

Full Length Research Paper

The Influence of Physical and Mechanical Properties on Quality of Wood Produced From *Pinus Patula* Tree Grown at Arsi Forest

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The main objective of the study was to investigate the physical and mechanical properties of *Pinus patula*. For this study, 28 years old *pinus patula* stand was used along the tree height from three portions, namely bottom, middle, top. Six trees were harvested and lumber used for testing were produced in Arsi Forest Enterprise mobile sawmill. A total of 336 samples free from visible defects were produced from three log positions of *Pinus patula*, each for modulus of elasticity, modulus of rupture, compression parallel to the grain, and impacts bending of dry and green and 84 samples of shrinkage were tested. For this experiment, variable of physical properties like basic density, initial moisture content and shrinkage were evaluated. The result showed that tree height had significant ($p<0.05$) effects on basic density and insignificant effects on initial moisture content and tangential and radial shrinkage. Basic density, initial moisture content and radial shrinkage shows decreasing trend from bottom to top log, but tangential shrinkage increase from bottom to top log. Similarly, the result indicated that highly significant ($p<0.01$) in all mechanical properties except specific impact resistance of green sample. The result of specific impact resistance of green sample was significant ($p<0.05$). The value of mechanical properties decreases from bottom to top log in all tests of green and dry samples. Generally, tree positions influence the physical and mechanical properties of wood.

Keywords: Density, compression; elasticity; moistures; resistance

INTRODUCTION

Man depends on forest products specially wood and wood products for several purposes (Zobel, *et al.*, 1987). The increase in population and consequently increase in demand of wood and resultant indiscriminate felling of trees, the forest cover diminished to a level that posed problem for saving the environment and the very existence of human life. This has paved a way to birth of the plantation forestry (Zobel, *et al.*, 1987). In the last few decades, plantations of short rotation fast growing exotic species as well as indigenous tree species have been carried out so that wood could be produced for different human needs and natural forest are to be not disturbed and maintained for environmental protection and ecological balance (Dyck, 2002). At present, in Ethiopia wood and wood products supplies for industrial,

construction and others including research purposes are mainly from remnants of natural forest, which is indigenous to the country (SFCDD, 1989). It is still indiscriminately and increasingly exploited and what is remaining is found mostly in unusable sizes and inaccessible areas. To reduce human pressure on the remaining natural forests and endangered indigenous trees, large hectares of plantations, mainly from exotic coniferous and Eucalyptus species, have been established with the objectives of supplying fuel wood, transmission poles, lumber and other products. Most of these plantations are found in the central, south and south-western Ethiopia. Arsi Forest Enterprise is one of the model plantations in the country. The enterprise supplies local markets with forest products like lumber



Figure 1. Map of the study area

mainly from tree species such as *Cupressus lusitanica*, Pine and transmission poles from Eucalyptus (NRC DMD/MOA, 1990).

Pinus patula is fast growing on good sites, and grows moderately on poorer sites. Management practices like pruning and thinning of trees is needed in plantations used for timber production. The trees can be used for fire wood and posts besides timber (Alemayehu Nigussie, 2002). In addition to industrial plantation, *Pinus patula* was also widely planted in the Ethiopian high lands in soil conservation and Community Forestry Programme, which was assisted by the FAO/WFP (World Food Programme, 1986). By the end of 1980s a total of 10,000-15,000 ha of the exotic tree species was established in the country. The volume of lumber produced from a certain volume of logs is affected by several factors related to wood (log diameter, length, defects) sawing pattern, lumber dimensions, quality of saw mills, training and experience of machine operators (Zavalla 1995). The unwise use of the scarce wood resources in this country has resulted in a decrease in total forest cover from around 40% to about 2.7% (EFAP 1994). Most of the remaining forests that can be easily reached are creamed out for their high value timbers for sawmilling and other purposes. An assessment of the physical and mechanical properties of wood has become a crucial issue in the operational value chain forestry and the wood processing industries are increasing under economic pressure to maximize extracted value. Foresters make wise management decisions; grow higher quality wood and lead to greater profitability for the forest industry (Harris et al. 2003).

