KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

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DEVELOPMENT OF KILN-DRYING SCHEDULES AND WITHIN TREE VARIABILITY IN THE PHYSICAL PROPERTIES OF TWO LESSER-KNOWN TIMBER SPECIES IN GHANA

By

Bernard Effah, B.Ed. (Hons.)

November, 2012

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By

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A Thesis submitted to the Department of Wood Science and Technology,
Kwame Nkrumah University of Science and Technology
In partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE

Faculty of Renewable Natural Resources,
College of Agriculture and Natural Resources

November, 2012

DECLARATION

I hereby declare that this submission is my own work towards the MSc. and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgment has been made in the text.

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ABSTRACT

Decreasing supply of most commercial wood as raw material inspires the forest products industry to look for other wood species which have similar or greater commercial values but are not currently utilized by the forest products industry. Wood is versatile and the oldest building material used by man. But there is limited knowledge about the properties of a large proportion of timber-grade wood species. Proper utilization of a particular wood species must be based on both basic properties and processing properties. Drying is one of the most important processing properties, because a proper drying process will be the main key to utilize efficiently and ensure high quality wood products. *Cola nitida* (Bese) and *Funtumia elastica* (Funtum) are two lesser- known species in Ghana that are not used for commercial timber purposes. The overall objective of this study was to develop kiln-drying schedules for *Cola nitida* (Bese) and *Funtumia elastica* (Funtum), as well as assess the variability of the physical properties as the basis for determining the potential uses that may encourage the utilization and promotion of these lesser known species. The basic properties were determined based on British Standard 373 (1957), whiles the drying schedules were determined using the quick drying test method developed by Terazawa (1965). The main statistical tools used were Descriptive Statistics and Analysis of Variance (ANOVA). Variation in physical properties was analyzed within the trees of the two species. Three trees each per species were used in the study. Results of the study showed that initial moisture content were 66.6% and 79.4% for *Cola nitida* and *Funtumia elastica* respectively. The basic density of *Cola nitida* was 623.8 kg/m^3 and 499.6 kg/m^3 for *Funtumia elastica*. According to TEDB (1994), *Cola nitida* is a Medium-Heavy species and *Funtumia elastica* a Medium Weight species. Mean total tangential shrinkage from green to oven-dry was 7.25 and 6.78% for *Cola nitida* and *Funtumia elastica*, respectively. Mean partial tangential shrinkage from green to 12% MC is very small (under 2.5%) for *Cola nitida* and medium (4.0-5.5%) for *Funtumia elastica*. The corresponding mean partial radial shrinkage values also showed that shrinkage was very small (under 1.0%) for *Cola nitida* and medium (2.0–3.0%) for *Funtumia elastica*. The shrinkage values for the two species compared favourably with those of some locally used species for timber production (like *Scottellia coriacea* and *Lannea welwitschii)*, and therefore could be

considered suitable for timber utilization. The drying schedules also comformed to those of *Sterculia rhinopetala* and *Alstonia boonei* as proposed by Ofori and Brentuo (2010b). Checks in the early stages of drying were less severe in both *Cola nitida* and *Funtumia elastica* samples (Class 3). There were no honeycombing (Class 1) in both *Cola nitida* and *Funtumia elastica* species. There was no deformation (Class 1) in both *Cola nitida* and *Funtumia elastica* species. Experimental dry kiln schedules for lumber of thickness up to 38 mm corresponding to two Madison schedules were proposed: *Cola nitida* (T_{10}-C_4) and *Funtumia elastica* ($T_{10} – D_4$). The results of the analysis of variance (ANOVA) revealed that the three axial sections of the trees showed significant differences at 5% probability level ($p < 0.05$). The technical values of the study results compared favourably with technical values of some locally used species for timber production (like *Scottellia coriacea* and *Lannea welwitschii*), and therefore could be considered suitable for timber utilization.

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LIST OF ABBREVIATIONS

B	–	Bottom/Buttress/ Breast height/ Butt end
BS	–	British Standard
CL	–	Confidence level
cm	–	Centimeters
EMC	–	Equilibrium moisture content
FORIG	–	Forestry Research Institute of Ghana
FRNR	–	Faculty of Renewable Natural Resources
FPL	–	Forest products laboratory (USA)
FSP	–	Fibre saturation point
ITTO	–	International Tropical Timber Organisation
KNUST	–	Kwame Nkrumah University of Science and Technology
MOE	–	Modulus of elasticity
MOR	–	Modulus of rupture
M	–	Middle
m	–	Meters
mm	–	Millimeters
MC	–	Moisture content
SD	–	Standard deviation
T	–	Top
TD	–	Dry-bulb temperature
TEDB	–	Timber Export Development Board
TIDB	–	Timber Industry Development Board
TIDD	–	Timber Industry Development Division
TW	–	Wet-bulb temperature
W_i	–	green mass
W_{od}	–	oven dry mass

ACKNOWLEDGEMENT

It is said that debts of gratitude are not easily paid. This is why I am sure I can never repay my creator, the Almighty God who gave me the wisdom and strength to complete my course. I would like to acknowledge the contributions and involvement of my academic advisors, Mr. Jonny Osei Kofi of the Department of Wood Science and Technology and Dr. N. A. Abukari of Wood Industry Training Center. My special gratitude goes to the management and staff of CSIR-FORIG, especially Madam Bridgette Brentuo for her wholehearted help and constant support since I started this project and for her enthusiasm for this project.

I wish as well to express my grateful acknowledgement to the lecturers and staff of the Department of Wood Science and Technology in the persons of Dr. N. A. Darkwah, Dr. C. Antwi – Boasiako and Prof. K. Frimpong Mensah, all of the Faculty of renewable natural resources for their positive inputs.

I am also grateful to my wife Ms. Stella Owusu and my sons Bernard Antwi Effah and Goodluck Owusu Effah, my family and friends for their encouragement to stay in school, for believing in me, and their understanding for the time that I could not spend with them because of my student responsibilities. Without the support of all of you, I could not have completed my graduate studies.

I cannot turn a blind eye to all my course mates and friends whose unconditional support and love made this achievement possible.

Finally, I would like to express my appreciation to all the authors whose works and ideas I cited and personally take responsibility for any errors and omissions in this project.

CHAPTER ONE

INTRODUCTION

1.1 Background

Decreasing supply of most commercial wood as raw material inspires the forest products industry to look for other wood species which have similar or greater commercial values but are not currently utilized by the forest products industry. Wood is a versatile and an aesthetically pleasing material as well as the oldest building material used by man. But there is limited knowledge about the properties of a large proportion of timber-grade wood species. This knowledge base is essential for greater or proper utilization because of changes that occur in wood under different service conditions.

Proper utilization of a particular wood species must be based on both basic properties and processing properties. Drying properties are a set of the most important processing properties. A proper drying process will be the main key to efficiently utilize and ensure high quality wood products (Hoadley, 2000).

Ghana, in West Africa, is a land of savannah and forest. It is roughly the same size as the United Kingdom but with only one third as many people. It depends strongly on its exports of minerals, cocoa and timber and it is pioneering ecotourism based on its forests and wildlife. Ghana is recognized as one of the most advanced tropical African countries in established forest policy, legislation, forest inventory, management planning, and in having a National Forest Standard and principles, criteria and indicators for judging the quality of forest management and usage (TEDB, 1994). Ghana has established a conservation classification to ensure that the supply of Ghanaian hardwood species can be maintained. In practice, this means that harvesting of the better known and commonly used species (like the redwoods, African mahogany and Sapele wood) is more limited, and much more encouragement is being given to the harvesting of lesser known species (Poku *et al.*, 2001).

One of the most threatened natural forests in the world is the Ghanaian tropical rainforest with an estimated 1.60 million hectres of permanent forest estate depleted (ITTO, 2006). Although there are many tree species in the world especially in the tropics, Ghana has considerable wealth in tropical hardwood timber resources. Forest product exports represent about 12% of total export of goods (Ofori & Appiah, 1998). Before the ban on round logs export in 1994, about 55-65% of the wood exported from Ghana was in the form of round logs and 32-47% in green lumber (Ofori *et al*., 2000). The Ghanaian government's policy was aimed at encouraging the production of added value timber products and the export of kiln-dried sawn timber and other machined wood products (Attah *et al*., 2005).

There are nearly seven hundred different tree species in Ghana (TEDB, 1994). Approximately 420 of these tree species attain timber size and therefore are of potential economic value (Hall & Swaine, 1981). Almost 126 of them occur in sufficient volumes to be considered exploitable as raw material base for the timber industry (Ghartey, 1989). However, about 90% of the country's wood exports are covered by 10 species (Jayanetti *et al.*, 1999), and only 4 species contribute roughly 60% of the total production (Upton & Attah, 2003).

Historically, most dealers in the Ghana wood industry have relied mainly on a traditional knowledge based on experience of use but with little information on their properties.

Most of the species are also not being put to wider utilization because of inadequate data on the physical and technological properties that relates to the utilization of the species. One such important data is the drying properties of the species. For many lesser-utilized species, there does not appear to be any published record of a recommended kiln schedule (Simpson & Verril, 1997), among them are *Cola nitida* and *Funtumia elastica*. For many end-uses and secondary manufacturing processes, lumber should be dried to avoid undesirable defects such as excessive shrinkage, warping, splitting and checking, stain and decay caused by fungal attack. Kiln schedules for drying the wood species chosen for the study have so far not been developed.

Since drying improves wood quality and maximum value-addition, the target for the wood industry-kiln-drying, should be encouraged. It is, therefore, important that certain fundamental physical and technological properties of wood (density, shrinkage, swelling, moisture content, thermal characteristics, etc) and the susceptibility of the wood species to drying defects (splits, checks, collapse, honey comb, etc), which are related to its interaction with moisture, be studied to provide important information on the ability of particular species at particular moisture contents to be utilized for specific purposes (Ofori & Appiah, 1998). Measurements of these physical and technological properties relevant to the drying of wood are also aimed at developing appropriate drying schedules for specific end-uses.

Presently, *Cola nitida* is widely used ceremonially and socially by the people of West and Central Africa and *Funtumia elastica* also gives the best indigenous rubber, and is the only true rubber tree of West African forests whiles their timber is used as firewood.

Because few tree species are being utilized commercially, there is an erroneous impression that there is an insufficient raw material base for the timber industry. The present kiln-drying schedules in use in Ghana were development for only the so-called ‘noble’ species.

There is, therefore, the need to draw up satisfactory drying schedules for the numerous lesser-known species that may (soon) be exploited (Ofori & Appiah, 1998). This means that suitable processing of *Cola nitida* and *Funtumia elastica* which are lesser-known to the timber industry are essential for the production of high quality products for national and international markets.

It has, therefore, become imperative to adopt systematic and scientific techniques to develop drying schedules and develop information about the physical and technological properties for *Cola nitida* and *Funtumia elastica* species to promote their utilization. This in turn may be followed by an evaluation of their utilization potential, marketability and performance, so as to serve as suitable substitutes for the fast-diminishing traditional market species in Ghana.

There is also very little information about the variability in timber properties with respect to drying, including how strongly they are correlated (Cabardo & Langrish, 2006). The variability of wood properties further complicates drying. Each species has different properties, and even within species, variability in drying rate and sensitivity to drying defects impose limitations on the development of standard drying procedures (Simpson, 1992). It is important that *Cola nitida* and *Funtumia elastic* to be subjected to these tests.

1.2 Statement of the problem

The forest in Ghana, like most tropical forest, is being utilized commercially for a few highly priced timber species, which are mere fraction of the timber species that are potentially useful (Chudnoff, 1979). There is significant utilization of these few tree species to satisfy market demands to the neglect of about 90 species that are of merchantable sizes and commercial quantities (FORIG, 1990). These constitute over 45% of the standing volume of trees in Ghana’s forest (Ghartey, 1989). Increases in population and the need to earn money from exports have put pressure on Ghana's forests which are limited in extent. Over the years, Ghana has worked to evolve sustainable use of forests which could go on to provide economic, social and environmental benefits.

Increasing market demand, both locally and internationally, has resulted in the over-exploitation of these ‘traditional’ market species, rendering some of them like Odum, Sapele, and others endangered (Poku *et al*., 2001). As prices of these traditional timber increase, and quality and quantities decline, manufacturers and producers have little option other than to pay attention to the lesser-known species that were previously ignored if they are to remain in business. One of the crucial questions in tropical forest management today is the future of lesser-known species (Basri, *et al*., 2007). Hundreds of potentially valuable trees are being left behind, often simply being burnt in forest clearing operations. Little is known at present about their possible end-uses or even their physical properties. There is, therefore, little hope for the future of the Ghanaian timber trade if diversification of market species is not encouraged to accommodate lesser-known species and to serve as a means for sustainable management of the tropical forest of Ghana. *Cola nitida* and *Funtumia elastic* are species that are in abundance in our forests and farms. These species have being left out of utilization due to lack of knowledge on their properties. It is therefore urgent to assess properties of these species to ascertain their possible utilization potentials.

1.3 Aims and objectives

1.3.1 General objective

The study aimed to adopt systematic and scientific techniques to develop kiln drying schedules and develop information about the physical properties for *Cola nitida* and *Funtumia elastica* species.

1.3.2 Specific objectives

The specific objectives of the study were:

- To determine fundamental physical properties (basic density, moisture content and shrinkage) of *Cola nitida* and *Funtumia elastica* species.
- To determine the drying behavior of *Cola nitida* and *Funtumia elastica* species as means to propose kiln-drying schedules to dry them.
- To examine the variation of the physical properties (moisture contents, basic density, and shrinkage) within the stems of *Cola nitida* and *Funtumia elastica* species in Ghana.

1.4 Limitations

The researcher had to go for practical experience and training at CSIR-FORIG to learn the Terazawa method of developing kiln-drying schedules. The acquisition and transportation of the logs (3 each) were very expensive. Equipment and tools were not always available when needed. Lack of sponsorship created a lot of financial difficulties to the researcher.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.0 Introduction

This chapter focused on the theoretical background of extensive studies on instability of wood and some basic wood properties which influence wood distortion and shape when the wood loses or gains moisture. These properties include anisotropic shrinkage (longitudinal and tangential), fiber saturation point and equilibrium moisture content, basic wood density and susceptibility to drying defects. The development of kiln drying schedule was also reviewed.

2.1 Tree descriptions of the two lesser known wood species studied

2.1.1 *Cola nitida* (Bese)

Cola nitida is a species in the genus Cola which contains 125 species and belongs to the family of the *Sterculiaceae* (*Cacao Family*) (Anon, 2008). The tree is grown chiefly from seeds which germinate after 3-4 weeks (Irvine, 1961). It is a common tree in the forest understory found in the closed forest habitat and it is a typical species of the Ashanti forest (Irvine, 1961). It is believed that Cola trees are native to Ghana and Ivory Coast and their spread was brought about by humans (Anon, 2008). There are over 50 species of cola. Of these, seven have edible nuts, but only two have been widely exploited. These are *Cola nitida* and *Cola acuminata*. *Cola nitida* is a medium sized (< 25 m) evergreen forest tree. The bole is usually unbranched reaching 8-20 m in height and sometimes attaining 24 m. The trunk may grow to 50 cm in diameter (in old trees) with narrow buttresses extending to about 1 m. The sapwood is whitish or pinkish and the heartwood, dull yellowish brown (Irvine, 1961). It is suitable for furniture, house and boat-building, coachwork, for plates and other domestic utensils, and for carving (Irvine, 1961). Cola nut, apart from the fact that it is widely consumed by virtually all categories of income groups, has been found to be useful in the production of beverages, flavouring material, alkaloids, caffeine, theobromine, laxatives, heart stimulants and sedatives (Anon, 2008).

2.1.2 *Funtumia elastica* (Funtum)

Funtumia elastica is a species in the genus Funtumia which contains 2 species and belongs to the family of the Apocynaceae (Anon, 2008). *Funtumia elastica* (Funtum) was first discovered in Ghana in about 1883, and plantations of it were made in many parts of West Africa (Irvine, 1961). *Funtumia elastica* (Funtum) is a tree up to 35 m high, bark pale with grey patches and dark brown twigs and found in the deciduous forest. It is a medium-sized tree with glossy opposite leaves, milky sap and paired long woody pods bearing numerous plumed seeds (Anon, 2008). This species gives the best indigenous rubber, and is the only true rubber tree of West African forests. The wood is white, and is sometimes used for making stools (Irvine, 1961).

2.2 Wood density

The terms density and specific gravity (SG) are both used to describe the mass of a material per unit volume. These terms are often used interchangeably although they each have precise and different definitions (Bowyer & Smith, 1998). Haygreen and Bowyer (1996), Zobel and Buijtenen (1989) and Hoadley (2000) defined specific gravity as the ratio between the mass per unit volume of water while wood density is defined as mass or weight per unit volume of water (such as pounds per cubic foot, grams per cubic centimeter, or kilograms per cubic meter). In other words, both terms are used to indicate the amount of actual wood substance present in a unit volume of wood and also both terms can be calculated from one another (Zobel & Jett, 1995). Therefore, they will be used interchangeably. Zobel and Jett (1995) pointed out that wood density is, in fact, not a single wood property but a combination of wood properties (latewood percent, wall thickness, cell size, and others). However, despite its complexity, wood density reacts generally as though it were a single, simple characteristic.

Wood density is not a simple characteristic. It is affected by the cell wall thickness, the cell diameter, the earlywood to latewood ratio and the chemical content of the wood (Simpson, 1991). Wood density is an important wood property for both solid wood and fibre products in both conifers and hardwoods (Hoadley, 2000). Panshin and de Zeeuw (1980) reported that density is a general indicator of cell size and is a good predictor of strength, stiffness, ease of drying, machining, hardness and various paper making properties. Shrivastava (2000) and Hoadley (2000) also expressed the opinion that density is one of the most important properties influencing the use of a timber. They emphasized that it affects the technical performance of wood and in particular the strength and processing behaviour of sawn wood and veneer, and the yields of wood fibre in pulp production. Rowell (2005) reported that wood density is a measure of the cell wall material per unit volume and as such gives a very good indication of the strength properties and expected pulp yields of timber. Basic density is closely related to end-use quality parameters such as pulp yield and structural timber strength (Rowell, 2005). Anon, (1994) reported that density of wood is recognized as the key factor influencing wood strength. Indeed according to Hoadley (1990), much of the variation in wood strength, both between and within species, can be attributed to differences in wood density. Research has shown that higher density species tend to have stronger timber than lower density species (TEDB, 1994; Rowell, 2005).

Density within a tree varies from pith to bark and with height in the stem. Wood density varies from earlywood tissue to latewood tissue within each annual ring. Latewood tissue is composed of cells of relatively small radial diameter with a thick wall and a small lumen and therefore, has a higher density than the thin walled earlywood cells with a larger cell lumen (Haygreen & Bowyer, 1996). Indeed in many conifers, the basic density of the latewood zone is more than twice that of earlywood, thus, any increase in the proportion of latewood inevitably leads to an increase in whole ring basic density (Hoadley, 2000). Frequently, the relative densities of the earlywood and latewood within a tree are strongly correlated (Wengert, 2006). Usually a tree with high-density earlywood will also have high density latewood (Zobel & Jett, 1995).

2. 3 Shrinkage and swelling

During drying of green wood, the freely available water evaporates easily, primarily due to low binding forces. This has no influence on the wood dimensions. However, as soon as the moisture content falls below the fiber saturation point, the more strongly bound water evaporates from the cell walls. Thus, the drying velocity decelerates and the wood changes its size with changing moisture content (Bauer, 2003). Shrinkage and swelling may occur in wood when the moisture content is changed (Reeb, 1995). Shrinkage occurs as moisture content decreases, while swelling takes place when it increases. Volume change is not equal in all directions. The greatest dimensional change occurs in a direction tangential to the growth rings. Shrinkage from the pith outwards, or radially, is usually considerably less than tangential shrinkage, while longitudinal (along the grain) shrinkage is so slight as to be usually neglected. Generally, longitudinal shrinkage is 0.1 to 0.3% in contrast to transverse shrinkages which are 2 to 10%. Tangential shrinkage is often about twice as great as in the radial direction, although in some species it may be as much as five times as great. Shrinkage is about 5-10% in the tangential direction and about 2 to 6% in the radial direction (Walker *et al.*, 1993).

The grade of total volumetric shrinkage is proportional to the wood moisture content and the wood density, whereby denser wood shrinks more than lighter wood. Therefore, an inhomogeneous density distribution in wood causes differential shrinkage and therefore deformations (Walker *et al.*, 1993).

2.4 Wood drying

Wood drying may be described as the art of ensuring that gross dimensional changes through shrinkage are confined to the drying process. Ideally, wood is dried to that equilibrium moisture content as will later (in service) be attained by the wood. Thus, further dimensional change will be kept to a minimum (Wengert, 2006). Drying timber is one method of adding value to sawn products from the primary wood processing industries (Attah *et al*., 2005).

Drying, if carried out promptly after felling of trees, also protects timber against primary decay, fungal stain and attack by certain kinds of insects. Organisms, which cause decay and stain, generally cannot thrive in timber with moisture content below 20% (Wengert, 2006). Several, though not all, insect pests can live only in green timber. Dried wood is less susceptible to decay than green wood above 20% moisture. In addition to the above advantages of drying timber, the following points are also significant (Walker *et al.*, 1993):

Dried timber is lighter, and the transportation and handling costs are reduced, dried timber is stronger than green timber in most strength properties. Timbers for impregnation with preservatives have to be properly dried if proper penetration is to be accomplished, particularly in the case of oil-type preservatives (Redman, 2000). In the field of chemical modification of wood and wood products, the material should be dried to certain moisture content for the appropriate reactions to occur. Dry wood works, machines, finishes and glues better than green timber. Paints and finishes last longer on dry timber. The electrical and thermal insulation properties of wood are improved by drying. Prompt drying of wood immediately after felling therefore significantly upgrades and adds value to raw timber. Drying enables substantial long-term economy by rationalizing the use of timber resources (Wengert, 2006).

2.4.1 Types of wood

Wood is divided, according to its botanical origin, into two kinds: softwoods from coniferous trees and hardwoods from broad-leaved trees. Hoadley (1990), described softwoods as lighter and generally simple in structure, whereas hardwoods are harder and more complex. Softwood like pine wood is much lighter and easier to process than heavy hardwood like fruit tree wood. The density of softwoods ranges between 350 - 700 kg/m³, while hardwoods are 450 - 1250 kg/m³ (Desch & Dinwoodie, 1996). Due to its more dense and complex structure, permeability of hardwood is very low in comparison to softwood, making it more difficult to dry (Redman, 2000).

2.4.2 Classification of timbers for drying

Redman (2000), classified timbers according to their ease of drying and their proneness to drying degrade:

Highly Refractory Woods: These woods are slow and difficult to dry if the final product is to be free from defects, particularly cracks and splits. They require considerable protection and care against rapid drying conditions for the best results.

Moderately Refractory Woods: These timbers show a moderate tendency to crack and split during seasoning. They can be seasoned free from defects with moderately rapid drying conditions (i.e. a maximum dry-bulb temperature of 85 °C can be used).

Non-Refractory Woods: These woods can be rapidly seasoned to be free from defects even by applying high temperatures (dry-bulb temperatures of more than 100 °C) in industrial kilns. If not dried rapidly, they may develop discolouration (blue stain) and mould on the surface (Redman, 2000; Shrivastava, 2000).

2.5.0 Wood and moisture relationship

2.5.1 Moisture content of wood

The water distribution in trees depends on both the wood species and the environmental conditions. The moisture can either be distributed equally in the whole log or significant moisture gradients can exist in radial or longitudinal direction. Next to the moisture differences in a single log, there can also exist significant differences of moisture content and distribution in different logs of the same wood species at the same growing conditions (Reeb, 1995).

Water is needed primarily in trees for the transportation of nutrients and minerals. Therefore, wood fibers contain water in their cell walls and cavities. The water in the cavities is called "free" water due to low binding forces. The water in the cell walls is called "bound" water due to the strong bonds caused by chemical and physical binding forces (Reeb, 1995). At wood moisture content between 0 and 6%, water is bound by a chemical-sorptive manner, between 6 and 15% by different types of adsorption forces and between 15 and about 30% by capillary condensation. The range in which the cell walls of the wood fibers are saturated and free water is available is called the fiber saturation point (FSP). The numerical value of the fiber saturation point depends not only on the wood species but also on the wood temperature and can therefore range between 22 and 35%. However, average values are given for softwood species with 26% and for hardwood species with 27% (Bauer, 2003).

The moisture content of wood is calculated by the formula:

Moisture content = $[(W_i - W_{od}) / W_{od}] \times 100\%$ ……………………. (1)

where, W_i is the green mass of the wood, W_{od} is its oven-dry mass (the attainment of constant mass generally after drying in an oven set at 103 ± 2 °C for 24 hours as mentioned by Walker *et al.* (1993). The equation can also be expressed as a fraction of the mass of the water and the mass of the oven-dry wood rather than a percentage.

2.5. 2 Equilibrium moisture content

Wood is a hygroscopic substance. It has the ability to take in or give off moisture in the form of vapour. Water contained in wood exerts vapour pressure of its own, which is determined by the maximum size of the capillaries filled with water at any time. If water vapour pressure in the ambient space is lower than vapour pressure within wood, desorption takes place. The largest-sized capillaries, which are full of water at the time, empty first. Vapour pressure within the wood falls as water is successively contained in smaller capillaries. A stage is eventually reached when vapour pressure within the wood equals vapour pressure in the ambient space above the wood, and further desorption ceases. The amount of moisture that remains in the wood at this stage is in equilibrium with water vapour pressure in the ambient space, and is termed the equilibrium moisture content or EMC (Siau, 1995). Because of its hygroscopicity, wood has been found to reach a moisture content that is in equilibrium with the relative humidity and temperature of the surrounding air. EMC of wood is reported to vary with the ambient relative humidity (a function of temperature) significantly and to a lesser degree, with the temperature (Redman, 2000). Siau (1995) reported that EMC also varies very slightly with species, mechanical stress, drying history of wood, density, extractive content and the direction of sorption in which the moisture change takes place (i.e. adsorption or desorption).

2.5.3 Influence of temperature, relative humidity and rate of air circulation on wood drying

2.5.3.1 Temperature

If relative humidity is kept constant, the higher the temperature, the higher would the drying rate be. Temperature influences the drying rate by increasing the moisture holding capacity of the air, as well as by accelerating the diffusion rate of moisture through the wood. The actual temperature in a drying kiln is the dry-bulb temperature (usually denoted by TD), which is the temperature of a vapour-gas mixture determined by inserting a thermometer with a dry bulb. On the other hand, the wet-bulb temperature (TW) is defined as the temperature reached by a small amount of liquid evaporating in a large amount of an unsaturated air-vapour mixture. The temperature sensing element of this thermometer is kept moist with a porous fabric sleeve (cloth) usually put in a reservoir of clean water. A minimum air flow of 2 m/s is needed to prevent a zone of stagnant damp air formation around the sleeve (Walker *et al.*, 1993). Since air passes over the wet sleeve, water is evaporated and cools the wet-bulb thermometer. The difference between the dry-bulb and wet-bulb temperatures, the wet-bulb depression, is used to determine the relative humidity from a standard hygrometric chart (Walker *et al.*, 1993). A higher difference between the dry-bulb and wet-bulb temperatures indicates a lower relative humidity and vice versa.

2.5.3.2 Relative humidity

The relative humidity of air is defined as the partial pressure of water vapour divided by the saturated vapour pressure at the same temperature and total pressure (Siau, 1995). If the temperature is kept constant, lower relative humidity result in higher drying rates due to the increased moisture gradient in wood, resulting from the reduction of the moisture content in the surface layers when the relative humidity of air is reduced. The relative humidity is usually expressed on a percentage basis. For drying, the other essential parameter related to relative humidity is the absolute humidity, which is the mass of water vapour per unit mass of dry air (kg of water per kg of dry air) (Basri *et al*., 2009).

