SEASONING AND DENSITY PROPERTIES OF Cordia alliodora TIMBER

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Research Report

Ethiopian Institute of Agricultural Research
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Introduction

The knowledge on basic wood properties including timber seasoning, density, and technology of utilization would determine rational utilization and large-scale development of each timber species. The quality, appearance, and performance of wood and wood-based products would seriously be affected by inappropriate drying (seasoning) and density. The different properties, its suitability for different purposes, and all other challenges associated with the wood and its utilization incurs moisture amount (Hodaley, 1989; 1989; Simpson, 1991; FPL, 1999; Denig et al., 2000), its influence, fluctuation with time and management. Thus, moisture content (MC), density and mechanical properties, shrinkage characteristics including tangential, radial, and longitudinal volumetric, seasoning rates and defects are among the major factors that determine the quality and utilization of wood as round and sawn lumber (Hodaley, 1989; Simpson, 1991; FPL, 1999; Denig et al., 2000; Getachew Desalegn, 2006).

Inappropriate lumber seasoning and handling and the lack of information on major wood properties are most overlooked but contributing to the major causes that led to

- quality losses of products,
- improper utilization of lumber and other products, and
- destruction of forests and endangering of certain valuable timber tree species such as Juniperus procera, Hagenia abyssinica, Cordia africana, Podocarpus falcatus and Pouteria adolfi-friederici in the country.

Thus, proper seasoning of lumber, determination of density and managing of MC in wood for the intended application and environment will be important considerations towards enhancing the properties and rational utilization of C. alliodora timber in the country. In this paper, timber refers wood other than fuel wood that can be usable for lumber (Helms, 1998)

The lumber species, Cordia alliodora is an introduced, fast-growing, and potential species for promotion and sustainable utilization in Ethiopia. The development sectors, manufactures, and end users in the country do
not yet know it since it is still under silvicultural research undertaking of the Forestry Research Center (FRC). It has been selected for this study since the species with good management could be among the new potential expectations of Ethiopia’s future forestry and forest industries development scenarios.

Wood characteristics study of the timber will help to know the properties, its quality and contribute to opt the future, either to plant and utilize it in large scale or not.

The objectives of this study were to:

- identify suitable seasoning methods for the timber;
- determine seasoning properties and density of the species at different MC levels;
- study appearance, shrinkage characteristics, seasoning defects and bio-deterioration attack during and after seasoning; and
- evaluate/select better handling techniques before, during- and after-sawing and seasoning of the timber.
Materials and Methods

Test materials
Sample trees of for wood property tests were harvested from 10 matured, morphologically defect-free, and good quality trees having a mean height of 20 m and a breast height diameter (DBH) of 39 cm. Trees were felled and bucked into 5 m logs. Logs, while green (> 30% MC) were transported to Forest Products Utilization Research Laboratory. The test materials were logs selected and collected from C. alliodora trees and converted to boards.

Sawing and sample preparation
Before commencing sawing, green logs were bucked into 2.5 m bolts. Logs were sawn to 3 cm thick tangential boards at mobile circular sawmill by applying through-and-through type of sawing method. Samples were prepared and selected proportionally from each tree and log along height and marked with identification codes using waterproof permanent ink.

For the following-up of the seasoning processes and determination of MC, rate of seasoning and defects, 30 defect-free sample boards with dimensions of 100 cm in length, 3 cm thickness and width equal to log-diameter were prepared and used from the sample trees. Green (hereafter, initial) MC of the timber species was determined from the samples, two small sections (1.2 cm length and 3 cm thickness and width equal to log diameter) cross-cut into 20 cm inwards from each sample board ends to eliminate the effects of end seasoning. Another, 30 defect-free sample specimen at initial state, with three replica and standard dimensions of 2x2x3 cm were used for to determine shrinkage and density.

Lumber stacking
Sawn boards were immediately transported to air-seasoning yard and compartment kiln-seasoning chamber, and were stacked with three replications at 3 cm spacing between successive boards. Boards were stacked horizontally in vertical alignments separated by well-seasoned, squared, and standard stickers as stated below, and top loading was applied to counteract against warping (cup, bow, twist, and crook/spring). In air seasoning stacks, 50 kgm^{-2}, 40 cm thick and two-
meter long solid wood blocks were applied; while in kiln seasoning, heavy stones weighing about 50 kg/m² were loaded and in all cases, the loads on the stacks were used at a spacing of 0.5 m interval.

