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ETHIOPIAN ENVIRONMNET AND FOREST RESEARCH INSTITUTE

Forest and Environment Research: Technologies and Information

Edited by: Mehari Alebachew
Getachew Desalegn
Wubalem Tadesse
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FOREST RESOURCES

IMPERATIVE PHYSICAL CHACARCTERSTICS AND POTENTIAL USES OF *Eucalyptus Pilularis*, *Eucalyptus Viminalis* and *Trichilia dregeana* Lumber Tree Species

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Abstract

Imperativetechnical information on lumber seasoning, moisture content (MC), density, mechanical, workability, anatomy, chemical characteristics and technologies of utilization would strongly determine rational utilization of each lumber species. A study was conducted on home-grown two *Eucalyptus* species *(Eucalyptus pilularis* and *Eucalyptus viminalis)* andindigenous *Trichilia dregeana*timbers with the main objective of determining some imperative seasoning and density characteristics of lumber that will indicate quality and proper utilization. Study species (*E. pilularis*, *E. viminalis* and *T. dregeana*) were harvested from Shashemene, Asella and Arjo-Jimma/Dedessa sites, respectively. The experimental design for seasoning and density was complete randomized design, a factorial experiment.The experiments were conducted using oven/microwave, air and kiln seasoning methods. The results indicated that the final mean MC for both air and kiln seasoning methods were 11.37%, 16.39 % and 11.61 %, respectively. Mean air seasoning for *E. pilularis, E. viminalis* and *T. dregeana* sawn boards of 3 cm thickness to reach to about 12 % MC was 100, 50 and 48 days, respectively. Mean kiln seasoning was 5, 4 and 6 days, respectively. Kiln seasoning technology was better than natural air seasoning in terms of seasoning rate and quality (low shrinkage and seasoning defects) of seasoned lumber. Kiln seasoning 9 to 19 times faster than air seasoning.The three species were classified as very rapid seasoning timbers but *E. pilularis* had rapid air seasoning rate. When *E. pilularis, E. viminalis and T. dregeana* lumbers seasoned from green (48-66 %) to 12 % MC, mean shrinkage (%) characteristic values were: Tangential (6.31, 4.94 and 4.43 %), radial (3.4, 4.02 and 2.10 %), and volumetric (9.46, 8.6 and 6.37 %), respectively. Seasoning defects such as cup, bow, crook, end split, surface- and end-checks were observed, though the extent varies with species. The density of *E. pilulalris, E. viminalis and T. dregeana at* 12% MC was 780, 810 and 530 Kg/m^3, respectively.The one way analysis of variance indicated that there was significant difference (p > 0.001) in initial MC, final MC, density values at different MC and shrinkage characteristics. Lumber species *E. pilularis, E. viminalis* and *T. dregeana* revealed good lumber characteristics and qualities, comparable with many indigenous and home-grown exotic timber species in density, seasoning rate and shrinkage. They have multipurpose lumber products, non-timber forest products, and live tree cultural and ecological services. The species have to be well grown and managed, logs properly harvested and sawn, boards stacked and seasoned to less than 20% MC, preferable with kiln seasoning method that can help to minimize seasoning time, seasoning defects, shrinkage characteristics and increase quality.

Keywords/phrases: Lumber quality, moisture content, seasoning defects, seasoning rate, shrinkage characteristics, timber species, uses.

Introduction

Human beings will be utilizing the renewable wood and bamboo products and services to contribute to their comfort and ever increasing demand.The demand and supply of forest products to industries, construction and energy sectors in Ethiopia has been highly exceeding the supply. The 2011/2012 forest products import amount in tone was 170721.3 with a value of about 3.2 billion Ethiopian birr. Based on annual incremental yield of forests demand, and supply for the year 2020 has been projected to 132,500,000 m^3 and 28,710,856 m^3 (CSA 2008/2009 and 2012; Habtemariam Kassa and Zeleke Ewnetu, 2014), respectively. Demand will exceed the supply by 103,789, 144 m^3 (4.6 times, > 460%). To satisfy the ever-increasing demand of consumers, large quantities of timber, panel and fiber products are being imported from different countries with hard currency.

Selection of limited tree species for every intended purpose paired with the low recovery rate of the saw mills and further processing industries as well as inappropriate utilization due to lack of lumber technical/ characteristics information and/or technologies on different wood properties (characteristics), and the rapid development of construction (industrial, commercial, and residential buildings) in the country, have resulted in the degradation of the existing forests both in quality as well as quantity.

