E. Afr. agric. For. J. (1987) 52 (3) 176–183

VARIATION IN THE WOOD QUALITY OF *PINUS PATULA* GROWN IN KENYA

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(Accepted for publication in August, 1987)

Pinus patula (Schied and Deppe) could be said to be a species in dispute readily accepted by the foresters as a fast growing species with rapid return on capital but reluctantly accepted by the paper industry as suitable especially when the age at which the material is harvested is given weight. Generally, growth in the species is rapid; Mean Annual Increment (MAI) culminates at 12 years, maximum return on capital is 14 years and merchantable volume on a good site is attained at 15 years. All these conditions are favourable for a reduction in rotation age. However, at the present rotation age of 18 years, kraft papers produced are of low strength. Compared with *P. radiata*, *P. patula* has slower growth rate, hence lower yield per unit volume and less, inferior pulp through lower yields per unit weight and poor strength properties. The industry is in favour of longer rotation age.

To-date, there is practically no information on the wood and fibre quality in plantation-grown *P. patula* in Kenya. Although success with the species has been achieved in the areas of regulating tree growth and form through thinning and spacing regimes, little has been done regarding the internal characteristics of wood apart from the work of Paterson (1966–68). This seems to be the missing link between foresters who produce the wood and paper manufacturers who consume it. The present study was therefore undertaken in an effort to bridge this existing gap. One of the objectives of the study covered in the paper was to investigate wood quality variation within trees, between trees, and between sites.

Materials and Methods

Material for the study was in two groups. Five 18-year-old sample trees were randomly selected from Kinale plantation site (from Central Kenya) for within tree evaluation. Disks 20 mm thick were removed from each sample tree at 1.3 m (bh), 5, 10, 15 and 20 m height—and clearly labelled. Sample blocks extending the entire diameter of the disk were then extracted from each disk. Since earlier studies had shown no significant variation between cardinal directions (Ringo, 1985) only one block per disk was finally used in the study (Fig. 1). The study on between tree and site variation was based on increment core values. Ten 18-year-old sample trees were randomly selected from each of the two sites, Kinale plantation site and Turbo plantation site (from Western Kenya). Increment cores were then extracted at bh from each tree.

Each sample block and core was marked at 1 cm from the pith and thereafter at 2-cm intervals to the cambium. Wood blocks and splints were removed from the marked regions. Distance from the pith was preferred because of the difficulties of counting growth rings in *P. patula* grown under tropical conditions. The splints were macerated with equal volumes of glacial acetic acid and 30 percent hydrogen peroxide solution. Drops of tracheid suspensions were dried on glass slides for tracheid length measurement. Meanwhile, wood blocks approximately 1×1×2 cm were softened by boiling in water until completely saturated. Cross sections 20 micrometres (μm) were cut from each block using a sliding microtome. The sections were stained in aqueous safranin solution, washed in 70 percent alcohol, stained in fast green and washed in 85 percent alcohol. Complete dehydration was achieved by washing the sections in xylene. The sections were finally mounted on microscope slides in permount and left in open air overnight to dry. They were used in measuring tracheid wall thickness and diameters.

Tracheid dimensions (length, wall thickness and diameter) were determined using a digitizer tablet linked to a computer system. The system and its computer software were developed by Dr. McIver and Mr. Ian Kennedy of the University of Toronto. Each slide is placed on a Bausch Lomb