Long stickers with a dimension of 2.5x2.5x180 cm, and short ones (2.5x2.5x20 cm) were prepared and placed at equal distance, 0.5 m interval across each layer of lumber, aligned on top of one another from the bottom of stack to top. This was done to facilitate uniform air circulation, distribute weight of lumber vertically from top to bottom and conduct uniform seasoning, minimize warp and avoid stain and decay during seasoning. Long stickers were used to separate boards while short strips placed on long stickers were used to access sample boards of each stack/replication, withdraw from stack, measure, and replace into stack.

Seasoning samples were distributed in each stack to represent lumber in sack and seasoning at top, bottom, and left-right positions. Weighing and replacing samples into stack was done repeated until MC reached desired amount of 12% MC.

Where heartwood and sapwood boards were separated, sapwood boards were placed at sides, top and bottom of the stacks. Heartwood boards, which have less MC, were placed in the middle. The ends of boards were made equal on both directions and the control sample boards were distributed and positioned in pockets of layers of each stack.

Air seasoning boards were stacked separately under air seasoning yard on firm foundations having 45 cm above ground clearance and a dimension of 4x1.80x0.45 m to facilitate good air circulation and reduce direct influence of fungi, temperature, wind, and relative humidity. Boards were stacked under shed without direct interference of moisture, rainfall, sunshine and aligned north south where ends did not face wind direction. After stacking boards out of kiln on transfer carriage with a dimension of 1.6x0.30x2.7 m was placed inside kiln-seasoning chamber.

**Seasoning tests**

**Air seasoning**

Immediately after planning and crosscutting, initial weights and dimensions of all air seasoning sample boards were measured using sensitive balance and calliper. Small sections (3cm thick and 1.2cm length) crosscut from seasoning sample boards (3cm thick and 1m length) to determine initial MC were weighed at four hour intervals as
soon as samples were withdrawn from oven drier to minimize moisture absorption and desorption.

The seasoning sample boards were re-weighed and re-placed into the stacks at one-week interval. This was continued until the difference between two successive weights of each specimen became 0.1-0.2 g and the final weight was taken as the oven dry weight. The process was continued until the average final MC of the stack reached about 12%, which is the equilibrium MC for in- and out- door purposes and standard for comparison within and between timber species.

Kiln seasoning
The kiln-seasoning machine (conventional type) has been well insulated and having about 2.5 m³ wood loading capacity room/ chamber per kiln operation was used in this study. In this type of kiln, the timber remains stationary and temperature and humidity of circulated air were altered in a set of sequence, which has been selected to suit the material being dried. The machine has controlled air circulation, temperature, and humidity mechanisms where temperature and humidity can be adjusted using psychrometers (dry bulb and wet bulb thermometers) to get quality lumber after seasoning.

To allow uniform air circulation and seasoning, control the seasoning process, and maintain quality of seasoned wood, measurements were taken and the direction of the fan was changed at eight-hour intervals, three times at 24 hours. All air and kiln seasoning boards of this test, were underwent an initial air seasoning before stacking and commencing the regular air and kiln seasoning processes so as to reduce kiln/electric charges during kiln seasoning.

Determining moisture content and seasoning rate
Moisture content was determined for both air and kiln seasoning stacks of the timber. The oven-dry weight-method of MC determination was applied. The general formula applied for MC (%) determination presented in equation 1.

\[
MC (\%) = \frac{IW - OD}{OD} \times 100 = \frac{IW}{OD - 1} \times 100 = \frac{W}{OD} \times 100
\]  

(1)

Where, IW= initial weight of wood with water (g), OD = oven dry weight of wood without water (g), W = weight of water alone (IW-OD) (g).
Air and kiln seasoning rates of the timber species were estimated from the MC samples of each replication/stack. Seasoning rate classification was done based on the adapted standard.