2.5.3.3 Air circulation rate

Drying time and timber quality depend on the air velocity and the uniform circulation of the air. At constant temperature and relative humidity, the highest possible drying rate is obtained by rapid circulation of air across the surface of the wood, giving rapid removal of moisture evaporating from the wood (Wengert, 2006). However, higher drying rate is not always desirable, particularly for impermeable hardwoods, because higher drying rates develop greater stresses that may cause the timber to crack or distort. At very low fan speeds, less than 1 m s-1, the air flow through the stack is often laminar flow, and the heat transfer between the timber surface and the moving air stream is not particularly effective (Walker *et al.*, 1993). The low effectiveness (externally) of heat transfer is not necessarily a problem if internal moisture movement is the key limitation to the movement of moisture, as it is for most hardwoods (Pordage & Langrish, 1999).

2.6 Methods of drying wood

Today, much emphasis is placed on producing seasoned timber as quickly and economically as possible within the quality limits of specified standards. Drying of timber is generally performed via air drying, kiln drying or a combination of the two (Redman, 2000).

2.6.1 Air drying

Redman (2000), described air drying as the process where timber is racked either outside or under a roof and is exposed to natural weather conditions. There is virtually no control of the temperature, relative humidity or speed of the air passing through the timber stacks. The rate of drying is therefore dependent on the whims of the local climate and can vary from practically zero on a calm, damp day to fast enough to cause timber degrade on a dry, windy day (Wengert, 2006).

2.6.2 Kiln drying

Shrivastava, (2000) stated that, in contrast to air drying a conventional drying kiln provides temperature and humidity control and a steady adequate flow of air over the timber surface. Fans control the rate of air flow and direction and the temperature and relative humidity of the air can be adjusted to suit the species and sizes of timber being dried. Kiln drying generally increases the rate of drying by raising the drying temperature to the maximum value that particular timber species can tolerate without excessive degrade (Basri *et al*., 2009). At the same time, the relative humidity can be controlled so that the moisture gradients in the wood are not steep enough to cause stress related degrade. In addition to the advantages of more rapid drying and limitation of degrade, the ability to control drying conditions in a kiln means that it is possible to achieve timber moisture contents suitable for specific uses.

2.6.3 Combined air and kiln drying

For those species and sizes which take a relatively long time to kiln dry, kiln drying tends to become uneconomical. Therefore, it is often more economical to air dry the timber to about 25-30% moisture content before completing the drying in the kiln (Redman, 2000). The economic advantage of this approach will be lost, however, if the air dried phase causes unacceptable levels of degrade.

2.7 Formulation of kiln drying schedules

Simpson, (1991) and Wengert, (2006) all defined drying schedule as a set of temperatures, relative humidities and corresponding equilibrium moisture contents of timber that change with either the actual average moisture content of the timber (a moisture-content based schedule) or the time from the start of drying (a time based schedule). The drying schedule is dependent on the timber species. A major challenge for industries in timber drying is to reduce the drying time and the loss of product due to drying degrades. Generally, longer drying times (low temperatures and high humidities in the early stages of drying, with a corresponding slow drying rate) for refractory hardwoods result in less product loss and vice versa. Satisfactory kiln drying can usually be accomplished by regulating the temperature and humidity of the circulating air to suit the state of the timber at any given time. This condition is achieved by applying kiln-drying schedules. The desired objective of an appropriate schedule is to ensure drying timber at the fastest possible rate without causing objectionable degrades (Wengert, 2006; Shrivastava, 2000).

2.7.1 Arranging kiln drying schedules

The task of schedule development has often been based on experience, essentially using trial and error approaches. However, this procedure can be very expensive due to the time required for testing. Drying schedules vary by species, thickness, grade, moisture content, and end use of lumber (Simpson, 1991). The two general types of kiln schedules are moisture content schedules and time-based schedules. Most hardwood lumber are dried by moisture content schedules. This means that the temperature and relative humidity conditions are changed according to the percentage moisture content of the lumber during drying. A typical hardwood schedule might begin at 49 °C (120 °F) and 80% relative humidity when the lumber is green. By the time the lumber has reached 15% moisture content, the temperature is as high as 82 °C (180 °F) (Simpson, 1991).

Both drying rate and susceptibility to drying defects are related to the moisture content of lumber, so kiln schedules are usually based on moisture content. The successful control of drying defects as well as the maintenance of the fastest possible drying rate in hardwood lumber depends on the proper selection and control of temperature and relative humidity in the kiln. Therefore, each combination of species and thickness (and in some cases, end product) has been classified into a schedule code of “T” number for temperature and “C” number for wet-bulb depression settings. To maintain a fast drying rate, relative humidity must be lowered gradually as soon as the moisture content and stress condition of the wood will permit (Ofori & Brentuo, 2010b; Wengert, 2006).

Table 2.1 lists 14 temperature schedules ranging from a very mild schedule, T_1, to a severe schedule, T_{14}. In all cases, initial temperatures are maintained until the average moisture content of the controlling samples reaches 30%. Table 2.2 lists the wet-bulb depression schedules for six moisture content classes. These classes are related to the green moisture content of the species (Table 2.3). There are eight numbered wet-bulb depression schedules; Number 1 is the mildest and Number 8, the most severe. The wet-bulb temperature to be set on the recorder-controller is obtained by subtracting the wet-bulb depression from the dry-bulb temperature (Simpson, 1991).

Table 2.1: Moisture content schedules for hardwoods

Dry-bulb temp step no.	Moisture content at start of step (%)	Dry-bulb temperatures for various temperature schedules													
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}
1	>30	37.8	37.8	43.3	48.9	48.9	4 8.9	54.4	54.4	60.0	60.0	65.6	71.1	76.7	82.2
2	30	40.6	43.3	48.9	43.3	54.4	54.4	60.0	60.0	65.5	65.6	71.1	76.7	82.2	87.8
3	25	40.6	48.9	54.4	54.4	60.0	60.0	65.6	65.6	71.1	71.1	71.1	76.7	82.2	87.8
4	20	46.1	54.4	60.0	60.0	65.6	65.6	71.1	71.1	71.1	76.7	76.7	82.2	87.8	93.3
5	15	48.9	65.6	71.1	82.2	71.1	82.2	71.1	82.2	71.1	82.2	82.2	82.2	87.8	93.3

Source: F.P.L. in Madison U.S.A. (1991)

Table 2.2: General wet-bulb depression schedules for hardwoods

Wet-bulb depression step no.	MC (%) at start for various moisture content classes						Wet-bulb depressions for various wet-bulb depression schedules							
	A	B	C	D	E	F	1	2	3	4	5	6	7	8
1	>30	>35	>40	>50	>60	>70	1.7	2.2	2.8	3.9	5.6	8.3	11.1	13.9
2	30	35	40	50	60	70	2.2	2.8	3.9	5.6	7.8	11.1	16.7	19.4
3	25	30	35	40	50	60	3.3	4.4	6.1	8.3	11.1	16.7	22.2	27.8
4	20	25	30	35	40	50	5.6	7.8	10.6	13.9	19.4	27.8	27.8	27.8
5	15	20	25	30	35	40	13.9	16.7	19.4	22.2	27.8	27.8	27.8	27.8
6 and 7	10	15	≤20	≤25	≤30	≤35	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8

Source: F.P.L. in Madison U.S.A. (1991)

Table 2.3: Moisture content classes for various green moisture content values

Green moisture content (percentage)	Moisture content classes
Up to 40	A
40 to 60	B
60 to 80	C
80 to 100	D
100 to 120	E
Above 120	F

Source: F.P.L. in Madison U.S.A. (1991)

2. 8 Drying defects

Drying defects are the most common form of degrade in timber, next to natural problems such as knots (Desch & Dinwoodie, 1996). There are two types of drying defects, although some defects involve both causes: Defects from shrinkage anisotropy, resulting in to warping, cupping, bowing, twisting, spring and diamonding. Defects from uneven drying, resulting in the rupture of the wood tissue, such as checks (surface, end and internal), end splits, honey-combing and case hardening. Collapse, often shown as corrugation, or "washboarding" of the wood surface, may also occur (Innes, 1996). Collapse is a defect that results from the physical flattening of fibres above the fibre saturation point and is thus not a form of shrinkage anisotropy.

Timber quality is generally measured by the severity of both natural and drying defects. Natural defects such as knots, sap stains, rot etc. are recognised as being out of the hands of the timber drier, however this is not the case for defects or degrade caused through timber drying (Wengert, 1991). The type and severity of timber drying degrade varies with tree age, species, position within the tree, board thickness, board width, cutting pattern, climate, location and latitude (Vermaas, 1995).

2.8.1 Surface checking

Surface checking is recognized as splitting or cracking on a board’s surface. It is caused by stresses induced by moisture gradients through drying. The cells within timber contain moisture known as ‘free moisture’. The cell walls of timber contain bound molecules of moisture known as ‘bound moisture’. When drying timber free moisture is removed first before bound water and the point at which this transition takes place is called the fiber saturation point. Once the moisture content of the surface dries below fiber saturation point, the timber shrinks due to the reduction of bound water in the wood fiber cell walls. The core of the timber is still above fiber saturation point and consequently will not shrink. This creates a stress gradient within the timber, as the shrinking surface fibers go into tension, and the core, which is restraining the shrinkage, goes into compression (Redman, 2000). This sets up a shrinkage/stress gradient between the inner core of the timber and the outer shell. If the tensile force on the outer shell is large enough the surface of the board will split or crack (Simpson, 1991).

2.8.2 End checking and splitting

Hoadley (2000), in his book said that timber can also develop end checks and splits as it dries. These are attributed to the relative ease with which moisture moves in the longitudinal direction and out of the ends. Wood near the ends of a board has a tendency to dry and shrink in advance of the centre section that may lead to stresses sufficient to cause end splits to develop and to extend along the length of the board (Wengert, 1991). It should be noted this type of end splitting caused by drying differs from end splitting caused by growth stresses. Generally end coating of boards with an impermeable coating is recommended to reduce end drying and minimize end checking and splitting (Shrivastava, 2000).

2.8.3 Case hardening

Case hardening is also caused by the shrinkage/stress gradient set up during drying. As mentioned the surface of a drying board will initially be under tension. In some timbers the drier surface fibres will stiffen or ‘set’ in tension and are not able to move further, a situation known as case hardening (Wengert, 1991). Once the core of the timber dries below fiber saturation point of a case hardened board the stresses in the timber reverse, with the shell now restraining the core as it tries to shrink. The core then goes into tension and the shell into compression. The effect of this can cause the final dried product to be dimensionally unstable and have unacceptable moisture gradients (usually in the form of a wet core) (Wengert, 2006).

2.8.4 Internal checking

Internal checking can result from the stress reversal explained above. If the internal tensile stresses become too large after stress reversal occurs the stretched fibers of the core may be torn apart forming splits inside the material. This is also referred to as honeycombing. Along with case hardening this form of degrade is particularly serious, as it cannot be visually detected immediately after drying (Hoadley, 2000).

2.8.5 Collapse

Collapse is a form of degrade that is usually recognized as an irregular corrugation or distortion of the timber surface. It is more likely to occur in certain species of timber especially in ash-type eucalypts (Wengert, 1991). Collapse occurs during the early stages of drying by the removal of free water from the cell lumens. The most widely accepted theory for the mechanism causing collapse is the hydrostatic liquid tension theory (Shupe *et al.*, 1995). The theory is based on the concept that collapse is due to hydrostatic tensions acting in the water filled lumens of cell fibers. If the tension exceeds the compressive strength of the cell walls, the cell collapses.

2.8.6 Distortion

Distortion of timber through drying is a direct result of either the anisotropy of shrinkage or as the result of moisture content gradients in timber as it dries. Differential shrinkage caused by differences in radial, tangential, and longitudinal shrinkage is a major cause of distortion of timber during drying. Shupe *et al.* (1995) stated that shrinkage differentials are generally the result of biological irregularities in timber. These include irregularities such as knots, distorted grain and tension wood. Distortion is given different names (cup, bow, spring, twist and diamonding) depending on which dimensional plane the distortions occur (Redman, 2000).

2.9 Variability in some hardwood properties

2.9.1 Green (initial) moisture content

Green (initial) moisture content is an important factor that affects the drying time and drying rate. Swett and Milota (1999) suggested that sorting by green moisture content before drying may narrow the distribution of the final moisture contents within a stack of timber. The variability of green moisture content is dependent on the tree species, the portion of the log from where it is taken between sites, between genetic variation and environment (Simpson, 1991). He also proposed that it might also be correlated with the season of the year when the tree is felled.

Most evidence from the literature indicates that the green moisture content values, between sapwood and heartwood within most hardwoods, are not significantly different from each other. The moisture contents of hardwoods such as yellow birch (*Betula* *lutea*) and shining gum (*Eucalyptus nitens*) are 75% (heartwood) and 70% (sapwood), and 115% (heartwood) and 125% (sapwood), respectively (Walker *et al.*, 2003). On another hand, Siau (1995) suggested that there was a possibility that the variability in green moisture content may be correlated with the variability in timber density.

2.9.2 Basic density

It has been suggested that basic density, which is the oven-dried weight (kg) divided by the volume of green wood (m^3), may be correlated with the variations of green moisture content and/or modulus of elasticity (MOE) (Siau, 1995; Alexiou, 1993). However, Cave and Walker (1994) found that basic density is not enough to explain the variation in the MOE. Basic density of hardwoods varies radially (Cave and Walker, 1994). Olson (2003) studied the wood properties of New Zealand silver beech (*Nothufagus menziesii*) and found that the density of the heartwood was slightly higher than that of the sapwood. The two yellow-poplar trees examined by Shupe *et al*. (1995), showed a general increase of basic density from pith to bark. More specifically, Andrews and Muneri (2002) reported that the basic density at the 'bark' was estimated to be 1.4 times the density at the pith, for black butt timber.

In addition, Bao *et al*. (2001) studied the timber properties of both plantation-grown and naturally-grown *Lemon eucalyptus* and *Lankao paulownia*. Their results showed that the juvenile wood of the trees had a significantly lower basic density than the mature part (i.e. the older part and outer section) of the trees. A possible explanation for this finding was that juvenile wood, which is the younger part and is found in the inner section of the tree, has significantly shorter fibers or tracheids with substantially thinner cell walls. In general, Bao *et al*. (2001) found that naturally-grown juvenile and mature wood had higher basic densities than plantation-grown juvenile and mature wood.

2.9.3 Shrinkage

Shrinkage occurs in timber when bound water is lost from the cell walls (i.e. as soon as the moisture content falls below fiber saturation point, X_{fsp}) and results in the diameters of the fibers shrinking (Keey *et al*., 2000). Oliver (1991) found linear shrinkage strains of around 0.04 m m^{-1} for various Australian eucalypts in the radial direction. Bao *et al*. (2001) studied the shrinkage (both in the radial and tangential directions) of three plantation grown hardwood species: *Lemon eucalyptus*, *Lankao paulownia*, and *Sanbei poplar*. With the exemption of lemon eucalyptus, the transverse shrinkage of juvenile timber was higher than the transverse shrinkage of mature timber.

CHAPTER THREE

MATERIALS AND METHODS

3.0 Introduction

This chapter seeks to provide an outline of the parameters used in selecting the samples and methods used to gather data for the study. They are discussed under the following headings: facilities, wood species used, sample and sampling procedures, experimental methods and data analysis. The properties investigated in this study were the moisture content, basic density, tangential, radial and longitudinal shrinkage and drying behavior of the selected species.

3.1 Study area

The study experiments were conducted at the Wood Physics and Drying Laboratory of the Forestry Research Institute of Ghana (Fumesua), the General Chemical and the Woodwork Laboratories of Faculty of Renewable Natural Resources (KNUST).

3.2 Materials

3.2.1 Facilities for laboratory work

The tools and equipment used were: Chain saw (Dolmar CT), Circular saw (Steton SCE 400), Band saw (Steton SN 600), Crosscut saw (Delta HP 5), Combined surfacer and thicknesser (Steton C. 400R x 2), Laboratory oven (Genlab experimental oven), Digital veneer caliper (0-150 mm, 0.01 mm), Micrometer screw gauge (Mauser micrometer screw gauge, 0-25 mm), Electronic balance (Sartorious, 0-620 g, 0.001 g), Deep freezer (Polar Queen HF 6396), Tape measure and a Nokia digital camera.

The chainsaw, circular saw, band saw, crosscut saw, and the thicknesser were used in preparing the samples. The laboratory oven was used in drying the samples. The veneer caliper, tape measure and micrometer screw gauge were used in measuring the dimensions of the samples. The electronic balance was used in weighing the samples. The digital camera was used for taking photographs. The standards used were BS 373 (1957) was used for Density, Moisture content, and Shrinkage whiles the methods of Terezawa (1965) and the US FPL of 1991 were used for the drying schedule test.

3.2.2 Species used and their origin

Three matured logs each of *Cola nitida* and *Funtumia elastica* species were procured from Siana in the Asunafo South district of the Brong Ahafo region within the southwestern part of Ghana to provide wood for evaluation of the physical properties and determination of drying schedule of the species. The logs were obtained from a cocoa farm in the same locality within the open forest of the area. Figure 3.1 and 3.2 shows the schematic representation of the dimensions of the trees and cutting heights of the six trees. The species were selected because of their availability in the forest, their commercial bye products of cola nuts and natural rubber respectively, whiles their timber resource are left unutilized.

3.2.3 Conversion and sampling

The logs were purposefully selected based on their diameters at the base (breast height) being greater than 40 cm and the overall straightness of the trunk. The clear boles were cut at heights of 50 cm and 70 cm from the ground respectively for the *Cola nitida* and *Funtumia elastica* trees. Although the standard breast height for cutting timber is 1.3 meters, these two species were cut at lower levels because of the unbuttressed nature of their bases so as not to waste the wood. The clear boles from each species had lengths of 476 cm, 414 cm, and 386 cm respectively for *Cola nitida* and 1,126 cm, 1,034 cm, and 974 cm for *Funtumia elastica* trees.

From each log, a section (billet) of 50 cm long was removed from the butt, the middle and the top portions of the clear bole as shown in Figures 3.1 and 3.2. The remaining portions of the trees were discarded from the study. The sections were further sawn through and through to get flat sawn boards (planks) with the Dolmar chain saw. One 5-cm thick flat sawn board (Labeled '2') for density, shrinkage and moisture content tests was taken from the middle, whiles two 5-cm thick flat grain boards (Labeled '1') for kiln schedule determination tests were sawn 10 cm away from left and right of the bark of the sections as illustrated in Figures 3.3(b). The above activities were performed at the harvesting site. The boards (planks) from the three axial stem sections were labeled, covered with polythene sheets, wrapped in sacks and transported to the FRNR Woodwork Laboratory the same day. The boards chosen from the sections were sawn, planed, trimmed and cut-off to the specific sample sizes at the FRNR Wood Laboratory, after which they were wrapped in polythene bag, marked and kept in a deep freezer to await the various tests.

The methodology used for sampling is represented schematically in Figures 3.1, 3.2 and 3.3.

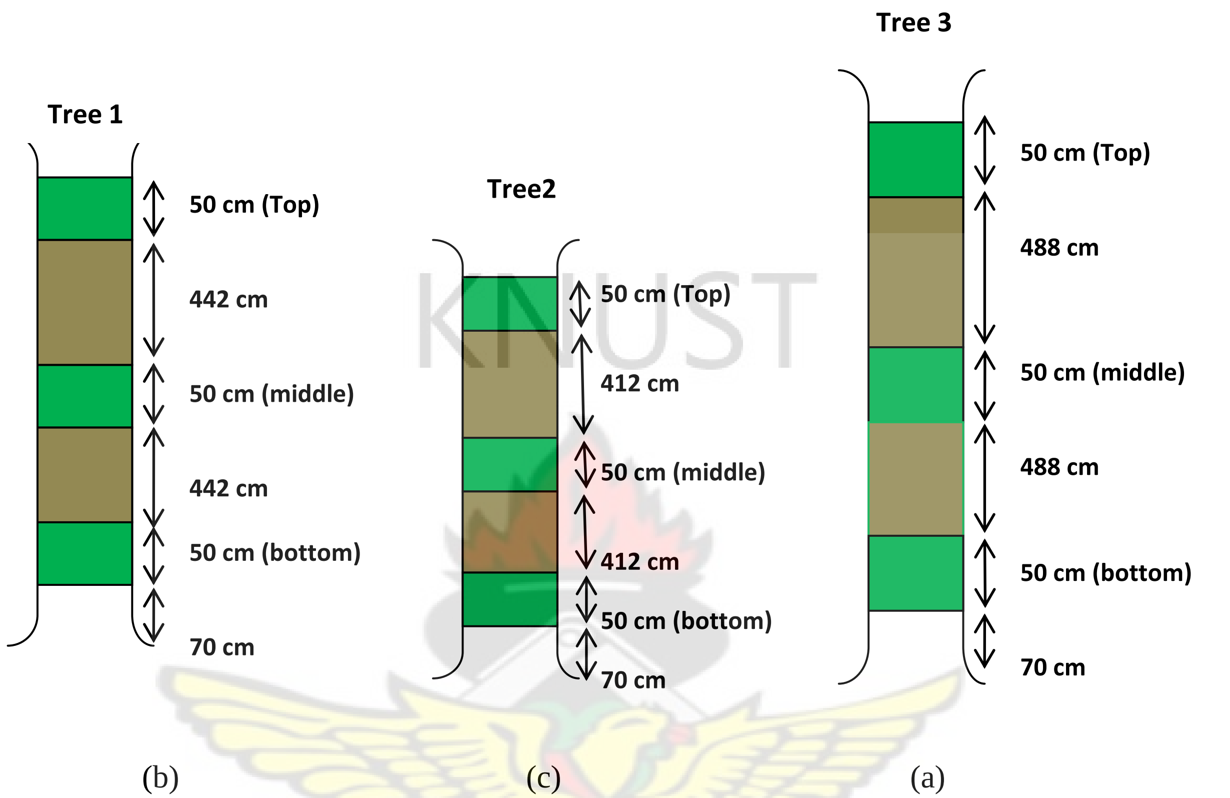
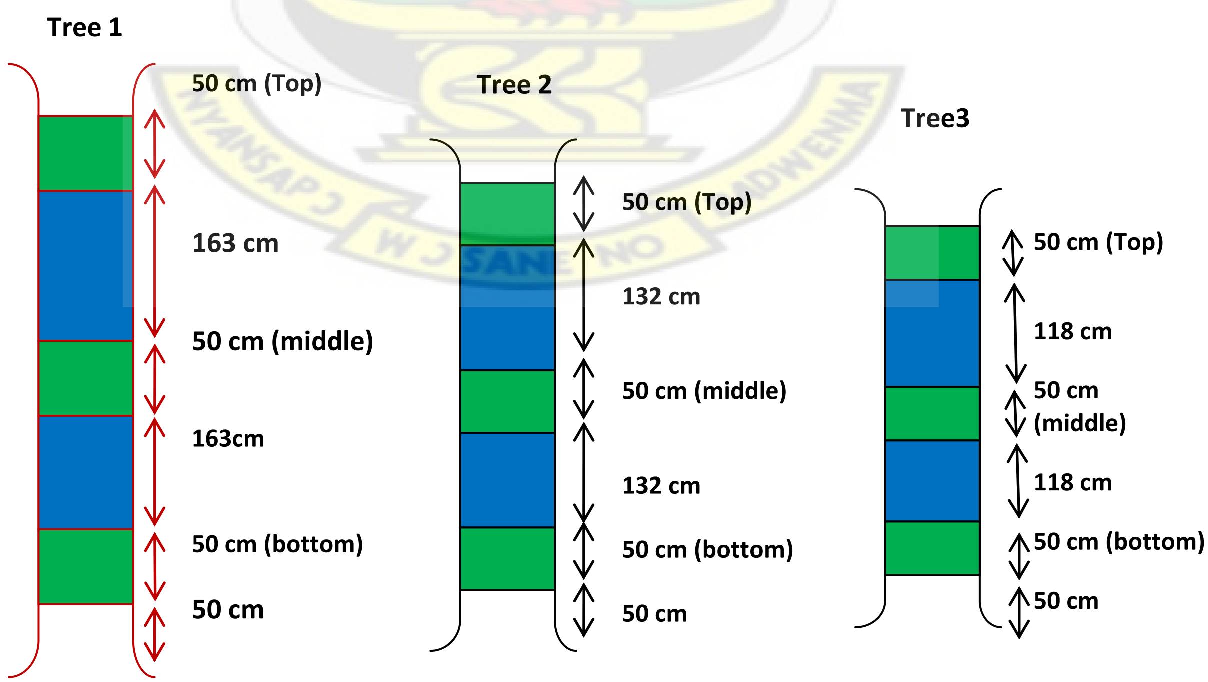
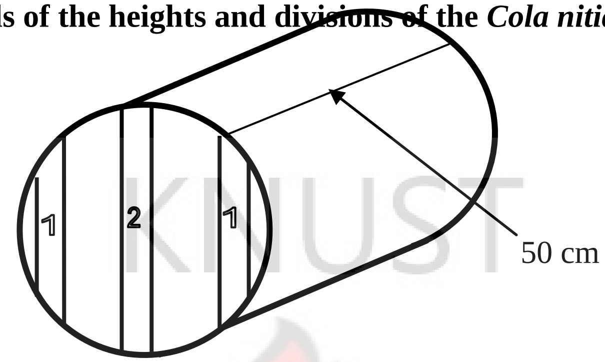


Figure 3.1 Details of the heights and divisions of the *Funtumia elastica* trees studied



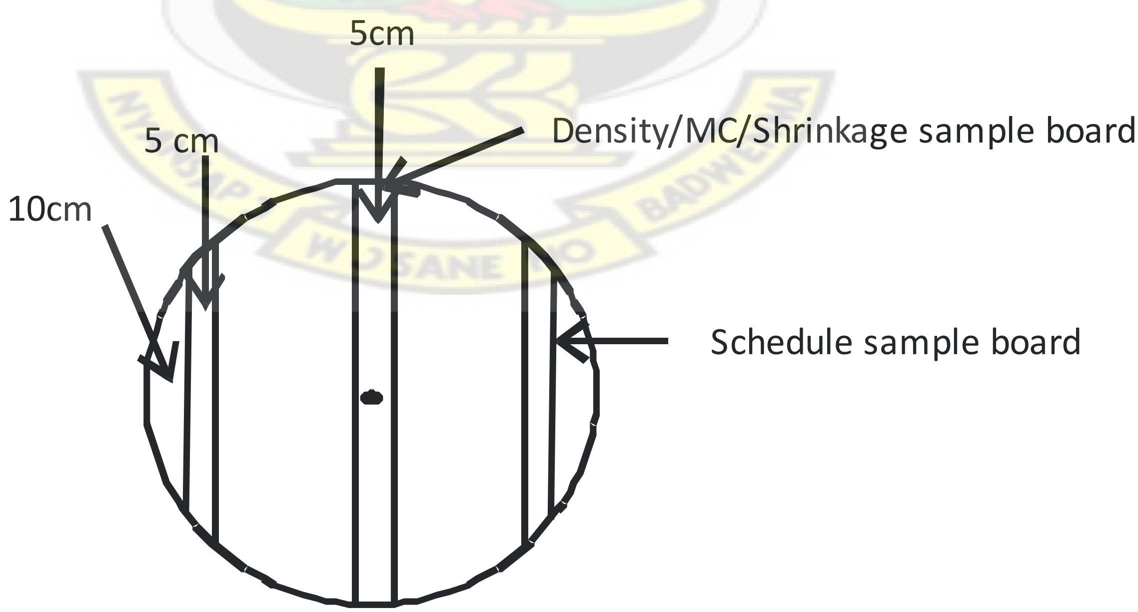
(a) (b) (c)

Figure 3.2 Details of the heights and divisions of the *Cola nitida* trees studied



Through-and-through sawing of 50 cm section

Figure 3.3a Conversion methods used (3 dimension)



Through-and-through sawing of 50 cm section

Figure 3.3b Conversion methods used (2-dimension)

3.3 Methods

3.3.1 Moisture content

The 5-cm flat-grain board (plank) of length 50 cm from the centre of the 50 cm section (billet) was sawn with the circular saw into 2.5 cm square section strips. One 2.5 cm x 2.5 cm x 50 cm strip was extracted from the sapwood and heartwood of each section for the determination of the green moisture content. The strips were planed, trimmed and cut off to 2 cm x 2 cm x 2 cm cubes. Twenty-five sapwood and 25 heartwood cubes were selected from each section. The green mass (W_i) of the specimen cubes was determined and over-dried at 103 ± 2^oC until constant mass (W_{od}) was obtained. Moisture content (MC) of the specimen cubes were then calculated according to the formula:

Moisture content = $[(W_i-W_{od}) / W_{od}] \times 100\%$ ………………………..(1)

3.3.2 Basic density

The 5-cm flat-grain board (plank) of length 50-cm from the centre of the 50-cm section (billet) was sawn into two and from which 2.5 cm square section strips were produced to give their radial and tangential faces. The samples were extracted from both the sapwood and heartwood regions of the 50-cm section. The strips were planed, trimmed and crosscut to specific sizes of 2 cm x 2 cm x 2 cm in thickness, width and length respectively. From each section (billet) 25 sapwood and 25 heartwood cubes were selected, making it 75 sapwood and 75 heartwood cubes from each of the three logs for each wood species. To determine the volumes of the specimens, each set of cubes was soaked in water overnight or swollen by means of vacuum impregnation with water. The swollen volume was determined by the hydrostatic or immersion method as follows: The weight of a container and the water it contained were determined. The wood specimens were then immersed, and the weights of container plus water plus specimens were determined. From the law of floatation, the increase in weight or the weight of water displaced by the specimen in grams is numerically equal to the volume of water displaced in cm^3. The samples were then oven-dried at 103 ± 2°C to constant weight and their oven dry masses determined. Basic densities for the samples were calculated using the formula.