There are more than 300 indigenous and home-grown exotic tree species whose quality, suitability and potential as lumber are not yet investigated and realized. This was not made possible due to lack of efficient technologies for alternative use of less utilized and potential forest resources. The quality and performance of wood and wood-based products have been seriously affected by the major factors, among which MC, inappropriate drying (here after, seasoning) and density are the preceding ones. More than 90 % of all the encounters related with wood and its rational utilization involves moisture amount, its influence, and fluctuation with time, environmental conditions and management (Hodaley, 1989; Simpson, 1991; Denig et al., 2000; FPL, 2010). About 75% of the manufacturing problems in furniture industries are related to inappropriate moisture content of lumber (Denig et al., 2000). Moisture content, density, mechanical characteristics, seasoning and shrinkage characteristics (tangential, radial, longitudinal volumetric), seasoning rates and defects, workability, anatomy, chemical composition and technologies of utilization indeed are among the major factors that determine the quality, suitability, rational utilization and service life of wood as round and sawn lumber (Hodaley, 1989; Simpson, 1991; Denig et al., 2000; Getachew Desalegn, 2006; FPL, 2010).

Increasing efficiency of utilization of forest products through product diversification, value addition and maximization of uses of wood and wood–based products, import substitution and export promotion will be possible in Ethiopia after determining the different characteristics, quality and suitability of each species. It is worth thus, to undertake integrated research on economically lesser known timber species (*E. pilularis*, *E. viminalis*and*T. dregeana*) that are not yet known by the development, processing and construction sectors, manufactures and end users in the lumber market of Ethiopia.

The hypotheses were:

- There is difference on MC, seasoning rate, shrinkage and density characteristics among *E. pilularis, E. viminalis* and *T. dregeana* sawn timbers
- Seasoning methods can make difference on lumber quality
- *E. pilularis, E. viminalis* and *T. dregeana* sawn trees have quality and potential uses as lumber
- *E. pilularis, E. viminalis* and *T. dregeana* sawn timbers could be alternative raw materials for forest industries and construction sectors.

The general objectives of this study were to investigate the different characteristics, generate technical information, appropriate utilization technologies, and assess potential uses of *E. pilularis, E. viminalis* and *T. dregeana* sawn timbers. Specific objectives were to: (i) evaluate seasoning methods for the timbers, (ii) determine appearance, moisture content, seasoning characteristics (seasoning rate, shrinkage characteristics, seasoning defects, possible remedies, handling techniques for seasoned lumber) and density of the timbers at different MC levels (iii) observe biodeterioration attack during and after seasoning, and (iv) assess potential uses of the timbers. Therefore, this technical report includes the results on imperative lumber seasoning and density characteristics, and potential uses of *E. pilularis E. viminalis* and *T. dregeana*lumber tree speciesgrown in Ethiopia.

Material and Methods

Study species

The tree species for this study were *Eucalyptus pilularis Sm.* [Family:Myrtaceae], *Eucalyptus viminalis* Labill. [Family:Myrtaceae]and *Trichilia dregeana* Sond [Family:Meliaceae]thathave fast growth, high yield (*E. viminalis* 10-20 m^3/ha/year), good performance (height, diameter and clear bole), versatile timber and non-timber forest products, socio- economical/ cultural and ecological benefits and services, good site adaptability and coppice ability (*E. pilularis* and *E. viminalis*) in the country.

Eucalyptus pilularis (blackbutt, pilularis gum) is a very large tree up to 70 m tall, with bole up to 4.1 m in diameter (Brink, 2008a; Anonymous, 2012ab). In Ethiopia, *E. pilularis* isavailable at Suba, Shashemene (Figure 1), Asella, and Belete plantations of the former Forestry Research Center now Central Ethiopia Environment and Forest Research Center (CEE-FRC) trial stations.
E. pilularis iseucalyptus species without lignotuber. It has easy regeneration and quick growth ability (Anonymous, 2012ab). *E. viminalis* is an evergreen, large tree up to 50 (–90) m tall; bole up to 120(–150) cm in diameter (Brink, 2008b).In Ethiopia it is planted on well-drained, deep soils. *E. viminalis* is resistant to fire (Brink, 2008b). In Ethiopia, *E. viminalis*isavailable at Suba, Shashemene, Asella (Figure 2) and Belete plantations, former CEE-FRC trial stations. The *E. viminalis* seed source stand at Asella/Ellna has been affected may be by disease of which about 8% dead.

The tree T. *dregeana*attains a height of up to 35 m, the tall main stem assuming a relatively straight trunk dividing into large branches and sometimes buttressed habit up to 1.8 m in diameter (Azene et al., 1993; Thirakul, 1993). T. *dregeana* is an excellent feature plant that is fast-growing and provides great shading for coffee and other crops (Anonymous, 2009b). Vernacular names in Ethiopia: Bonga (Am), Desh (Gm), Luiya (Kf) Konu, Luya, Shego (Or.) (Wolde Michael Kelecha, 1987; Azene et al., 1993; Thirakul, 1993). In Arjio/Wollega area it is called Ambaressa (Or.) where, Gm- Gimirigna; Kf- Kefgna and Or- Oromugna and Sh- Gumuz (Wolde Michael Kelecha, 1987). Common (English) names:forest mahogany, forest natal mahogany, muchichiri, white mahogany, cape mahogany, thunder tree, Christmas bells, red ash (Eng.) (Anonymous, 2009a; Anonymous, 2009b).