**Determining shrinkage**

For shrinkage values estimation, samples were seasoned in oven-seasoning chamber/microwave to a constant dimension at a temperature of 105°C. Initial and current dimensions and weight of all samples were measured like MC tests, but in this case, measurements were done once per day. Then, final weights and dimensions were taken as oven dry weight and dimensions.

Shrinkage characteristics (tangential, radial and longitudinal directions, and volumetric) and shrinkage rate of each specimen from green (54.5%) to 12% MC, and to oven dry (0%) MC, were determined using the different formulas adapted. The general and specific formulas for the shrinkage characteristics (%) presented in equation 2.

\[
\text{Shrinkage characteristics (\%) = (Decrease in dimension (mm)/green (Initial) dimension (mm))} \times 100
\]

- Tangential shrinkage (%): \( \frac{(T1-T2)}{T1} \times 100 = \frac{(1-T2)}{1} \times 100 \) (3)
- Radial shrinkage (%): \( \frac{(R1R2)}{R1} \times 100 = \frac{(1-R2)}{1} \times 100 \) (4)
- Longitudinal shrinkage (%): \( \frac{(L1-L2)}{L1} \times 100 = \frac{(1-L2)}{1} \times 100 \) (5)
- Volumetric shrinkage (%): \( \frac{(V1-V2)}{V1} \times 100 = \frac{(1-V2)}{1} \times 100 \) (6)

Where, T1, R1, L1, V1 - green/initial tangential, radial, longitudinal, and volumetric dimensions in mm before oven seasoning progression, respectively, and T2, R2, L2, V2 - final/seasoned tangential, radial, longitudinal, and volumetric dimensions in mm after oven seasoning progression, respectively.

**Density test**

The density (gcm\(^{-3}\) or kgm\(^{-3}\)) and/or specific gravity values of the species were determined from the shrinkage samples, procedures, and measurements as stated earlier using mathematical formulas. Density determined at different MC and sample volume conditions.

\[
\text{Basic density} = \frac{\text{Sample oven dry weight}}{\text{Sample green volume}}
\]

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
Getachew

4°C has a density of 1 gcm-3 or 1000 Kgm-3 (Haygreen and Bowyer, 1996; Denig et al., 2000; MTC, 2002). The dry density values have been converted to standard 12% equilibrium MC by applying the formula (equation 8) and classified based on the adapted standard classification.

\[
\text{Density at 12\% MC (}\rho_{12}\text{)} = Pw \times (1-0.01*(1-Ko)*(W-12)
\]

(8)

Where, Ko= coefficient of volumetric shrinkage for a range in 1\% MC. For approximate calculations the value of Ko= 0.85*10^{-3}*Pw when density is expressed in Kgm^{-3} and Ko= 0.85*Pw when density is expressed in gcm^{-3}.

**Experimental design and data analysis**

Experimental design of the study was CRD. One-way ANOVA using SAS 2000
Results and Discussion

Moisture content

There were significant differences (P< 0.01) in the mean air and kiln seasoning green (initial) and final MC of sawn boards. The mean initial MC before air and kiln seasoning commenced was 54.5%. In air seasoning, mean initial MC of *C. alliodora* using control sample boards of each stack was 45.8%; while for kiln seasoning was 69.28% (Table 1); where mean for the two seasoning methods was 57.54% MC. Kiln seasoning samples, especially, replication 3 revealed high MC than air seasoning since the samples were covered with sawdust until seasoning started.

The mean initial MC of *C. alliodora* 54.5% means that the timber before seasoning was holding water/moisture 0.55 times its own weight. Seasoned boards in the two seasoning methods were in average holding about 13.31% final MC which is about 0.13 times their own weight of moisture (Table 2 and fig. 2), where the wood substance occupied about 87% or 0.87 times its own weight.