Basic density, (kg/m^3) = (oven-dry in mass kg) / (mass of water displaced by swollen specimen in m^3). ……………………………… (2)

3.3.3 Shrinkage

Three 2.5 cm square strips of length 50 cm were further extracted from the 5 cm board sawn from the middle portion of each section of the three axial locations (B.M.T) for all trees.

Twenty clear samples each of sapwood and heartwood were planed, trimmed and cut-off to a size of 2 cm x 2 cm x 10 cm from each axial location for each log. One hundred and eighty each of sapwood and heartwood square samples for each wood species were dried at room temperature in the General Chemical Laboratory (FRNR) over 21 days, conditioned to 12% moisture content in constant humidity atmosphere. They were oven dried at 40°C, 60°C and 105°C, respectively. The samples were weighed periodically and their dimensional changes in length, width and thickness were monitored through measurements using a micrometer screw gauge in the radial and tangential directions and digital veneer calipers in the longitudinal direction. Shrinkage in drying at the various moisture contents and from the green to 12% moisture content and oven-dried state were calculated for the tangential, radial and longitudinal directions. It was expressed as a percentage using the formula:

Shrinkage = [(Change in dimension) / (Green dimension)] x 100% ………… (3)

3.3.4 Kiln schedule determination and susceptibility to drying defects

The flat-sawn boards of length 50 cm from both left and right sides of each axial section (billet) of the species were chosen for this test because those parts had more moisture (sapwood). The method used in this experiment was the quick drying test at 100℃ developed by Terazawa (1965) as described by Ofori and Brentuo (2010b) and Ofori and Appiah (1998).

All the chosen boards which were in green condition were planed, trimmed and crosscut to specific sizes of 2 cm x 10 cm x 20 cm in thickness, width and length respectively. From every axial section (B.M.T), 12 defect-free specimens were selected for the study totaling 36 specimens for each tree. On one face of each sample, the widest growth ring and the widest rays were marked off. Both face edges of each sample were marked for end checking observation. The test was run in a set of six samples. The initial weight, length, width and thickness of the test specimens were measured and placed edge-wise in an oven at 103 ± 2^{o}C until oven-dry condition was reached. During the first eight hours, the test specimens were weighed and critically observed for drying defects, ie, end and surface-check occurrences every hour.

Afterwards, two observations and measurements were made on the 24th and 30th hours on the second day and on the 48th hour on the third day. During the drying and monitoring processes, checks occurred, movements of maximum check and check closing occurred were observed and their corresponding moisture contents noted. A scale of 1 to 8 was used to evaluate initial checks and deformation, while another from 1 to 6 was used to evaluate honeycombing. The condition of maximum checking was compared with the checking criteria set by Terazawa (1965) and the specimens were then awarded a corresponding checking classification.

When the test specimens reached oven-dry condition, they were taken out from the oven and their weight, width and thickness directly measured. Afterwards, the test specimens were crosscut in the middle part to measure their degree of deformation. The specimens were then awarded a deformation classification according to Terazawa's method.

The newly exposed faces were examined to determine whether honeycomb had occurred in them or not, and the number of honeycombs recorded. The samples were then individually awarded honeycomb classification according to the Terazawa method and their mean value determined. The maximum and minimum thicknesses of each specimen along its freshly sawn face were measured with a micrometer screw gauge. The difference between the two measurements on each sample was recorded as the cross-sectional spool-like deformation and the mean value determined. From each section, two rounds of drying tests were conducted. Initial and final temperatures as well as the wet bulb depression for the drying process of each species were set based on the highest scale of defects.

3.4 Statistical analysis

Estimations of the tested physical and drying properties of the species (i.e. basic density, green moisture content, and shrinkage) were conducted for each tree within each species. The variation in the tested physical and drying properties of the species were conducted for each tree within each species at the three axial locations (B.M.T) and the overall variations between the three axial locations for all trees within each species. The main statistical tools used were descriptive statistics and ANOVA to determine any significant variation in properties (all variations were tested at 95% p = 0.05, CL). Computation of the drying schedules were conducted using the Terazawa tables and charts for classifying checks, spool-like deformation, degree of honeycomb, and others, after which the schedules were arranged based on the general wet-bulb depression, and moisture content classes for hardwoods developed by U.S.F.P.L .and Terazawa methods.

CHAPTER FOUR

RESULTS

4.0 Introduction

This chapter outlines results of the study from the data gathered from the experiments during the research. The results of the green moisture content, basic density, shrinkage and drying tests for the two species are shown according to the sequence of the experiments. Data gathered were recorded in tables and analyzed.

4.1 Results of moisture content test

Tables 4.1a and 4.1b are summaries of the basic statistics for the green moisture content of the three *Cola nitida* (Bese) and *Funtumia elastica* (Funtum) trees respectively. The green moisture content for the *Cola nitida* ranged from 44.32 to 115.22%. The overall average was 66.61% with SD of 9.39. The analysis of variance indicates that differences between the averages of the green moisture contents of the three *Cola nitida* trees were not significant as can be found in Appendix table C4.

Table: 4.1a Summary of descriptive statistics of the green moisture content of *Cola nitida* (Bese) trees studied

Statistic	Tree 1	Tree 2	Tree 3	All Trees
Mean MC	70.6	63.23	66.01	66.61
SD	4.35	5.78	13.6	9.39
Minimum	60.04	53.33	44.32	44.32
Maximum	92.9	75	115.22	115.22
Count	150	150	150	450
95% C.L	0.7	0.93	2.2	0.87

Table: 4.1b Summary of descriptive statistics of the green moisture content of *Funtumia elastica* (Funtum) trees studied

Statistic	Tree 1	Tree 2	Tree 3	All Trees
Mean MC	80.22	79.7	78.3	79.4
SD	7.87	7.49	8.23	7.89
Minimum	62.5	64.1	60.5	60.5
Maximum	94.44	94.34	94.44	94.44
Count	150	150	150	450
95% C.L	1.27	1.21	1.33	0.73

Similarly, the green moisture content for *Funtumia elastica* (Funtum) ranged from 60.5 to 94.44% with an overall average of 79.41% and a standard deviation of 7.89. Table 4.2 is a summary of the descriptive statistics of green moisture content of *Cola nitida* and *Funtumia elastica.* A summary of the analysis of variance (ANOVA) of the green moisture content of individual trees of *Cola nitida* and *Funtumia elastica* species is represented in Table 4.3. The difference between the average green moisture contents of the trees of each species were not significant for *Funtumia elastica* (Funtum) F (2,447) = 2.356 (*p*-value > 0.001) and highly significant in *Cola nitida* (Bese) F (2,447) = 26.29 (*p* – value > 0.001). The within tree average green moisture content ranged from 66.01% to 70.6% for *Cola nitida* (Bese) and 78.3% to 80.22% for *Funtumia elastica* (Funtum).

Table: 4.2 Summary of descriptive statistics of the green moisture content of *Cola nitida* and *Funtumia elastica*

Green moisture content statistics	*Cola nitida* (Bese)	*Funtumia elastica* (Funtum)
Mean MC (%)	66.61	79.41
SD	9.39	7.89
Minimum,%	44.32	60.5
Maximum, %	115.22	94.44
Count	450	450
95% Confidence Level	0.87	0.73

Table: 4.3 Summary of ANOVA of mean green moisture content of individual trees of *Cola nitida* and *Funtumia elastica*

Wood species	Mean ± S.D	ANOVA between individual trees	
		Degrees of freedom	F
Cola nitida (Bese)	66.61 ± 9.39	F (2,447)	26.29
Funtumia elastica (Funtum)	79.41 ± 7.89	F (2,447)	2.356

Table 4.3 is ANOVA for within tree moisture content tests for *Cola nitida* and *Funtumia elastica* trees which have F values of 26.29 and 2.36 respectively, an indication of a significant source of variation of moisture content in these two species.

Table 4.4 shows results of statistics for moisture contents of *Cola nitida* trees (Billet and Plank divisions).

Table: 4.4 Results of descriptive statistics for moisture contents of *Cola nitida* and *Funtumia elastica* trees (Billet and Plank divisions).

Billet/Section	Statistic %	Sapwood			Heartwood		
		Tree 1	Tree 2	Tree 3	Tree 1	Tree 2	Tree 3
Cola nitida							
	Mean	69.92	65.54	68.69	71.65	57.5	63.04
	S.D	3.54	3.15	12.39	5.59	2.25	15.76
	Minimum	63.74	59.65	53.85	65.28	53.33	45.71
Buttress	Maximum	77.3	72.22	93.9	92.9	61.11	115.22
	Count	25	25	25	25	25	25
	Conf. Level	1.46	1.3	5.12	2.31	0.93	6.51
	Mean	71.96	66.97	66.77	70.06	60.08	66.61
	S.D	3.93	3.38	14.09	4.2	2.79	13.17
	Minimum	64.31	60.34	49.09	63.86	55.93	50
Middle	Maximum	79.47	72.73	97.4	80.19	67.86	100.1
	Count	25	25	25	25	25	25
	Conf. Level	1.62	1.4	5.81	1.73	1.15	5.44
	Mean	68.55	71.47	69.77	71.49	57.81	61.2
	S.D	4.2	1.67	12.05	3.72	2.02	13.21
Top	Minimum	60.04	66.67	53.19	63.78	54.1	44.32
	Maximum	77.55	75	88.64	78.5	62.71	94.02
	Count	25	25	25	25	25	25
	Conf. Level	1.73	0.69	4.97	1.54	0.84	5.45
Funtumia elastica	Mean	67.97	68.68	65.97	81.41	80.98	79.41
	S.D	3.21	2.9	3.21	5.68	5.75	5.68
	Minimum	62.5	64.1	60.5	75.61	70.66	73.61
Buttress	Maximum	73.68	73.68	71.68	94.29	94.34	92.3
	Count	25	25	25	25	25	25
	Conf. Level	1.33	1.2	1.33	2.35	2.37	2.35
	Mean	80.59	77.51	76.19	85.88	83.8	84.03
	S.D	6.36	6.45	7.15	3.8	4.92	3.83
	Minimum	65.79	65.79	62	78.38	73.68	76.4
Middle	Maximum	92.12	87.18	85.2	92.11	92.11	92

	Count	25	25	25	25	25	25
	Conf. Level	2.62	2.66	2.95	1.57	2.03	1.58
Top	Mean	80.41	84.34	79.83	85.04	82.9	84.44
	S.D	4.75	6.41	4.75	7.01	4.01	7.01
	Minimum	72.5	72.27	72	70.27	78.5	70.27
	Maximum	91.43	92.44	89.43	94.44	91.43	94.44
	Count	25	25	25	25	25	25
	Conf. Level	1.96	2.65	1.96	2.89	1.66	2.9

Results of the moisture contents of the 3 billets and plank divisions for *Cola nitida* and *Funtumia elastica* trees were recorded in Table 4.4. They indicated an inconsistent trend of higher mean from the middle and decrease to the top and butt end sections for *Cola nitida* trees. The *Funtumia elastica* trees had a consistent trend of lower mean from the butt end and increase to the top as can be seen in Table 4.15.

4.2 Results of basic density test

A summary of the basic statistics for the basic density of the three trees each of *Cola nitida* (Bese) and *Funtumia elastica* (Funtum) are shown in Tables 4.5(a) and 4.5(b) respectively. Basic density for *Cola nitida* ranged from 424 to 843.75 kg/m^3 and 148.01 to 571.4 kg/m^3 for *Funtumia elastica*. The overall average for *Cola nitida* was 623.75kg/m^3 with SD of 81.7. The *Funtumia elastica* trees had an overall average of 499.57 kg/m^3 with SD of 25.9 (Table 4.6).

Table: 4.5a Summary of descriptive statistics of the basic density of *Cola nitida* trees studied

Statistic	Tree 1	Tree 2	Tree 3	All Trees
Mean, (kg/m^3)	577.82	653.75	639.67	623.75
SD	37.8	47.88	114.48	81.7
Minimum, (kg/m^3)	489.1	561.22	424	424
Maximum, (kg/m^3)	666.6	725	843.75	843.75
Count	150	150	150	450
95% C.L	6.1	7.7	18.5	7.6

Table: 4.5b Summary of descriptive statistics of the basic density of *Funtumia elastica* trees studied

Statistic	Tree 1	Tree 2	Tree 3	All Trees
Mean, (kg/m^3)	499.54	497.9	501.3	499.57
SD	20.1	34.54	20.5	25.9
Minimum, (kg/m^3)	460.5	148.01	460.5	148.01
Maximum, (kg/m^3)	569.4	559.4	571.4	571.4
Count	150	150	150	450
95% C.L	3.2	5.8	3.3	2.4

The within tree average basic density range was 577.82 to 653.75kg/m^3 for *Cola nitida* (Bese) and 497.9 kg/m^3 to 501.3 kg/m^3 for the *Funtumia elastica* (Funtum) trees as shown in Tables 4.5a and 4.5b respectively. The analysis of variance revealed that differences between average basic densities of the 3 trees were highly significant and highly insignificant for *Cola nitida* and *Funtumia elastica* respectively.

Table 4.6 has being presented to show the basic densities of the densities of the two species.

Table: 4.6 Summary of descriptive statistics of the basic density of *Cola nitida* and *Funtumia elastica*

Basic density statistics	*Cola nitida* (Bese)	*Funtumia elastica* (Funtum)
Mean , (kg/m^3)	623.75	499.57
SD	81.7	25.9
Minimum, (kg/m^3)	424	148.01
Maximum, (kg/m^3)	843.75	571.4
Count	450	450
95% Confidence Level	7.57	2.4

A summary of the analysis of variance (ANOVA) of the basic density of individual trees of the two species is shown in Table 4.7. The differences between the average basic density of the trees of each wood species were highly significant F (2,447) = 43.62 (*p* – value > 0.001 for *Cola nitida* (Bese) and significant for *Funtumia elastica* (Funtum) F (2,447) = 0.67 (*p* – value > 0.001). The basic density values of the species could be classified as ‘Medium Heavy (575-725 kg/m^3) for *Cola nitida* (Bese) and ‘Medium’

(425-575 kg/m^3) for *Funtumia elastica* (Funtum) according to ATIBT, 1990 and TEDB, 1994.

Table: 4.7 Summary of ANOVA of basic density of *Cola nitida* and *Funtumia elastica*

Wood species	Mean ± S.D	ANOVA between individual trees Degrees of freedom	F
Cola nitida (Bese)	623.75 ± 81.7	F(2, 447)	43.62
Funtumia elastica (Funtum)	449.57 ± 25.9	F(2, 447)	0.67

Results of the three billets and plank divisions for *Cola nitida* and *Funtumia elastica* trees in Table 4.8 showed an inconsistent trend in basic density for *Cola nitida* trees. The *Funtumia elastica* trees had higher density means at the buttress and a decrease to the top and middle sections.

Table: 4.8 Results of descriptive statistics for basic density of *Cola nitida* trees and *Funtumia elastica* trees (Billet and Plank divisions)

Billet/Section	Statistic kg/m^3	Sapwood			Heartwood		
		Tree 1	Tree 2	Tree 3	Tree 1	Tree 2	Tree 3
Cola nitida							
	Mean	620.82	570.32	612.25	545.7	664.61	641.17
	S.D	26.07	6.38	114.17	16.94	48.64	103.82
	Minimum	556.44	561.22	458.33	489.12	577.32	443.88
Buttress	Maximum	652.97	583.33	777.9	576.91	722.89	833.33
	Count	25	25	25	25	25	25
	Conf. Level	10.76	2.63	47.13	6.99	20.08	42.86
	Mean	581.16	657.63	652.99	539.05	693.78	611.92
	S.D	29.44	10.67	111.09	12.78	12.95	119.52
	Minimum	533.56	642.86	447.65	504.73	658.82	424
Middle	Maximum	636.68	682.35	788.24	564.31	725	823.53
	Count	25	25	25	25	25	25
	Conf. Level	12.15	4.4	45.85	5.28	5.34	49.34
	Mean	565.16	637.54	621.55	615.02	698.6	698.15
	S.D	17.82	6.69	123.51	19.51	8.52	100
	Minimum	537.27	619.05	444.95	579.77	682.35	501.26
Top	Maximum	605.91	647.06	843.75	666.63	717.65	835.29
	Count	25	25	25	25	25	25
	Conf. Level	7.36	2.76	50.98	8.05	3.52	41.28
Funtumia elastica	Mean	527.64	525.04	531.75	495.77	493.52	497.77
	S.D	20.56	20.87	19.96	14.65	15.28	14.65
	Minimum	493.33	483.41	495.25	466.67	466.67	468.67
Buttress	Maximum	569.44	559.44	571.44	519.48	519.48	521.48
	Count	25	25	25	25	25	25
	Conf. Level	8.49	8.61	8.24	6.05	6.31	6.05
	Mean	495.68	497.24	497.62	495.91	486.31	496
	S.D	15.61	12.42	14.83	11.84	71.57	11.3
	Minimum	462.5	468.35	469	468.35	148.01	469.35
Middle	Maximum	520.55	519.48	522.55	519.48	520.55	513.48
	Count	25	25	25	25	25	25
	Conf. Level	6.45	5.13	6.12	4.89	29.54	4.67
	Mean	498.83	485.4	499.85	483.42	499.64	484.95
	S.D	14.55	12.12	14.24	11.78	14.81	11.84
	Minimum	460.53	461.54	460.53	460.53	460.53	460.5

Top	Maximum	526.32	512	526.32	500	526.32	500
	Count	25	25	25	25	25	25
	Conf. Level	6.01	5	5.88	4.86	6.11	4.89

4.3 Results of Shrinkage measurements

Shrinkage from green to 12% moisture content and the oven – dry state was expressed as a percentage using the formula:

Shrinkage = (Change in dimension/green dimension) x 100%............................... (3)

Mean partial shrinkage (Tangential, Radial and Longitudinal) from green to 12% MC for the *Cola nitida* tree was 1.05, 0.49 and 0.27%, respectively. The mean total shrinkage was 7.25, 3.02 and 0.29%, respectively from green to oven dry. A summary of the shrinkage measurements for the *Cola nitida* trees is shown in Table 4.9.

Table: 4.9 Summary of some descriptive statistics (Mean) of shrinkage of *Cola nitida*

Shrinkage parameter (%)	Tree 1	Tree 2	Tree 3	All Tree
Total Tangential, T,	7.25	7.27	7.23	7.25
Total Radial, R,	3	3.04	3.01	3.02
Total Longitudinal, L	0.28	0.31	0.29	0.29
Tangential at 12% MC, (T_{12})	0.73	1.63	0.79	1.05
Radial at 12% MC, (R_{12})	0.38	0.69	0.39	0.49
Longitudinal at 12% MC, (L_{12})	0.25	0.27	0.29	0.27
T / R Ratio	2.61	2.79	2.56	2.65
T_{12} / R_{12} Ratio	2.59	2.28	2.4	2.43

Table 4.10 summarizes the shrinkage measurements for all the *Funtumia elastica* (Funtum) trees. Mean total shrinkage (tangential, radial and longitudinal) from green to oven dry was 6.78, 3.2 and 0.4% whiles shrinkage from green to 12% MC was 4.88, 2.79 and 0.3, respectively.

Table: 4.10 Summary of some descriptive statistics (Mean) of shrinkage of *Funtumia elastica*

Shrinkage parameter (%)	Tree 1	Tree 2	Tree 3	All Tree
Total Tangential, T,	5.57	5.9	8.85	6.78
Total Radial, R,	3.2	3.2	3.2	3.2
Total Longitudinal, L	0.35	0.5	0.4	0.4
Tangential at 12% MC, (T_{12})	4.9	4.86	4.9	4.88
Radial at 12% MC, (R_{12})	2.7	2.8	2.9	2.79
Longitudinal at 12% MC, (L_{12})	0.3	0.3	0.37	0.3
T / R Ratio (Total)	1.8	1.8	1.8	1.8
T_{12} / R_{12} Ratio	1.8	1.8	1.78	1.79

Below is a summary of the shrinkage measurements for *Cola nitida* and *Funtumia elastica*. *Cola nitida* had a higher tangential shrinkage of 7.25% as against 6.78% for *Funtumia elastica.* The total anisotropic factors were 2.65% and 1.8% respectively. Total longitudinal shrinkage was very high in *Funtumia elastica (*0.4) and normal in *Cola nitida* (0.29).

Table: 4.11 Summary of some derived descriptive statistics of shrinkage of *Cola nitida* (Bese) and *Funtumia elastica* (Funtum). (Mean ± SD)

Shrinkage parameters (%)	*Cola nitida* (Bese)	*Funtumia elastica* (Funtum)
Total Tangential, T	7.25 ± 1.33	6.78 ± 20.2
Total Radial, R	3.02 ± 0.9	3.2 ± 0.65

Total Longitudinal, L	0.29 ± 0.29	0.4 ± 1.04
Tangential at 12% MC, (T_{12})	1.05 ± 4.34	4.88 ± 0.76
Radial at 12% MC, (R_{12})	0.49 ± 1.84	2.79 ± 0.52
Longitudinal at 12% MC, (L_{12})	0.27 ± 0.32	0.3 ± 0.2
T / R Ratio	2.65 ± 1.36	1.8 ± 0.39
T_{12}/R_{12} Ratio	2.43 ± 2.67	1.79 ± 0.41

4.4 Results of Susceptibility to drying defects

The result of the 100°C – test is shown in Tables 4.12a and 4.12b. Visual observations made with respect to seasoning defects included checking and splitting, collapse and twisting. Table 4.13 shows the results of the types of defects (checking, honey comb and cross-sectional spool-like deformation) and classes of drying defects obtained for the two species.

Table: 4.12a Types and classes of drying defects and their critical drying conditions of the *Cola nitida* trees studied

Part of tree	Types of defects & initial MC%	Defects Types classes				Critical drying condition corresponding to adopted defect type class		
		Mean for tree No.			Class adopted	Initial Temp. °C	Initial WBD °C	Final Temp. °C
		1	2	3				
Breast height	Initial checks	2	3	3	3	60	4.3	85
	Honey comb	1	1	1	1	70	6.5	95
	Spool-like Deformation	1	2	2	2	65	5.5	90
	Initial MC%	67	57	63	62			
Middle	Initial checks	2	3	3	3	60	4.3	85
	Honey comb	1	1	1	1	70	6.5	95
	Spool-like Deformation	1	1	1	1	70	6.5	95
	Initial MC%	68	59	62	63			
Top	Initial checks	3	3	3	3	60	4.3	85
	Honey comb	1	1	1	1	70	6.5	95
	Spool-like Deformation	1	1	1	1	70	6.5	95
	Initial MC%	72	63	67	67			

Table: 4.12b Types and classes of drying defects and their critical drying conditions of the *Funtumia elastica* trees studied

Part of tree	Types of defects & initial MC%	Defects Types classes				Critical drying condition corresponding to adopted defect type class		
		Mean for tree No. 1	2	3	Class adopted	Initial Temp. (°C)	Initial WBD (°C)	Final Temp. (°C)
Breast height	Initial checks	3	3	3	3	60	4.3	85
	Honey comb	1	1	1	1	70	6.5	95
	Spool-like Deformation	1	1	1	1	70	6.5	95
	Initial MC%	87	83	89	86			
Middle	Initial checks	3	3	3	3	60	4.3	85
	Honey comb	1	1	1	1	70	6.5	95
	Spool-like Deformation	1	1	1	1	70	6.5	95
	Initial MC%	82	82	86	83			
Top	Initial checks	3	3	3	3	60	4.3	85
	Honey comb	1	1	1	1	70	6.5	95
	Spool-like Deformation	1	1	1	1	70	6.5	95
	Initial MC%	93	88	88	90			

Table: 4.13 Summary of the types and classes of drying defects and their critical drying conditions for *Cola nitida* and *Funtumia elastica*

Species	Types of defects & initial MC%	Defects Types classes				Critical drying condition corresponding to adopted defect type class		
		Mean for tree No. 1	2	3	Class adopted	Initial Temp. (°C)	Initial WBD (°C)	Final Temp. (°C)
Cola	Initial checks	2	3	3	3	60	4.3	85

nitida	Honey comb	1	1	1	1	70	6.5	95
(Bese)	Spool-like Deformation	1	1	1	1	70	6.5	95
	Initial MC%	69	60	64	64			
Funtumia	Initial checks	3	3	3	3	60	4.3	85
elastica	Honey comb	1	1	1	1	70	6.5	95
(Funtum)	Spool-like Deformation	1	1	1	1	70	6.5	95
	Initial MC%	87	84	88	86			

Checks in the early stage of drying were less severe in both *Cola nitida* (Bese) and *Funtumia elastica* (Funtum) samples (Class 3). Initial checking in the samples is strictly related to initial relative humidity but less related to initial temperature. Moderately higher initial dry bulb temperature of 60^{o}C for both *Cola nitida* and *Funtumia elastic*, and a larger wet bulb depression of 4.3^{o}C for both species are critical to the drying of the species to prevent them from severe splitting in the early stages of drying.

There were no honey combing (Class 1) in both *Cola nitida* and *Funtumia elastica* species. Honey combing is generally related to the initial and final temperatures and the initial relative humidity, but not to the final relative humidity. Since the species did not show honey combing, a high initial dry bulb temperature 70^{o}C and high initial WBD of 6.5^{o}C may be used. There was no spool-like deformation (Class 1) in both *Cola nitida* and *Funtumia elastica* species. Spool-like deformation is related to the initial and final temperatures and less so, to the initial relative humidity, but not to the final relative humidity. A higher initial dry bulb temperature of 70^{o}C and a higher WBD of 6.5^{o}C may be employed for drying both *Cola nitida* and *Funtumia elastica*.