Fig. 1a E. pilularis stand from Fig. 1b E. viminalis Asella/ EIena CEF-FRC Fig. 1c T. dregeana from at Jimma

*T. dregeana*available in Wellega (Arjo-Jimma/Dedessa), Illubabor (Yayu, Chora), Kefa (Bonga, Bebeka) regions and Teppi areas of Ethiopia (Hedberg and Edwards, 1989). Some harvested logs of *T. dregeana* heartwood (pith) along height were deep hollowed may be by red ants/ termites. Sample trees of *T. dregeana* were harvested from Abote Dedessa of river Dedessa area on the way Nekemt to Bedele.

Selection and harvesting of sample trees (Sampling techniques)

Matured trees (5-10 m^3 woods) representative of merchantable log size were selected from different sites with good morphological quality, straight and cylindrical stem, relatively free from visible defects. Trees were selected and harvested from natural and plantation forests taking into account the height (≥ 10 m), breast height diameter (≥ 20 cm) and quality of the tree bole. Trees were felled, cross- cut into a series of 2.5 m long logs up to top merchantable diameter of 20 cm.

Study species *E. pilularis, E. viminalis* and *T. dregeana* were harvested from Shashemene/Hamulu, Asella/Elena and Arjo-Jimma/Abote Dedessa sites, respectively. The sample trees were harvested and tests conducted during three consecutive years 2012-2014, respectively. The sample trees of E. pilularis, E. viminalis and T. dregeana had mean height of 27, 36 and 15 m, respectively, and mean breast height diameter at 1.3 m above ground was 50, 39 and 210 cm, respectively.

Log sawing and sample preparation

Harvested logs while green (> 30% MC) were sized to 2.5 m and transported to WTRC for the preparation and testing of samples.Logs were sawn to 3 cm thick tangential boards at WTRC

mobile circular sawmill by applying through-and-through type of sawing method. This sawing method was used to obtain approximately equal proportions of sapwood and heartwood as well as to make the radial, tangential and longitudinal surfaces conspicuous.
Sawn logs were converted to appropriate dimensions and number of samples for each wood characteristic test. Samples were prepared and selected proportionally from each tree and log at 1 m interval along height and marked with identification codes using an indelible pencil or waterproof permanent ink.

In this study, the types, dimensions and number of specimens required to undertake the imperative wood characteristic tests were prepared following the ISO standards/protocols (ISO 3129, 1975; ISO 3130, 1975; ISO 3131, 1975); Burley and Wood, 1977; Lavers, 1983; Simpson, 1991; Denig et al., 2000; FPL, 2010.

From the sample trees felled per species, 10-18 defect- free sample boards per tree species with dimensions of 100 cm in length, 3 cm thickness and width equal to log-diameter were prepared. The samples were used for the following-up the seasoning process and determination of the characteristics. The green (initial) MC of each timber species were determined from the two small sections cross-cut 20 cm inwards from each sample board ends having 1.2 cm length and 3 cm thickness.

Defect-free specimens of each timber species (2x2x3 cm) (width, thickness and length, respectively) at green state were used to determine shrinkage characteristics (ISO/DIS 4469, 1975). The shrinkage samples and the measurements were also used to determine the density values of the species at different MC using mathematical formulas.

Stacking sawn boards

After sawing, boards were transported to the air drying (seasoning) yard (Figure 2) and compartment kiln-seasoning chamber (Figure 2) areas and air seasoned for a week to reduce kiln seasoning electric charge. Boards of each species were stacked at 3 cm spacing between successive boards. They were stacked horizontally in vertical alignments separated by well-seasoned, squared and standard stickers. To facilitate uniform air circulation and seasoning, minimize warp, avoid stain and decay occurrence during the seasoning process long stickers with a dimension of 2.5x2.5x180 cm (width, thickness and length, respectively) were used to separate boards while the short strips (2.5x2.5x20 cm) placed up on the long stickers were used to easily access the control sample boards of each stack.

Top loading was applied to offset/minimize warping (Simpson, 1991; Denig et al., 2000; FPL, 2010). Based on the availability of the materials and nature of each test, in air and kiln seasoning, heavy stones weighing about 50 Kg/m^2 were loaded at a spacing of 0.5 m.

In each stack of the air and kiln seasoning, when clearly separated clearly separated, the heartwood boards, which have less moisture content, were placed in the middle while the sapwood boards were placed along the sides, top and bottom of the stacks since they have more MC than the heartwood. The ends of boards were made equal in both directions. The control sample boards were properly distributed and positioned in the pockets of the different layers of each stack each stack.