The tree growth characteristics and wood properties that have a significant impact on softwood timber quality include stem straightness, stem taper, log diameter, growth rate, branching/knottiness, grain angle, wood density, juvenile wood and reaction wood. Generally, economics, environmental concerns and improved properties are the driving forces behind the unprecedented interest in plantation wood for the intended purpose. The goal of the work is to assess the quality of lumber produced from *Pinus patula* based on its physical and mechanical properties.

MATERIAL AND METHODS

Material

The wood was arranged from aris forest. Arsi Forest Enterprise owns forest plantations in two zones (eastern Arsi and western Arsi) of Oromia National Regional State, at about 240 km South of Addis Ababa, located at $6^{\circ} 50'' - 7^{\circ} 38''$ North latitude and $38^{\circ} 30'' - 39^{\circ} 06''$ East longitude, along the eastern escarpment of the rift valley. The total concession area of the enterprise (former) is estimated to be 21,384 ha of which 6230 ha is plantation forest and the rest (15,154 ha) is natural forest. The entire forest area is divided into three forest districts, namely Munessa, Gambo and Shashemene. The study was conducted at Gambo District. The altitude of the study sites ranges from 2100m – 2450 m. a.s.l (Kedir Nino, 2009) Figure 1.

Methods

Physical property Tests

(I). Determination of Moisture content

Three replicates of green samples with dimension of about 3 cm thick were taken from the bottom, middle and top parts of the *P. patula* tree to investigate the moisture variations within the logs. The method used for the determination of moisture content is based on TAPPI (Technical Association of Pulp and Paper Industry, 1994) Standard method. The green weight of all samples from each of the logs were determined and recorded immediately after harvesting, the samples were then transported to the laboratory with proper handling by covering with polythene plastics for drying. Samples were dried at a temperature of 103 ± 2 °C in an oven until constant weight. After cooling for 30 minutes in the desiccators, the initial moisture content of the sample was calculated as follows:

$$\text{Moisture content} = \frac{W_g - W_o}{W_o} \times 100\% \quad (1)$$

Where,

W_g = the green weight of the sample (gm)

W_o = the oven dry weight of the sample (gm)

(II). Determination of basic density

The basic density of *P. patula* were measured from fresh samples based on the most commonly used wood basic density measure, which is defined as the weight of any given volume of substance divided by the weight of an equal volume of water. Using displacement method, the volume of wood samples was obtained by immersing the samples in water (Panshin and De Zeeus, 1980). Three replicated samples of about 3-cm thick disc sample were cut from the bottom, middle and top parts of the log. The volumes of each piece were determined by water displacement method by immersing the wood disc in a beaker. The volume of water displaced from the beaker by the submerged samples was recorded. The samples were then dried at 103 ± 2 °C until constant weight was obtained. The basic density of the samples was calculated as follows:

$$\text{Basic density} = \frac{\text{oven dried weight of sample (g)}}{\text{Volume of displaced water (cm}^3\text{)}} \quad (2)$$

(III). Measuring Radial and tangential shrinkages

Furniture maker and designers rely on unit shrinkage information to build and design shrinkage/swelling

allowances. Shrinkages were evaluated from samples at green condition and after drying up to constant weight is obtained. For this study, the specimens were prepared from bottom, middle and top portions of the lumbers. The dimensions of the specimens were 20x20x30mm. The dimension of all samples was measured at green level. Then the samples were dried in an oven drier at 103 ± 2 °C until the sample weight was constant. Calculations were made by the use of the following relationships.

$$B = \frac{L1 - L2}{L1} \quad (3)$$

Or

$$B\% = \frac{L1 - L2}{L1} \times 100 \quad (3.1)$$

Where,

B=Shrinkage (cm/cm or %)

L1=green or initial dimension (cm)

L2=dry or final dimension (cm)

Mechanical property tests

(I). Static bending: The strength of wood in bending under transverse loads is one of the most important properties because of the major use made in construction of flexural elements for roofs and floors of buildings, and as stringers and girders in bridges (Gurfinkel 1973). The strength properties determined from this test were the modulus of rupture, and modulus of elasticity. Static bending is one of the important properties for end use, because it is the measure of the load carrying capacity of a piece of wood when used as a beam in the case of rafters, bridges, stringers and flooring joists. A total of 42 samples from dry specimen and 42 samples from green specimen free from knots were tested by using the universal Strength Testing Machine, type FM2750 with a maximum loads of 50 Kilo Newton (KN). In this test, a specimen of 20x20x300mm was supported over a span length of 280mm in trunnions carried on roller bearings. The load was applied to the center of the specimen, on the radial face at a constant speed of 0.11mm/s. The orientation of growth rings was parallel to the direction of loading. Load of the force plate and corresponding deflection was recorded from the dial gauge manually for each sample. The recording is continued until it failed to support one tenth of the maximum load or deflected by more than 60mm.