4.5 Results of variability in some physical properties of *Cola nitida* (Bese) and *Funtumia elastica* (Funtum)

Variability is a key in the processing of many biological materials, in this case the drying of *Cola nitida* (Bese) and *Funtumia elastica* (Funtum). Variability was considered within trees for the initial moisture content, basic density and shrinkage.

4.5.1 Results of green (Initial) moisture content tests

Green (initial) moisture content is an important factor that affects the drying time and drying rate. Differences between the three axial sections in terms of the moisture content for Tree 1of *Cola nitida* was not significant, (F_{actual}, 0.711 < $F_{expected,}$ 3.06). For the same Tree, at a 0.05 significance level the heartwood and sapwood difference was highly significant (F_{actual}, 13.6 > $F_{expected,}$ 3.9) in Appendix C 1. The moisture content variation for Tree 2 of *Cola nitida* was significant between the butt, middle and top parts (F_{actual}, 3.89 > $F_{expected,}$ 3.06). The difference between the sapwood and heartwood parts of this Tree was highly significant (F_{actual}, 322.18 > $F_{expected,}$ 3.9). Tree 3 of *Cola nitida* had the moisture content distribution not significant at a 0.05 significance level (F_{actual}, 0.1 < $F_{expected,}$ 3.06).

For *Funtumia elastica* Tree 1, the moisture content variation was highly significant between the butt, middle and top, (F_{actual}, 24.32 > $F_{expected,}$ 3.06). The difference between the sapwood and heartwood moisture content was significantly different $F_{(2,147)}$ = 48.38. *Funtumia elastica* Tree 2 also showed highly significant differences between the three axial sections F (2,147) = 23.09. The variance between the sapwood and heartwood was also highly significant (F_{actual}, 25.45 > $F_{expected,}$ 3.9).

Meanwhile, between the sapwood and heartwood of the same tree, there was a highly significant difference (F_{actual}, 4.78 > $F_{expected,}$ 3.9). *Funtumia elastica* Tree 3 had moisture content between butt, middle and top, highly different (F_{actual}, 23.83 > $F_{expected,}$ 3.08). The moisture content distribution between sapwood and heartwood was highly significant (F_{actual}, 56.7 > $F_{expected,}$ 3.91) within the tree.

Table: 4.14a Descriptive statistics of the green moisture content of the *Cola nitida* trees studied

Statistic		Sapwood			Heartwood	
	Tree 1	Tree 2	Tree 3	Tree 1	Tree 2	Tree 3
Mean	70.14	68	68.4	66.51	58.46	63.61
SD	4.1	3.78	12.76	7.48	2.62	14.1
Minimum	60.04	59.65	49.1	54.1	53.3	44.32
Maximum	79.5	75	97.4	92.9	67.86	115.22
Count	75	75	75	75	75	75
95% C.L	0.94	0.87	2.94	1.72	0.6	3.24

Table: 4.14b Descriptive statistics of the green moisture content of the *Funtumia elastica* trees studied

Statistic		Sapwood			Heartwood	
	Tree 1	Tree 2	Tree 3	Tree 1	Tree 2	Tree 3
Mean	76.3	76.84	73.99	84.1	82.1	82.63
Standard	7.7	8.44	7.88	5.9	5.02	6.03
Minimum	62.5	64.1	60.5	70.27	70.66	70.22

Maximum	92.12	92.44	89.43	94.44	94.34	94.44
Count	75	75	75	75	75	75
95% C.L	1.8	1.9	1.8	1.4	1.2	1.4

Table: 4.15 Summaries of means of MC for all trees for *Cola nitida* and *Funtumia elastica* (Radial and Axial sections)

Species	Axial section	Sapwood	Heartwood	Overall
Cola nitida	Butt end	68.05	64.06	66.06
	Middle	68.57	65.58	67.08
	Top	69.93	63.5	66.72
	Butt end	67.54	80.6	74.07
Funtumia elastica	Middle	78.2	84.57	81.39
	Top	81.53	84.13	82.83

Table: 4.16 Summaries of means of MC for all trees for *Cola nitida* and *Funtumia elastica* (Radial sections)

Species	Sapwood	Heartwood	Overall
Cola nitida	68.85 ± 6.49	64.38 ± 6.97	66.62 ± 6.73
Funtumia elastica	75.76 ± 5.02	83.1 ± 5.3	79.43 ± 5.16

4.5.2 Results of density test

There were highly significant differences between the butt, middle and top sections for *Cola nitida* (Bese) tree one (F_{actual}, 9.63 > $F_{expected,}$ 3.06).

The differences between sapwood and heartwood of this tree was highly significant F (1,148) *p* – value < 0.001 (*p* = 0.00021). *Funtumia elastica* (Funtum) Tree 1, had highly significant differences between the three axial sections (butt, middle and top) (F_{actual}, 17.61 > $F_{expected,}$ 3.06).

The differences between the sapwood and the heartwood of the same tree was significantly different between the two parts (F_{actual}, 26.75 > $F_{expected,}$ 3.91). Tree 2 of the *Cola nitida* (Bese) species had differences between the butt, middle and top parts F (2,147) = 30.5, *p* –value > 0.001 (*p* = 8.49). Between the sapwood and the heartwood were also extremely significant differences. In the third *Cola nitida* tree, the difference between the three sections was highly insignificant (F_{actual}, 1.2 < $F_{expected,}$ 3.06).Similarly, there was no significant difference between the sapwood and the heartwood (F_{actual}, 1.32 < $F_{expected,}$ 3.91).

There were highly significant differences between the butt, middle and top sections for *Funtumia elastica* (Funtum) tree two (F_{actual}, 4.29 > $F_{expected,}$ 3.06). Between sapwood and heartwood of this tree, there was no significant difference (F_{actual}, 2.81< $F_{expected,}$ 3.9). The last *Funtumia elastica* tree had highly significant differences between the different sections F (2,147) = 21.25, *p* – value > 0.001. Differences between sapwood and heartwood were highly significant for Tree 3 of Funtumia *elastic*.

Table: 4.17a Summary of the descriptive statistics of the basic density of the axial sections of the *Cola nitida* trees studied

Statistic		Sapwood			Heartwood	
	Tree 1	Tree 2	Tree 3	Tree 1	Tree 2	Tree 3
Mean, (kg/m^3)	589.05	621.83	628.93	566.59	685.66	650.4
SD	34.05	38.4	116.12	38.28	32.77	112.6
Minimum, (kg/m^3)	533.56	561.2	444.95	489.12	577.32	424
Maximum (kg/m^3)	652.97	681.4	843.75	666.63	725	835.3
Count	75	75	75	75	75	75
95% C.L	7.8	8.8	26.72	8.8	7.5	25.9

Table: 4.17b Summary of the descriptive statistics of the basic density of the axial sections of the *Funtumia elastica* trees studied

Statistic		Sapwood			Heartwood	
	Tree 1	Tree 2	Tree 3	Tree 1	Tree 2	Tree 3
Mean, (kg/m^3)	507.38	502.6	509.7	491.7	493.2	492.9
SD	22.2	22.77	22.6	13.96	42.9	13.8
Minimum, (kg/m^3)	460.5	461.54	460.5	460.5	148.01	460.5
Maximum (kg/m^3)	569.4	559.4	571.4	519.5	526.3	521.5
Count	75	75	75	75	75	75
95% C.L	5.12	5.2	5.2	3.2	9.7	3.2

Table: 4.18 Summaries of means of density for all trees for *Cola nitida* and *Funtumia elastica* (Radial and Axial sections)

Species	Axial section	Sapwood	Heartwood	Overall
Cola nitida	Butt end	601.13	617.16	609.15

	Middle	630.59	614.92	622.76
	Top	608.08	670.59	639.34
	Butt end	528.14	495.69	511.92
Funtumia elastica	Middle	496.85	492.74	494.8
	Top	494.69	489.34	492.02

Table: 4.19 Summaries of means of density for all trees of the species studied (Radial section)

Species	Sapwood	Heartwood	Overall
Cola nitida	613.27 ± 49.54	634.22 ± 49.19	623.75 ± 49.37
Funtumia elastica	506.56 ± 16.13	492.59 ± 19.75	499.58 ± 17.94

4.5.3 Results of shrinkage test

Shrinkage in *Cola nitida* (Bese) increased from the butt to the middle and decreased at the top. There were highly significant differences within the trees. Total tangential shrinkage was higher in the sapwood than the heartwood. Total radial shrinkage was vice versa. *Funtumia elastica* (Funtum) had little higher radial shrinkage in the sapwood than the heartwood. Total tangential shrinkage was also higher in the sapwood than the heartwood. There were highly significant differences within the trees.

Results from shrinkage experiments for *Cola nitida* and *Funtumia elastica* trees (billet and plank divisions) are shown in Tables 4.21a and 4.21b. Table 4.21a showed an inconsistent pattern in increase and decrease of shrinkage from one section to another (ie. from buttress to the top) for the *Cola nitida* trees. The *Funtumia elastica* trees showed (Table 4.21b) the opposite of a consistent trend of increase in shrinkage from the buttress to the top section.

Table: 4.20a Summary of some descriptive statistics of shrinkage of *Cola nitida* (Bese) trees studied

Shrinkage Parameter (%)	Sapwood Tree 1	Tree 2	Tree 3	Heartwood Tree 1	Tree 2	Tree 3
Total Tangential, T	7.85	7.9	7.91	6.65	6.64	6.55
Total Radial, R	2.53	2.55	2.56	3.47	3.51	3.46
Total Long., L	0.31	0.34	0.32	0.25	0.27	0.26
Tangential to 12%MC, (T_{12})	0.71	2.49	0.77	0.75	0.77	0.81
Radial to 12% MC, (R_{12})	0.35	0.94	0.34	0.42	0.44	0.43
Long. To 12% MC, (L_{12})	0.34	0.37	0.38	0.15	0.16	0.19
T / R Ratio	3.08	3.14	3.1	2.13	2.43	2.03
T_{12} / R_{12} Ratio	2.29	2.61	2.66	2.9	1.96	2.11

Table: 4.20b Summary of some descriptive statistics of shrinkage of *Funtumia elastica* (Funtum) trees studied

Shrinkage	Sapwood	Heartwood

Parameter (%)	Tree 1	Tree 2	Tree 3	Tree 1	Tree 2	Tree 3
Total Tangential, T	5.5	5.55	11.98	5.68	6.34	5.7
Total Radial, R	3.3	3.31	3.4	3.1	3.1	3.1
Total Long., L	0.3	0.68	0.39	0.39	0.38	0.4
Tangential to 12% MC, (T_{12})	4.8	4.77	4.8	4.98	5	5
Radial to 12% MC, (R_{12})	2.8	2.88	3.05	2.63	2.7	2.66
Long. To 12% MC, (L_{12})	0.28	0.3	0.36	0.3	0.32	0.39
T / R Ratio	1.7	1.74	1.7	1.88	1.9	1.9
T_{12} / R_{12} Ratio	1.7	1.7	1.65	1.8	1.9	1.9

Table: 4.21a Results of shrinkage statistics for *Cola nitida* trees (Billet and Plank divisions)

Tree No	Axial section	Radial section	Total shrinkage at oven dry				Shrinkage at 12% MC			
			T	R	L	T/R	T_{12}	R_{12}	L_{12}	T_{12}/R_{12}
	Butt end	Sapwood	8.6	2.8	0.64	3.07	1.12	0.56	0.61	2.2
		Heartwood	5.9	3.34	0.2	1.77	0.21	0.15	0.03	1.4
1	Middle	Sapwood	8	2.35	0.08	3.4	0.5	0.24	0.15	2.08
		Heartwood	7.24	4.02	0.22	1.8	1.33	0.61	0.09	2.18
	Top	Sapwood	6.95	2.43	0.25	2.86	0.5	0.26	0.26	2.38
		Heartwood	6.8	3.06	0.34	2.36	0.72	0.49	0.33	1.78
	Butt end	Sapwood	8.76	2.86	0.69	3.09	5.06	0.56	0.66	2.63
		Heartwood	5.9	3.4	0.2	1.92	0.15	0.16	0.03	1.54
2	Middle	Sapwood	8	2.4	0.07	3.42	1.92	0.25	0.19	2.96
		Heartwood	7.24	4.08	0.21	1.96	1.49	0.66	0.09	2.58
	Top	Sapwood	6.96	2.43	0.28	2.93	0.49	2.01	0.27	2.23
		Heartwood	6.79	3.05	0.4	3.41	0.67	0.5	0.37	1.77
	Butt end	Sapwood	8.81	2.79	0.59	3.21	1.3	0.52	0.64	3.21
		Heartwood	5.94	3.35	0.25	1.9	0.29	0.16	0.03	2.09

3	Middle	Sapwood	7.99	2.45	0.08	3.25	0.52	0.24	0.17	2.67
		Heartwood	7.24	4.03	0.21	1.94	1.41	0.66	0.19	2.42
	Top	Sapwood	6.91	2.42	0.29	2.84	0.48	0.28	0.33	2.18
		Heartwood	6.67	3.02	0.3	2.25	0.72	0.48	0.36	1.84

Table: 4.21b Results of shrinkage statistics for *Funtumia elastica* trees (Billet and Plank divisions)

Tree No	Axial section	Radial section	Total shrinkage at oven dry				Shrinkage at 12% MC			
			T	R	L	T/R	T_{12}	R_{12}	L_{12}	T_{12}/R_{12}
	Butt end	Sapwood	6.16	3.76	0.29	1.65	4.94	2.94	0.24	1.7
		Heartwood	6.46	3.88	0.47	1.72	5.47	3.2	0.41	1.72
1	Middle	Sapwood	6.14	2.92	0.33	2.14	5.57	2.65	0.37	2.16
		Heartwood	5.58	2.81	0.39	2.0	5.11	2.43	0.31	1.88
	Top	Sapwood	4.06	3.2	0.28	1.32	3.86	2.82	0.24	1.37
		Heartwood	5	2.6	0.32	1.92	4.56	2.25	0.27	1.93
	Butt end	Sapwood	6.09	3.75	0.4	1.65	4.91	3.01	0.33	1.65
		Heartwood	8.47	3.8	0.47	1.77	5.42	3.4	0.42	1.74
2	Middle	Sapwood	6.17	2.94	0.36	2.21	5.58	2.61	0.31	2.13
		Heartwood	5.67	2.79	0.37	1.96	5.1	2.43	0.3	2.1
	Top	Sapwood	4.37	3.23	1.28	1.37	3.81	3.05	0.26	1.31
		Heartwood	4.97	2.59	0.31	1.93	4.34	2.24	0.26	1.94
	Butt end	Sapwood	6.26	3.87	0.48	1.62	5.12	3.15	0.42	1.66
		Heartwood	6.48	3.86	0.49	1.71	5.44	3.26	0.48	1.69
3	Middle	Sapwood	6.17	2.98	0.35	2.1	5.45	2.72	0.36	2.07

	Heartwood	5.6	2.7	0.41	2.09	5.13	2.46	0.35	2.09
Top	Sapwood	4.49	3.31	0.33	1.36	3.82	3.27	0.3	1.22
	Heartwood	5.07	2.62	0.34	1.91	4.44	2.27	0.33	1.92

CHAPTER FIVE

DISCUSSIONS

5.0 Introduction

This chapter discusses results of the study from the data gathered during the research. The results are discussed according to outcome of the experiments and how the results were displayed. The discussions were done on the following parameters: moisture content, basic density, shrinkage and drying schedule determination.

5.1 Discussion of results of green moisture contents of *Cola nitida* and *Funtumia elastica*

The amount of moisture in wood is termed moisture content and it is expressed as a percentage of the dry weight. Approximate moisture content of each 20 mm cube sample was determined by the oven dry testing method. The overall mean for all three *Cola nitida* trees was 66.61%, ranging from 44.32% to 115.22% high as shown in Table 4.1a. Tree 2 had the lowest mean of 63.23% whiles tree 3 had the minimum MC of 44.32% at

95% confidence level. Both minimum and maximum moisture contents of the three trees were in line with Simpson (1991) who stated that the moisture content of some species may be as low as 30% and as high as 200% due to variations in site and the seasons of felling.

The *Funtumia elastica* species also had overall mean moisture content for all trees at 79.4%. Tree 3 had the lowest moisture content of 78.3% with tree 1 having the highest mean moisture content of 80.22% as depicted in Table 4.1b. These results affirm that the moisture content of *Funtumia elastica* is higher than that of *Cola nitida*. This result is in tune with the range of moisture contents for species in Ghana by TEDB (1994).

5.2. Discussion of results of basic density of *Cola nitida* and *Funtumia elastica*

The basic densities of *Cola nitida* (Bese) and *Funtumia elastic* (Funtum) presented in Tables 4.5a and 4.5b shows that *Cola nitida* had overall average density of 623.75 kg/m^3 whiles *Funtumia elastica* had 499.57 kg/m^3. *Cola nitida* Tree 1 had the lowest average of 557.82kg/m3 and Tree 2 had the highest density of 653.75 kg/m^3. On the other hand, the basic density for all the 450 samples of *Funtumia elastica* ranged from 148.01 to 571.4 kg/m^3. The density for *Cola nitida* almost corresponds to the densities of *Nauclea diderrichii* (635 kg/m^3) and *Celtis mildbraedii* (619 kg/m^3) as stated by Ofori *et al.* (2009) and could be classified as “Medium Heavy” (575-725 kg/m^3) according to ATIBT, (1990) and TEDB, (1994). The density of Funtum could also be classified as ‘Medium’ (425 – 575 kg/m^3) according to Anon, (1990) and Anon, (1994). According to the densities of these two lesser known species, as presented in Table 4.6, *Cola nitida* could be used for heavy construction whiles *Funtumia elastica* could also be used for medium construction. By knowing the densities of these two species, it may in a way assist in predicting the wood strength as reported by Rowell (2005) that basic density is closely related to end-use quality. Hoadley (2000) also contended that wood density is a key factor that influences the wood strength.

5.3 Discussion of results of shrinkage of *Cola nitida* and *Funtumia elastica*

The tangential and radial shrinkage values obtained from the experimental results showed that shrinkage is very small in *Cola nitida* and medium in *Funtumia elastica* as presented in Tables 4.9 and 4.10 respectively. The total longitudinal shrinkage from green to oven-dry was 0.29% and 0.4% for *Cola nitida* and *Funtumia elastica* respectively. According to Wengert (2006) and Bauer (2003) wood shrinks a maximum of 0.3% longitudinally which is so small to be ignored. *Funtumia elastica* exhibited excessive longitudinal shrinkage of 0.4%, whiles *Cola nitida* shrinked 0.29% which fell within the permissible range of 0.3%. Attention should be paid to *Funtumia elastica* when using it in designs where longitudinal stability is important. Both species had higher tangential to radial shrinkage index as shown in Table 4.11 which is above the acceptable index of 1.5 as proposed by Wengert (2006). The ratio of tangential shrinkage to radial shrinkage (T/R) is used as an index of dimensional stability. Ratios higher than 1.5 are considered pronounced (Haygreen & Bowyer, 1996). The pronounced differential shrinkage in the two species studied is likely to cause wide splits, checks and distortions if the necessary precautions are not taken during the kiln drying of these species (Ofori *et al*., 2009). Table 4.11 summarizes the shrinkage measurements for both species.

5.4 Proposed experimental kiln drying schedules for *Cola nitida* and *Funtumia elastica*

A kiln drying schedule is a series of temperatures and relative humidities that are applied at various stages of drying. Tables 4.12a and 4.12b showed the type and class of drying defects obtained from each of the three trees of the two species. Using the adopted classes for each drying defect (initial check, honey comb and deformation), three possible drying conditions (initial temperatures, initial wet bulb depression and final temperatures) were obtained from the table of Terazawa (1965). The drying condition is inferred from the most severe grade of defects so it would be the mildest one and more safely. Table 5.1 is a summary of the initial moisture content and adopted classifications of defect types used in proposing the drying conditions.

Table 5.1: Summary of initial moisture content and adopted classification of defect types used in proposing the critical drying conditions as shown in Table 4.13

Species	Initial Moisture content	Adopted classification of defect type			Proposed critical drying conditions			
		Check on early stage	Honey comb	Deformation	Initial temp. (°C)	Wet bulb dep. (°C)	Final temp(°C)	Corresponding Madison Schedule
Cola nitida (Bese)	64	3	1	1	60	4.3	85	T_{10}-C_4
Funtumia elastica (Funtum)	86	3	1	1	60	4.3	85	T_{10}-D_4

The Forest Products Laboratory (FPL), Madison, USA has provided general temperature schedules for hardwoods ranging from a very mild schedule, T_1, to a severe schedule, T_{14} (Table 2.1) (Rasmussen, 1961; Simpson, 1991). According to Simpson (1991) initial temperatures, in all cases, are maintained until the average moisture content of the control specimens reach 30%. Wet-bulb depression schedules for six moisture content classes (A to F) (Table 2.3) that are related to the green moisture content of the wood (Class A, being green moisture content of up to 40%, and Class F being green moisture content above 120%) are also provided. In addition, there are eight numbered wet-bulb depression schedules (No. 1, being the mildest and No. 8, the most severe) (Table 2.2). In the view of Ofori and Appiah (1998) the method developed by Terazawa (1965) that was adopted attempts to estimate drying time, sensitivity to drying defects, and ultimately a kiln schedule by observing drying time and characterizing the various kinds of defects (initial checks, cross-sectional deformation, and honeycomb) that developed. The specimens (of size 2 cm thick by 10 cm wide by 20 cm long) used dried much faster than would a full-thickness lumber, so the method was very efficient in both time and material. The method has the limitation that subjecting specimens of that size to temperatures of about 100°C imposed the severest conditions on them. However, the method at least indicates the mildest kiln schedule from which modifications could be made to obtain a commercial kiln schedule. As described by Ofori and Brentuo (2010) the procedure above took into consideration, only initial check, cross-sectional deformation, and honeycomb as presented in Tables 4.12a, 4.12b and 4.13. Other defects such as warp, properties such as drying rate and basic density, and grade of lumber should be taken into consideration in adjusting the experimental kiln drying schedules to suit the conditions of the wood to be dried in commercial kiln runs to improve upon them. Simpson (1991) schedules for severely warped lumber or high basic density and slow drying species might be modified by lowering both the initial DBT and WBD; while schedules for upper grade lumbers or fast drying species might be modified by raising both the initial DBT and WBD (Terazawa, 1965), (Wengert, 2006; Simpson, 1991; Ofori & Brentuo, 2010; Ofori & Appiah 1998).

The experimental dry kiln schedules for lumber of thickness up to 38 mm have been assembled in Tables 5.2 and 5.3. In the schedules for both species, the initial WBD of 4.3°C as determined in Table 5.1 was rounded to the nearest figures. Mild and moderate kiln schedules of T_{10}-C_4 and T_{10}-D_4 were proposed for *Cola nitida* (Bese) and *Funtumia elastica* (Funtum) respectively. These proposed schedules conform to those of *Sterculia rhinopetala* and *Alstonia boonei* respectively as proposed by Ofori and Brentuo (2010b).

Table 5.2: Experimental kiln drying schedule for *Cola nitida*

			Madison Kiln Schedule T_{10}-C_4		
Step No.	Moisture content Range %	Dry Bulb Temp. °C	Wet Bulb Depression °C	Relative Humidity %	Equilibrium Moisture Content %
1	Above 40	60	4	82	14
2	40-35	60	6	74	11.4
3	35-30	60	9	63	9.2
4	30-25	65	15	45	6.4
5	25-20	70	25	23	3.5
6	20-15	75	30	20	2.8
7	15 to Final	80	30	23	2.9
	Equalize and condition as necessary				

Table 5.3: Experimental kiln drying schedule for *Funtumia elastica*

			Madison Kiln Schedule T_{10}-D_4		
Step No.	Moisture content Range %	Dry Bulb Temp. °C	Wet Bulb Depression °C	Relative Humidity %	Equilibrium Moisture Content %
1	Above 50	60	4	82	14
2	50-40	60	6	74	11.4
3	40-35	60	9	63	9.2
4	35-30	60	15	44	6.4
5	30-25	65	25	21	3.4
6	25-20	70	30	18	2.7
7	20-15	75	30	20	2.8
8	15 to Final	80	30	23	2.9
	Equalize and condition as necessary				

5.5. Discussion of results of variability in physical properties of *Cola nitida* and *Funtumia elastica*

Variability is a key issue in the processing of many biological materials, in this case the drying of hardwood timber. The properties considered in this discussion are. Green MC, basic density and shrinkage. The following discussions present what trends have been found regarding the variability of the above properties with respect to *Cola nitida* and *Funtumia elastica.*

5.5.1 Green (initial) moisture content within *Cola nitida* and *Funtumia elastica*

The initial moisture content for the *Cola nitida* (Bese) trees decreased from bark to pith as depicted in Table 4.14a. The sapwood had higher moisture content than the heartwood. There was significant differences between the sapwood and heartwood portions for all the three tress (F_{actual}, 13.7, 322.2 and 4.8 > $F_{expected,}$ 3.9), respectively. This result is in line with Simpson (1991), who contended that the sapwood moisture content in hardwood species was somewhat higher than or about equal to that of the heartwood. Also Walker (2003) got 115% (heartwood) and 125% (sapwood) for shining gum *(Eucalyptus nitens).*

Between the three axial sections (B.M.T), there was no dominant pattern of the moisture content. There was no significant differences between the three sections for Trees 1 and 3 ($F_{actual,}$ 0.71 < $F_{expected,}$ 3.06) and (F_{actual}, 0.1 < $F_{expected,}$ 3.06). There was significantly different increase from the breast height to the middle to the top for tree 2, as shown in Table 4.4. This pattern conforms to Reeb (1995) claim of inconsistent pattern of variation of green moisture content.

On the other hand, all the *Funtumia elastica* (Funtum) trees had the initial moisture content decreased from pith to bark as can be seen from Table 4.14b. Overall, the analysis of variance (ANOVA) for within tree test (95% confidence level) showed highly significant differences between the heartwood and sapwood (F_{actual}, 48.4, 25.4, and 56.7 > $F_{expected}$, 3.9) respectively. These results agreed with Walker (2003) who stated that the moisture contents of hardwoods such as yellow birch *(Betula lutea)* was 75% (heartwood) and 70% (sapwood). The results were also in line with Shupe *et al*. (1995a) that found that two yellow-poplar trees exhibited a general decrease of green moisture content from heartwood to sapwood. The breast height, middle and top parts of all the trees showed an inconsistent pattern of increase in green MC from the breast height to the top. This increase from the breast height to the top falls in line with Shupe *et al*. (1995) who said that the moisture content for heartwood varied with height. This result also confirms the assertion of Simpson (1991) that in species such as redwood, the butt logs of trees may contain more water than the top logs. The variability of green moisture content is dependent on the tree species, the portion of the log from where it is taken, between sites, between genetic variation and environment (Wimmer, 2000). Dinwoodie (2000) also proposed that it might be correlated with the season of the year when the tree was felled.

5.5.2 Basic density within *Cola nitida* and *Funtumia elastica*

The result of the basic densities of the *Cola nitida* (Bese) trees as in Table 4.15a showed an increase from the pith to the bark. This assertion agrees well with Walker *et al.* (1993) and Wimmer (2000) that observed an increase in basic density from pith to bark. ANOVA for the three Trees of *Cola nitida* showed that there were significant differences for tree 1 ($F_{actual,}$ 14 > $F_{expected,}$ 3.9) and tree 2 ($F_{actual,}$ 120 > $F_{expected}$, 3.9) between the heartwood and the sapwood (Table 4.8). Meanwhile, Tree 3 showed no significant differences.