Figure 2: Air seasoning stacks of *E. pilularis, E. viminalis* and *T. dregeana* lumbers.

Boards for air seasoning were stacked under shed without direct interference of moisture, rainfall or sunshine. Boards were stacked on firm foundations/ yards having 45 cm clearance above the ground and a dimension of 1.80x0.45x4 m. The boards were aligned in a north-south direction where the ends were not exposed to the direction of the wind. The north-south direction alignment of boards was done to facilitate good air circulation and reduce the direct influence of fungi, temperature, wind and relative humidity. Boards for kiln seasoning were stacked out of the kiln on the transfer carriage having a dimension of 2.7x1.6x 0.30 m and placed in the kiln-seasoning chamber (Figure 3) and tested one species at a time.

Figure 3: Kiln seasoning stacks of *E. pilularis, E. viminalis* and *T. dregeana* lumbers.

Seasoning methods applied

Air seasoning

Natural air and artificial kiln seasoning methods were used for testing and determination of seasoning characteristics. Green weights and dimensions of all air seasoning samples were measured immediately after planing and cross-cutting using sensitive electrical balance and caliper, respectively. Weighing of initial MC samples at 4 hours interval was carried out as soon as samples were withdrawn from the oven drier to minimize moisture absorption and desorption (Desch, 1986). The process was continued until the difference between two successive weights of each specimen is between 0.1-0.2 g and the final weights were taken as the oven- dry weight (ISO 3130, 1975; FPL, 2010).The control sample boards were weighed, re-placed into the stack, re-weighed and MC determined for the stack at one-week interval continuously until the average final MC of the stack reached about 12 % MC, which is the equilibrium MC for in- and out-door purposes and standard for comparison within and between timber species.

Kiln seasoning

The conventional type of artificial kiln seasoning machine was used in this study. The machine is well insulated and has about 2.5 m^3 wood loading capacity room or chamber per kiln operation. It has controlled air circulation, temperature and humidity that can be adjusted according to each species characteristics using psychrometers (dry bulb and wet bulb thermometers) and has been equipped with fans to force air circulation, and air outlet at a temperature range of 40 -70 ºC.

The kiln seasoning schedules are steps/norms involving serious of temperature and relative humidity at different corresponding MC levels were selected based on the initial MC of timbers (Tack, 1969) adapted from England, Sweden and other schedules. While carrying out seasoning of each timber species independently, kiln seasoning schedule Ethiopia 3 was applied for *E. pilularis* and *E. viminalis,* and kiln schedule Ethiopia 8 for *T. dregeana.*

In kiln seasoning samples were weighed and the direction of the fan changed at 8 hours interval (three times in 24 hours) to allow uniform air circulation and seasoning, control the seasoning process and maintain quality of the seasoned wood. The process was continued until the difference between two successive weights of each specimen is between 0.1-0.2 g and the final weights were taken as the oven- dry weight (ISO 3130, 1975; FPL, 2010).

All air and kiln seasoning boards were gone under an initial air seasoning before stacking and commencing the regular air and kiln seasoning processes. This was done to reduce kiln charge since there will be no characteristics change above and up fiber saturation point (30% MC) (Haygreen and Bowyer, 1996; FPL, 2010).

Moisture content seasoning determination

MC was determined for both air and kiln seasoning stacks of the timbers. The oven- dry weight method of MC determination (the standard way) (Haygreen and Bowyer, 1996; Reed, 1997; FPL, 1999; Denig et al., 2000; MTC, 2002) was applied in this test since it is an indication of the amount of solid substance present. In both seasoning methods, the MC (%) was determined by the formula adapted from (FPL, 2010; Denig et al., 2000; Anonymous, 2002).

Rate of seasoning determination

Air and kiln seasoning rates of each timber species were estimated from the MC samples of each species. Seasoning rate (%/hour) = IMC-FMC (%)/Drying time (Hour) (Moya et al, 2013) where, IMC-initial moisture content and FMC- final moisture content. Air and kiln seasoning rates classification of timbers was done based on the adapted standard Longwood (1961) and Farmer (1987), respectively.

Shrinkage characteristics determination

The differential shrinkage characteristics caused by the differences in tangential, radial and longitudinal directions, outer and inner fibers are the major causes of warp (cup, bow, twist, crook/spring), distortion in and around knots, and other seasoning stresses (cracks and checks) (Denig et al., 2000; FPL, 2010).

Samples of the timbers with a dimension of 2x2x3 cm (Denig et al., 2000) were seasoned in the oven seasoning chamber to a constant dimension at a temperature of 105°c. Initial and current dimensions and weights of all the shrinkage samples were measured once per day. The measurements like MC tests were continued until the difference between the two successive weights of each specimen was constant i.e. between 0-0.2 g. Then, the final weights and dimensions were taken as oven dry weight and dimensions, respectively. Shrinkage rates of each specimen at tangential, radial, longitudinal direction and volumetric were determined from green (≥ 48 %) to 12 % MC and from green to 0 % MC, respectively.