![Figure 2. Mean moisture content of *C. alliodora* lumber based on air and kiln seasoning methods](image)
Table 1: Some important seasoning and density properties of *C. alliodora* timber

<table>
<thead>
<tr>
<th>Replication</th>
<th>Initial MC of sections before seasoning commenced</th>
<th>Air seasoning stacks MC (%) and rate of seasoning*</th>
<th>Kiln seasoning stacks MC (%) and rate of seasoning**</th>
<th>Density g cm⁻³***</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. of days in air seasoning (days) and rate of seasoning</td>
<td>No. of days in kiln seasoning (days) and rate of seasoning</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.36</td>
<td>49.1</td>
<td>121.6</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>0.38</td>
<td>49.8</td>
<td>124.3</td>
<td>0.39</td>
</tr>
<tr>
<td>2</td>
<td>0.39</td>
<td>49.9</td>
<td>124.8</td>
<td>0.35</td>
</tr>
<tr>
<td>3</td>
<td>0.40</td>
<td>49.0</td>
<td>124.8</td>
<td>0.40</td>
</tr>
</tbody>
</table>

Mean values: 0.38 (121.8). Values classified as: exceptionally light (< 300), light (300-450), medium (450-650), heavy (650-800), very heavy (> 800) g cm⁻³.

*Air seasoning rates (days) have been adapted from Longwood (1961) and classified as: very rapid < 77 days; rapid, 77-119; moderate, 120-182; slow, 183-189; very slow > 189 days.

**Kiln seasoning rates (days) have been adapted from Farmer (1987) and classified as: very rapid <10.5 days; rapid, up to 10.5 days; moderate, 10.5-17.5 days; slow, 17.5-30 days; very slow, over 30 days.

***The density values were determined according to the formula (ISO 3131, 1975): (i) Green/initial density = Initial weight (Kg)/Green volume (m³), (ii) Oven dry density = Oven dry weight/Oven dry volume, (iii) Basic density = Green weight/Initial volume and (iv) Density at 12% MC = Material weight (Kg)/Green volume. The density values were adapted from Farmer (1987) and classified as: exceptionally light (< 300), light (300-450), medium (450-650), heavy (650-800), very heavy (800-1000), and exceptionally heavy (> 1000) g cm⁻³.
The results indicated that mean final air seasoning and range of MC for this species was 12.38% (11.93-12.75%). The final kiln seasoned mean MC of the stacks was 14.24% (10.48-17.42%) (Table 1 and fig 2). The mean initial MC in air and kiln seasoning stacks was different within species while the final was similar within the species/replications and seasoning methods. The mean final MC of kiln-seasoned wood based on its purpose may vary from 0 to 25% (Denig et al., 2000).

Rate of seasoning
The mean air-seasoning rate for *C. alliodora* timber sawn boards of 3 cm thickness to reach to about 12% MC was 35 days. Air seasoning of 2.9-3.2 cm thick *C. alliodora* lumber from green to 18% MC took 154 days, medium seasoning rate (Longwood, 1961). The mean kiln-seasoning rate was 2.2 (1.3-3) days. Based on the adapted rate of seasoning categories (Farmer, 1987), the timber species has been classified as very rapid in both air and kiln seasoning methods (Table 1).

Kiln seasoning compared to open-air seasoning gave better possibility of controlling the relative humidity and temperature, MC, rate of seasoning, seasoning defects, shrinkage characteristics, appearance and the quality of seasoned timber besides reducing MC to the desired amount (about 12%) in a relatively very short period of time, i.e., 2 days. The kiln seasoning schedule applied was suitable for the species that was achieved faster seasoning compared to air seasoning and with no pronounced seasoning defects occurred.

Shrinkage characteristics
Shrinkage of wood is the basic cause of many problems that occur in wood during seasoning to ≤ 25% MC and in service (Denig et al., 2000). The major shrinkage characteristics are warp (cup, bow, twist, and crook/spring-side bend), distortion/split in- and-around knots, and other seasoning stresses (cracks and checks) (FPL, 1999; Denig et al., 2000). The major cause of warp is differential shrinkage caused by the differences in tangential, radial, and longitudinal directions during the seasoning process (FPL, 1999; Denig et al., 2000; MTC, 2002).

