BASIC DENSITY AND STRENGTH PROPERTIES OF PINES IN UGANDA

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ABSTRACT

Basic density and strength properties and their variations in 25 year - old *Pinus caribaea, P. oocarpa* and *P. kesiya* grown in Katugo, Uganda were investigated. Six trees for each species were selected representing three diameter classes. The trees were felled after measuring their diameter at breast height. Three disks were cut from each tree at 1.3 m, 45% and 75% of total tree height for growth ring width and basic density assessment. For strength properties determination, a central plank measuring 65 mm thick was extracted from each sample tree starting at breast height upwards. Basic density was determined using water displacement. Tests of various strength properties were done in accordance with standard procedures. The data were analyzed using the Statistical Analysis System. Results for the studied properties of *Pinus caribaea, P. kesiya* and *P. oocarpa* respectively were as follows: Basic density: 424, 431, and 444 kg/m^3; Modulus of rupture: 54.51, 56.31 and 60.69 N/mm^2; Modulus of elasticity: 8590,8752 and 8825 N/mm^2; Work to maximum load: 0.088. 0.099 and 0.101 mmN/mm^3; Maximum compression strength: 33.38, 33.83and 34.66 N/mm^2; Maximum shear strength: 9.43, 9.80 and 10.37 N/mm^2 and cleavage: 11.79, 12.15 and 12.48 n/mm. There were no significant differences in all wood properties between the three species. Between tree variations in wood properties were statistically insignificant ($p<0.05$) in all the species, indicating a low potential of improving wood quality through selection. Growth rate had no significant influence on wood properties. Wood properties studied decreased significantly from stump upwards the stem and increased from pith outwards in the three species. Strength properties of the three pine species were strongly correlated to basic density with regression coefficients (R^2) of above 0.88. Wood strength property values obtained in this study were within the range of pines grown in Kenya and Tanzania. These findings indicate that there are possibilities of expanding the use of these species through promotion. Butt end logs and inner wood can be used for non-structural applications and the outer wood for structural purposes.

Key words: Basic density, strength properties, properties variation, *Pinus caribaea, P. kesiya, P. oocarpa*, Katugo, Uganda

INTRODUCTION

Uganda has an area of 240,000 km^2 out of which 47% is covered by forests (MPED, 1996). Currently more than 70% of 14,000 ha of total softwood plantations are mainly covered by three pine species which are Pinus caribaea, P. Kesiya and P. oocarpa (FD 1990). These species have been widely planted on lower altitude sites since 1950s.

The species are fast growing, mainly used for general construction and joinery timber. However, little is known about their wood qualities and therefore their potential uses due to little research (Aluma and Ndimukulaga, 1996).

The overall objective of this study was to assess the quality of the plantation pinewood growing at Katugo in Central Uganda. The specific objectives were to determine and compare basic densities and some strength properties of the three pine species. The strength properties considered are those important in general construction including modulus of rupture, modulus of elasticity, work to maximum load in bending, maximum compressive strength, maximum strength and cleavage strength. Other specific objectives were to investigate the variation in basic density and strength properties between and within species and individual trees and to establish relationship between tree basic density and strength values and growth characteristics.

MATERIALS AND METHODS

Study Area Description

The study materials were obtained from Katugo Industrial softwood Plantations in Central Uganda. The plantation is located in Luwero District about 100 km North of Kampala City, covering 3,318 ha, between longitude 43 10' E – 44 01' E and latitude 12 25' N – 13 20' N (FD 1990). This area is 1,080 meters above sea level with annual bimodal rainfall averaging 1230 mm. Average daily temperatures vary between 22 – 23°C in July and March respectively. The soil is of three main types; first the Red Buruli soils which are dark reddish, moderately deep, strongly acidic and low in organic matter. Second are the Lwampanga soils which are brown and dark reddish, deep, strongly acidic and low inorganic matter. The third type consists of alluviums of the recent deposits.

Data Collection

Six trees for each species, aged 25 years were selected representing three diameter classes that is small (10 – 14 cm), medium (15 – 19) and large (20 – 24 cm). The trees were felled after measuring their diameter at breast height. For growth ring width and basic density assessment, three disks were cut from each tree at 1.3 m, 45% and 75% of the total tree height (Burley and Wood, 1976). For strength properties determination of each tree, a central plank measuring 65 mm thick was extracted from each sample tree starting at breast height upwards.