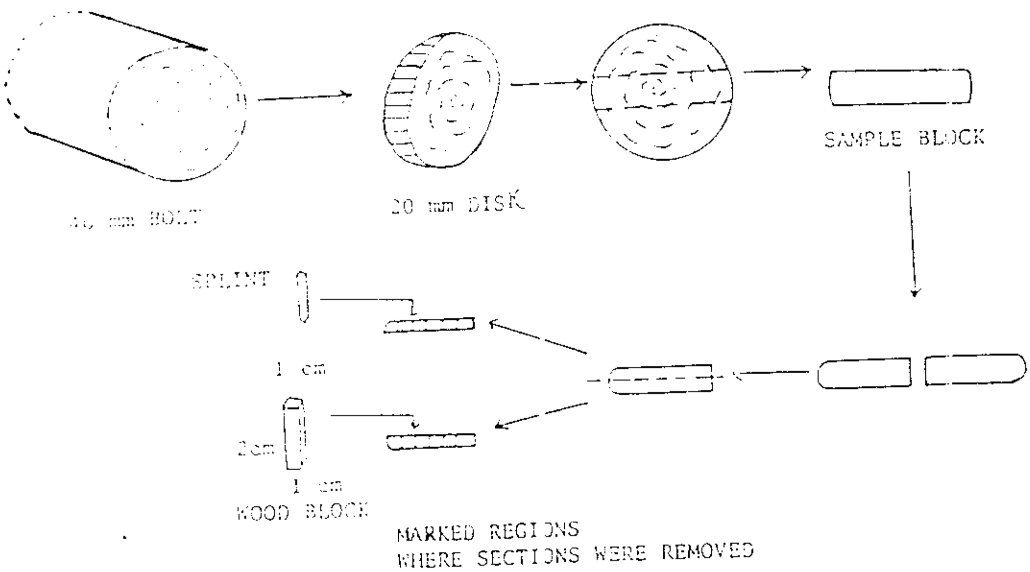

Fig. 1. Schematic diagram showing sequence of extractine wood blocks and splints from bolts.

type of projection microscope. The image is then projected onto a digitizing tablet situated 60 cm from the projector lens. Measurements are therefore based on projected images. The computer is programmed to measure a total of 20 tracheids and calculates a numerical average and standard deviation. The figure of 20 tracheids is based on earlier analysis which showed that it was statistically sufficient. Specific gravity (SG) was determined from oven dry weight and volume of saturated wood blocks. Each sectioned wood block was further divided to provide a replicate hence the value of SG reported is the mean of two measurements.

Results and Discussion

Specific gravity

The results for within tree variation in SG are shown graphically in Fig. 2. The pattern of variation from pith to cambium at all the heights show a drop in SG within 3–5 cm followed by a steady and rapid increase. An examination of SG and bh reveals that increase close to the cambium was more gradual. The major factor responsible for a drop in SG from the pith appears to be the **tremendous increase in tracheid diameters rather than tracheid wall thickness. This seems true because when results on SG, tracheid wall thickness (Fig. 4) and tracheid diameters (Fig. 5) are** examined, it is observed that whereas SG drops within 3–5 cm from the pith, wall thickness increases in a more or less linear manner towards the cambium. The increase in wall thickness therefore does not explain the drop in SG since it is known that such an increase results in a corresponding increase in wall substance hence SG. However, maximum **diameters (mean and lumen diameters) occurred** at about 5 cm from the pith. Tracheid lumens represent voids or empty spaces in the tracheids hence occurrence of maximum values between 3–5 cm indicate that there was minimum wall substance per unit area and ultimately low density or SG. Increase in SG after 5 cm from the pith appears to be influenced more by increase in cell wall thickness.

Mean weighted SG was 0.43 with a standard deviation (std. dev.) of 0.04. Regression analysis performed revealed a strong positive relationship between SG and distance from pith once effect of high SG at or near pith was removed. A similar analysis for SG and height revealed a negative relationship but was not significant at 0.05 level. Overall, SG decreased with height.

Between tree variation was significant at 0.01 level. The results are in agreement with the work of Paterson (1967) and Ringo (1985). Differences among trees present a major source of variation. Differences between sites was significant. This is