(II). Modulus of Rupture The bending strength of wood is usually presented as a modulus of rupture which is the equivalent stress in the extreme fibers of the specimens at the point of failure assuming that the simple theory of bending applies. Modulus of rupture measures the ability of a beam to support a slowly applied load for a short time in the case of beams, joists, flooring, furniture and timbers subjected to transverse bending (Gurfinkel

1973).

$$\text{MOR (in N/mm}^2\text{)} = \frac{3PL}{2bh^2} \quad (4)$$

Where: MOR=Modulus of rupture

P= Maximum Load in Newton's

L= Span Length (mm)

b= Width of the beam (mm)

h= Thickness of the beam (mm)

(III). Modulus of Elasticity: Modulus of elasticity measures stiffness of wood or measures the ability of the wood to bend freely and regain normal shape and dimension after termination of force action. This applies e.g. in the case of ceiling, joists and long columns. Stiffness is the slope of the load deflection curve within elastic range. It was calculated using the following equation (Gurfinkel 1973).

$$\text{MOE (N/mm}^2\text{)} = \frac{P^1 L^3}{4d^1 bh^3} \quad (5)$$

Where: MOE=Modulus of elasticity

P¹= Load at the limit of proportionality (N)

L= Span (mm)

d¹= Deflection at the limit of proportionality (mm)

b= Width of specimen (mm)

h= Thickness of specimen (mm)

(IV). Impact Bending (Specific impact resistance):

Specific impact resistance is the work consumed in causing total failure in impact bending. In other words, it is the resistance of wood to suddenly applied forces as in the case of sport goods, handles of axes, hammer, etc. A total of 42 samples from dry specimen and 42 samples from green specimen free from knots were tested for their impact resistance by using a pendulum hammer, type of Impact Bending Testing Machine type PW5-S. The sample was properly placed on the machine and the load was applied to the centre and perpendicular to the radial face of the test sample (tangential bending). The joule value was read from the force plate of the test machine and the strength was computed from the following formula.

$$\text{Sp.Im.Res.} = \frac{P}{bh} \quad (6)$$

Where: SP.Im.Res.-specific impact resistance

P-Joule value (Nm)

b-width of the sample (m)

h-Thickness of the sample(m)

(V). Compression parallel to the grain (Maximum crushing strength):

In the compression-parallel-to-grain test, a 20x20x60mm specimen was compressed in the direction of its length at a constant rate. The load is applied through a spherical bearing block, preferably of the suspended self-aligning type, to ensure uniform

distribution of stress. On some of the specimens, the load and the deformation in a 15cm central gage length were read simultaneously until the proportional limit is passed. The test is discontinued when the maximum load is passed and the failure occurs. A total of 42 samples from dry specimen and 42 samples from green specimen free from knots were tested by using the universal Strength Testing Machine, type FM2750 with maximum loads of 50KN. The strength properties determined from this test were the maximum crushing strength. This was determined from the following formula;

$$\text{M.C.S} = \frac{C}{bh} \quad (7)$$

Where:

M.C.S-Maximum crushing strength (N/mm²)

C-Maximum load (N)

b-width of the sample (mm)

h-Thickness of the sample(mm)

Since strength and density are influenced by moisture content, the experimental value were adjusted to 12% moisture content by using computer, based on the following formula. It was made for comparison purpose.

$$Y_{12} = Y_i [1 + \alpha (W - 12)]$$

Where: $\alpha = 0.02$

W-moisture content at test

Y_i –strength at W

$$\rho_{12} = \rho_w [(1 - 0.01)(1 - k)(W - 12)]$$

Where: ρ_w -specific gravity at test

K-0.85x ρ_w

W-Moisture content at test

Experimental Design and Statistical Analysis

Factorial experiment was used to conduct this experiment by considering three tree heights (bottom, middle, top log portions). The statistical analyses were conducted to evaluate the effects of physical and mechanical properties on tree height. Statistical Analysis Software (SAS) were used to analyze the data using analysis of variance (ANOVA) procedure and a least significant difference (LSD) method was used for mean comparison at $p \leq 0.05$ (SAS Institute, 2000).