Shrinkage characteristics (tangential, radial and longitudinal directions, and volumetric) of values the timbers were determined using the different formulas adapted from ISO/DIS 4469, 1975; ISO/DIS 4858, 1975; Chudnoff, 1984; Simpson, 1991; Reeb, 1997;Denig et al., 2000; Anonymous, 2002; FPL, 2010. Shrinkage values from green to oven dry were classified based on Chudnoff (1984) and Anonymous (2002) and Anonymous (2012d).

Seasoning defects determination

Initial and after seasoning defects of timbers including knots, cup, bow, twist, end split, end and surface checks were determined.

Storing and handling of seasoned lumber

Seasoned boards were properly piled in the air seasoning yard, board on board, without stickers and no top weighting as has been done in the lumber market, industries and construction sectors. Boards were handled and conditioned well without direct access of moisture and sunshine to avoid/minimize dimensional movement (shrinkage and swelling), seasoning defects, infestation and biodegradation attack. Follow-up of seasoned boards was done for more than six months and observations were recorded.

Density test

The density (specific gravity) values of timbers were determined, as prime indicator of wood quality, since it has strong influence on wood characteristics (seasoning rate, defects and possible remedies, shrinkage, physical and mechanical characteristics, etc.) and timber quality (SO 3131, 1975; Denig et al., 2000; MTC, 2002; FPL, 2012). Specific gravity is unit less and is the density of wood per density of water, numerically equal to density since an equal volume of water at 4°c has a density of 1 g/cm3 or 1000 Kg/m3 (Haygreen and Bowyer, 1996; Denig et al., 2000; MTC, 2002).

The samples (2x2x3 cm), procedures and measurements applied during shrinkage tests were used to determine the density values of each species using mathematical formulas at different MC and sample volume conditions. Basic density was determined based on green volume and oven dry weight, since the two are relatively constant conditions (ISO/DIS 3131, 1975).

The dry density values have been converted to standard 12% equilibrium MC (Table 1) by applying the formula adapted from Haygreen and Bowyer, 1996; Denig et al., 2000; MTC, 2002 and classified based on the adapted standard classification (Framer, 1987).

Experimental design

The experimental design for seasoning and density characteristics was complete randomized design (CRD), a factorial experiment with 3 tree species, 3 positions along tree height, ≥ 10 samples per species and two main factors (three timber species and two seasoning methods).

Data collection and analysis

The measurements of dimension (length, width and thickness) and weight were helped to determine the followingparameters/characteristics: (i) moisture content (%) at green/initial, current and final, (ii) density (gm/cm^3) at green/initial and air dry conditions, (iii) rate of drying (%/day), (iv) shrinkage (%) from green to 12 % MC and green to 0 % MC in tangential, radial and longitudinal directions and volumetric, and (v) initial and seasoning defects (observation and measurements). The one-way analysis of variance (ANOVA) using SAS (2004) statistical software package was applied for the analysis of the collected data. Comparison was made within and between the timber species initial and final MC amounts, shrinkage characteristics, and density values.

Results and Discussion

Appearance

Heart wood of *E. pilularis* is yellowish brown to light brown (Figure 4a) (Anonymous, 2012b). Heart wood of *E. viminalis* is pale yellow or pink and is not clearly demarcated from sapwood

Fig. 4a Fig. 4b Fig. 4c

Figure 4b: (Brink, 2008).

Figure 4: Lumber pictures of study tree species (*a- E. pilularis* lumber, b-E. viminalis lumber, c-*T.dregeana* lumber).

The wood of *T. dregeana* was a pale pink *(*Figure 4c) (Anonymous, 2009a). The odor from *T.dregeana* lumber while planning and cross-cutting made all machine operators, other participating staff and daily workers of WTRC to vomit and become very dizzy for several days.

Moisture content

The results indicated that before air and kiln seasoning commenced, the mean initial MC for the three timber species were 48.25 %, 56.1 % and 65.45 %, while the final mean MC for both air and kiln seasoning were 11.37 %, 16.39 % and 11.61 %, respectively (Table 1). After seasoning, *E. pilularis* and *T. dregeana* attained 12 % mean MC. This means that 0.12 times the weight of wood substance occupied by moisture/water, while 88% was only wood substance. The one way analysis of variance indicated that there was significant difference ($p > 0.001$) in initial MC, final MC, density values at different MC and shrinkage characteristics.