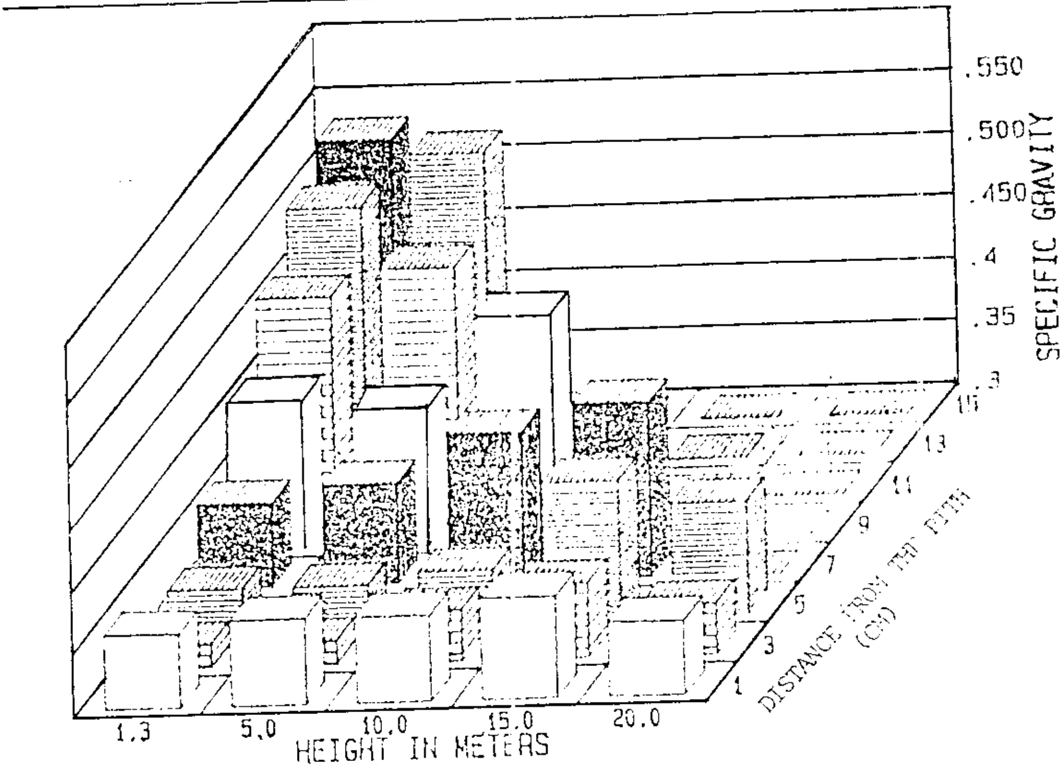

Fig. 2. Radial and vertical variation in specific gravity.

contrary to the results of Palmer *et al.* (1982/83) who found no significant differences among the three sites studied. However, the sites in their case were within one broad ecological zone (West of Rift Valley). In the present study, Kinale site is East of the Rift Valley with high amounts of rainfall (over 1,500 mm) and fertile soil compared with Turbo site that experiences occasionally longer and drier conditions resulting in a moisture stress. The mean height and dbh for the sites were 26.2 m and 29.5 cm for Kinale while for Turbo it was 24.3 m and 26.0 cm.

Tracheid length

There was a general increase in tracheid length towards the cambium at all heights (Fig. 3). The increase was rapid from the pith to about 11 cm and was followed by a gradual rise towards the cambium; this was particularly clear for bh and 5-cm levels. The pattern of tracheid length exhibited is typical of the juvenile mature growth phases explained tor most softwoods (Rendle, 1959 and Panshin *et al.*, 1980). At 18 years, juvenile wood in *P. patula* occupies about 60 percent of the wood volume.

Mean weighted tracheid length was 3.71 mm with a standard deviation of 0.22 mm. There was a strong relationship between tracheid length and distance from the pith following log transformation on distance. The need for the transformation arises from change in the slope with the onset of mature wood formation.

Variation between trees was significant on both sites showing that it is a major factor in lack of uniformity in wood properties. However, there was no significant variation between the sites.