According to Denig et al., (2000), the only factors of importance that causes shrinkage and swelling are moisture loss, and gain, respectively. There were significant differences (P<0.01) among the shrinkage characteristics of the sawn timber. The mean tangential, radial, longitudinal, and volumetric shrinkage percentage values from green
(54.5%) to seasoned (12% MC) were 3.8%, 2.45%, 0.36%, and 6.36%, respectively. Shrinkage values at oven dry MC were 6.33%, 4.08%, 0.60% and 10.61%, respectively. Compared to values at 12% MC seasoning to 0% MC was increased in average by more than 1.7 times (Table 2 and fig.3). Lumber from Costa Rica seasoned from green to 12% MC indicated shrinkage values of 3.26%, 1.42%, 0.04% and 6.15 %, respectively. The shrinkage values of this test at 12% MC are in agreement with Longwood (1961).

The ratio of mean tangential shrinkage to radial shrinkage of C. alliodora from green to both 12% and oven dry MC was about 1.55%. This means that mean tangential shrinkage of the species was 1.55 times higher than that of radial shrinkage (Table 2 and fig.3). Wood shrinks about 1.5 to 2 times (Simpson, 1991) and more than half times (Denig et al., 2000) as parallel to the growth rings (tangential) as it does at right angle to the growth rings (radial). The shrinkage along the grain (longitudinal) is small (≤ 0.2%) and thus can be considered as negligible (Simpson, 1991). As the MC decreases, shrinkage value increases, and the more difficult will be the lumber because of high shrinkage. Thus, care is needed for its rational utilization.

<table>
<thead>
<tr>
<th>Replication</th>
<th>MC</th>
<th>Tangential</th>
<th>Radial</th>
<th>Longitudinal</th>
<th>Volumetric</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>4.57</td>
<td>3.39</td>
<td>0.49</td>
<td>7.99</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>3.59</td>
<td>2.08</td>
<td>0.22</td>
<td>5.74</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>3.24</td>
<td>1.88</td>
<td>0.38</td>
<td>5.36</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>3.8</td>
<td>2.45</td>
<td>0.36</td>
<td>6.36</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>7.61</td>
<td>5.64</td>
<td>0.82</td>
<td>13.32</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>5.98</td>
<td>3.47</td>
<td>0.36</td>
<td>9.57</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>5.4</td>
<td>3.13</td>
<td>0.63</td>
<td>8.93</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>6.33</td>
<td>4.08</td>
<td>0.60</td>
<td>10.61</td>
</tr>
</tbody>
</table>

The multiplying shrinkage coefficients for each 1% MC reduction below 30% have been estimated for tangential, radial, longitudinal directions and volumetric as 0.21, 0.14, 0.02, and 0.35, respectively. The lower the shrinkage value and the shrinkage class, the better will be the species for the purpose intended.
Figure 3. Shrinkage characteristics (%) of *C. alliodora* based on mean values at 12% and 0% MC

Tangential and radial shrinkage values from green to oven dry were classified based on Chudnoff (1980). Tangential shrinkage: class 1 < 5%; class 2, 5-6.5%; class 3, 6.5-8%; class 4, 8-9.5% and class 5 > 9.5%. Radial shrinkage: class 1 < 3%; class 2, 3-4%; class 3, 4-4.5%; class 4, 5-6%, and class 5 > 6% (Farmer, 1987). Thus, the tangential (3.8%) and radial (2.45%) shrinkage values of *C. alliodora* classified as class 1.

All the shrinkage values of the species were fallen within the range of shrinkage classes given for timbers, i.e., tangential shrinkage (3.5-15%), radial shrinkage (2.4-11%) and longitudinal (0.1-0.90%) (Kollmann and Côté, 1968). In both air and kiln seasoning methods, *C. alliodora* revealed lower shrinkage values, which are good for proper utilization.

**Appearance of *C. alliodora* sawn timber**

It is an attractive, durable, and much used wood throughout the American tropics. The wood is moderately strong and hard, resembling Mexican mahogany (*Swietenia macrophylla*). The freshly cut heartwood is light greenish brown to olive brown in color, frequently with darker streaks. Seasoned wood becomes a pale golden-brown to brown, and narrow dark lines of pores delineate the darker streaks. Small dark rays
give the wood a lightly mottled appearance on quarter-sawed surfaces. The sapwood is lighter in color than the heartwood and not clearly delineated from it (Fig.1).