The ANOVA for the three axial sections also showed that the height effect was a significant source of variation for the basic densities for Trees 1 and 2. For the same species, Tree 3 showed no differences between the three axial sections ($F_{actual,}$ 1.3 < $F_{expected}$, 3.9), these results support the suggestion by Olson (2003) that the basic density of hardwoods varies radially.

On the other hand, the *Funtumia elastica* (Funtum) trees showed significant differences between the butt, middle and top parts (Table 4.18). Results of the descriptive statistic (Table 4.19) revealed that the sapwood had lighter densities than the heartwood. There was an inconsistent pattern of variation from the butt to the top. This pattern conforms to claim of inconsistent pattern of variation of density within tree height, especially among hardwoods (Innes & Redman, 2005).

5.5.3 Shrinkage within *Cola nitida* and *Funtumia elastica*

There was no dominant pattern of shrinkage variability in both species as shown in Tables 4.9, 4.10 and 4.11. Tangential shrinkage from green to 12%MC was slightly higher in the heartwood than the sapwood for all the *Funtumia elastica* (Funtum) trees. Meanwhile the radial shrinkage was a little higher in the sapwood than the heartwood for all the *Funtumia elastica* (Funtum) trees (Table 4.10). Tangential shrinkage from green to 12% MC was higher in sapwood than heartwood in all the *Cola nitida* (Bese) trees (Table 4.9). Radial shrinkage from green to 12% MC was higher in heartwood than in sapwood in the *Cola nitida* trees.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.0 Introduction

This chapter concludes the study with general conclusions drawn from the results and recommendations for future work. The study looked at the green moisture content, basic density and shrinkage of *Cola nitida* and *Funtumia elastica* species. Quick drying test was also conducted to propose kiln-drying schedules for *Cola nitida* and *Funtumia elastica* species. Mean green moisture content were 66.6% and 79.4% for *Cola nitida* and *Funtumia elastic* respectively. Mean basic densities were 623.75 kg/m^3 for *Cola nitida* and 499.59 Kg/m^3 for *Funtumia elastica.* The proposed kiln schedules were *Cola nitida* (Bese) ($T_{10} – C_4$) and *Funtumia elastica* (Funtum) ($T_{10} – D_4$).

6.1 Conclusions

This study on the development of kiln drying schedules for *Cola nitida* and *Funtumia elastica* was necessitated by the over dependence of the timber industry on few species and the lack of technical data on the many species growing in Ghana's forests.

The results of the study lead to the following conclusions;

Mean green moisture content were 66.6% and 79.4% for *Cola nitida* (Bese) and *Funtumia elastica* (Funtum) species respectively. Mean basic densities ranged from a high of 623.75 kg/m^3 for *Cola nitida* to a low of 499.59 kg/m^3 for *Funtumia elastica*. The basic density values indicate that the species are Medium heavy and Medium weight species respectively.

The mean total tangential shrinkage from green to oven-dry was 7.25 and 6.78% for *Cola nitida* and *Funtumia elastica*. Mean partial shrinkage (tangential) values obtained shows that shrinkage from green to 12% MC is very small (under 2.5%) for *Cola nitida* and Medium (4.0-5.5%) for *Funtumia elastica*. The corresponding radial shrinkage values also shows that shrinkage is very small (under 1.0%) for *Cola nitida* and Medium (2.0 – 3.0%) for *Funtumia elastica*.

The total longitudinal shrinkage from green to oven-dry was 0.29 and 0.4% for *Cola nitida* and *Funtumia elastica* respectively. Typically, total longitudinal shrinkage is only 0.1-0.2% for most species and rarely exceeds 0.4% (Wengert, 2006). Both species exhibited excessive longitudinal shrinkage. Both species had higher tangential to radial shrinkage index which is above the acceptable index of 1.5. The ratio of tangential shrinkage to radial shrinkage (T/R) was very high (2.43 – 2.65) for *Cola nitida* and a high (1.8 – 1.79) for *Funtumia elastica*. The shrinkage values compared favourably with shrinkage values of some locally used species (like *Scottellia coriacea* and *Lannea welwitschii*) for timber production, and therefore could be considered suitable for timber utilization.

Checks in the early stage of drying were less severe in both *Cola nitida* and *Funtumia elastica* samples (Class 3). There were no honey combing (Class 1) in both *Cola nitida* and *Funtumia elastica* species. There was no deformation (Class 1) in both *Cola nitida* (Bese) and *Funtumia elastica* (Funtum) species during drying.

The following experimental kiln dry schedules for lumber of thickness up to 38 mm corresponding to the FPL Madison schedules are proposed: *Cola nitida* (Bese) (T_{10} – C_4) and *Funtumia elastica* (Funtum) (T_{10} – D_4). The results of the analysis of variance (ANOVA) revealed that the three axial sections of the trees showed significant variations in densities and moisture contents at 5% probability level ($p < 0.05$). The technical values of the study results compares favourably with technical values of some locally used species (like *Scottellia coriacea* and *Lannea welwitschii*) for timber production, and therefore could be considered suitable for timber utilization.

6.2 Recommendations

Based on the research findings, the following recommendations are proposed for the promotion, utilization and market acceptance of these two lesser-known species: the mechanical and working properties of *Cola nitida* (Bese) and *Funtumia elastica* (Funtum) species should be tested. The results of such studies should be recommended to the local wood industry. There is the need for collaboration between the department and the wood industry so that industry can sponsor such research work. There should be cooperation between the Faculty and other research institutions such as CSIR-FORIG so that students can be assisted when the need arises during research work. Also the Faculty should get adequate equipment and tools for students research work. Finally, further research work on the drying of these species should be undertaken to generate more data on the species. This in turn may be followed by an evaluation of their utilization potential, marketability and performance, so as to determine suitable substitutes for the fast-diminishing traditional species in the Ghanaian market.

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APPENDICES

APPENDIX A
Drying Test of *Cola nitida* (Bese)

TREE 1
<u>BUTTRESS</u>

Sample No.	Initial MC %	Initial Checks	Spool-Like Deformation	Honey Combing	Initial Temp.°C	Initial WBD °C	Final Temp. °C	Schedule
1	65	2	1	1	65	5.5	90	T11-C5
2	67	2	1	1	65	5.5	90	T11-C5
3	63	2	1	1	65	5.5	90	T11-C5
4	71	2	1	1	65	5.5	90	T11-C5
5	69	2	1	1	65	5.5	90	T11-C5
6	67	3	1	1	60	4.3	85	T10-C4
7	66	2	1	1	65	5.5	90	T11-C5
8	68	2	3	1	58	4.7	83	T9-C5
9	75	2	1	1	65	5.5	90	T11-C5
10	65	3	1	1	60	4.3	85	T10-C4

11	65	3	1	1	60	4.3	85	T10-C4
12	62	3	1	1	60	4.3	85	T10-C4
MEAN	**67**	**2**	**1**	**1**				

<u>MIDDLE</u>

Sample No.	Initial Mc %	Initial Checks	Spool-Like Deformation	Honey Combing	Initial Temp.°C	Initial WBD °C	Final Temp. °C	Schedule
1	71	2	1	1	65	5.5	90	T11-C5
2	70	2	1	1	65	5.5	90	T11-C5
3	68	3	1	1	60	4.3	85	T10-C4
4	69	2	1	1	65	5.5	90	T11-C5
5	72	2	1	1	65	5.5	90	T11-C5
6	68	3	1	1	60	4.3	85	T10-C4
7	65	2	1	1	65	5.5	90	T11-C5
8	67	2	1	1	65	5.5	90	T11-C5
9	65	2	1	1	65	5.5	90	T11-C5
10	66	2	1	1	65	5.5	90	T11-C5
11	66	3	1	1	60	4.3	85	T10-C4
12	73	3	1	1	60	4.3	85	T10-C4
MEAN	**68**	**2**	**1**	**1**				

Cola nitida **TREE 1**

<u>TOP</u>

Sample No.	Initial Mc %	Initial Checks	Spool-Like Deformation	Honey Combing	Initial Temp.°C	Initial WBD °C	Final Temp. °C	Schedule
1	64	3	1	1	60	4.3	85	T10-C4
2	70	3	1	1	60	4.3	85	T10-C4
3	68	3	1	1	60	4.3	85	T10-C4
4	69	2	1	1	65	5.5	90	T11-C5
5	78	3	1	1	60	4.3	85	T10-C4
6	78	3	1	1	60	4.3	85	T10-C4
7	73	2	1	1	65	5.5	90	T11-C5
8	70	3	1	1	60	4.3	85	T10-C4
9	70	3	1	1	60	4.3	85	T10-C4
10	69	3	1	1	60	4.3	85	T10-C4
11	73	3	1	1	60	4.3	85	T10-C4
12	76	3	1	1	60	4.3	85	T10-C4
MEAN	**72**	**3**	**1**	**1**				
GRAND MEAN	**69**	**2**	**1**	**1**				

Cola nitida (Bese)

TREE 2

BUTTRESS

Sample No.	Initial Mc %	Initial Checks	Spool-Like Deformation	Honey Combing	Initial Temp.°C	Initial WBD °C	Final Temp. °C	Schedule
1	53	3	1	1	60	4.3	85	T10-B4
2	55	2	1	1	65	5.5	90	T11-B5
3	59	2	2	1	65	5.5	90	T11-B5
4	59	2	2	1	65	5.5	90	T11-B5
5	61	2	4	1	54	4	80	T7-C4
6	59	3	4	1	54	4	80	T7-B4
7	57	2	1	1	65	5.5	90	T11-B5
8	56	2	1	1	65	5.5	90	T11-B5
9	63	3	1	1	60	4.3	85	T10-C4
10	56	3	2	1	60	4.3	85	T10-B4
11	55	3	1	1	60	4.3	85	T10-B4
12	54	3	1	1	60	4.3	85	T10-B4
MEAN	**57**	**3**	**2**	**1**				

TREE 2

MIDDLE

Sample No.	Initial Mc %	Initial Checks	Spool-Like Deformation	Honey Combing	Initial Temp.°C	Initial WBD °C	Final Temp. °C	Schedule
1	66	3	1	1	60	4.3	85	T10-C4
2	57	2	2	1	65	5.5	90	T11-B5
3	69	3	1	1	60	4.3	85	T10-C4
4	57	2	1	1	65	5.5	90	T11-B5
5	59	3	1	1	60	4.3	85	T10-B4
6	56	2	2	1	65	5.5	90	T11-B5
7	63	2	1	1	65	5.5	90	T11-C5
8	55	3	1	1	60	4.3	85	T10-B4
9	56	3	1	1	60	4.3	85	T10-B4
10	58	3	1	1	60	4.3	85	T10-B4
11	56	2	1	1	65	5.5	90	T11-B5
12	53	2	3	1	58	4.7	83	T9-B5
MEAN	**59**	**3**	**1**	**1**				

TREE 2

TOP

Sample No.	Initial Mc %	Initial Checks	Spool-Like Deformation	Honey Combing	Initial Temp.°C	Initial WBD °C	Final Temp. °C	Schedule
1	63	2	1	1	65	5.5	90	T11-C5
2	64	3	1	1	60	4.3	85	T10-C4
3	62	2	1	1	65	5.5	90	T11-C5
4	63	3	1	1	60	4.3	85	T10-C4
5	62	2	1	1	65	5.5	90	T11-C5
6	66	3	1	1	60	4.3	85	T10-C4
7	61	3	1	1	60	4.3	85	T10-C4
8	69	2	1	1	65	5.5	90	T11-C5
9	64	3	1	1	60	4.3	85	T10-C4
10	61	2	2	1	65	5.5	90	T11-C5
11	61	3	2	1	60	4.3	85	T10-C4
12	65	3	1	1	60	4.3	85	T10-C4
MEAN	**63**	**3**	**1**	**1**				
GRAND MEAN	**60**	**3**	**1**	**1**				

APPENDIX A
DRYING TEST
Cola nitida
(Bese)
TREE 3
BUTTRESS

Sample No.	Initial Mc %	Initial Checks	Spool-Like Deformation	Honey Combing	Initial Temp.°C	Initial Wbd °C	Final Temp. °C	Schedule
1	67	2	2	1	65	5.5	90	T11-C5
2	71	3	1	1	60	4.3	85	T10-C4
3	55	2	1	1	65	5.5	90	T11-B5
4	63	2	2	1	65	5.5	90	T11-C5
5	59	3	1	1	60	4.3	85	T10-B4
6	61	2	4	1	54	4	80	T7-C4
7	55	2	1	1	65	5.5	90	T11-B4
8	66	2	4	1	54	4	80	T7-C4
9	62	3	1	1	60	4.3	85	T10-C4
10	70	3	1	1	60	4.3	85	T10-C4

11	56	3	1	1	60	4.3	85	T10-B4
12	75	3	2	1	60	4.3	85	T10-C4
MEAN	**63**	**3**	**2**	**1**				

MIDDLE

Sample No.	Initial Mc %	Initial Checks	Spool-Like Deformation	Honey Combing	Initial Temp.°C	Initial Wbd °C	Final Temp. °C	Schedule
1	53	2	1	1	65	5.5	90	T11-B5
2	62	3	2	1	60	4.3	85	T10-C4
3	64	2	2	1	65	5.5	90	T11-C5
4	58	3	1	1	60	4.3	85	T10-B4
5	69	2	1	1	65	5.5	90	T11-C5
6	64	2	1	1	65	5.5	90	T11-C5
7	56	3	1	1	60	4.3	85	T10-B4
8	60	3	1	1	60	4.3	85	T10-C4
9	65	3	2	1	60	4.3	85	T10-C4
10	63	3	1	1	60	4.3	85	T10-C4
11	59	2	1	1	65	5.5	90	T11-B5
12	70	2	3	1	58	4.7	83	T9-C5
MEAN	**62**	**3**	**1**	**1**				

APPENDIX A

TREE 3

TOP

Sample No.	Initial Mc %	Initial Checks	Spool-Like Deformation	Honey Combing	Initial Temp.°C	Initial Wbd °C	Final Temp. °C	Schedule
1	63	2	1	1	65	5.5	90	T11-C5
2	67	2	1	1	65	5.5	90	T11-C5
3	65	3	1	1	60	4.3	85	T10-C4
4	63	3	2	1	60	4.3	85	T10-C4
5	78	3	1	1	60	4.3	85	T10-C4
6	66	2	1	1	65	5.5	90	T11-C5
7	71	3	2	1	60	4.3	85	T10-C4
8	69	2	1	1	65	5.5	90	T11-C5
9	70	2	2	1	65	5.5	90	T11-C5
10	61	3	1	1	60	4.3	85	T10-C4
11	73	3	1	1	60	4.3	85	T10-C4

12	63	3	1	1	60	4.3	85	T10-C4
MEAN	**67**	**3**	**1**	**1**				
GRAND MEAN	**64**	**3**	**1**	**1**				

APPENDIX B

DRYING SCHEDULE DETERMINATION

Funtumia elastica

TREE 1

BUTTRESS

NO.	Initial MC%	Initial checks	Spool-like Deform.	Honey comb	Initial Temp.	Initial WBD	Final Temp.	Proposed schedule
1	86	3	1	1	60	4.3	85	T10-D4
2	85	4	1	1	55	3.6	83	T8-D4
3	91	3	1	1	60	4.3	85	T10-D4
4	87	3	1	2	55	3.6	83	T8-D4
5	86	3	1	2	55	3.6	83	T8-D4
6	88	3	1	1	60	4.3	85	T10-D4
7	87	3	1	1	60	4.3	85	T10-D4
8	78	3	1	1	60	4.3	85	T10-D4
9	93	2	1	1	65	5.5	90	T11-D5
10	87	3	1	1	60	4.3	85	T10-D4
11	84	3	1	1	60	4.3	85	T10-D4

12	90	3	1	1	60	4.3	85	T10-D4
MEAN	**87**	**3**	**1**	**1**				

MIDDLE

NO.	**Initial MC%**	**Initial checks**	**Spool-like Deform.**	**Honey comb**	**Initial Temp.**	**Initial WBD**	**Final Temp.**	**Proposed schedule**
1	71	3	1	1	60	4.3	85	T10-C4
2	93	3	3	1	58	4.7	83	T10-D4
3	89	3	2	1	60	4.3	85	T10-D4
4	81	3	1	2	55	4.5	83	T8-D4
5	84	2	1	1	65	5.5	90	T11-D5
6	75	3	1	1	60	4.3	85	T10-C4
7	88	3	1	1	60	4.3	85	T10-D4
8	91	3	1	1	60	4.3	85	T10-D4
9	79	3	1	1	60	4.3	85	T10-C4
10	78	3	1	1	60	4.3	85	T10-C4
11	76	3	1	1	60	4.3	85	T10-C4
12	82	3	3	1	58	4.7	83	T10-D4
MEAN	**82**	**3**	**1**	**1**				

APPENDIX B

TREE 1

TOP

NO.	**Initial MC%**	**Initial checks**	**Spool-like Deform.**	**Honey comb**	**Initial Temp.**	**Initial WBD**	**Final Temp.**	**Proposed schedule**
1	94	3	1	1	60	4.3	85	T10-D4
2	87	3	1	1	60	4.3	85	T10-D4
3	93	3	1	1	60	4.3	85	T10-D4
4	97	3	1	1	60	4.3	85	T10-D4
5	96	3	1	1	60	4.3	85	T10-D4
6	99	3	1	1	60	4.3	85	T10-D4
7	87	3	1	1	60	4.3	85	T10-D4
8	96	3	1	1	60	4.3	85	T10-D4
9	90	3	1	1	60	4.3	85	T10-D4
10	92	3	1	1	60	4.3	85	T10-D4
11	96	3	1	1	60	4.3	85	T10-D4
12	88	2	1	1	65	5.5	90	T11-D5
	93	**3**	**1**	**1**				

MEAN				
GRAND MEAN	**87**	**3**	**1**	**1**

DRYING SCHEDULE DETERMINATION
FUNTUM
TREE 2
<u>BUTTRESS</u>

NO.	Initial MC%	Initial checks	Spool-like Deform.	Honey comb	Initial Temp.	Initial WBD	Final Temp.	Proposed schedule
1	82	3	1	1	60	4.3	85	T10-D4
2	82	3	1	1	60	4.3	85	T10-D4
3	86	4	1	1	55	3.6	83	T8-D4
4	82	2	1	1	65	5.5	90	T11-D5
5	82	3	1	1	60	4.3	85	T10-D4
6	85	3	1	1	60	4.3	85	T10-D4
7	86	3	2	1	60	4.3	85	T10-D4
8	75	3	1	1	60	4.3	85	T10-C4
9	89	3	1	1	60	4.3	85	T10-D4
10	84	3	1	1	60	4.3	85	T10-D4
11	79	2	3	1	58	4.7	83	T10-C4
12	86	3	1	1	60	4.3	85	T10-D4
MEAN	**83**	**3**	**1**	**1**				

TREE 2
<u>MIDDLE</u>

NO.	Initial MC%	Initial checks	Spool-like Deform.	Honey comb	Initial Temp.	Initial WBD	Final Temp.	Proposed schedule
1	69	3	1	1	60	4.3	85	T10-C4
2	89	3	1	1	60	4.3	85	T10-D4
3	86	3	1	1	60	4.3	85	T10-D4
4	78	3	2	1	60	4.3	85	T10-C4
5	80	2	1	1	65	5.5	90	T11-D5
6	73	3	1	1	60	4.3	85	T10-C4
7	86	3	1	1	60	4.3	85	T10-D4
8	88	3	1	1	60	4.3	85	T10-D4
9	78	3	1	1	60	4.3	85	T10-C4
10	79	3	3	1	58	4.7	83	T10-C4
11	82	2	1	1	65	5.5	90	T11-D5
12	92	2	1	1	65	5.5	90	T11-D5

MEAN	**82**	**3**	**1**	**1**

TOP

NO.	Initial MC%	Initial checks	Spool-like Deform.	Honey comb	Initial Temp.	Initial WBD	Final Temp.	Proposed schedule
1	76	3	1	1	60	4.3	85	T10-C4
2	93	3	1	1	60	4.3	85	T10-D4
3	90	3	1	1	60	4.3	85	T10-D4
4	91	4	1	1	55	3.6	83	T8-D4
5	91	3	2	1	60	4.3	85	T10-D4
6	94	3	1	1	60	4.3	85	T10-D4
7	90	3	1	1	60	4.3	85	T10-D4
8	88	3	1	1	60	4.3	85	T10-D4
9	92	3	1	1	60	4.3	85	T10-D4
10	87	3	1	1	60	4.3	85	T10-D4
11	76	3	1	1	65	5.5	90	T11-C5
12	82	2	1	1	60	4.3	85	T10-D4
MEAN	**88**	**3**	**1**	**1**				
GRAND MEAN	**84**	**3**	**1**	**1**				

APPENDIX B

DRYING SCHEDULE DETERMINATION

FUNTUM

TREE 3

BUTTRESS

NO.	Initial MC%	Initial checks	Spool-like Deform.	Honey comb	Initial Temp.	Initial WBD	Final Temp.	Proposed schedule
1	88	3	1	1	60	4.3	85	T10-D4
2	88	3	1	1	60	4.3	85	T10-D4
3	93	3	1	1	60	4.3	85	T10-D4
4	86	2	1	1	65	5.5	90	T11-D5
5	90	3	2	1	60	4.3	85	T10-D4
6	92	3	1	1	60	4.3	85	T10-D4
7	91	3	1	1	60	4.3	85	T10-D4
8	82	4	1	1	55	3.6	83	T8-D4
9	95	3	1	1	60	4.3	85	T10-D4
10	90	3	3	1	58	4.7	83	T10-D4

11	86	2	1	1	65	5.5	90	T11-D5
12	92	3	1	1	60	4.3	85	T10-D4
MEAN	**89**	**3**	**1**	**1**				

MIDDLE

NO.	Initial MC%	Initial checks	Spool-like Deform.	Honey comb	Initial Temp.	Initial WBD	Final Temp.	Proposed schedule
1	72	3	1	1	60	4.3	85	T10-C4
2	96	3	1	1	60	4.3	85	T10-D4
3	88	3	1	1	60	4.3	85	T10-D4
4	86	3	2	1	60	4.3	85	T10-D4
5	91	3	1	1	60	4.3	85	T10-D4
6	82	3	1	1	60	4.3	85	T10-D4
7	94	3	1	1	60	4.3	85	T10-D4
8	93	2	1	1	65	5.5	90	T11-D5
9	87	3	1	1	60	4.3	85	T10-D4
10	84	3	3	1	58	4.7	83	T10-D4
11	78	4	1	1	55	3.6	83	T8-C4
12	79	3	1	1	60	4.3	85	T10-C4
MEAN	**86**	**3**	**1**	**1**				

APPENDIX B

TREE 3

TOP

NO.	Initial MC%	Initial Checks	Spool-like Deform.	Honey comb	Initial Temp.	Initial WBD	Final Temp.	Proposed schedule
1	88	3	1	1	60	4.3	85	T10-D4
2	93	3	1	1	60	4.3	85	T10-D4
3	88	2	1	1	65	5.5	90	T11-D5
4	93	3	1	1	60	4.3	85	T10-D4
5	97	3	1	1	60	4.3	85	T10-D4
6	98	3	1	1	60	4.3	85	T10-D4
7	90	3	1	1	60	4.3	85	T10-D4
8	71	3	1	1	60	4.3	85	T10-C4
9	86	2	2	1	65	5.5	90	T11-D5
10	86	3	1	1	60	4.3	85	T10-D4

11	84	3	1	1	60	4.3	85	T10-D4
12	82	3	1	1	60	4.3	85	T10-D4
MEAN	**88**	**3**	**1**	**1**				
GRAND MEAN	**88**	**3**	**1**	**1**				

APPENDIX C 1

Cola nitida (Bese)

TREE 1

Descriptive statistics for MC% for Sapwood & Heartwood

	Sapwood	Heartwood
Mean	70.144	66.505
SD.	4.09618015	7.4772
Minimum	60.04	54.1
Maximum	79.47	92.9
Count	75	75
Confidence Level (95.0%)	0.94244545	1.7203

SUMMARY

Groups	*Count*	*Average*	*Variance*
Sapwood	75	70.144	16.778691
Heartwood	75	66.505	55.909149

ANOVA

Source of Variation	*SS*	*MS*	*F*	*P-value*	*F crit*
Between Groups	496.39	496.38	13.66	0.000308	3.91
Within Groups	5378.90	36.34			
Total	5875.29				

APPENDIX C 2

Cola nitida (Bese) TREE 2

Descriptive statistics for MC% for Sapwood & Heartwood

Statistics	Sapwood	Heartwood
Mean	67.99	58.46
SD	3.78	2.62
Minimum	59.65	53.33
Maximum	75	67.86
Count	75	75
Confidence Level (95.0%)	0.87	0.60

ANOVA for MC% for Sapwood & Heartwood

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Sapwood	75	5099.46	67.9928	14.3071421
Heartwood	75	4384.61	58.46147	6.84105052

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3406.74	1	3406.7	322.18	5.6082E-	3.91
Within Groups	1564.97	148	10.57			
Total	4971.70	149				

APPENDIX C 3

Cola nitida (BESE) TREE 3

Descriptive statistics for MC% for Sapwood & Heartwood

Statistics	Sapwood	Heartwood
Mean	68.4116	63.614
SD	12.75911	14.092
Minimum	49.09	44.32
Maximum	97.4	115.22
Count	75	75
Confidence Level (95.0%)	2.9356065	3.2422

ANOVA for MC% for Sapwood & Heartwood

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Sapwood	75	5130.87	68.412	162.7951
Heartwood	75	4771.07	63.614	198.5763

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	863.04	1	863.04	4.78	0.03	3.91
Within Groups	26741.49	148	180.69			
Total	27604.53	149				

APPENDIX C 4

Cola nitida (Bese)

MC% for Tree 1, 2, & 3

TREE 1	TREE 2	TREE 3	TREE 1	TREE 2	TREE 3
68.48	61.82	67.69	74.02	58.93	115.22
71.22	67.27	59.72	67.82	57.89	56.64
69.53	66.67	81.82	74.53	56.9	68.75
76.27	70.91	93.9	70.41	56.9	59.7
77.2	67.27	56.92	72.33	59.65	59.65
72.64	65.45	72.64	69.72	56.14	58.35
67.27	68.52	84.09	70.13	53.33	45.71
67.8	62.5	57.97	79.32	67.27	97.4
68.07	67.27	82.22	67.72	69.09	58.46
64.25	64.29	54.59	73.15	67.86	89.77
72.9	68.52	57.81	76.88	70.91	60
77.2	72.22	64.33	70.97	72.73	87.17
66.32	63.64	53.85	76.1	69.06	58.46
69.56	63.64	69.56	72.09	63.18	72.09
69.52	62.5	76.09	69.95	64.29	49.09
65.99	59.65	55.36	70.25	63.18	59.27
71.13	66.07	80.43	72.94	62.5	76.09
72.8	60.71	72.8	75.97	65.45	63.15
69.46	67.86	57.58	75.62	64.29	54.55
69.76	64.29	83.75	67.7	68.52	67.7
70.42	67.27	82.22	68.67	62.96	53.13
67.09	63.16	57.44	68.56	67.86	57.33
68.9	67.27	82.22	74.01	69.09	84.44
63.74	61.82	54.69	74.6	72.73	62.25
70.53	67.86	57.58	69.46	63.16	53.73
66.89	57.89	49.25	72.48	60.34	87.54
67.76	56.9	56.5	79.47	70.91	86.67
66.57	59.65	72.34	64.31	66.07	54.01
65.98	58.93	55.63	73.54	65.45	65.45
65.28	58.93	50	67.02	68.52	56.29
73.51	58.93	73.52	69.81	70.37	57.81
74.23	61.11	51.56	68.42	68.52	57.38
71.81	58.93	88.6	73.9	59.32	91.29
77.01	53.33	53.33	63.86	59.32	50.72
66.42	53.33	56.22	64.7	56.9	78.81
69.91	55	66	74.55	61.4	52.24
70.64	59.65	59.22	66.16	60.34	79.68
72.53	56.14	47.76	75.4	55.93	67.35