Tracheid wall thickness

Tracheid wall thickness increased from pith to cambium—at all heights (Fig. 4). The increase towards the cambium seems to be influenced by increases in proportion of latewood bands in the mature wood. Mean weighted wall thickness was 4.58 μm with a standard deviation of 0.38 μm. There was a positive linear relationship between wall thickness and distance from the pith. Variation with

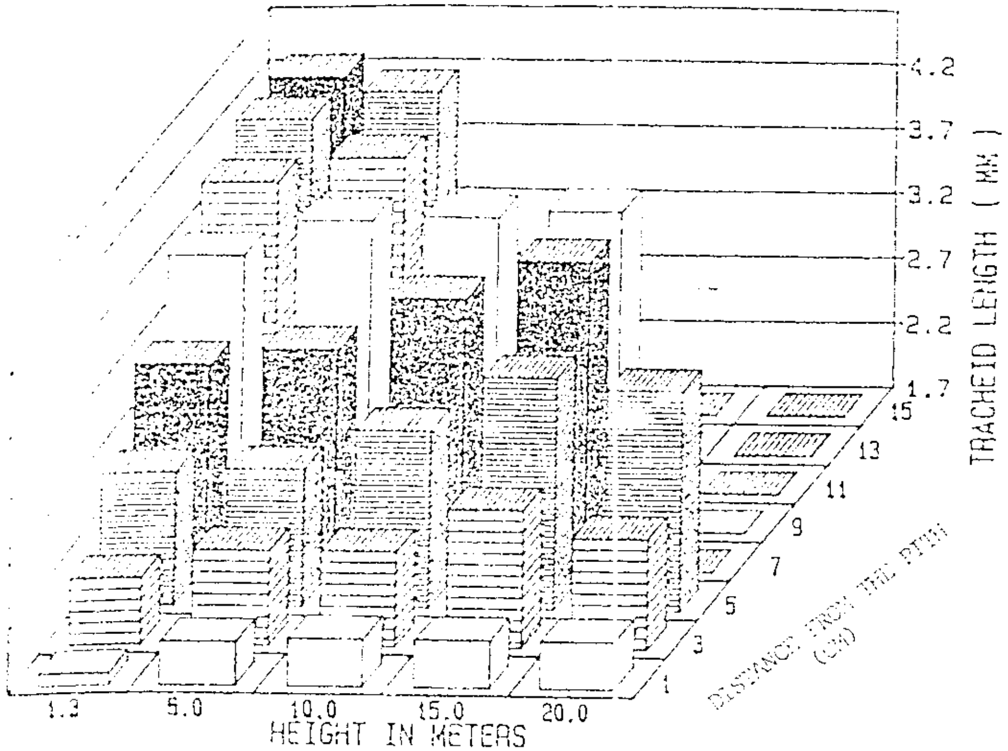

Fig. 3. Radial and vertical variation in tracheid length (mm).

height was negative indicating that the proportion of latewood cells decreases as one moves towards a region of active cambial growth.

Tracheid diameters

These include both the lumen diameters and mean tracheid diameters. There was an increase in lumen diameter radially towards the pith followed by an inconsistent pattern of flactuation. Maximum lumen diameters at all heights occurred at about 5 cm from the pith except for bh where the peak was at 7 cm while two-peak maxima at 5 cm and 11 cm were observed for 5-m height level (Fig. 5).

Mean tracheid diameters followed a similar pattern as the lumen diameters (Fig. 6). Diameters at bh and 5-m heights showed two maxima each, at 5 and 7 cm for bh level; for 5-m height, the maxima were at 5 and 11 cm from the pith. Mean weighted tracheid diameter was 40.4 μm with a standard deviation of 11 μm. According to the Panshin classfication (1980), *P. patula* is a coarse textured softwood.

Relationship with distance from the pith gave a moderate positive correlation significant at 0.05 level. A mild negative relationship was observed between tracheid diameters and height but was not signif cant.

Prediction of whole tree properties from bh core values

The study was desirable because the section on between tree and site variation was based on increment cores extracted from bh. The results of the analysis are presented in Table I.

There was a strong positive correlation between whole tree and bh values for the four parameters. The results show that it is possible to use bh values for *P. patula* in predicting total tree values for a given wood quality parameter.