The grain is generally straight, texture is fine to mostly medium, and luster is medium to high. Odor and taste are generally lacking. The appearance and working properties of well-seasoned C. alliodora have been comparable with C. africana and E. deglupta (Getachew Desalegn, 2005; Getachew Desalegn et al., 2005; Getachew Desalegn, 2006; Melaku Abegaz et al., 2006).

**Seasoning defects and bio-deterioration attack**

On some boards, wormholes were observed. Knots and initial seasoning defect of cup were observed on C. alliodora. During- and after-seasoning loosening of knots, cup, bow, twist, slight end split, and end checks were observed. Lumber from Costa Rica also revealed seasoning defects cup (2), bow (2), twist (3) and crook (4), where 1- none, 2- very slight, 3- slight, 4- moderate, 5- severe and 6- very severe seasoning defects (Longwood, 1961).

The control measures recommended minimizing seasoning defects, shrinkage and stain on C. alliodora lumber are

- proper stacking using stickers and top loading, where this can reduce cup, bow and twist. Stacking in way that reduce rapid seasoning (end not facing the wind direction) will also minimize surface tension and the accompanying checking and distortion (Longwood, 1961; Simpson, 1991; Haygreen and Bowyer, 1996; Denig et al., 2000; MTC, 2002),
- applying stickers at < 3 cm narrow spacing,
- coating ends with a moisture-resisting paint or wax emulsion and slow seasoning schedule (Denig et al., 2000). Bio-deterioration attack was not observed before, during- and after- seasoning except some stain marks.

**Storing and handling post-seasoned lumber**

Seasoned boards of the species were transported from the seasoning laboratories and piled in a well-conditioned room on supports of 45 cm from the ground, board on board and without stickers, and no top loading was used. The observations made for more than two years revealed that there was no stain and/or fungal attack for boards of the timber. After
seasoning and during storage of the boards, no pronounced seasoning defects were observed.

**Density**

The density values of the timber were determined, as prime indicators of wood quality, as a guide to seasoning behaviour, rate of seasoning and as an index of weight since it has strong influence on the different properties (seasoning rate and defects, shrinkage, physical and mechanical properties, etc.) and timber quality (ISO 3131, 1975; Denig et al., 2000; MTC, 2002).

There was a significant difference at P< 0.01 in the density of sawn timber at different MC. Mean green (initial) density at 54.5% MC was 550 kgcm\(^{-3}\). Samples of *C. alliodora* have a mean basic density (dry weight and green volume) of 350-360 kgm\(^{-3}\) and at 12% MC a density of 380-400 kgm\(^{-3}\). The density and mechanical properties of *C. alliodora*, at 12% MC was comparable to timber *C. africana*, *C. lusitanica*, *E. deglupta*, *H. abyssinica*, *P. patula*, *P. radiata* and *P. falcatus* (Tiruneh Kide, 1988; Lamprecht, 1989; WUARC, 1995; Getachew Desalegn, 1997; Getachew Desalegn, 2005) (Table 2 and Fig. 4).

There was no significant difference between the densities at oven dry and 12% MC. The classification of density based on Farmer (1987) and mean value at 12% MC for *C. alliodora* (390 kgm\(^{-3}\)) was light. Seasoning and density properties of the species varied at different MC levels (Table 1). Plantation grown *C. alliodora* has a density of 360 kgm\(^{-3}\) and lumber from natural forest has a density of 560-800 kgm\(^{-3}\) at 15% MC (Longwood, 1961; Lamprecht, 1989).

Studies on seasoning and density properties showed that *C. alliodora* could be used as sawn timber. It is also used as substitute of the endangered indigenous timber species such as *C. africana*, *C. lusitanica*, *E. deglupta*, *H. abyssinica*, *J. procera*, *P. patula*, *P. radiata* and *P. falcatus*, provided that care is taken during felling, sawing, stacking and seasoning of wood/lumber, and appropriate preservative treatments made against fungal, beetle, borer and termite attacks. For some applications, it is also used as a substitute for teak (*Tectona grandis*), walnut (*Lova tirchilioides*), or mahogany (*S. macrophylla*).
In general, physical and mechanical properties of the wood are quite good and similar to mahogany. It is a freshly felled material seasons rapidly with only slight warping and checking. Wood is easy to work, finishes smoothly, and glues readily. Heartwood is not permeable to preservative treatments but has some resistance to fungi, termites, and marine borers. The wood preservation study in Ethiopia at Meisso and Ziway stations revealed that it was non-durable against termite and fungal attack.