Initial MC along height of timbers during air seasoning varies slightly. In case of *E. pilularis* bottom part had 63% to 75% MC; middle part had 69.52% MC, while top part had the least MC (43%). *E. viminalis* kiln seasoning stack had high initial MC (67.71%) for bottom part, middle part had 58.93% and top part 48.56 % MC. *T. dregeana* kiln seasoning lumber stack had 62.3% initial MC for bottom part, middle part had 65.40% and top part 69.11% MC. Initial MC increased along height of *T. dregeana* lumber since the bottom part changed to heartwood having less MC.

Rate of seasoning

Compared to air seasoning, kiln seasoning of *E. pilularis* lumber was 99.95 times faster (Table 1). In other words, air seasoning took extremely much time, i.e, it took more than 99.95 times greater than kiln seasoning.

Air seasoning rate of *E. pilularis* was0.36 %/day and that of *T. dregeana* lumber was 1.19 %/day. Kiln seasoning rate of *E. pilularis, E. viminalis and T. dregeana* lumber was 7 %/day, 9.15 %/day and 8.94 %/day, respectively (Table 1). Based on the adapted rate of seasoning categories (Longwood, 1961; Farmer, 1987), the three lumber species classified as rapid (77-119 days) to very rapid (< 77 days) in air seasoning methods and in kiln seasoning all classified as very rapid (< 10.5 days). *E. pilularis* took more air seasoning days (100 days) since it was long rainy season (June-August), while kiln seasoning took similar days (4-6 days) for the three timbers. According to Brink (2008a), *E. pilularis* has been indicated as slow seasoning.

Kiln seasoning technology was better than natural air seasoning in terms of seasoning rate and quality (low shrinkage and seasoning defects) of seasoned lumber. Kiln seasoning 9 to 19 times faster than air seasoning. Controlling of environmental conditions and seasoning defects was less likely during the air seasoning process.

Table 1: Seasoning and density characteristics of *E. pilularis*, *E. viminalis* and *T. dregeana* lumber species.

Timber species studied	Air seasoning stacks MC (%) and rate of seasoning(%/day)			Kiln seasoning stacks MC (%) and rate of seasoning (%/day)			Density classification at 12% MC*			
	Initial MC of air seasoning	Final air Seasoning	No. of days in air and rate	Initial MC of kiln	Final kiln seasoning	No. of days in kiln and rate	Green /Initial	Basic density	At 12% MC	Density value (Kg/m^3)at
E. pilularis	48.5	10.21	100 (0.36 %/day)	48	13	5 (7 %/day)	1000	670 (±19.27)	780 (±21.6)	Heavy
E. viminalis	59.13		50	53	16.39	4 (9.15 %/day)	990	820 (±13.02)	810 (±13.24)	*Very heavy*
T.dregeana	65.8	11.21	46 (1.19 %/day)	65.61	12	6 (8.94 %/day)	940	500 (±1.0)	530 (±10.5)	*Light*

*-SEM for density (basic and at 12% MC) are presented in bracket, respectively.

Shrinkage and swelling (Dimensional changes)

When lumber of *E. pilularis, E. viminalis and T. dregeana* timbers seasoned from green (48-66 %) to 12 % MC, the mean shrinkage percentage values were tangential (6.31, 4.94, 4.43 %), radial (3.4, 4.02, 2.10 %), and volumetric (9.46, 8.6, 6.37 %), respectively (Figure 5). Shrinkage percentage values of *E. pilularis, E. viminalis and T. dregeana* timbers at 12% MC were classified tangential (Large, Medium, Medium), radial (Fairly large, Large, Small), and volumetric (Fairly large, fairly large, Small), respectively.

The maximum longitudinal shrinkage varies from 0.1 %-0.3 %; maximum radial shrinkage: 2.1-7.9 %; maximum Tangential shrinkage: 4.7-12.7 %. Tangential shrinkage is generally 1.5 to 2 times greater than radial shrinkage (Anonymous, 2012d).

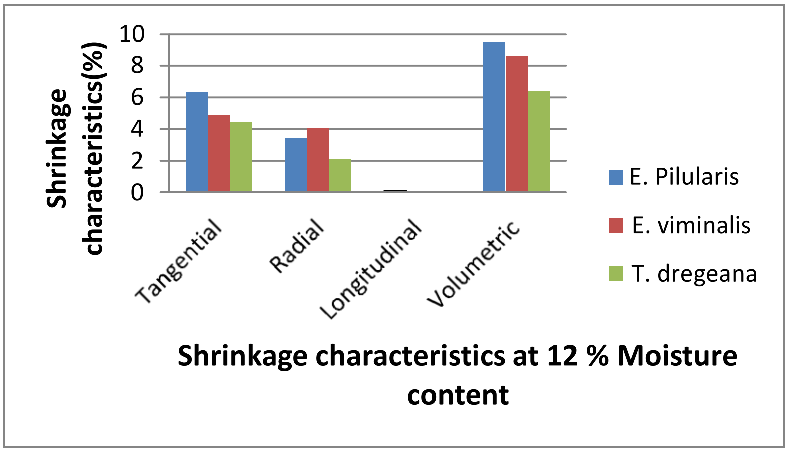

Figure 5: Mean shrinkage characteristics of *E. pilularis, E. viminalis and T. dregeana*lumber species at 12% MC.