Correlation between wood properties

The study was aimed at examining the type of interdependency that exists among the parameters which could be traced to the nature of growth and development. Table II presents the results.

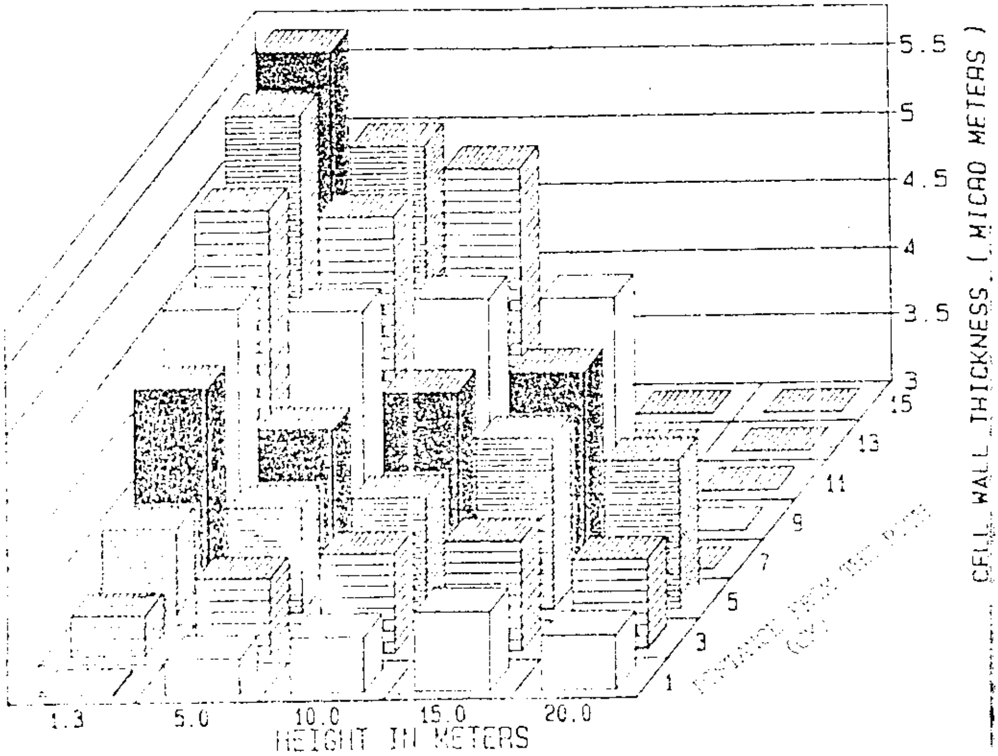

Fig. 4. Radial and vertical variation in cell wall thickness (micro meters).