RESULT AND DISCUSSION

Basic Density

The mean basic density of the three portions (bottom, middle and top) of *P. patula* tree ranged between 0.46 gm/cm³ and 0.57gm/cm³, which are summarized with moisture content and shrinkage percentage in Table 2.

Almost the basic density of the bottom (0.57) gm/cm³

Table 2. Mean values of basic density, initial moisture content and tangential and radial shrinkage

n	Height	Density(g/cm ³)	M.C%	Shrinkage at 12 M.C%	
				Tangential (%)	Radial (%)
14	Bottom	0.57	127.20	3.65	2.61
14	Middle	0.48	106.54	3.51	2.41
14	Top	0.47	105.69	3.96	2.08

n- number of test samples

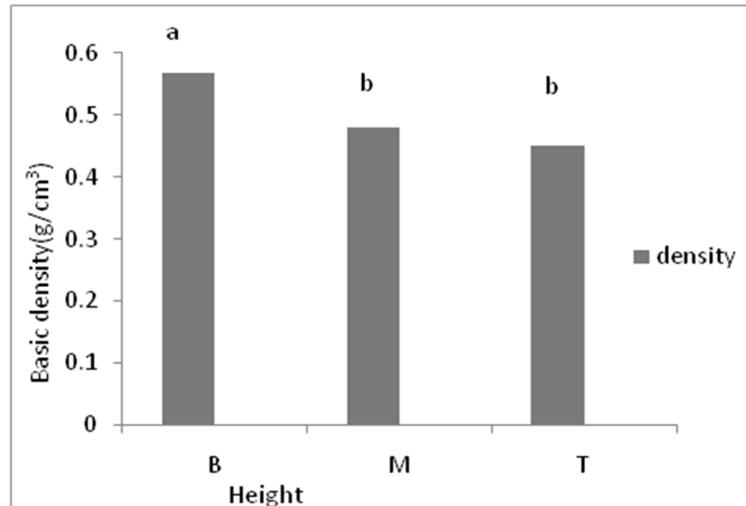


Figure 2: Basic density along the tree height

Note: Means having the same letter were not significantly different

Table 3: ANOVA on physical properties of *Pinus patula*

Source of variation	DF	Density	M.C.	Shrinkage at 12%M.C	
Height	2	(g/cm ³) 0.26*	(%) 890.24ns	Tangential 1.07ns	Radial 1.55ns

Note: ns-not significant at p>0.05,*-significant at p<0.05, **-highly significant at P<0.01

log is higher than the other two, i.e. middle and top logs (0.48, 0.47) gm/cm³, respectively. The density of *P. patula* (based on oven dry weight) was significantly different (P<0.05) among the three portions studied. Juvenility increases from bottom to top and as juvenility increases, basic density decreases. Due to maturity of wood tissues in the bottom portion, density show decreasing trend towards top portion. As indicated in Table 2 the tree height had insignificant effect in all variables except basic density, which is shown Figure.2

Ishengoma et al., (1998) noted that density was the main criterion for prediction of clear wood strength properties. This study has confirmed that knowledge of density of any species is vital in the preliminary selection and utilisation of wood for structural purposes. This was also the case with (Ishengoma et al., 1997) who reported that core wood or juvenile wood is significantly lower in density than mature wood and hence the

reduction in density as you move away from the butt end. This implies that the high-density wood from butt end logs should be used for structural purposes where high strength is required. Goker(1977) studied the properties of mature black pine wood. The basic density found was 0.560g/cm³.In these findings of *P. patula* wood, the average basic density observed was 0.51g/cm³. The study made on *Cupressus lusitanica* by Tiruneh Kide (2002), density could be used for strength grading boards of both species based on defined dimension and moisture content. In this study also, mechanical properties have direct relationship with basic density, i.e. as mechanical property increases from top to bottom log basic density also increases. This shows that basic density is a good indicator of strength properties of wood. The analyses of variance (ANOVA) on physical properties are presented in Table 3.