Basic density was determined using water displacement method. Tests of various strength properties were done in accordance with standard procedures as described by BS No 373 (1957), ASTM (1965), Desch (1973) and Hughes and Plumptre (1976) and Basic density was determined using water displacement.

Data Analysis

Simple statistics were conducted to determine mean, coefficient of variation and standard deviation of the studied properties. In addition, analysis of variance (ANOVA) and Duncan's Multiple Range Tests were conducted to determine the variation in basic density within and between both trees and species. Simple linear regression analysis was employed to determine the relationship between basic density and strength properties.

RESULTS AND DISCUSSION

Growth Ring Width

Growth ring width is an important indicator of wood development and of its quality. Comparisons of the effect of the growth rate on wood properties can only be made on rings of the same age (Zobel & Buijtenen, 1989). Consistent patterns of growth ring width were observed in all species. The number of latewood bands was much higher in butt end discs and decreased towards the top. The first 10 rings near the pith were 5 – 15 mm wide while the outer growth rings were rarely above 3 mm wide. This trend is similar to what has been reported by Larson (1956) and Elliot (1970).

The influence of ring growth width on basic density in pines has been difficult to substantiate due to the decrease in ring width and increase in tree age (Larson 1956, Elliot 1970). Ringo (1983) reported that growth ring width in P.patula does not significantly affect wood density.

Wood Density

Wood density variation among species

It can be noted that P. oocarpa produced the heaviest wood and P. caribaea the lightest. (Table 1). The type of cells, their proportions and arrangements might have contributed to these differences (Panshin and de Zeeuw, 1970). However, these differences were statistically insignificant ($p<0.05$).

Table 1 Mean basic density values (kg/m^3) for Pinus caribaea, Pinus kesiya and Pinus oocarpa grown in Katugo, Uganda

	Pinus caribaea	Pinus kesiya	Pinus oocarpa
Basic density s.d CV	424.3a 63.30 14.92	431.4a 89.48 20.74	444.4a 66.89 15.05

Where: CV = coefficient of variation
s.d = standard deviation

Note: Means within a row having the same letter are not significantly different at $p<0.05$ (Duncan's multiple range test).

Wood density variation between trees

There were differences in wood density between trees of same species. Density ranged from 387 to 456 kg/m^3 in Pinus caribaea, 423 to 502 kg/m^3 in P. oocarpa and 418 to 445 kg/m^3 in P. kesiya. The variations in basic density between trees were statistically significant for P. caribaea and P. oocarpa. Several studies have shown the same for pine trees within a given species and even within same sites (Ringo & Klem, 1980; Plumptre, 1984; Khiari & Iddi, 1989).

Much of the tree-to-tree density variation may be attributed to genetically differences in individual trees (Zobel & van Buijtenen, 1989).

Density variation within trees

Axial variation

The results (Table 2) show that for all species, basic density decreased significantly from bottom to top of trees. It decreased from 452.8 to 397.4 kg/m^3, from 452.0 to 413.7 kg/m^3 and from 468.8 to 420.1 kg/m^3 for P. caribaea, P. kesiya and P. oocarpa respectively. This may be explained in terms of crown effect. Crown influence auxin production, which directly regulate cell dimensions in the stem both across the growth rings and spatially down the stem. Wood within the vicinity of the crown is mostly core wood whose proportion increases with height (Larson, 1956; Elliott, 1970).

Table 2 Axial variation in basic density and basic density differences between Pinus caribaea, P. kesiya and P.oocarpa grown at Katugo, Uganda

Species	1.3 m	Height level 45%	Height level 75%
P. caribaea basic density	452.8a	422.8ab	397.4b
P. kesiya basic density	452.0a	428.4ab	413.7bB
P. oocarpa basic density	68.8a	444.4ab	420.1b

Note: Means within a column having the same letter are not significantly different at $p<0.05$ (Duncan's multiple range tests).

Radial density variation

In all species, variation in basic density in the radial direction i.e from pith outwards was statistically significant different as indicated by the results of Duncan's multiple range tests (Table 3). The results showed that in all species, basic density increased from pith outwards. Similar trends have been observed by Lema et al. (1978) and Silinge and Iddi (1990) for Pinus patula. This trend might be caused by differences in the proportion of early wood to late wood. The higher the proportion of late wood to early wood the higher the density (Zobel & Van Buijtenen, 1989).