74.24	58.93	74.24
92.9	54.24	65.31
67.64	58.93	56.47
77.22	56.9	48.53
71.71	60	87.57
74.98	57.63	69.39
72.99	57.63	60.89
75.43	58.62	70.83
65.27	60.71	54.59
73.22	64.29	64.29
71.97	67.86	60.33
71.21	65.52	79.17
66.4	55.93	55.42
68.14	58.33	70
67.85	60.34	56.65
70.36	63.16	63.16
66.7	60.34	81.78
67.32	58.33	50
67.54	59.32	56.6
60.04	71.7	71.73
72.41	72.22	72.22
71.29	75	86.98
70.62	73.58	60.94
77.55	72.22	56.07
66.45	72.22	88.64
73.61	72.22	61.84
74.28	72.22	86.36
66.31	70.37	59.57
71.13	72.22	59.38
63.82	70.37	82.57
67.52	71.7	66.67
72.3	66.67	58.84
70.45	71.7	62.5
71.6	74.07	85.03
69.8	71.7	58.73
69.6	69.81	80.88
66.09	72.22	59.38
68.65	70.37	61.94
61.94	70.37	86.36
67.11	70.37	53.19
62.42	69.09	88.64

67.15	60.34	56.33
68.05	59.32	71.43
71.6	60.34	72.6
66.53	60.34	51.47
80.19	60.34	100.1
69.35	60	58.19
71.84	54.1	46.48
71.63	57.63	71.63
75.1	58.62	70.83
74.2	60.34	62.1
72.95	57.63	49.28
68.5	56.67	57.43
71.77	55.74	66.67
68.37	57.63	57.33
68.15	56.67	56.67
76.55	56.67	94.02
76.62	55.93	55.93
74.33	55.93	61.95
71.84	59.32	66.04
71.94	55.93	59.41
65.76	56.9	47.83
65.57	55.93	54.64
63.78	60.34	51.47
72	58.33	58.33
68.63	59.32	84.36
78.5	58.33	50
76.14	61.02	63.02
69.15	62.71	44.32
73.07	55.93	92.67
65.73	71.7	60.32
64.24	70.37	69.86
71.47	57.63	49.28
68.78	72.22	65.73

APPENDIX
C4

Descriptive statistics (MC) for tree 1, 2, & 3

Statistics	Tree 1	Tree 2	Tree 3
Mean	70.60	63.23	66.01
SD	4.35	5.78	13.61
Minimum	60.04	53.33	44.32
Maximum	92.9	75	115.22
Count	150	150	150
Confidence Level (95.0%)	0.70	0.93	2.20

ANOVA for tree 1,2,&3

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Tree 1	150	10591	70.6046	18.8962961
Tree 2	150	9484.1	63.2271	33.3671347
Tree 3	150	9901.9	66.0129	185.265305

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4163.55	2	2081.78	26.29	1.6E-11	3.02
Within Groups	35391.78	447	79.18			
Total	39555.34	449				

APPENDIX D 1

Funtumia elastica Tree 1

Descriptive statistics for MC% for Sapwood & Heartwood

Statistics	Sapwood	Heartwood
Mean	76.32	84.12
SD	7.69	5.91
Minimum	62.5	70.27
Maximum	92.12	94.44
Count	75	75
Confidence Level (95.0%)	1.77	1.36

ANOVA for MC% for Sapwood & Heartwood

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Sapwood	75	5724.23	76.32307	59.09785
Heartwood	75	6308.23	84.10973	34.88702

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2273.71	1	2273.71	48.38	1.05E-10	3.91
Within Groups	6954.88	148	46.99			
Total	9228.59	149				

APPENDIX D 2

Funtumia elastica Tree 2

Descriptive statistics for MC% for Sapwood & Heartwood

Statistics	Sapwood	Heartwood
Mean	76.84253	82.56147
SD	8.437809	5.02017
Minimum	64.1	70.66
Maximum	92.44	94.34
Count	75	75
Confidence Level (95.0%)	1.941363	1.155036

ANOVA for MC% for Sapwood & Heartwood

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Sapwood	75	5763.19	76.84253	71.19662
Heartwood	75	6192.11	82.56147	25.20211

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1226.48	1	1226.48	25.45	1.31E-06	3.91
Within Groups	7133.51	148	48.2			
Total	8359.988	149				

APPENDIX D 3

Funtumia elastica Tree 3

Descriptive statistics for MC% for Sapwood & Heartwood

Statistics	Sapwood	Heartwood
Mean	73.9948	82.6256
SD	7.879154	6.037345
Minimum	60.5	70.27
Maximum	89.43	94.44
Count	75	75
Confidence Level (95.0%)	1.812829	1.389067

ANOVA for MC% for Sapwood & Heartwood

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Sapwood	75	5549.61	73.9948	62.08106
Heartwood	75	6196.92	82.6256	36.44954

ANOVA

Source of Variation	*SS*	*Df*		*F*	*P-value*	*F crit*
Between Groups	2793.4	1	3.402	56.7012	4.61E-12	3.91
Within Groups	7291.26	148	653			
Total	10084.67	149				

APPENDIX
D 4

MC% for Trees 1, 2, & 3			*Funtumia elastica*		
TREE 1	TREE 2	TREE 3	TREE 1	REE 2	TREE 3
65	64.4	63	75.68	80.38	73.68
66.67	68.5	64.67	73.68	70.38	80.5
71.79	72.7	69.79	92.12	75.68	73.68
67.5	66.66	65.5	84.62	74.45	71.68
72.5	72.4	70.5	86.11	81.08	84.11
71.05	68.6	69.05	84.62	79.4	82.62
66.67	70.8	64.67	84.62	65.79	82.62
73.68	67.4	71.68	75.68	81.08	81.58
67.5	66.4	65.5	89.19	92.44	89.19
64.1	67	62.1	81.58	89.19	75.68
62.5	72.8	60.5	75	84.84	72
66.67	73.1	64.67	78.95	81.58	78.95
63.41	67.05	61.41	81.58	80.21	74.49
64.1	69.79	62.1	84.21	72.27	79.49
67.5	71.79	65.5	72.5	78.32	72.5
70	70	68	79.49	78.38	82.5
67.5	67.5	65.5	79.49	80.05	81.58
65.85	65.85	63.85	89.19	74.38	76.92
65.79	66.67	63.79	75	90.29	77.5
65	64.1	63	83.78	80.05	83.78
71.79	73.68	69.79	77.5	91.67	75
70.73	70	68.73	76.92	92.44	89.2
69.05	65	67.05	78.95	90.67	80.58
70	65.79	68	81.58	90.67	78.95
72.97	69.05	70.97	81.58	84.84	79.49
87.18	84.7	85.2	79.49	90.67	81.58
81.08	65.79	79.08	81.58	86.84	75.68
84.62	82.5	62	75.68	90.67	81.58
84.62	78.38	62	81.58	82.84	79.68
65.79	68.42	63.79	75	90.67	76
82.5	75.68	80.5	91.43	80.49	89.43
81.08	84.62	79.1	83.33	72.97	82.33
84.62	71.79	82.62	80	79	78
87.18	82.3	85.18	78.05	79.05	76.05
78.38	78.38	76.38	77.5	80	75.5

73.68	82.5	71.4	80	77.22	78
78.38	87.18	76.4	76.32	70.66	74.3
81.08	73.68	79.1	75.68	79.8	73.7
84.62	71.79	82.62	80	80.1	78
68.42	70.59	66.4	75.61	76.31	73.61
71.79	84.62	69.79	80	79.8	78
75.68	87.18	73.68	77.5	77.6	75.5
82.5	80.38	80.5	77.5	78.4	75.5

94.29	94.3	92.29	79.49	79.95	91.67
78.05	80.05	76.05	91.67	81.58	81.08
94.29	92.12	92.29	86.84	84.21	86.84
84.62	80.62	82.62	91.67	78.5	91.67
77.5	73.5	75.5	91.67	80.49	94.44
77.5	76.5	75.5	94.44	89.19	91.67
84.21	82.21	82.21	91.67	80	91.67
77.5	79.5	75.5	82.05	89.19	82.05
80	79.05	78	94.29	83.78	78.38
80	79.05	78	78.38	80.5	94.29
86.11	84.62	84.11	82.05	78.92	82.05
84.21	94.34	82.2	82.05	78.95	82
94.29	86.2	92.3	78.38	81.58	80.38
84.62	84.6	82.6	76.32	89.58	78.38
84.62	84.62	82.6	70.27	80.49	81.08
84.21	89.47	82.2	84.21	81.58	92.44
89.74	90.11	87.74	81.58	80.68	90.19
81.08	80	79.08	86.84	81.58	88.84
89.47	84.62	87.5	89.19	80.5	81.58
86.84	86.21	84.8	94.44	91.43	70.27
89.47	80.5	87.5	81.08	88.33	76.32
86.49	80.5	84.5	89.19	88.2	87.2
84.62	78.38	82.62	84.62	90.11	82.6
89.47	92.11	87.5	84.21	82.05	82.2
92.11	84.62	90	82.5	84.5	80.5
89.19	89.47	87.2	82.5	75.68	80.5
89.74	82.5	87.74	78.38	78.38	76.4
92.11	82.5	92	82.05	73.68	80
82.5	78.38	80.5	81.08	80.68	80.49
87.18	82.5	85.2	91.67	89.19	79.49
80	89.47	80	72.97	81.58	91.67
84.62	86.49	82.6	91.67	80	71.97

APPENDIX D 4

Descriptive statistics MC% for Trees 1, 2, & 3

Statistics	Tree 1	Tree 2	Tree 3
Mean	80.2164	79.702	78.3102
SD	7.869995	7.490481	8.226927
Minimum	62.5	64.1	60.5
Maximum	94.44	94.34	94.44
Count	150	150	150
Confidence Level (95.0%)	1.269751	1.20852	1.327339

ANOVA for Trees 1, 2 & 3

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Tree 1	150	12032.46	80.2164	61.93682
Tree 2	150	11955.3	79.702	56.1073
Tree 3	150	11746.53	78.3102	67.68232

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	291.7657	2	145.8828	2.356414	0.095	3.015899
Within Groups	27673.24	447	61.90882			
Total	27965.01	449				

APPENDIX E1

Density for *Colanitida*

TREE 1

Descriptive statistics for density of Sapwood and Heartwood

Statistics	Sapwood	Heartwood
Mean	589.0449	566.591
SD	34.04850	38.2805
Minimum	533.56	489.12
Maximum	652.97	666.63
Count	75	75
Confidence Level (95.0%)	7.833848	8.80756

ANOVA for Sapwood and Heartwood

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
SAPWOOD	75	44178.37	589.044	1159.300
HEARTWOOD	75	42494.38	566.591	1465.403

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	18905.48	1	18905.4	14.40580	0.000214	3.9050
Within Groups	194228.0	148	1312.35			
Total	213133.5	149				

APPENDIX E 2

Density for *Cola nitida* Tree 2

Descriptive statistics for density of Sapwood and Heartwood

Statistics	Sapwood	Heartwood
Mean	621.8302	685.66413
SD	38.43693	32.766278
Minimum	561.22	577.32
Maximum	682.35	725
Count	75	75
Confidence Level (95.0%)	8.84	7.54

ANOVA for Sapwood and Heartwood

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
SAPWOOD	75	46637.27	621.8302	1477.39
HEARTWOOD	75	51424.81	685.66413	1073.62

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	152803.59	1	152803.59	119.797	8.49E-	3.91
Within Groups	188775.99	148	1275.51			
Total	341579.58	149				

APPENDIX E 3

Density for *Cola nitida* Tree 3

Descriptive statistics for density of Sapwood and Heartwood

Statistics	Sapwood	Heartwood
Mean	628.92706	650.4158
SD	116.12467	112.5683
Minimum	444.95	424
Maximum	843.75	835.29
Count	75	75
Confidence Level (95.0%)	26.717860	25.89961

ANOVA for Sapwood and Heartwood

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
SAPWOOD	75	47169.53	628.9270	13484.9395
HEARTWOOD	75	48781.19	650.4158	12671.6219

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	17316.31	1	17316.3	1.3240516	0.2517219	3.9050599
Within Groups	1935585.	148	13078.2			
Total	1952901.	149				

APPENDIX E 4

COLA NITIDA (Bese)

DENSITY FOR TREES 1,2 & 3 (kg/m^3)

TREE 1	TREE 2	TREE 3	TREE 1	TREE 2	TREE 3
642.27	572.92	677.08	535.89	682.93	560.98
614.44	567.01	732.78	570.38	678.57	683
646.54	562.5	458.33	536.68	698.8	578.31
630.41	561.22	512.07	546.88	690.48	644.53
632.83	567.01	670.1	534.55	678.57	678.57
615.26	567.01	615.26	541.07	686.75	646.11
634.83	562.5	458.33	576.04	714.29	833.33
638.53	577.32	746.75	548.57	654.76	447.65
620.78	567.01	463.92	588.79	647.06	764.71
624.31	571.43	734.81	569.62	658.82	463.16
648.51	562.5	666.67	630.01	647.06	764.71
591.72	562.5	710.06	620.65	647.06	503.56
645.23	578.95	684.21	625.39	647.06	764.71
594.58	572.92	594.58	636.68	670.59	633.61
556.44	583.33	479.17	556.2	658.82	647.06
608.06	581.63	724.88	547.46	678.57	646.26
599.26	571.43	469.39	568.98	666.67	547.62
562.38	565.66	562.38	590.77	654.76	714.1
640.69	571.43	673.47	609.25	658.82	776.47
632.66	565.66	526.96	604.7	650.6	605.41
630.24	572.92	468.75	564.76	650.6	771.08
651.53	575.76	760.94	583.77	666.67	694.09
598.94	567.01	463.92	541.67	654.76	535.71
652.97	578.95	777.9	592.24	654.76	710.59
607.04	571.43	673.47	556.27	670.59	788.24
544.57	581.63	683.67	551.71	682.35	458.57
545.54	591.84	654.24	533.56	654.76	535.71
555.4	587.63	484.54	586.13	666.67	701.12
552.88	583.33	655.76	553	662.65	662.65
554.52	577.32	680.41	580.22	642.86	686.92
538.87	583.33	538.87	607.5	642.86	761.9
541.53	666.67	790.12	581	650.6	739.08

547.61	674.7	443.88	534.62	694.12	429.29
533.3	722.89	722.89	504.73	702.38	821.43
553.09	714.29	652.89	559.72	690.48	458.6
545.55	714.29	595.24	527.78	678.57	797.62
551.33	678.57	657.37	555.85	690.48	461.51
535.51	678.57	797.62	529.24	702.38	583.33
535.44	682.93	535.44	551.96	690.48	660.12
489.12	710.84	590.36	537.45	686.05	569.77
543.68	682.93	650.75	538.44	690.48	535.31
556.22	690.48	809.52	564.31	682.35	800
576.91	662.65	460.86	529.82	698.8	424

541.28	702.38	583.33	614.77	694.12	701.06
537.93	702.38	642.02	619.24	697.67	739.76
533.83	690.48	571.43	593.4	717.65	835.29
541.06	691.36	643.47	581.97	702.38	584.71
537.74	682.93	682.93	602.33	682.35	564.71
527.6	658.82	630.71	617.57	690.48	738.8
525.55	682.35	505.26	626.39	694.12	811.76
555.34	702.38	664.62	616.77	714.29	736.55
545.89	714.29	595.24	601.81	709.3	593.02
539.81	725	644.47	620.91	702.38	737.74
528.52	686.75	686.75	620.25	705.88	705.88
546.67	690.48	446.77	636.8	697.67	515.41
546.02	705.88	823.53	647.38	702.38	746.84
535.16	702.38	636.6	591.95	694.12	706.12
575.07	638.55	480	616.77	686.05	588.26
537.73	642.86	843.75	588.09	694.12	708.64
555.71	619.05	459.19	624.6	690.48	831.33
566.23	638.55	752.94	623.57	710.84	659.45
559.88	635.29	744.3	666.63	690.48	809.52
583.89	635.29	517.65	626.27	697.67	697.67
555.13	635.29	686.09	615.5	702.38	501.26
573.13	642.86	523.81	617.64	697.67	813.95
559.17	642.86	699.32	609.52	702.38	734.56
587.02	635.29	761.9	544.37	635.29	537.85
605.91	642.86	477.23	537.27	638.55	759.04
581.14	623.53	642.86	553.88	642.86	592.72
587.02	642.86	674.33	615.6	694.12	811.76
564.48	630.95	761.9	579.77	694.12	579.77
560.92	642.86	444.95			
540.46	630.95	750			
594.52	630.95	460.52			
565.36	635.29	761.9			

566.76	642.86	566.6
567.18	642.86	523.81
545.64	642.86	598.35
561.15	647.06	517.65

APPENDIX E
4
COLA NITIDA

Descriptive statistics for density of Trees 1,2 & 3

Statistics	Tree 1	Tree 2	Tree 3
Mean	577.8183	653.747	639.6714
SD	37.82098	47.8798	114.4846
Minimum	489.12	561.22	424
Maximum	666.63	725	843.75
Count	150	150	150
Confidence Level (95.0%)	6.102067	7.72497	18.47103

ANOVA for Trees 1, 2 ,& 3

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TREE 1	150	86672.75	577.818	1430.42668
TREE 2	150	98062.08	653.747	2292.48045
TREE 3	150	95950.72	639.671	13106.7239

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	489456.45	2	244728.	43.6245266	4.9317E-	3.01589
Within Groups	2507615.0	447	5609.87			

Total	2997071.	449

APPENDIX F 1

Funtumia elastica Tree 1

Descriptive statistics for density of sapwood & heartwood

Statistics	Sapwood	Heartwood
Mean	507.38052	491.7018
SD	22.23623642	13.95955
Minimum	460.526	460.526
Maximum	569.444	519.481
Count	75	75
Confidence Level (95.0%)	5.11609329	3.2118

ANOVA for SAPWOOD & HEARTWOOD

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Sapwood	75	38053.539	507.3805	494.4502
Heartwood	75	36877.635	491.7018	194.8689

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9218.334781	1	9218.335	26.74	7.41E	3.90
Within Groups	51009.61763	148	344.6596			

Total	60227.95242	149

APPENDIX F 2

Funtumia elastica Tree 2

Descriptive statistics of density for Sapwood and Heartwood

Statistics	Sapwood	Heartwood
Mean	502.5598	493.1585
SD	22.77449	42.87255
Minimum	461.54	148.013
Maximum	559.44	526.316
Count	75	75
Confidence Level (95.0%)	5.24	9.864078

ANOVA for SAPWOOD & HEARTWOOD

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Sapwood	75	37691.99	502.5598	518.6776
Column 2	75	36986.89	493.1585	1838.056

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3314.393	1	3314.393	2.812701	0.095632	3.90506
Within Groups	174398.3	148	1178.367			
Total	177712.7	149				

APPENDIX F

Funtumia elastica Tree 3

Descriptive statistics of density for Sapwood and Heartwood

Statistics	Sapwood	Heartwood
Mean	509.7395	492.9073
SD	22.64229	13.7531
Minimum	460.526	460.5
Maximum	571.444	521.481
Count	75	75
Confidence Level (95.0%)	5.209518	3.164302

ANOVA for SAPWOOD & HEARTWOOD

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Sapwood	75	38230.46	509.7395	512.6733
Heartwood	75	36968.05	492.9073	189.1479

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10624.58	1	10624.58	30.27	1.61E-	3.90506
Within Groups	51934.77	148	350.9106			
Total	62559.34	149				

APPENDIX F 4

Density for Trees 1, 2 & 3 *Funtumia elastica*

TREE 1	TREE 2	TREE 3			
555.556	493.333	557.556	506.667	487.179	506.67
534.247	520.481	536.247	481.013	500	483.013
527.027	528.423	529.027	493.671	493.333	495.67
540.541	554.054	542.541	473.684	468.354	475.68
493.827	523.027	495.247	506.494	506.494	508.5
493.506	522.481	508.667	513.158	481.013	513.2
534.247	527.778	557.556	506.849	476.359	493.506
506.667	559.444	515.15	480.519	488.486	519.481
555.556	512.28	514.821	513.514	474.359	513.514
513.158	547	522.1	519.481	481.013	480.519
512.821	520.231	556.054	493.506	469.136	506.849
520	527.027	529.027	493.506	500	500
554.054	512.821	528.316	493.506	500	500
527.027	513.157	549.945	500	480.519	493.506
526.316	555.556	514.821	520	512	493.506
547.945	506.671	571.444	500	487.5	520
512.821	524.247	529.778	486.842	493.33	500
569.444	483.406	521.481	526.316	473.527	506.494
527.778	483.827	529.027	474.359	493.671	493.827
519.481	540.541	556.054	493.827	480	474.359
527.027	537.027	529.027	506.494	488.486	526.316
554.054	524.247	556.054	487.179	473.684	493.179
525	555.556	527	506.667	487.197	506.667
519.481	540.541	521.481	500	461.538	493.671
493.333	512.821	495.333	493.671	480	500
500	506.494	502	500	486.486	500
500	500	502	513.889	493.671	500
487.5	504.329	489.5	500	500	513.889
493.671	519.481	495.671	500	467.532	500
520.548	493.671	522.548	460.526	486.486	460.526
519.481	506.494	521.481	500	500	506.494
486.842	487.179	488.842	487.805	472.973	489.805
493.671	512.821	495.48	506.173	506.444	508.173
481.481	512.821	469	493.827	480	495.827
462.5	487.179	486.05	506.329	500	508.329
487.179	506.329	489.179	493.506	475	495.506
486.842	493.506	488.8	500	485.5	502
500	493.333	502	500	512.882	502
487.5	481.842	489	512.5	512.6	514.5
469.136	493.671	471.14	512.821	500	514.821

513.158	480.519	513.2
513.889	495.671	515.89
500	506.494	502

513.889	512.821	513.89
466.667	506.329	468.667
487.5	500	489.5
493.827	487.5	495.827
519.481	493.506	521.481
475	506.329	477
500	519.481	502
506.329	472.973	508.329
493.827	480	495.827
480	512.05	482
481.013	493.506	483.013
472.973	512.5	474.973
506.494	472.973	508.494
506.494	513.158	508.484
487.179	473.684	489.178
493.671	506.494	495.672
468.354	493.671	469.345
493.506	486.013	495.51
481.013	500	483.1
487.179	513.889	489.18
486.842	486.842	486.84
506.494	493.671	506.494
487.179	500	489.18
493.506	500	490.51
493.333	513.158	490.51
493.671	506.667	493.33
487.179	486.179	506.329
506.329	481.481	487.18
500	519.481	506.494
512.821	500	512.82
506.494	513.889	478.519
480.519	513.158	502
506.494	148.013	487.19
487.179	520.548	513.481
519.481	487.5	506.33
506.329	493.671	506

512.821	493.506	514.821
500	466.667	502
472.973	487.5	474.973

512.5	487.805	514.5
473.684	500	473.684
480	486.84	461.538
480	526.316	487.5
493.671	474.359	494
460.526	493.827	460.5
493.333	506.494	480
487.5	487.179	500
500	500	493.333
480.519	506.667	480
493.506	493.671	500
500	500	493.506
481.013	513.889	500
469.136	513.889	481.013
481.013	500	474.359
474.359	500	486.486
486.486	460.526	474.359
474.359	500	481.013
500	500	506.329
506.494	506.667	500
500	506.849	493.671
467.532	480.519	486.486
500	513.514	500
486.486	519.481	467.532
493.671	493.506	500
480	493.506	487.5
487.197	500	487.197
461.538	520	480

APPENDIX F 4

ANOVA for Tree 1, 2, & 3

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Tree 1	150	74931.17	499.5412	404.2144
Tree 2	150	74678.88	497.8592	1192.702
Tree 3	150	75198.51	501.3234	419.8614

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	900.3162	2	450.1581	0.66962	0.512416	3.015899
Within Groups	300500	447	672.2594			
Total	301400.3	449				

APPENDIX G1

SHRINKAGE FOR *COLA NITIDA* (BESE)

TREE 1

Descriptive statistics for oven-dry shrinkage

	L	*R*	*T*	*T/R*
Mean	0.29	3.00	7.25	.61
SD	0.28	0.89	1.29	.86
Minimum	0.02	2.03	4.45	.20
Maximum	1.30	6.03	10.10	.40
Count	120.00	120.00	120.00	20.00
Confidence Level (95.0%)	0.05	0.16	0.23	.15

Descriptive statistics for 12% shrinkage

	L	*R*	*T*	*T/R*
Mean	0.25	0.38	0.73	.59
SD	0.31	0.24	0.56	.66
Minimum	0.01	0.01	0.01	.05
Maximum	1.90	0.90	2.25	0.00
Count	120.00	120.00	120.00	20.00
Confidence Level (95.0%)	0.06	0.04	0.10	.66

ANOVA for oven-dry

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	120	34.53	0.29	0.08
R	120	360.08	3.00	0.79
T	120	869.78	7.25	1.68
T/R	120	312.83	2.61	0.74

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3027.7	3	1009.233	1229.7	1E-223	2.62
Within Groups	390.6678	476	0.820731			
Total	3418.368	479				

ANOVA for 12%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	120	29.43	0.25	0.10
R	120	46.16	0.38	0.06
T	120	87.38	0.73	0.32
T/R	120	311.28	2.59	13.37

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	427.50	3	142.50	41.19	0.00	2.62
Within Groups	1646.67	476	3.46			
Total	2074.17	479				

APPENDIX G 2

SHRINKAGE FOR *COLA NITIDA* (BESE)

TREE 2

Descriptive statistics for oven-dry shrinkage

	L	*R*	*T*	*T/R*
Mean	0.31	3.04	7.27	2.79
SD	0.30	0.92	1.33	2.04
Minimum	0.02	2.03	4.45	0.90
Maximum	1.30	6.30	10.50	23.00
Count	120.00	120.00	120.00	120.00
Confidence Level (95.0%)	0.05	0.17	0.24	0.37

Descriptive statistics for 12% shrinkage

	L	*R*	*T*	*T/R*
Mean	0.27	0.69	1.63	2.28
SD	0.32	3.17	7.45	1.98
Minimum	0.01	0.02	0.02	0.10
Maximum	1.90	35.00	78.00	11.50
Count	120.00	120.00	120.00	120.0
Confidence Level (95.0%)	0.06	0.57	1.35	0.36

ANOVA for oven-dry

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	120.00	37.03	0.31	0.09
R	120.00	364.25	3.04	0.85
T	120.00	872.58	7.27	1.76
T/R	120.00	334.30	2.79	4.15

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3005.4	3.00	1001.8	584.82	0.00	2.62
Within Groups	815.41	476.00	1.71			
Total	3820.8	479.00				

ANOVA for 12%

SUMMARY

Groups	Count	Sum	Average	Variance
L	120.00	32.14	0.27	0.10
R	120.00	82.72	0.69	10.04
T	120.00	195.61	1.63	55.57
T/R	120.00	274.00	2.28	3.94

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	298.45	3.00	99.48	5.71	0.00	2.62
Within Groups	8287.32	476.00	17.41			
Total	8585.77	479.00				

APPENDIX G 3

SHRINKAGE FOR *COLA NITIDA* (BESE)
TREE 3

Oven-dry Shrinkage

	L	*R*	*T*	*T/R*
Mean	0.29	3.01	7.23	2.56
SD	0.28	0.90	1.37	0.84
Minimum	0.02	2.03	4.45	1.00
Maximum	1.25	6.30	10.50	5.10
Count	120.00	120.00	120.00	120.00
Confidence Level (95.0%)	0.05	0.16	0.25	0.15