Table 1: The mean values of modulus of rupture, modulus of elasticity, compression parallel to the grain, Specific impact resistance (all at the green and oven dry basis)

Compartment Location	Mean value 12% M.C.							
	MOR(N/mm ²)		MOE(N/mm ²)		Compression to grain (N/mm ²)		Sp. Im. Res. (N/mm ²)	
Lephis-1C	green	dry	green	dry	green	dry	green	dry
		51.43	93.65	3339.45	6486.72	18.44	50.95	7192.43

Table 2: The means values of strength properties at dry basis

Tested properties	Bottom log	Middle log	Top log
Modulus of elasticity(N/mm ²)	7193.31	6344.86	5922.00
Modulus of Rupture(N/mm ²)	109.36	87.74	83.84
Maximum crushing strength (N/mm ²)	64.71	48.14	40.00
Impact resistance (Nm/m ²)	7417.2	6131.5	4780.9

Table 3: The means values of strength properties at green basis

Tested properties	Bottom log	Middle log	Top log
Modulus of elasticity(N/mm ²)	3907.24	2869.84	2821.36
Modulus of Rupture(N/mm ²)	63.61	47.55	43.14
Compression // to grain(N/mm ²)	22.65	17.92	14.76
Impact resistance (Nm/m ²)	8152.3	6852.7	5722.2

Initial Moisture content

The Initial moisture content of *P. patula* along the portions was not significantly different along the tree height. High initial moisture content was observed at bottom portion (127.2%) and somewhat similar at middle and top (106.54%, 105.69%) at portion of the sample log, respectively. The initial moisture content was discussed in Table 2.

Radial and tangential shrinkages

Radial and tangential shrinkages of *P. patula* tree portions (height) (2.61%, 2.41%, and 2.08%) and (3.65%, 3.51%, and 3.96%) from bottom, middle and top were determined, respectively. The radial and tangential shrinkage of *Pinus patula* (based on oven dry weight) was not significantly different along the three stem portions (Bottom, middle, Top). Regardless of tree height high or average shrinkage values was observed at tangential direction (3.7%) than the radial (2.36%) (Table 4).

According to George Tsoumis (1991), the wood shrinks more tangentially than radial because the difference between radial and tangential shrinkage may also be accounted for strands in the fiber walls being bent around the pits that predominate in the radial walls of the fibers, rather than being parallel to the long axis of the fiber. In some species the ratio of shrinkage in

Tangential and radial direction is 2:1, respectively. The findings of this study also support this result.

Modulus of Elasticity (MOE)

The values of MOE of dry samples ranged between 7193.31 N/mm², 6344.86 N/mm² and 5922.00N/mm²

from bottom, middle to top respectively and MOE of green samples ranged between 3907.24 N/mm², 2869.84N/mm² and 2821.36 N/mm² (Table 4). This shows that MOE decreases from bottom to top log in dry and green sample log (Table 6,7). There were significant differences in Modulus of elasticity (MOE) values of dry and green samples (at P=0.046, p=0.035) respectively between the portions of tree height (Table 5).

The statistical analysis of variance shows that the effect of *P. patula* tree height on mechanical properties .As depicted in (Table 5) tree height caused highly significant differences between dry and green samples.

As depicted in Figure 3 the MOE shows decreasing trend towards the top portion .The highest values for stiffness in the bottom portion of this tree species. The important factors influencing the stiffness of timber are its density and the micro fibril angle, but there are many other variables, some anatomical in origin such as knots, fiber length and spiral grain and some environmental such as moisture content and temperature (Huang *et al.*, 2003).