**Uses of *C. alliodora***

Product/lumber uses: *C. alliodora* exhibits excellent growth characteristics and its wood is satisfactory for processing and utilization. The wood has high durability that should qualify it for many of the same uses as cedero hembra (*Cedrela odorata*) and mahogany, but it is probably most valuable for decorative purposes (Longwood, 1961). The timber with appropriate seasoning methods, handling of seasoned wood, at a specified MC, shrinkage allowances, and density can be used for different construction and furniture purposes.
Because of its ease in working, and low shrinkage, and attractiveness, it is a pioneer tree for a general-purpose softwood timber and is used to produce fine and decorative office and household furniture and cabinetwork. It is also useful for indoor and outdoor construction purposes and millwork, carving, turnery, inlay work, interior trim, balusters, excelsior, floor lamps, mouldings, parquet flooring, and wainscoting, poles, posts and decorative and figured veneers, plywood, cooperage, bridge timbers, ship decking, boat planking, and other boat parts, turnings and instruments, production of industrial wood and pulpwood for the paper industry, etc. It is very popular for knife handles and pens because of the extreme figure available. It can be used as long fiber pulp, paper, and plywood (Longwood, 1961; Tack, 1969; Lamprecht, 1989).

Improved uses will be possible when knot-free timber with more consistent physical and mechanical properties is available (Lamprecht, 1989; WUARC, 1995). It is good for earthworks and hydraulic engineering applications. In Bebeka area, it is used as firewood, poles, posts, and timber.

Special uses: role in land use includes shade and shelter, windbreak and hedging, ornamental, and live fence (Webb et al., 1984; Bowen, 1985). Throughout its range, _C. alliodora_ is also used as a shade tree for coffee and cacao plantations as well as in pastures. Humans eat fruits in some places. Both seeds and leaves are used for home medicinal purposes. _C. alliodora_ is suitable for ornamental use in urban residential areas and has been tried for use in honey production because of its copious flowering. In Brazil, it yielded 266 liters of ethanol per ton of dry material; this compares well with a yield of 325 liters of ethanol per ton produced from _Protium_ spp., the best of 25 species tested as source of ethanol.
Conclusions and Recommendations

C. alliodora timber using natural air and artificial kiln seasoning methods have shown good timber properties including density, appearance, and shrinkage characteristics and seasoning properties. The density values were comparable with some indigenous and homegrown exotic timbers grown in the country. It is an important fast growing and decorative timber tree species that have to be studied further for its timber quality and other properties and promoted for large-scale plantations in the country.

The following recommendations are made regarding properties and rational utilization of C. alliodora timber:

- **C. alliodora**, which is prone to various forms of distortion have to be seasoned very carefully and slowly,
- applying proper stacking methods including stickers and top loading but avoid overhanging ends,
- kiln seasoning using appropriate schedule have to be used, if lower MC at faster seasoning rate below 30% and minimizing of shrinkage and seasoning defects are required,
- care and control measures have to be taken into account against MC level (≥ 12% for outdoor construction, and 8-12% for indoor construction and furniture purposes). Proper MC, shrinkage allowances and density values have to be considered before installing and/or manufacturing lumber and other wood-based products from timber,
- applying lumber for ground and moisture contact construction purposes strongly entails adequate preservative measures, and
- tree planting activities of the species with best provenance in large-scale with good silvicultural management practices to improve yield, recovery rate and obtain quality lumber are recommended. Therefore, the timber species has to be grown and well managed, timber properly seasoned to less than 20% MC, with a method that can help minimize seasoning defects and shrinkage characteristics, handled and rationally utilized at specified MC and density for intended construction and furniture purposes.

Finally, proper seasoning, handling and storing of C. alliodora lumber has improved the properties, which will ensure quality of the products
Seasoning and density of *C. alliodora* timber

and enhance rational utilization of this timber species as one competent and potential source of construction and furniture material in Ethiopia.

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