12% Shrinkage

	L	*R*	*T*	*T/R*
Mean	0.29	0.39	0.79	2.40
SD	0.33	0.23	0.64	2.03
Minimum	0.01	0.02	0.04	0.10
Maximum	1.90	0.90	2.70	11.00
Count	120.00	120.00	120.00	120.00
Confidence Level (95.0%)	0.06	0.04	0.12	0.37

ANOVA for Oven-dry Shrinkage
SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	120.00	34.48	0.29	0.08
R	120.00	361.13	3.01	0.81
T	120.00	867.36	7.23	1.89
T/R	120.00	307.50	2.56	0.70

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3015.66	3.00	1005.22	1155.35	0.00	2.62
Within Groups	414.15	476.00	0.87			
Total	3429.81	479.00				

ANOVA for 12% shrinkage

SUMMARY

Groups	Count	Sum	Average	Variance
L	120.00	34.35	0.29	0.11
R	120.00	46.65	0.39	0.05
T	120.00	94.44	0.79	0.41
T/R	120.00	287.80	2.40	4.12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	345.47	3.00	115.16	98.23	0.00	2.62
Within Groups	558.04	476.00	1.17			
Total	903.51	479.00				

APPENDIX G 4

SHRINKAGE FOR *COLA NITIDA* (BESE) ALL TREES

ALL TREES OVENDRY				ALL TREES 12%			
L	R	T	T/R	L	R	T	T/R
1.25	2.28	8.80	3.10	1.11	0.42	0.79	1.80
0.40	3.04	8.10	2.60	0.53	0.70	1.00	1.40
0.22	3.00	10.10	3.40	0.43	0.89	2.24	2.50
0.59	2.80	7.90	3.00	0.33	0.70	1.30	1.80
0.19	2.90	8.80	3.03	0.17	0.76	1.00	1.30
0.25	3.00	9.00	3.00	1.90	0.90	2.20	2.40
0.22	3.04	8.50	2.70	0.30	0.55	1.50	2.70
1.25	2.90	7.77	2.60	0.23	0.34	0.30	1.10
0.90	3.05	10.00	3.30	0.25	0.67	0.48	1.00
0.60	2.44	8.30	3.40	0.27	0.25	0.69	3.10
0.20	2.28	7.90	2.80	0.32	0.50	0.25	0.50
0.40	3.01	9.25	3.10	0.29	0.33	0.22	0.60
1.25	2.99	7.50	2.50	0.55	0.76	1.50	2.10
0.40	2.50	7.70	3.10	1.50	0.85	1.00	1.20
0.37	2.90	8.80	3.03	1.20	0.50	1.30	2.60
1.15	2.03	9.01	4.40	1.30	0.43	2.25	5.20
1.20	3.01	7.59	2.50	0.17	0.27	2.18	8.00
1.30	3.03	8.99	3.00	0.45	0.77	1.20	1.50
0.50	3.00	8.50	3.03	0.43	0.29	0.59	2.00
0.10	2.80	9.50	3.40	0.55	0.31	0.33	1.10
0.12	2.30	8.00	3.50	0.10	0.20	0.50	2.50
0.04	2.60	8.10	3.10	0.01	0.30	0.70	2.30
0.06	2.31	8.32	3.60	0.02	0.20	0.65	3.25
0.03	2.70	7.50	2.70	0.03	0.20	0.66	3.30
0.04	2.60	8.40	3.20	0.01	0.30	0.40	1.30
0.15	2.40	8.20	3.40	0.03	0.20	0.27	1.35
0.31	2.21	8.25	3.70	0.02	0.30	0.50	1.60
0.06	2.06	8.30	4.00	0.03	0.10	0.30	3.00
0.04	2.03	8.40	4.10	0.03	0.20	0.80	4.00
0.13	2.80	8.10	2.80	0.10	0.30	0.60	2.00
0.02	2.20	7.35	3.30	0.40	0.20	0.63	3.15
0.07	2.25	7.30	3.20	0.20	0.30	0.40	1.30
0.05	2.15	8.70	4.00	0.20	0.20	0.66	3.30
0.12	2.05	8.10	3.90	0.20	0.10	0.47	4.70
0.03	2.30	8.50	3.60	0.10	0.20	0.32	1.60

0.02	2.30	7.10	3.10	0.30	0.30	0.44	1.50
0.14	2.70	8.29	3.10	0.20	0.40	0.43	1.10
0.10	2.60	7.20	3.00	0.50	0.20	0.25	1.25
0.04	2.29	7.50	3.30	0.10	0.30	0.35	1.20
0.07	2.20	8.32	4.00	0.40	0.30	0.70	2.30
0.10	2.40	7.60	3.20	0.09	0.35	0.66	1.80
0.10	2.50	7.30	3.00	0.34	0.10	1.10	11.00
0.08	2.44	7.94	3.30	0.02	0.30	0.25	1.00
0.20	2.48	5.54	2.20	0.10	0.25	0.10	0.40
0.14	2.13	7.26	3.40	0.07	0.35	0.65	2.00
0.20	2.50	8.10	3.20	0.15	0.30	0.55	1.80
0.20	2.50	5.56	2.20	0.26	0.10	0.37	3.70
0.15	2.30	6.30	2.70	0.20	0.26	0.64	2.50
0.50	2.45	7.60	3.10	0.40	0.34	0.15	0.40
0.30	2.50	7.33	2.90	0.35	0.29	0.22	0.70
0.80	2.70	6.40	0.20	0.33	0.33	0.10	0.30
0.90	2.40	5.77	2.40	0.27	0.27	1.50	5.50
0.12	2.44	8.00	3.30	0.25	0.35	0.61	1.70
0.10	2.40	8.00	3.30	0.23	0.33	0.70	2.10
0.30	2.50	7.30	3.00	0.40	0.15	0.39	2.60
0.20	2.48	7.95	3.20	0.50	0.25	0.44	2.00
0.14	2.12	7.30	3.40	0.70	0.10	0.35	3.50
0.10	2.14	5.50	2.50	0.10	0.20	0.25	1.20
0.10	2.25	6.76	3.00	0.20	0.21	0.35	1.60
0.20	3.00	5.56	1.80	0.29	0.33	0.62	1.80
0.24	4.22	4.45	1.05	0.04	0.25	0.40	1.60
0.13	2.17	6.98	3.20	0.02	0.15	0.20	1.30
0.19	2.94	5.58	2.00	0.01	0.01	0.20	20.00
0.14	3.90	4.76	1.20	0.04	0.12	0.16	1.30
0.20	2.27	7.98	3.50	0.02	0.20	0.50	2.50
0.24	4.22	5.58	1.30	0.01	0.15	0.10	0.60
0.13	2.19	6.98	3.20	0.03	0.12	0.15	1.25
0.20	2.90	5.73	2.10	0.05	0.22	0.50	2.30
0.12	4.00	7.00	2.00	0.02	0.24	0.16	0.60
0.24	3.90	4.99	1.30	0.04	0.02	0.20	1.00
0.20	2.99	5.05	2.10	0.01	0.15	0.30	2.00
0.14	3.50	4.55	1.30	0.01	0.01	0.30	30.00
0.50	4.05	4.45	1.10	0.03	0.11	0.50	4.50
0.13	4.30	6.50	1.50	0.04	0.12	0.17	1.40
0.20	3.77	4.76	1.30	0.02	0.15	0.20	1.30
0.17	2.94	5.58	2.09	0.05	0.25	0.04	0.20
0.25	2.22	7.98	3.60	0.03	0.24	0.02	0.10

0.30	4.17	8.00	2.00	0.01	0.20	0.02	0.10
0.20	3.90	4.80	1.20	0.03	0.17	0.01	0.05
0.12	2.27	6.20	3.00	0.04	0.13	0.03	0.23
0.14	3.78	7.77	2.10	0.08	0.74	1.05	1.40
0.12	6.03	6.20	1.00	0.07	0.90	1.40	1.50
0.10	3.90	7.20	2.00	0.06	0.10	1.20	12.00
0.24	2.80	7.90	3.00	0.11	0.82	1.60	2.00
0.20	2.44	7.70	3.20	0.15	0.45	0.90	2.00
0.30	3.66	6.20	2.00	0.07	0.82	1.05	1.30
0.40	4.50	7.50	1.60	0.08	0.74	2.10	3.00
0.70	5.50	8.00	1.40	0.06	0.10	1.40	14.00
0.10	6.03	6.66	1.10	0.10	0.90	1.60	2.00
0.12	3.90	6.50	1.60	0.12	0.45	2.00	4.40
0.15	2.80	7.35	3.00	0.08	0.35	0.90	2.60
0.20	3.78	7.60	2.00	0.05	0.27	1.20	4.40
0.24	5.40	7.77	1.40	0.13	0.77	1.60	2.10
0.20	3.50	6.20	2.00	0.09	0.60	0.15	0.25
0.30	2.30	7.20	3.10	0.11	0.82	1.70	2.10
0.14	4.50	6.50	1.40	0.15	0.45	1.50	3.30
0.10	2.50	8.20	3.30	0.07	0.74	1.60	2.20
0.24	3.25	6.70	2.10	0.06	0.66	1.20	2.00
0.30	6.03	7.90	1.30	0.08	0.82	0.25	0.30
0.12	3.78	7.77	2.10	0.10	0.70	2.10	3.00
0.13	2.35	8.85	3.70	0.08	0.49	0.54	1.10
0.10	4.20	7.32	1.70	0.04	0.69	1.38	2.00
0.38	2.15	8.35	3.80	0.11	0.05	0.34	6.80
0.25	2.47	6.77	2.70	0.04	0.35	0.86	2.40
0.47	2.63	4.80	1.80	0.23	0.30	0.46	1.50
0.50	3.72	5.77	1.50	0.07	0.50	0.44	1.00
0.39	2.50	6.35	2.50	0.20	0.39	0.54	1.40
0.42	4.00	4.85	1.20	0.33	0.69	0.85	1.20
0.50	4.20	5.77	1.40	0.50	0.69	0.76	1.10
0.90	2.47	8.50	3.40	0.74	0.49	0.60	1.20
0.37	3.30	7.70	2.30	0.25	0.35	0.69	1.90
0.24	2.99	8.88	2.90	0.15	0.27	0.54	2.00
0.18	3.00	7.40	2.50	0.66	0.68	0.32	0.50
0.33	2.25	5.25	2.30	0.59	0.67	0.78	1.20
0.25	2.49	5.15	2.10	0.23	0.44	0.39	1.00
0.38	3.50	4.90	1.40	0.78	0.50	0.59	1.20
0.10	4.20	5.75	1.40	0.11	0.35	0.22	1.00
0.13	4.00	8.32	2.10	0.29	0.40	1.38	3.40
0.15	2.63	8.05	3.10	0.76	0.60	1.40	2.30

0.60	2.15	7.32	3.40	0.39	0.90	1.29	1.40
0.20	2.44	8.80	3.60	0.55	0.42	0.80	1.90
0.40	3.05	8.10	2.60	0.43	0.70	0.33	0.50
1.25	2.90	10.10	3.50	0.45	0.90	0.59	0.60
0.40	3.04	7.90	2.60	0.17	0.76	1.00	1.30
0.37	3.00	8.80	3.00	1.30	0.55	2.24	4.10
1.15	2.90	9.00	3.10	1.20	0.89	1.30	1.50
1.20	2.80	8.50	3.00	1.50	0.70	2.20	3.10
1.30	3.00	7.90	2.60	0.55	0.34	1.00	2.90
0.50	3.04	10.00	3.30	0.29	0.31	2.20	7.10
1.10	2.82	8.30	2.90	0.32	0.29	0.48	1.60
1.25	2.80	9.50	3.40	0.27	0.77	0.69	1.10
0.40	3.00	8.50	2.80	0.25	0.27	0.22	0.80
0.22	3.03	8.99	3.10	1.11	0.43	2.24	5.20
0.59	3.01	7.59	2.50	0.53	0.50	2.27	5.40
0.19	2.03	9.01	4.40	0.43	0.85	1.30	1.50
0.25	2.90	8.80	3.00	0.33	0.76	0.59	0.70
0.22	2.50	7.60	3.00	0.17	0.33	0.33	1.00
1.25	2.99	9.25	3.10	0.30	0.50	1.20	2.40
0.90	3.10	10.50	3.40	1.90	0.25	2.18	8.70
0.60	2.82	8.00	2.80	1.12	0.67	78.00	1.20
0.07	2.80	8.32	3.10	0.40	0.30	0.63	2.10
0.04	2.03	7.50	3.60	0.20	0.30	0.60	2.00
0.10	2.06	7.20	3.50	0.10	0.20	0.80	4.00
0.14	2.21	8.29	3.70	0.30	0.40	0.30	1.10
0.02	2.40	7.10	3.00	0.30	0.30	0.50	1.60
0.03	2.60	8.50	3.30	0.20	0.20	0.27	1.30
0.12	2.70	8.10	3.00	0.10	0.10	0.40	4.00
0.05	2.31	8.70	4.10	0.03	0.20	0.66	3.30
0.07	2.60	7.30	2.80	0.02	0.30	0.65	2.20
0.02	2.30	7.35	3.20	0.01	0.20	0.70	3.50
0.12	2.20	8.00	3.60	0.10	0.30	0.50	1.60
0.04	2.29	8.10	3.50	0.40	0.20	2.30	11.50
0.06	2.60	8.32	3.20	0.10	0.40	0.28	0.70
0.03	2.70	7.50	2.70	0.50	0.30	0.25	0.80
0.04	2.30	8.40	3.60	0.20	0.10	0.50	5.00
0.15	3.30	8.20	2.50	0.30	0.20	0.43	2.10
0.13	2.05	8.25	4.00	0.10	0.20	0.63	3.10
0.06	2.15	8.30	4.10	0.40	0.10	0.70	7.00
0.04	2.25	8.40	3.70	0.02	0.20	0.35	1.70
0.09	2.20	8.10	4.10	0.01	0.40	27.00	0.60
0.20	2.48	7.26	2.90	0.29	35.00	0.62	1.70
0.10	2.50	5.54	2.20	0.20	0.10	0.35	3.10

0.10	2.40	7.94	3.30	0.10	0.30	0.25	1.00
0.14	2.44	7.30	3.00	0.70	0.25	0.35	1.40
0.20	2.40	7.60	3.20	0.50	0.35	0.44	1.30
0.10	3.00	5.60	3.00	0.09	0.33	0.66	2.00
0.10	2.25	8.10	3.60	0.34	0.21	1.10	5.20
0.08	2.14	6.30	2.90	0.20	0.20	0.25	1.20
0.20	2.12	7.33	3.40	0.10	0.10	0.10	1.00
0.14	2.48	7.60	3.10	0.07	0.25	0.65	2.60
0.30	2.40	6.40	2.60	0.40	0.30	0.70	2.30
0.10	2.50	5.56	2.20	0.23	0.10	0.61	6.10
0.12	2.44	6.76	2.70	0.25	0.26	0.10	0.40
0.90	2.48	5.50	2.20	0.27	0.20	1.50	7.50
0.80	2.13	7.30	3.40	0.33	0.27	0.22	1.00
0.20	2.50	7.95	3.20	0.15	0.90	0.55	2.10
0.80	2.70	8.00	2.90	0.26	0.33	0.35	1.10
0.15	2.40	8.00	3.30	0.20	0.35	0.64	2.00
0.30	2.44	5.77	2.40	0.40	0.27	0.15	0.50
0.50	2.45	7.30	3.10	0.35	0.20	0.22	1.10
0.20	4.99	4.80	0.90	0.05	0.25	0.03	0.10
0.14	3.90	6.20	1.60	0.02	0.16	0.13	1.00
0.50	4.00	8.00	2.00	0.04	0.17	0.10	0.50
0.13	2.90	7.98	2.70	0.01	0.13	0.02	0.10
0.20	2.19	5.58	2.50	0.01	0.20	0.15	1.00
0.17	4.22	4.76	1.10	0.03	0.24	0.16	0.60
0.27	2.27	6.50	2.80	0.02	0.25	0.20	0.80
0.30	3.90	4.45	1.10	0.05	0.15	0.20	1.30
0.20	2.94	4.55	1.50	0.04	0.12	0.40	3.30
0.12	2.17	5.05	2.30	0.01	0.07	0.30	4.30
0.24	4.22	4.45	1.00	0.02	0.02	0.17	8.50
0.12	4.30	4.99	1.20	0.02	0.24	0.10	0.40
0.20	2.27	7.00	3.10	0.04	0.02	0.02	1.00
0.13	3.90	5.73	1.50	0.05	0.40	0.50	1.20
0.24	4.17	6.98	2.10	0.01	0.03	0.04	1.30
0.20	2.22	5.58	2.50	0.02	0.20	0.03	0.20
0.14	2.94	7.98	2.70	0.04	0.25	0.02	0.10
0.19	3.77	5.58	1.50	0.03	0.13	0.16	1.20
0.13	4.50	4.76	1.10	0.01	0.06	0.14	2.30
0.24	2.17	6.98	3.20	0.04	0.09	0.15	1.60
0.15	3.78	6.20	1.60	0.08	0.70	0.90	1.30
0.20	6.03	7.77	1.30	0.05	0.82	2.00	2.40
0.24	3.09	7.20	2.30	0.13	0.66	1.60	2.40
0.20	2.80	7.90	3.00	0.09	0.74	1.40	2.10
0.30	2.44	7.70	3.10	0.11	0.45	2.40	5.30

0.14	3.78	6.50	1.70	0.15	0.82	1.05	1.30
0.10	6.03	7.35	1.20	0.07	0.60	0.90	1.50
0.24	3.25	7.60	2.30	0.06	0.77	2.10	2.70
0.30	2.50	7.77	3.10	0.08	0.27	1.60	6.00
0.12	4.50	6.20	1.40	0.10	0.35	1.20	3.40
0.14	3.66	7.20	2.10	0.08	0.45	1.40	3.10
0.12	4.50	7.70	1.70	0.07	0.90	1.05	1.20
0.10	5.50	7.90	1.40	0.06	0.75	2.15	2.80
0.24	6.30	6.70	1.10	0.11	0.74	2.25	3.00
0.20	3.90	8.20	2.10	0.15	0.82	1.20	1.50
0.30	4.50	6.50	1.40	0.07	0.45	1.60	3.50
0.15	2.30	6.20	3.10	0.09	0.82	1.50	1.80
0.70	3.50	7.50	2.10	0.06	0.45	1.75	3.80
0.10	5.40	8.00	1.50	0.12	0.90	0.15	0.20
0.20	3.78	6.66	1.70	0.08	0.74	1.60	2.20
0.72	2.15	8.85	4.10	0.39	0.49	1.29	2.60
0.50	2.63	7.32	3.10	0.76	0.69	1.40	2.00
0.10	4.00	8.35	2.10	0.11	0.50	1.38	3.10
0.20	4.20	6.77	1.60	0.29	0.39	0.22	1.10
0.47	3.50	4.80	1.40	0.78	0.66	0.59	1.00
0.30	2.49	5.77	2.30	0.33	0.30	0.39	1.30
0.63	2.25	6.35	2.80	0.59	0.35	0.78	2.20
0.47	3.00	4.85	1.60	0.66	0.05	0.32	6.40
0.13	2.99	5.77	1.90	0.15	0.69	0.54	0.70
0.10	3.30	8.50	2.50	0.25	0.49	0.69	1.40
0.36	2.35	7.32	3.10	0.76	0.90	0.60	0.60
0.25	4.20	8.05	1.90	0.69	0.44	0.54	1.20
0.47	2.15	8.32	4.10	0.05	0.60	0.38	2.30
0.50	2.47	5.75	23.00	0.11	0.40	0.34	1.00
0.39	2.33	4.90	2.10	0.04	0.35	0.86	2.40
0.42	3.72	5.15	1.40	0.32	0.67	0.46	0.60
0.90	2.50	5.25	2.10	0.07	0.27	0.44	1.60
0.60	4.00	7.40	1.80	0.20	0.35	0.54	1.50
0.15	4.20	8.88	2.10	0.33	0.69	0.85	1.20
0.38	2.47	7.40	3.10	0.50	0.70	0.76	1.10
1.10	2.03	8.50	4.20	0.33	0.34	2.20	6.50
1.25	2.90	9.00	3.10	0.17	0.31	2.40	7.70
0.40	2.50	8.80	3.50	0.30	0.29	2.20	7.50
0.22	2.99	7.90	2.60	1.90	0.77	0.48	0.60
0.59	3.10	8.10	2.60	1.12	0.27	0.69	2.50
0.20	2.82	8.80	3.10	0.43	0.30	1.00	3.00
0.40	2.44	8.00	3.30	0.53	0.76	0.59	0.70

1.25	3.05	9.25	3.00	1.00	0.86	0.80	0.90
0.40	2.90	7.60	2.60	0.25	0.50	0.24	0.50
0.37	3.04	10.50	3.40	0.27	0.67	1.00	1.50
0.60	3.00	8.80	2.90	0.29	0.25	2.20	8.80
0.90	2.90	7.59	2.60	0.55	0.50	1.30	2.60
1.25	2.82	8.99	3.20	0.43	0.33	0.33	1.00
0.22	3.10	8.50	2.70	0.45	0.43	1.20	2.70
0.24	2.99	9.50	3.20	0.17	0.27	2.18	8.10
0.19	2.50	10.00	4.00	1.30	0.70	0.78	1.10
1.25	2.90	7.90	2.70	1.20	0.89	2.70	3.00
0.40	2.03	10.10	5.10	0.32	0.55	1.30	2.40
0.22	2.80	8.30	3.10	0.29	0.90	2.24	2.50
0.40	3.01	10.10	3.30	1.50	0.42	0.22	0.50
0.15	3.30	8.20	2.50	0.20	0.20	0.37	1.30
0.31	2.05	8.25	4.00	0.12	0.10	0.40	4.00
0.06	2.15	8.30	3.80	0.03	0.20	0.66	3.30
0.04	2.25	8.40	3.70	0.02	0.30	0.65	2.20
0.09	2.20	8.10	3.60	0.01	0.20	0.70	3.50
0.07	2.80	8.32	2.90	0.04	0.30	0.63	2.10
0.04	2.03	7.50	3.60	0.20	0.30	0.60	2.00
0.10	3.06	7.20	3.50	0.10	0.20	0.80	4.00
0.14	2.21	8.29	3.70	0.30	0.40	0.30	0.70
0.02	2.40	7.10	2.90	0.30	0.30	0.50	1.60
0.12	2.20	8.00	3.60	0.01	0.40	0.27	0.60
0.04	2.29	8.10	3.50	0.02	0.20	0.35	1.70
0.06	2.60	8.32	1.30	0.40	0.10	0.70	7.00
0.03	2.70	7.50	2.70	0.10	0.20	0.63	3.10
0.04	2.30	8.40	3.60	0.30	0.30	0.50	1.60
0.03	2.60	8.50	3.30	0.10	0.10	0.28	2.80
0.12	2.70	8.10	3.00	0.20	0.40	0.43	1.10
0.05	2.31	8.70	3.70	0.40	0.30	0.30	1.00
0.07	2.60	7.30	2.80	0.30	0.20	0.66	3.30
0.02	2.30	7.35	3.20	0.20	0.10	0.65	6.50
0.15	3.00	7.30	2.40	0.15	0.35	0.39	1.10
0.50	2.25	7.60	3.40	0.23	0.25	0.70	2.80
0.30	2.14	7.94	3.70	0.25	0.30	0.61	2.00
0.20	2.12	5.44	2.50	0.27	0.50	1.00	0.10
0.20	2.48	5.54	2.20	0.33	0.35	0.10	0.30
0.80	2.50	7.26	2.90	0.30	0.30	0.55	1.80
0.90	2.40	8.10	3.40	0.40	0.26	0.37	1.40
0.10	2.44	5.56	2.30	0.50	0.10	0.64	6.40
0.10	2.15	7.60	3.00	0.70	0.34	0.15	0.40

0.80	2.40	7.34	3.10	0.10	0.29	0.22	0.70
0.14	2.50	5.56	2.20	0.29	0.27	0.44	1.60
0.30	2.44	6.76	2.70	0.20	0.33	0.35	1.10
0.12	2.48	5.50	2.20	0.90	0.35	0.25	0.70
0.10	2.13	7.30	3.40	0.02	0.25	0.35	1.40
0.14	2.11	7.95	3.70	0.34	0.15	0.62	4.10
0.10	2.50	7.30	2.90	0.10	0.20	0.66	3.30
0.10	2.40	8.00	3.20	0.70	0.10	1.10	11.00
0.20	2.50	8.00	3.20	0.15	0.21	0.25	1.20
0.15	3.00	5.77	1.90	0.27	0.33	0.10	0.30
0.30	2.49	6.40	2.50	0.40	0.34	0.65	1.90
0.17	3.90	7.98	2.00	0.04	0.25	0.90	3.60
1.25	2.99	4.76	1.60	0.01	0.24	0.40	1.60
0.30	3.50	5.58	1.60	0.02	0.20	0.20	1.00
0.12	4.05	6.98	1.70	0.02	0.17	0.20	1.20
0.20	4.30	4.45	1.00	0.04	0.13	0.16	1.20
0.24	3.77	6.50	1.70	0.02	0.15	0.20	1.30
0.20	2.27	4.75	2.10	0.04	0.12	0.16	1.30
0.13	3.90	5.58	1.40	0.01	0.11	0.50	4.50
0.50	4.17	7.98	1.90	0.03	0.10	0.15	1.50
0.14	2.22	8.00	3.60	0.04	0.15	0.50	3.30
0.24	2.94	4.80	1.60	0.02	0.10	0.04	0.40
0.13	4.00	6.20	1.50	0.05	0.12	0.20	1.60
0.20	2.90	6.98	2.40	0.01	0.22	0.17	0.70
0.12	2.19	5.73	2.60	0.01	0.24	0.50	2.10
0.24	4.22	7.00	1.60	0.03	0.12	0.30	1.50
0.20	3.90	4.99	2.30	0.02	0.02	0.15	7.50
0.14	2.29	5.05	2.20	0.02	0.12	0.50	4.20
0.19	2.27	4.55	2.00	0.04	0.21	0.16	0.70
0.13	2.94	6.50	2.20	0.01	0.15	0.20	1.30
0.24	4.22	4.45	1.00	0.04	0.25	0.30	1.20
0.30	3.78	6.20	1.60	0.08	0.70	1.60	2.30
0.20	6.03	7.20	1.20	0.12	0.82	1.75	2.10
0.24	3.25	7.70	2.40	0.60	0.66	0.15	0.20
0.20	2.50	7.90	3.20	0.90	0.74	1.50	2.00
0.15	4.50	6.70	1.50	0.07	0.45	1.60	3.50
0.14	3.78	8.20	2.20	0.08	0.82	2.40	2.90
0.12	6.03	6.50	1.10	0.05	0.74	1.40	2.10
0.10	3.09	6.20	2.00	0.13	0.90	1.60	1.70
0.24	2.80	7.50	2.60	0.09	0.45	2.00	4.40
0.20	2.44	8.00	3.30	0.11	0.82	0.90	1.10
0.20	2.78	6.66	1.70	0.10	0.45	2.50	5.50
0.10	5.40	7.70	1.40	0.80	0.82	0.15	2.60