Table 4: ANOVA on mechanical properties of *P. Patula*

Source of variation	MOR(N/mm ²)		MOE(N/mm ²)		M.C.E N/mm ²)		Sp. Im Re.(N/mm ²)	
	green	dry	green	dry	green	dry	green	dry
Height	21624.9	2645.6	3867907.	7022391.7	340.077**	2219.66	20702723.	2432953.9
	5**	4**	8**	4**		**	25**	1**

Note; ns-not significant at p>0.05,*-significant at p<0.05, **-highly significant at P<0.01
M.C.S-Maximum compression strength
Sp.Im.Res-Specific impact resistance

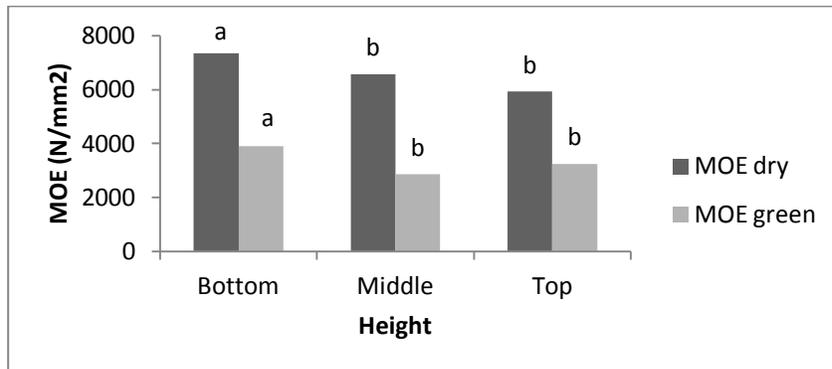


Figure 3: Modulus of elasticity (MOE) along *Pinus patula* tree height

Note: Means having the same letter were not significantly different

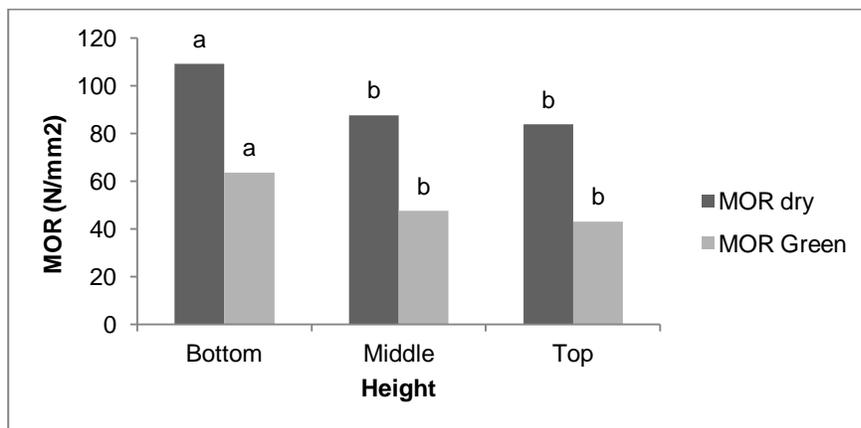


Figure 4: Modulus of Rupture (MOR) along *Pinus patula* tree height

Note: Means having the same letter were not significantly different

Kumar (2004) reported that, an important element of wood quality is that of “stiffness” or its modulus of elasticity (MOE). The end-use of wood material, especially for structural timber is strongly related to MOE. Schneider *et al* (1991) reported that, the mechanical properties and basic density varied along the tree height from but logs to top log. Haygreen and Bowyer (1989) stated that modulus of elasticity in

bending increasing linearly with basic density (specific gravity).

Modulus of Rapture (MOR)

As indicated in Figure 4 dry and green samples MOR shows decreasing trend from bottom to top. This has