The shrinkage characteristics of *E. pilularis*, *E. viminalis* and *T. dregeana*along height (bottom, middle and top parts) were not much significant when boards seasoned from green condition (47 %-62 % MC) to 12 % MC.Tangential shrinkage of *E. pilularis*, *E. viminalis* and *T. dregeana* were 1.86, 1.21 and 2.11 times greater than radial shrinkage, respectively. The shrinkage values of the lumbers up to oven dry (0 %) MC compared at 12 % MC was increased by about 1.66-1.68 times.

Tangential (4.94 %) and radial (4 %) shrinkage values of *E. viminalis* compared with similar study of Brink (2008), tangential (9.7-31 %) and radial shrinkage (5.2-13 %) was very low. *T. dregeana* had the least while *E. pilularis* the highest shrinkage characteristics. The lower the shrinkage value, the higher the quality of lumber for application. The respective mean tangential, radial, and volumetric swelling characteristics of *E. pilularis* (7.10, 3.63, 11.32 %), *E. viminalis* (5.34, 4.34, 10.06 %) and *T. dregeana* (4.48, 2.21, 4.86 %) lumbersat 12 % MC.

Seasoning defects and possible remedies
Seasoning defects such as cup, bow, twist, end split and checks were observed, though the extent varies with species (Table 2).

Table 2: Seasoning defects.

Timber species	Bow	Cup	Crook/ spring	End split	Surface check	End check	Knot
E. pilularis	x	x	x	x	x	x	
E. viminalis	x	x	x	x	x	x	x
T.dregeana	x	x			x	x	x dead knot

Preventions or remedies for seasoning defects indicated below: Bow and spring: Avoid seasoning low grade material with irregular grain, juvenile wood or reaction wood. Cup: Weights or adjustable strapping can minimize this defect. Distortion: Pile carefully with correct sticker spacing. Make sure sticker thickness is uniform. Support the ends of all boards. Careful control on the uniformity of the thickness of the boards being cut can reduce distortion. End splitting: Use end sealants or plastic end cleats. Stickers have to be placed up to the ends of the boards. Use timber shades if strong sunlight or warm winds are likely. Surface checks: Modify stacks to retard air circulation that can help to minimize checking. Internal checking: Use same measures as for end splits and surface checks. Twist: Avoid lumber with spiral, interlocked or irregular grain.

In brief, preventions or remedies for seasoning defects: Proper stacking using standard and well seasoned stickers, end sealants or plastic end cleats, top loading/ adjustable strapping …

Storing and handling of seasoned lumber

Seasoned boards were properly piled board on board foundation (under shed), without stickers and no top weighing. Boards were handled and conditioned well without direct access of moisture and sunshine to avoid dimensional movement (shrinkage and swelling), seasoning defects, infestation and biodegradation attack. Seasoned boards were inspected for more than six months and no infestation and biodegradation attack observed.

Density characteristics

Mean green (initial), basic and dry density of *E. pilularis, E. viminalis and T. dregeana* lumber speciesat 12 % MC were 780, 810 and 530 Kg/m^3, respectively (Table 1). The three lumber species in density at 12 % MC categorized light to very heavy. The density of *E. pilulalris* (780 kg/m^3) classified as heavy, *E. viminalis* (810 kg/m^3) classified as very heavyand the density of *T. dregeana* (530 kg/m^3) at 12 % MC, classified as light densitylumber species. The density of *E. pilulalris* was 740–960 kg/m^3 at 12% MC (Brink, 2008a) while that of *E.viminalis* was 670–940 Kg/m^3 (Brink, 2008b).

Comparable lumber species in density values at 12% MC with accuracy of ± 5% were selected with those same method and laboratory (WUARC, 1995; Getachew Desalegn et al., 2012). E. pilularis was comparable with*Celtis africana, Diospyros abyssinica, Eucalyptus globulus, Eucalyptus nitens, Syzygium guineense* and *Warburgia ugandensis. Lumber species Acacia decurrens, Eucalyptus paniculata, Olea welwitschii* were comparable withE. viminalis while lumber species *Albizia schimperiana, Eucalyptus delegatensis, Grevillea robusta* and *Podocarpus falcatus* are comparable withT. *dregeana.*

Potential uses/applications of study timber species

E. pilularis, *E. viminalis* and *T. dregeana* timber species have versatile lumber and wood-based products, non-timber forest products and live tree uses/cultural aspects.Based on the results on seasoning, moisture content and density characteristics and references each timber species recommended for the different potential applications/uses accordingly.