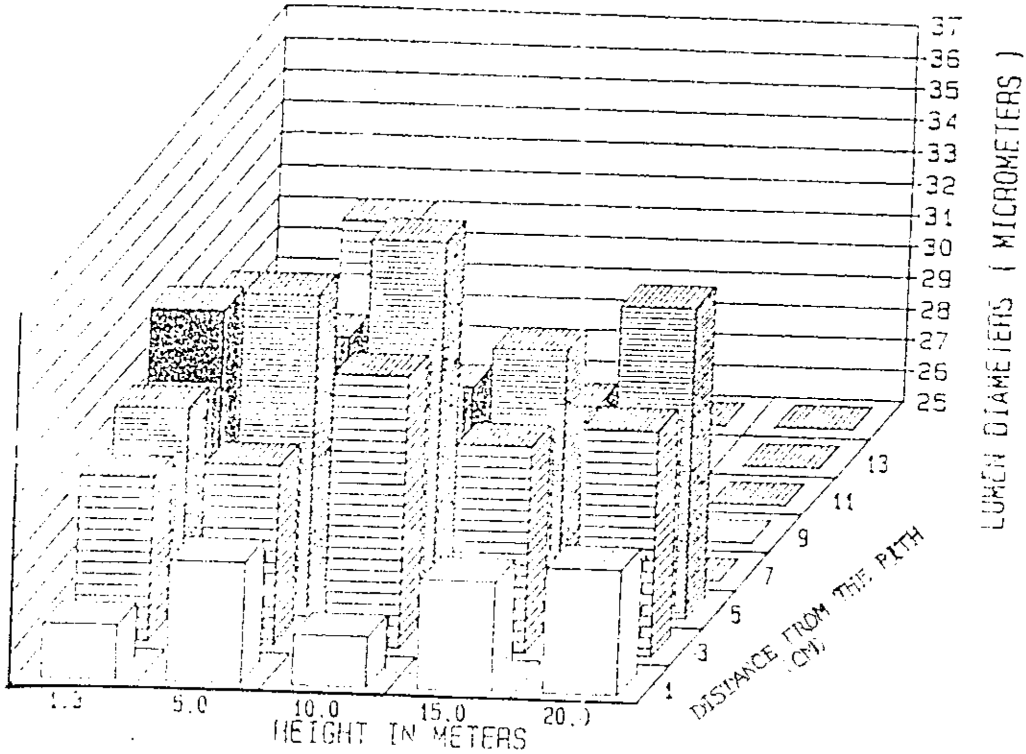

Fig. 5. Radial and vertical variation in lumen diameters.

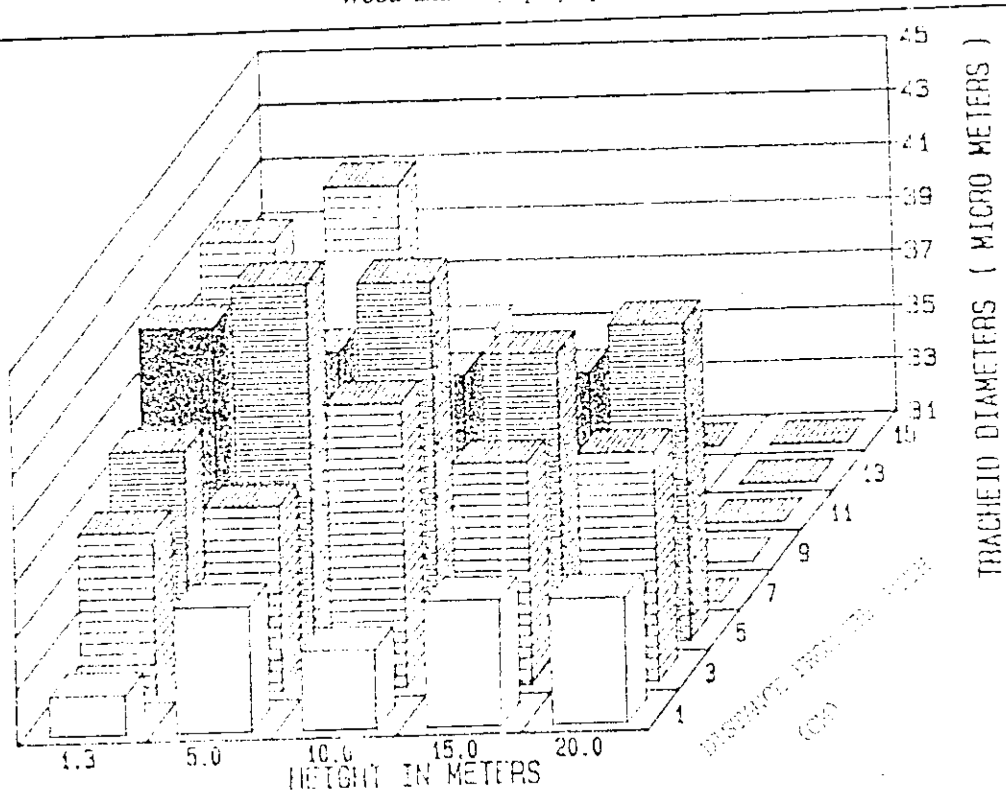

Fig. 6. Radial and vertical variation in tracheid diameters (micro meters).