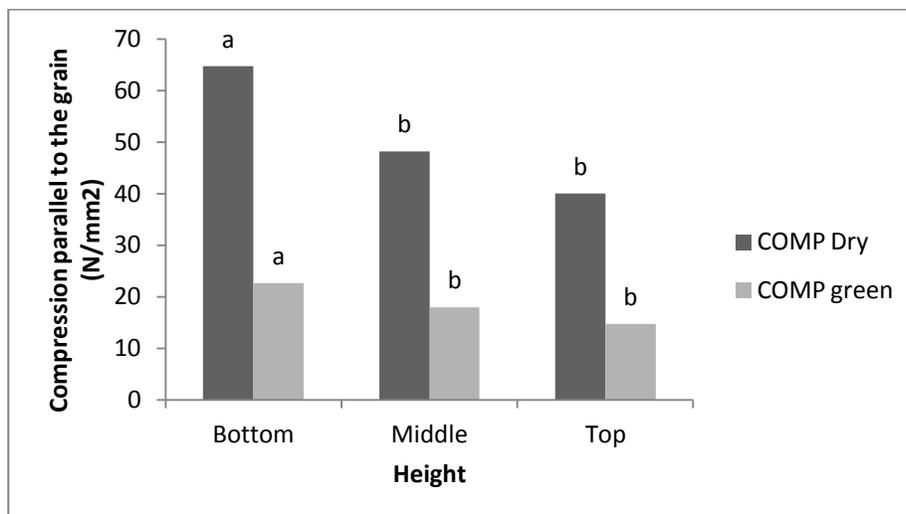


Figure 5: Maximum crushing strength along *Pinus patula* tree height

Note: Means having the same letter were not significantly different

indicated that as juvenility increases MOR decreases. The highest value of MOR was observed at bottom (109.36N/mm^2) portion of dry sample. This might be due to the presence of mature wood at the bottom and the maturity of wood decreases from bottom to top of the tree height.

According to (Desch, 1981), in species such as Scots pine (*Pinus sylvestris*) a slight decrease in basic density and strength properties with increasing height was noted. This was also the case with (Ishengoma and Gillah, 1992) who reported that core wood or juvenile wood is significantly lower in density than mature wood and hence the reduction in density as you move away from the butt end. In this study also we observed high value of MOR at the bottom of log and almost in similar class. This implies that the high density and strength properties wood from butt end logs should be used for structural purposes where high strength is required. In this study we also observed also the difference values of MOR of dry and green logs (109.36 , 87.74 , 83.84) N/mm^2 and (63.61 , 47.55 , 43.14) N/mm^2 of bottom, middle and top logs respectively (Table 6). High values MOR was observed at dry sample logs.

One of the study made by Kityo and Plumtre (1997), was timber for structural use should have MOE of $6260 - 14700 \text{ N/mm}^2$, MOR of $39 - 132 \text{ N/mm}^2$ and should be durable, easy to plane and nail. In this study also *P. patula* wood had properties within the specified ranges since the average values of MOE and MOR is 6486.72 and 93.65N/mm^2 and thus can also be used for making structural elements such as tie beams, rafters and purlins in house construction. According to Tiruneh kide (2002), the average values of MOR and MOE of

Cupressus lusitanica were 88 and 8372N/mm^2 , respectively at dry basis which were found in the same class with *P. patula* lumber, based on the result observed in these findings (Table 4).

Compression parallel to grain

As MOR and MOE, maximum crushing strength also shows decreasing trends from the bottom to top. This implies that the strength is high at the bottom of the *Pinus patula* tree because high maximum crushing strength shows that high strength, which is shown in Figure 5.

High maximum crushing strength (50.95 , 18.44) N/mm^2 and (22.65 N/mm^2) in bottom portion of dry and green samples. This shows that *Pinus patula* has high compression strength at the bottom portion than middle and top. Goker (1977) reported on mechanical properties of mature black pine wood. The Modulus of rupture (MOR) and Maximum crushing strength observed was 109.6 and 47.9 N/mm^2 respectively. In this study the MOR and maximum crushing strength found the average values found was 93.65 and 50.95N/mm^2 . The values observed in this study and in Turkey by Goker was classified in the same class.

Specific impact resistance

High impact resistance (8152.3 Nm/m^2) was observed at the bottom of the green sample tree (Table 7). This implies that the strength is high at the bottom of the green sample tree because high impact resistance, which is shown in Figure 6.