***E. pilularis* potential uses/ applications**

Lumber and wood-based products uses: Itis one of the main hardwoods of Australia, a significant commercial species. It is well regarded by foresters for the high quality of timber, easy regeneration and quick growth. The wood is moderately heavy, with a density of 740–960 kg/m³ at 12 % MC, strong, tough and moderately hard, not particularly difficult to work (Brink, 2008a). *E. pilularis* timber can be used as poles, posts, railway sleepers, flooring as used in the flooring of Parliament House (Canberra) panelling, construction, building framework, cladding, joinery, lining boards, furniture, veneer wood chipping and decking. It makes good charcoal and fuel wood (Brink, 2008a; Anonymous 2012a; Anonymous, 2012abc).

***E. viminalis*potential uses/ applications**

Lumber and wood-based products uses:The wood can be used for poles, tool handles, shingles, indoor construction, flooring, boards, panelling, interior trim, joinery, ship and boat building, vehicle bodies, furniture, ladders, sporting goods, veneer, plywood, boxes, crates, particle board and fuel wood (Brink, 2008b).

E. viminalis as potential source of pulp for paper making compared to pulps from *E. globulus* and *E. grandis*, which are currently the main sources of *Eucalyptus* pulpwood, pulp from *E. viminalis* had a high strength, high opacity and low porosity, making it especially suited for wood free printing and writing papers and specialty papers (Brink, 2008b). When the wood is to be used for pulping, coppice rotations of 6–8 years are applied.The wood contained 44% cellulose, 22% glucuronoxylan and 29% lignin (Hills and Brown, 1978; Webb et al., 1984;Brink, 2008b).

Non-timber forest products: *E. viminalis* is bee forage. Branchlets have been used for weaving. A decoction of the leafy twigs is used in baths against rheumatism in the legs. In Ethiopia, leaves yield 0.8% essential oil, with main components 1, 8-cineole (50.9%), α-pinene (28.2%), globulol (5.1%) and limonene (4.3%). The essential oil content is highest in the summer season, when temperature and humidity are high (Brink, 2008b).

Live tree uses/ cultural aspects: The species is planted as an ornamental and shade tree, and in shelter belts and wind breaks. The trees coppices well. It is resistant to fire (Brink, 2008b).
Prospects:*E. viminalis* suitable for regions where frost is common. It is considered as good alternative of *Eucalyptus glubulus* at higher altitudes. It has also good prospects for paper making and as source of cineole –rich essential oil (Brink, 2008a).

***Trichilia dregeana* potential uses/ applications**

Lumber and wood-based products and uses: The wood easily worked making it very suitable for carving (Wyk et al, 2000 cited in Anonymous, 2009a). It is used for furniture and household implements, plywood and veneers, furniture, mortars, joinery, cabinetworks and interior decoration, construction and firewood (Azene et al, 1993; Thirakul, 1993*)*.

Non-timber forest products: The seeds are edible after removing seed coat and the seed arils are cooked as a vegetable or crushed to yield a milky juice taken as a drink or with side dishes (Wyk et al 2000, cited in Anonymous, 2009a). The seeds are also rich in fat. This fat being used in soaps, as body ointment and hair oil as well as for cooking (Von Breitenbach 1965 cited in Anonymous, 2009a). The species is also an important medicinal plant with the seed, oil, leaves, roots and bark being used for such purposes (Pooley, 1993, cited in Anonymous, 2009a).

Live tree uses/ cultural aspects: The forest mahogany, owing to its attractive nature and the fact that it makes an effective shade tree, is now a commonly cultivated species. *T. dregeana* is highly ornamental species with considerable cultural and ecological values. Flowers October to December and fruiting between January to May. Tree provides suitable nesting sites for a number of birds (Anonymous, 2009a).

Conclusion and Recommendations

Timber species revealed good lumber characteristics and qualities. These species were comparable with many indigenous and home-grown exotic timbers in density, seasoning rate and shrinkage. They have multipurpose lumber and wood-based products, non-timber forest products and live trees have ecological uses/ cultural aspects.

These lumber tree species *E. pilularis*, *E. viminalis* and *T. dregeana* have to be well grown and managed, timber properly sawn, stacked and seasoned to less than 20% MC. *E. pilularis*, *E. viminalis* and *T. dregeana* boards seasoned preferably with kiln seasoning method that can help to minimize seasoning time, seasoning defects and shrinkage characteristics thereby increase quality. Seasoned lumber of all study species have to be properly handled and rationally utilized at specified MC and density for intended construction and furniture purposes. Lumber species namely *E. pilularis*, *E. viminalis* and *T. dregeana*, to a certain extent can substitute accordingly comparable and endangered timber species in Ethiopia.

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