TABLE I.—REGRESSION COEFFICIENTS AMONG WOOD PROPERTY PARAMETERS

Parameter	R^2	F	PR/F	CV
Specific gravity (SG)	0.975	231.56	0.0001	2.34
Tracheid length (TL) (mm)	0.989	532.17	0.0001	2.76
Cellwall thickness (CW) (μm)	0.991	677.47	0.0001	1.88
Tracheid diameter (TD) (μm)	0.727	13.29	0.0148	4.37

TABLE II—CORRELATION COEFFICIENTS AND SIGNIFICANT LEVELS FOR THE INTERACTION BETWEEN INDEPENDENT VARIABLES

Parameter	SG.	TL	CW	TD
SG	1.0000 0.0000	0.9233* 0.0030	0.9921* 0.0001	0.044 0.9336
TL		1.0000 0.0000	0.9369* 0.0006	0.6644 0.1035
CW			1.0000 0.0000	0.5888 0.1642
TD				1.0000 0.0000

Note.—*means significant at 0.01 level.

Specific gravity showed a strong correlation to tracheid wall thickness but a low correlation to tracheid diameters. Tracheid wall thickness is a measure of wall substance hence a high coefficient of determination (R^2) with SG confirms dependence of the latter on wall thickness. Low correlation of tracheid diameters to SG can be traced to differences in variation between the two and distance from the pith. For instance SG and distance from pith had an R^2 of 0.98 while tracheid diameter and distance had an R^2 of 0.63. Tracheid length was strongly correlated to SG but this may have been largely due to the fact that longer tracheids were found near the cambium which was invariably the area of thickest walls, again with a high proportion of latewood bands.

Tracheid length was strongly correlated to wall thickness and moderately correlated to tracheid diameters radially. Distance from the pith seems to have a strong influence on these parameters. It follows that as the cambium matures, it not only gives rise to long cambial initials but that the xylem cells undergo greater postcambial development in length, wall thickening and diameter growth.

Conclusions

Wood quality variation in *Pinus patula* grown in Kenya followed clear and discernible trends. The variation was more distinct within trees. Radially, SG decreased 3–5 cm from the pith followed by increase towards the cambium. Specific gravity decreased slightly with height. Tracheid length and wall thickness increased significantly with radius from the pith and decreased slightly with height. Tracheid diameter on the other hand showed only modest changes with a tendency towards increase with radius from pith and decrease with height. In general, there is significant amount of variation within trees.

In addition to variability existing within trees, lack of uniformity in wood quality arises from tree to tree differences as well as between site differences.

Total tree wood quality in *P. patula* can be reliably predicted from BH core values.

Summary

Variations in wood quality (specific gravity, SG), tracheid length, tracheid wall thickness, mean tracheid diameter and tracheid lumen diameter) were examined from 18-year-old *Pinus patula* from two sites in Kenya, Kinale and Turbo. Five co-dominant trees for within tree evaluation were chosen at random from Kinale site and discs of 20 cm thickness obtained at five height levels from each tree. Studies on between trees and sites was based on increment cores extracted from breast height level (1.3 m) of each tree. Ten trees per site were sampled for this purpose. Wood quality variation within trees followed fairly distinct trends. Radially, from the pith outward, SG decreased within the first 3–5 cm followed by increase toward the cambium. Specific gravity decreased slightly with height. Tracheid length increased significantly with distance from the pith but decreased slightly with height. Tracheid wall thickness and diameter followed different patterns from each other: wall thickness increased significantly with distance from pith but decreased with height while tracheid diameter showed only modest changes. There was a significant difference in SG between trees as well as sites. Tracheid length showed significant difference between trees but not sites. Except for tracheid diameters the other wood qualities showed strong correlation among themselves. Total tree wood quality can be reliably predicted from breast height (BH) core values.

Acknowledgement

The author is grateful to Dr. J. J. Balatinecz for his guidance in this study, to Pan Africa Paper Mills and University of Toronto for providing facilities for the research and to the Kenya and Canadian governments for financing the project.

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