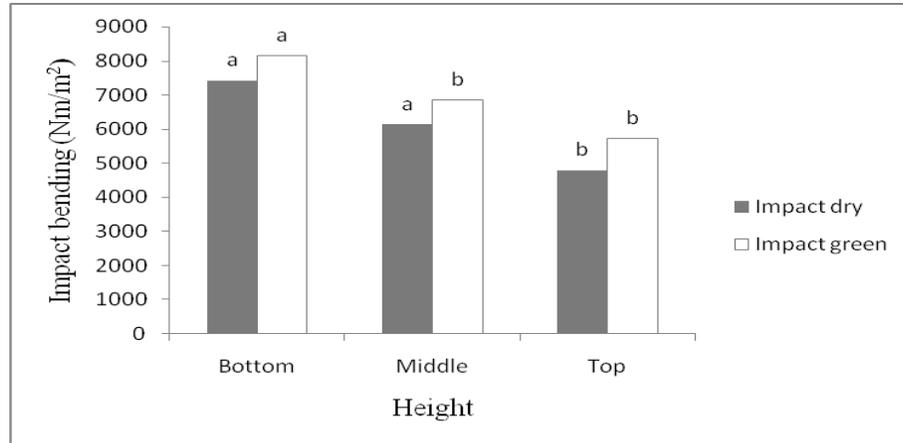


Figure 6: Specific impact resistance along *Pinus patula* tree height
 Note: Means having the same letter were not significantly different

Table 5: Comparison of *P.patula* with some commercially important tree species in Ethiopia (all are at dry basis)

Species	Shrinkage		Basic density (g/cm ³)	MOR (N/mm ²)	MOE (N/mm ²)	M.C.S (N/mm ²)	Sp.Im.Res (N/mm ²)
	tangential	radial					
<i>Pinus patula</i>	3.70	2.36	0.51	94	6487	51	5728
<i>Pinus radiata</i>	2.93	2.58	0.48	77	8983	40	5624
<i>Cupressus lusitanica</i>	1.36	0.52	0.45	64	6145	33	5888
<i>Podocarpus falcutus</i>	4.6	2	0.53	88	9617	40	4836
<i>Anigeria adolfi-friderici</i>	6	3.4	0.67	107	11394	46	7916

Note: Except *P.patula* species all species test are taken from Wood utilization and research centre Bulletin (WUAR CENTRE, 1985).

A research carried out at Wood Utilization and Research Centre (WUAR CENTRE ,1985) ,showed that the impact resistance done on the same species was 5728 Nm/m² and the results were recommended for light building and general construction, boxes ,crates, covered flooring , cheap joinery ,pulp, shuttering and furniture. In this study the value of specific impact resistance of dry sample observed were 7202.93Nm/m².The difference observed were may be due to silvicultural measures and other factors. Since the value observed in this study is superior to the result observed by WUAR, we can use the bottom part of this wood for many uses, such as construction, sports goods, or tool handles.

As compared in Table 8 below, *P. patula* is inferior to *Anigeria adolfi-friderici* and *Podocarpus falcutus* in Tangential and radial shrinkage, basic density, Modulus of elasticity. But it is inferior to *Anigeria adolfi-friderici* in Modulus of rupture and superior to *Podocarpus falcutus* (Table 8). It is also superior to *P. radiata* and *C. lusitanica* in Tangential and radial shrinkage, basic density, modulus of rupture, maximum crushing strength and in specific impact resistance *P. patula* inferior to *C.*

lusitanica and *Anigeria adolfi-friderici*. However, *P. patula* can be considered supplementary tree for light construction, boxes, crates, covered flooring and for furniture production than of some exotic tree species and inferior to some indigenous tree species listed in Table 8.

CONCLUSION

The basic density showed significant difference along *Pinus patula* tree height. High shrinkage was observed in tangential direction than radial direction. The amount of the shrinkage depends on its direction relative to grain orientation (i.e radial and tangential direction). Modulus of rupture, modulus of elasticity, maximum crushing strength and green samples and specific impact resistance were high had high value in all at green and dry basis. There was significant difference between modulus of elasticity of dry and green samples and specific impact resistance of dry samples .Modulus of rupture of dry and green, maximum crushing strength of

dry and green samples and specific impact resistance of green samples were found to have highly significant differences. Basic density, initial moisture content, radial shrinkage, modulus of elasticity of dry and green samples, modulus of rupture, maximum crushing strength of dry and green samples and specific impact resistance dry and green samples values increases along the tree height vertically from bottom to top. But tangential shrinkage decreased from top log to but log. All strength properties of the *Pinus patula* tree species were positively correlated with basic density. Therefore, basic density should be considered a reliable indicator and predictor of most timber strength properties. The values of modulus of elasticity, modulus of rupture, maximum compression strength of dry samples were higher than green wood samples. Generally, high values were observed at the bottom part of trees investigated. The bottom part of *Pinus patula* tree can be used where high strength material is required.

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