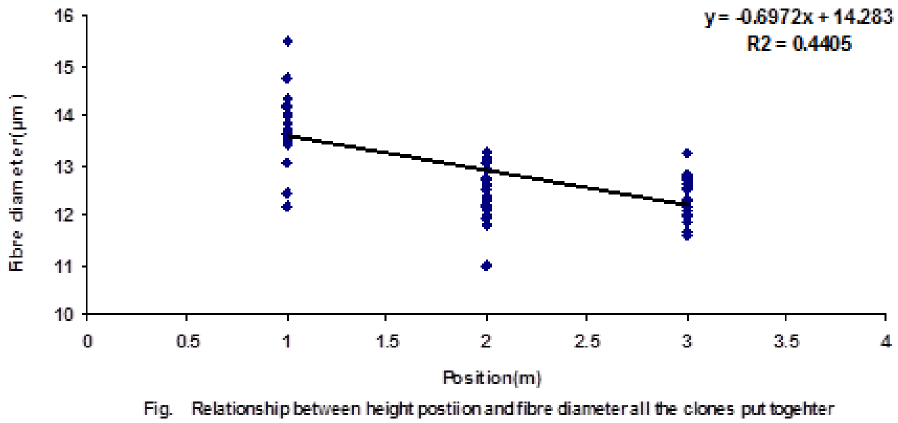

Fig.3

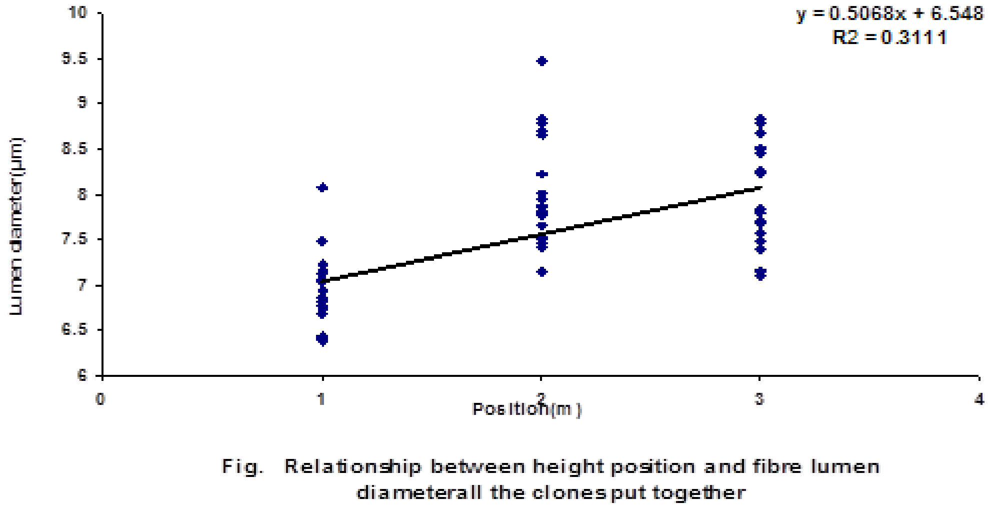

Fig.4

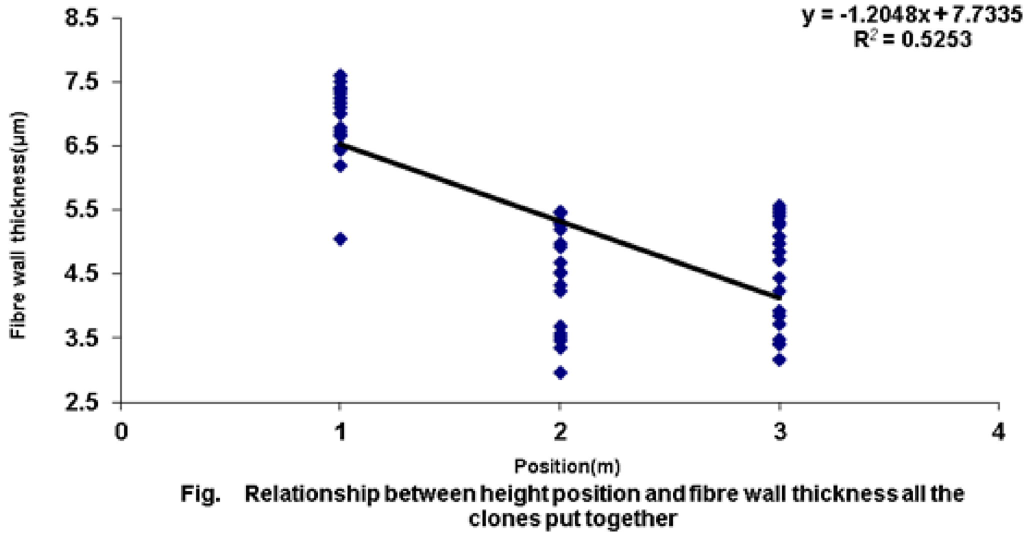

Fig.5

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