Table 3 Radial variation in basic density in Pinus caribaea, P. kesiya and P. oocarapa grown at Katugo, Uganda.

Species	Radial levels from pith to bark (%)		
	17	50	83
P. caribaea basic density	370.6c	413.2b	489.2a
P. kesiya basic density	341.9c	410.2b	542.0b
P. oocarpa basic density	389.3c	427.6b	516.2a

Note: Means within a column having the same letter are not significantly different at $p<0.05$ (Duncan's multiple range tests).

Strength Properties

Duncan's multiple range tests results indicated that there were no significant differences in strength properties between the species. This shows that the three species exhibit roughly the same strength properties at same age and site (Table 4).

Variation in strength properties between trees and within species was statistically significant ($p<0.05$) in Pinus caribaea and P. oocarpa but insignificant in P. kesiya.

Table 4 Strength properties of Pinus caribaea, P. kesiya and P. oocarpa grown in Katugo, Uganda

Strength property	Pinus caribaea	P. kesiya	P. oocarpa
MOR (N/MM^2)	53.5	56	57.5
MOE (N/MM^2)	7000	8700	7300
Wmax (N/mm^3)	0.0825	0.1	0.103
MCS (N/mm^2)	34.6	36.3	10.45
MSS (N/mm^2)	10.95	11.25	11.55
CLR (N/mm)	13.5	12.3	13.6

Where:

MOR = Modulus of elasticity (N/mm^2), MOE = Modulus of rupture (N/mm^2), Wmax = Work to maximum load (N/mm^2), MCS = Maximum Crushing Strength (N/mm^2), MSS = Maximum Shearing Strength (N/mm2) and CLV = Cleavage Strength (N/mm)

Regression results as presented in Table 5 show strong positive coefficients indicating that strength properties are strongly and directly influenced by basic density, which continues therefore to be the best prediction of timber strength (Dinwoodie, 1981).

Table 5 Regression equations for the relationship between strength properties and basic density of Pinus caribaea, P. kesiya and P. oocarpa grown at Katugo, Uganda

Strength properties	**Species**	**Regression equation (y=a+bx)**	R^2
MOR (N/mm^2)	P. caribaea	Y = 0.30X – 75.78	0.86
	P. kesiya	Y= 0.13X – 0.250	099
	P. oocarpa	Y = 0.187X-24.04	0.91
MOE (N/mm^2)	P. caribaea	Y = 0.36.73x –7122.4	0.91
	P. kesiya	Y = 4.22x-75.78	0.86
	P. oocarpa	Y = 0.304x – 75.78	0.86
Wmax (N/mm^3)	P.caribaea	Y = 0.0006 – 0.156	0.92
	P. kesiya	Y = 0.0001X – 0338	0.93
	P. oocarpa	Y = 006X – 0.155	0.63
MCS (N/mm^2)	P. caribaea	Y = 0.14X – 23.66	0.94
	P.kesiya	Y = 0.048X – 15.56	0.97
	P. oocarpa	Y = 0.096X – 5.99	0.86
MSS (N/mm^2)	P. caribaea	Y = 0.044X – 9.31	0.97
	P. Kesiya	Y = 0.049X – 11.34	0.98
	P. oocrpa	Y = 0.020X – 1.52	0.53

Strength properties	Species	Regression equation (y=a+bx)	R^2
CLR (N/mm)	P. caribaea	Y = 0.29X – 0.446	0.66
	P. kesiya	Y = 0.0097X – 75.78	0.85
	P. oocarpa	Y = 0.018X – 4.59	0.73

CONCLUSION AND RECOMMENDATIONS

There is no significant difference in basic density and all strength properties studied among the three species, this implies that there is little to choose between these species for all wood products as well as selection. Basic density differed significantly between trees in each species. This is a clear indication that there is enormous potential of improving the plantations through selection and breeding. Since tree diameter neither influences density nor strength, except in P. oocarpa, management practices which favour fast tree growth may be employed without adverse effects on theses properties. Wood basic density and strength properties decreased significantly from butt end to top of the stem. Log assortment should be done and butt logs with high proportion of mature wood be priced higher and used for structural purposes while top logs with core wood be priced lower and used for non-structural uses.

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