0.70	3.50	7.90	2.30	0.06	0.74	1.20	1.60
0.15	2.30	7.20	3.10	0.07	0.75	1.60	2.10
0.30	4.50	7.77	1.70	0.15	0.90	2.10	2.30
0.12	3.66	6.20	1.60	0.08	0.45	1.40	3.10
0.30	4.50	6.50	1.40	0.07	0.35	1.60	4.50
0.24	5.50	7.35	1.30	0.06	0.27	0.15	0.50
0.10	6.30	7.60	1.20	0.11	0.77	1.75	2.30
0.14	3.90	7.77	1.90	0.15	0.60	0.90	1.50
0.25	2.15	8.85	4.10	0.74	0.49	0.46	0.90
0.38	2.63	7.32	2.70	0.50	0.69	0.86	1.20
0.10	4.00	8.35	2.10	0.33	0.05	0.34	6.80
0.13	4.20	6.77	1.60	0.20	0.35	1.38	3.90
0.15	3.50	4.80	1.40	0.07	0.30	0.54	1.80
0.60	2.49	5.77	2.30	0.76	0.44	0.60	1.30
0.37	2.25	6.35	2.80	0.04	0.67	0.76	1.10
0.24	3.30	4.85	1.50	0.11	0.68	0.85	1.20
0.18	2.47	5.77	2.30	0.04	0.27	0.54	2.00
0.33	4.20	8.50	2.00	0.23	0.35	0.44	1.30
0.90	4.00	7.32	1.80	0.39	0.49	0.69	1.40
0.50	2.50	8.05	3.20	0.76	0.90	0.54	0.60
0.47	3.72	8.32	2.30	0.26	0.60	0.32	0.50
0.25	2.63	5.75	2.20	0.11	0.40	0.78	1.90
0.38	2.47	4.90	1.90	0.78	0.35	0.39	1.10
0.10	2.15	5.15	2.40	0.25	0.50	0.59	1.20
0.13	4.20	5.25	1.20	0.15	0.50	0.22	0.40
0.18	2.35	7.70	3.30	0.66	0.39	1.38	3.50
0.24	2.99	4.85	1.60	0.59	0.69	1.40	2.00
0.13	2.15	4.80	2.20	0.23	0.49	1.29	2.60

Descriptive statistics for oven-dry shrinkage

	L	*R*	*T*	*T/R*
Mean	0.29	3.02	7.25	2.65
SD	0.29	0.90	1.33	1.36
Range	1.28	4.27	6.05	22.80
Minimum	0.02	2.03	4.45	0.20
Maximum	1.30	6.30	10.50	23.00
Count	360.00	360.00	360.00	360.00
Confidence Level (95.0%)	0.03	0.09	0.14	0.14

Descriptive statistics for 12% shrinkage

	L	*R*	*T*	*T/R*
Mean	0.27	0.49	1.05	2.43
SD	0.32	1.84	4.34	2.67
Range	1.89	34.99	77.99	29.95
Minimum	0.01	0.01	0.01	0.05
Maximum	1.90	35.00	78.00	30.00
Count	360.00	360.00	360.00	360.00
Confidence Level (95.0%)	0.03	0.19	0.45	0.28

ANOVA for oven-dry shrinkage

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	360.00	106.04	0.29	0.08
R	360.00	1085.46	3.02	0.81
T	360.00	2609.72	7.25	1.77
T/R	360.00	954.63	2.65	1.86

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9046.94	3.00	3015.65	2666.86	0.00	2.61
Within Groups	1623.81	1436.00	1.13			
Total	10670.75	1439.00				

ANOVA for 12% shrinkage

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	360.00	95.92	0.27	0.10
R	360.00	175.53	0.49	3.38
T	360.00	377.43	1.05	18.83
T/R	360.00	873.08	2.43	7.12

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*

Between Groups	1015.68	3.00	338.56	46.01	0.00	2.61
Within Groups	10566.48	1436.00	7.36			
Total	11582.16	1439.00				

APPENDIX H 1

SHRINKAGE FOR *FUNTUMIA ELASTICA* TREES

Funtumia elastica Tree 1

Descriptive statistics for oven-dry shrinkage

	L	*R*	*T*	*T/R*
Mean	0.35	3.19	5.57	1.79
SD	0.13	0.64	1.10	0.38
Minimum	0.14	2.47	0.05	0.77
Maximum	0.71	4.81	7.64	2.57
Count	120.00	120.00	120.00	120.00
Confidence Level (95.0%)	0.02	0.12	0.20	0.07

Descriptive statistics for 12% shrinkage

	L	*R*	*T*	*T/R*
Mean	0.31	2.72	4.89	1.79
SD	0.20	0.42	0.77	0.41
Minimum	0.12	2.17	3.38	1.12
Maximum	2.00	3.65	6.91	2.84
Count	120.00	120.00	120.00	120.00
Confidence Level (95.0%)	0.04	0.08	0.14	0.07

ANOVA for oven-dry shrinkage

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	120.00	41.51	0.35	0.02
R	120.00	383.33	3.19	0.41
T	120.00	668.00	5.57	1.21
T/R	120.00	215.04	1.79	0.15

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1779.11	3.00	593.04	1324.32	0.00	2.62
Within Groups	213.16	476.00	0.45			
Total	1992.27	479.00				

ANOVA for 12% shrinkage

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	120.00	36.73	0.31	0.04
R	120.00	325.82	2.72	0.18
T	120.00	586.55	4.89	0.59
T/R	120.00	215.32	1.79	0.17

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1324.52	3.00	441.51	1814.14	0.00	2.62
Within Groups	115.84	476.00	0.24			
Total	1440.37	479.00				

APPENDIX H 2

Funtumia elastica Tree 2

Descriptive statistics for oven-dry shrinkage

	L	*R*	*T*	*T/R*
Mean	0.53	3.19	5.94	1.81
SD	1.80	0.64	3.96	0.41
Minimum	0.15	2.46	3.85	1.02
Maximum	20.00	4.82	47.66	3.00
Count	120.00	120.00	120.00	120.00
Confidence Level (95.0%)	0.32	0.12	0.72	0.07

Descriptive statistics for 12% shrinkage

	L	*R*	*T*	*T/R*
Mean	0.31	2.79	4.86	1.81
SD	0.13	0.52	0.75	0.41
Minimum	0.13	2.04	3.39	0.84
Maximum	0.68	4.00	6.33	2.75
Count	120.00	120.00	120.00	120.00
Confidence Level (95.0%)	0.02	0.09	0.14	0.07

ANOVA for oven-dry shrinkage
SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	120.00	63.74	0.53	3.23
R	120.00	382.24	3.19	0.41
T	120.00	712.87	5.94	15.68
T/R	120.00	217.78	1.81	0.17

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1933.37	3.00	644.46	132.27	0.00	2.62
Within Groups	2319.25	476.00	4.87			

Total	4252.62	479.00

ANOVA for 12% shrinkage

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	120.00	37.74	0.31	0.02
R	120.00	334.59	2.79	0.27
T	120.00	583.30	4.86	0.57
T/R	120.00	217.45	1.81	0.17

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1307.24	3.00	435.75	1700.45	0.00	2.62
Within Groups	121.98	476.00	0.26			
Total	1429.22	479.00				

APPENDIX H 3

Funtumia elastica Tree 3

Descriptive statistics for oven-dry shrinkage

	L	*R*	*T*	*T/R*
Mean	0.40	3.22	8.85	1.80
SD	0.15	0.67	34.73	0.38
Minimum	0.16	2.31	3.86	1.01
Maximum	0.80	4.83	386.00	2.58
Count	120.00	120.00	120.00	120.00
Confidence Level (95.0%)	0.03	0.12	6.28	0.07

Descriptive statistics for 12% shrinkage

	L	*R*	*T*	*T/R*
Mean	0.37	2.86	4.90	1.78
SD	0.24	0.59	0.75	0.41
Minimum	0.14	2.19	3.34	0.70
Maximum	2.30	5.00	6.34	2.44
Count	120.00	120.00	120.00	120.00
Confidence Level (95.0%)	0.04	0.11	0.14	0.07

ANOVA for oven-dry shrinkage

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	120.00	48.02	0.40	0.02
R	120.00	386.54	3.22	0.44
T	120.00	1061.50	8.85	1206.31
T/R	120.00	215.72	1.80	0.14

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4937.41	3.00	1645.80	5.45	0.00	2.62
Within Groups	143623.11	476.00	301.73			
Total	148560.52	479.00				

ANOVA for 12% shrinkage

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	120.00	44.69	0.37	0.06
R	120.00	342.62	2.86	0.35
T	120.00	588.03	4.90	0.57
T/R	120.00	213.05	1.78	0.16

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1312.40	3.00	437.47	1528.89	0.00	2.62
Within Groups	136.20	476.00	0.29			
Total	1448.60	479.00				

APPENDIX H 4

FUNTUMIA ELASTICA

	ALL TREES OVENDRY				ALL TREES 12%		
L	R	T	T/R	L	R	T	T/R
0.3	3.5	6.5	1.85	0.25	2.3	4.7	2.04
0.2	4.2	5.9	1.4	0.2	3.2	4.6	1.43
0.24	3.55	4.87	1.37	0.21	3.29	4.2	1.27
0.21	4.47	7.26	1.62	0.14	3.05	5.12	1.67
0.5	3.09	6.28	2.03	0.4	2.84	6.91	2.08
0.3	3.5	6.5	1.85	0.25	2.3	4.7	2.04
0.2	4.2	5.9	1.4	0.2	3.2	4.6	1.43
0.24	3.55	4.87	1.37	0.21	3.29	4.2	1.27
0.21	4.47	7.26	1.62	0.14	3.05	5.12	1.67
0.5	3.09	6.28	2.03	0.4	2.84	5.91	2.08
0.3	3.5	6.5	1.85	0.25	2.3	4.7	2.04
0.2	4.2	5.9	1.4	0.2	3.2	4.6	1.43
0.24	3.55	4.87	1.37	0.21	3.29	4.2	1.27
0.21	4.47	7.26	1.62	0.14	3.05	5.12	1.67
0.5	3.09	6.28	2.03	0.4	2.84	5.91	2.08
0.3	3.5	6.5	1.85	0.25	2.3	4.7	2.04
0.2	4.2	5.9	1.4	0.2	3.2	4.6	1.43
0.24	3.55	4.87	1.37	0.21	3.29	4.2	1.27
0.21	4.47	7.26	1.62	0.14	3.05	5.12	1.67
0.5	3.09	6.28	2.03	0.4	2.84	5.91	2.08
0.25	3.11	5.42	1.74	0.23	2.71	5.06	1.87
0.15	2.7	6.67	2.47	0.12	2.43	5.68	2.34
0.28	2.84	6.48	2.28	0.19	3.03	5.62	1.85
0.27	3.28	5.33	1.63	2	2.78	5.18	1.86
0.71	2.65	6.8	2.57	0.67	2.3	6.32	2.75
0.25	3.11	5.42	1.74	0.23	2.71	5.06	1.87
0.15	2.7	6.67	2.47	0.12	2.43	5.68	2.34
0.28	2.84	6.48	2.28	0.19	3.03	5.62	1.85
0.27	3.28	5.33	1.63	0.2	2.78	5.18	1.86
0.71	2.65	6.8	2.57	0.67	2.3	6.32	2.75
0.25	3.11	5.42	1.74	0.23	2.71	5.06	1.87
0.15	2.7	6.67	2.47	0.12	2.43	5.68	2.84
0.28	2.84	6.48	2.28	0.19	3.03	5.62	1.85
0.27	3.28	5.33	1.63	0.2	2.78	5.18	1.86
0.71	2.65	6.8	2.57	0.67	2.3	6.32	2.75
0.25	3.11	5.42	1.74	0.23	2.71	5.06	1.87
0.15	2.7	6.67	2.47	0.12	2.43	5.68	2.34
0.28	2.84	6.48	2.28	0.19	3.03	5.62	1.85

0.27	3.28	5.33	1.63	0.2	2.78	5.18	1.85
0.71	2.65	6.8	2.57	0.67	2.3	6.32	2.75
0.43	2.84	0.05	0.77	0.37	2.48	4.33	1.73
0.14	3.36	4.05	1.2	0.12	3	3.38	1.12
0.26	3.77	3.84	1.01	0.2	3.1	3.53	1.13
0.39	2.83	4.72	1.66	0.36	2.48	4.35	1.75
0.19	3.2	3.89	1.21	0.15	3.05	3.43	1.12
0.43	2.84	5.05	1.77	0.37	2.48	4.33	1.74
0.14	3.36	4.05	1.2	0.12	3	3.38	1.12
0.26	3.77	3.84	1.01	0.2	3.1	3.53	1.13
0.39	2.83	4.72	1.66	0.36	2.48	4.35	1.75
0.19	3.2	3.89	1.21	0.15	3.05	4.33	1.12
0.43	2.84	5.05	1.77	0.37	2.48	4.33	1.74
0.14	3.36	4.05	1.2	0.12	3	3.38	1.12
0.26	3.77	3.84	1.01	0.2	3.1	3.83	1.13
0.39	2.83	4.72	1.66	0.36	2.48	4.35	1.75
0.19	3.2	3.89	1.21	0.15	3.05	3.43	1.12
0.43	2.84	5.05	1.77	0.37	2.48	4.33	1.74
0.14	3.36	4.05	1.2	0.12	3	3.38	1.12
0.26	3.77	3.84	1.01	0.2	3.1	3.53	1.13
0.39	2.83	4.72	1.66	0.36	2.48	4.35	1.75
0.19	3.2	3.89	1.21	0.15	3.05	3.43	1.12
0.43	4.68	7.64	1.63	0.39	3.56	5.47	1.53
0.48	4.81	7.19	1.49	0.41	3.65	5.18	1.41
0.53	2.9	6.39	2.2	0.46	2.7	6.5	2.24
0.46	3.55	4.88	1.37	0.41	3.39	4.57	1.34
0.43	3.18	6.21	1.95	0.38	2.78	5.79	2.08
0.43	4.68	7.64	1.63	0.39	3.56	5.47	1.53
0.48	4.68	7.19	1.49	0.41	3.65	5.8	1.41
0.52	4.81	6.39	2.2	0.46	2.7	6.05	2.24
0.46	2.9	4.88	1.37	0.41	3.39	4.57	1.34
0.43	3.18	6.21	1.95	0.38	2.78	5.79	2.08
0.43	4.68	7.64	1.63	0.39	3.56	5.47	1.53
0.48	4.81	7.19	1.49	0.41	3.65	5.18	1.41
0.53	2.9	6.39	2.2	0.46	2.7	6.05	2.24
0.46	3.55	4.88	1.3	0.41	3.39	4.57	1.34
0.43	3.18	6.21	1.95	0.38	2.78	5.79	2.08
0.43	4.68	7.64	1.63	0.39	3.56	5.47	1.53
0.48	4.81	7.19	1.49	0.41	3.65	5.18	1.41
0.53	2.9	6.39	2.2	0.46	2.4	6.05	2.24
0.46	3.55	4.88	1.37	0.41	3.39	4.57	1.34
0.43	3.18	6.21	1.95	0.38	2.78	5.79	2.08
0.46	2.83	5.12	1.81	0.37	2.37	4.75	1.41

0.42	2.92	5.29	1.81	0.32	2.52	4.87	1.93
0.38	2.62	5.84	2.22	0.27	2.42	5.36	2.21
0.26	2.83	5.71	2.01	0.21	2.42	5.12	2.12
0.43	2.83	5.93	2.1	0.35	2.43	5.46	2.25
0.46	2.83	5.12	1.81	0.37	2.37	4.75	1.41
0.42	2.92	5.29	1.81	0.37	2.52	4.87	1.93
0.38	2.62	5.84	2.23	0.27	2.42	5.36	2.21
0.26	2.83	5.71	2.02	0.21	2.42	5.12	2.12
0.43	2.83	5.93	2.1	0.35	2.43	5.46	2.25
0.46	2.83	5.12	1.81	0.37	2.37	4.75	1.41
0.42	2.92	5.29	1.81	0.32	2.52	4.87	1.93
0.38	2.62	5.84	2.23	0.27	2.42	5.36	2.21
0.26	2.83	5.71	2.02	0.21	2.42	5.12	1.12
0.43	2.83	5.93	2.1	0.35	2.43	5.46	2.25
0.46	2.83	5.12	1.81	0.37	2.37	4.75	1.41
0.42	2.92	5.29	1.81	0.32	2.52	4.87	1.93
0.38	2.62	5.84	2.32	0.27	2.42	5.36	2.21
0.26	2.83	5.71	2.02	0.21	2.42	5.12	1.12
0.43	2.83	5.93	2.1	0.35	2.43	5.46	2.25
0.36	2.51	4.46	1.77	0.33	2.21	3.99	1.8
0.41	2.57	5.07	1.97	0.36	2.17	4.54	2.09
0.28	2.78	5.17	1.85	0.24	2.42	4.59	1.89
0.26	2.47	5.25	2.12	0.2	2.22	4.52	2.03
0.27	2.68	5.04	1.88	0.21	2.23	4.15	1.86
0.36	2.51	4.46	1.77	0.33	2.21	3.99	1.8
0.41	2.57	5.07	1.97	0.36	2.17	4.54	2.09
0.28	2.78	5.17	1.85	0.24	2.42	4.59	1.89
0.26	2.47	5.25	2.12	0.2	2.22	4.52	2.03
0.27	2.68	5.04	1.88	0.21	2.23	4.15	1.86
0.36	2.51	4.46	1.77	0.33	2.21	3.99	1.8
0.41	2.57	5.07	1.97	0.36	2.17	4.54	2.09
0.28	2.78	5.17	1.85	0.24	2.42	4.59	1.89
0.26	2.47	5.25	2.12	0.2	2.22	4.52	2.03
0.27	2.68	5.04	1.88	0.21	2.23	4.15	1.86
0.36	2.51	4.46	1.77	0.33	2.21	3.99	1.8
0.41	2.57	5.07	1.97	0.36	2.17	4.54	2.09
0.28	2.78	5.17	1.85	0.24	2.42	4.59	1.89
0.26	2.47	5.25	2.12	0.2	2.22	4.52	2.03
0.27	2.68	5.04	1.88	0.21	2.23	4.15	1.86
0.5	3.3	6.4	1.94	0.27	2.5	4.5	1.8
0.4	4.4	5.7	1.3	0.4	3.4	4.7	1.38
0.25	3.52	4.86	1.38	0.23	3.28	4.3	1.31
0.23	4.45	7.24	1.63	0.16	3.07	5.14	1.67

0.6	3.1	6.27	2.02	0.6	2.82	5.9	2.09
0.3	3.3	6.4	1.94	0.27	2.5	4.5	1.8
0.4	4.4	5.7	1.3	0.4	3.4	4.7	1.38
0.25	3.52	4.86	1.38	0.23	3.28	4.3	1.31
0.23	4.45	7.24	1.63	0.16	3.07	5.14	1.67
0.6	3.1	6.27	2.02	0.6	2.82	5.9	2.09
0.5	3.3	6.4	1.94	0.27	2.5	4.5	1.8
0.6	4.4	5.7	1.3	0.4	3.4	4.7	1.38
0.25	3.52	4.86	1.38	0.23	3.28	4.3	1.31
0.23	4.45	7.24	1.63	0.16	3.07	5.14	1.67
0.6	3.1	6.27	2.02	0.6	2.82	5.9	2.09
0.5	3.3	6.4	1.94	0.27	2.5	4.5	1.8
0.4	4.4	5.7	1.3	0.4	3.4	4.7	1.38
0.25	3.52	4.86	1.38	0.23	3.28	4.3	1.31
0.23	4.45	7.24	1.63	0.16	3.07	5.14	1.67
0.6	3.1	6.27	2.02	0.6	2.82	5.9	2.09
0.26	3.12	5.44	1.74	0.24	2.72	5.07	1.86
0.46	2.8	6.68	2.39	0.13	2.44	5.69	2.33
0.29	2.85	6.49	2.28	0.21	3.04	5.63	1.85
0.28	3.29	5.35	1.63	0.3	2.79	5.19	1.86
0.71	2.66	6.9	3	0.68	2.3	6.33	2.75
0.26	3.12	5.44	1.74	0.24	2.72	5.07	1.86
0.16	2.8	6.68	2.39	0.13	2.44	5.69	2.33
0.29	2.85	6.49	2.28	0.21	3.04	5.63	1.85
0.28	3.29	5.35	1.63	0.3	2.79	5.19	1.86
0.71	2.66	6.9	3	0.68	2.3	6.33	2.75
0.26	3.12	5.44	1.74	0.24	2.72	5.07	1.86
0.16	2.8	6.68	2.39	0.13	2.44	5.69	2.33
0.29	2.85	6.49	2.28	0.21	3.04	5.63	1.85
0.28	3.29	5.35	1.63	0.3	2.79	5.19	1.86
0.71	2.66	6.9	3	0.68	2.3	6.33	2.75
0.26	3.12	5.44	1.74	0.24	2.72	5.07	1.86
0.16	2.8	6.68	2.39	0.13	2.44	5.69	2.33
0.29	2.85	6.49	2.28	0.21	2.04	5.63	1.85
0.28	3.29	5.35	1.63	0.3	2.79	5.19	1.86
0.71	2.66	6.9	3	0.68	2.3	6.33	2.75
0.44	2.85	5.06	1.78	0.38	2.49	4.34	1.74
0.15	3.37	4.06	1.2	0.13	4	3.39	0.84
0.27	3.78	3.85	1.02	0.3	3.2	3.54	1.11
0.4	2.84	5.73	1.66	0.36	2.49	4.36	1.75
0.2	3.3	3.9	1.18	0.15	3.06	3.44	1.12
0.44	2.85	5.06	1.78	0.38	2.49	4.34	1.74

0.15	3.37	4.06	1.2	0.13	4	3.39	0.84
0.27	3.78	3.85	1.02	0.3	3.2	3.54	1.11
0.4	2.84	4.73	1.66	0.36	2.49	4.36	1.75
20	3.3	3.9	1.18	0.15	3.06	3.44	1.12
0.44	2.85	5.06	1.78	0.38	2.49	4.34	1.74
0.15	3.37	4.06	1.2	0.13	4	3.39	0.84
0.27	3.78	3.85	1.02	0.3	3.2	3.54	1.11
0.4	2.84	4.73	1.66	0.36	2.49	4.36	1.75
0.2	3.3	3.9	1.18	0.15	3.06	3.44	1.12
0.44	2.85	5.06	1.78	0.38	2.46	4.34	1.74
0.15	3.37	4.06	1.2	0.13	4	3.39	0.84
0.27	3.78	3.85	1.02	0.3	3.2	3.54	1.11
0.4	2.84	4.73	1.66	0.36	2.49	4.36	1.75
0.2	3.3	3.9	1.18	0.15	3.06	3.44	1.12
0.44	4.67	7.66	1.64	0.4	3.57	5.48	1.54
0.47	4.82	7.2	1.49	0.42	3.67	5.19	1.41
0.54	2.8	6.38	2.28	0.48	2.6	6.06	2.33
0.47	3.54	4.89	1.83	0.43	3.38	4.46	1.35
0.45	3.19	6.23	1.95	0.39	2.76	5.77	2.09
0.44	4.67	7.66	1.64	0.4	3.57	5.78	1.45
0.47	4.82	7.2	1.49	0.42	3.67	5.19	1.41
0.54	2.8	6.38	2.28	0.48	3.6	6.06	2.33
0.47	3.54	4.89	1.38	0.43	3.38	4.56	1.35
0.45	3.19	6.23	1.95	0.39	3.76	5.77	2.09
0.44	4.67	47.66	1.64	0.4	3.57	5.48	1.54
0.47	4.82	7.2	1.49	0.42	3.67	5.19	1.41
0.54	2.8	6.38	2.28	0.48	3.6	6.06	2.33
0.47	3.54	4.89	1.38	0.43	3.38	4.56	1.35
0.45	3.19	6.23	1.95	0.34	3.76	5.77	2.09
0.44	4.67	7.66	1.64	0.4	3.57	5.48	1.54
0.47	4.82	7.2	1.49	0.42	3.67	5.19	1.41
0.54	2.8	6.38	2.28	0.48	2.6	6.06	2.33
0.47	3.54	4.89	1.38	0.43	3.38	4.56	1.35
0.45	3.19	6.23	1.95	0.39	2.76	5.77	2.09
0.44	2.81	5.11	1.82	0.36	2.36	4.73	2
0.41	2.91	5.27	1.81	0.31	2.51	4.86	1.94
0.34	2.61	5.83	2.23	0.26	2.41	5.35	2.22
0.25	2.81	5.7	2.02	0.2	2.41	5.11	2.12
0.41	2.81	5.92	2.11	0.34	2.42	5.45	2.25
0.44	2.81	5.11	1.82	0.36	2.36	4.73	2
0.41	2.91	5.27	1.81	0.31	2.51	4.86	1.94
0.37	2.61	5.83	2.23	0.26	2.41	5.35	2.22
0.25	2.81	5.7	2.02	0.23	2.41	5.11	2.12

0.41	2.81	5.92	2.11	0.34	2.42	5.45	2.15
0.44	2.81	5.11	1.82	0.36	2.36	4.73	2
0.41	2.91	5.27	1.81	0.31	2.51	4.86	1.94
0.37	2.61	5.83	2.23	0.26	2.41	5.35	2.22
0.25	2.81	5.7	2.02	0.2	2.41	5.11	2.12
0.41	2.81	5.92	2.11	0.34	2.42	5.45	2.25
0.44	2.81	5.11	1.82	0.36	2.36	4.73	2
0.41	2.91	5.27	1.1	0.31	2.57	4.86	1.94
0.37	2.61	5.83	2.23	0.26	2.41	5.35	2.22
0.25	2.81	5.7	2.02	0.2	2.41	5.11	2.12
0.41	2.81	5.92	2.11	0.34	2.42	5.45	2.25
0.35	2.5	4.45	1.78	0.32	2.2	3.98	1.81
0.4	2.56	5.06	1.98	0.35	2.16	4.53	2.09
0.27	2.77	5.16	1.86	0.23	2.41	4.58	1.9
0.25	2.46	5.24	2.13	0.2	2.21	4.51	2.04
0.26	2.67	5.03	1.88	0.21	2.22	4.14	1.86
0.35	2.5	4.45	1.78	0.32	2.2	3.98	1.81
0.4	2.56	5.66	1.98	0.35	2.16	4.53	2.09
0.27	2.77	5.16	1.86	0.23	2.41	4.58	1.9
0.25	2.46	5.24	2.13	0.2	2.21	4.51	2.04
0.26	2.67	5.03	1.88	0.21	2.22	4.14	1.86
0.35	2.5	4.45	1.78	0.32	2.2	3.98	1.81
0.4	2.56	5.06	1.98	0.35	2.16	4.35	2.09
0.27	2.77	5.16	1.86	0.23	2.41	4.58	1.9
0.25	2.46	5.24	2.13	0.2	2.21	4.51	2.04
0.25	2.67	5.03	1.88	0.21	2.22	4.14	1.86
0.35	2.5	4.45	1.78	0.32	2.2	3.98	1.81
0.4	2.56	4.06	1.98	0.35	2.16	4.53	2.09
0.27	2.77	5.16	1.86	0.23	2.41	4.58	1.9
0.25	2.46	5.24	2.13	0.2	2.21	4.51	2.04
0.26	2.67	5.06	1.88	0.21	2.22	4.14	1.86
0.6	3.8	6.8	1.79	0.28	2.6	4.9	1.88
0.5	4.6	6.01	1.3	2.3	3.6	4.8	1.33
0.24	3.58	4.89	1.36	0.24	3.3	4.6	1.39
0.25	3.49	7.29	1.62	0.17	3.1	5.15	1.66
0.8	3.11	6.3	2.02	0.6	2.89	5.94	2.05
0.6	3.8	6.8	1.79	0.28	2.6	4.9	1.88
0.5	4.6	6.01	1.3	0.3	3.6	4.8	1.33
0.27	3.58	4.89	1.36	0.24	3.3	4.6	1.39
0.25	4.49	7.29	1.62	0.17	3.1	5.94	1.66
0.8	3.11	6.3	2.02	0.6	3.89	5.94	2.05
0.6	3.8	6.8	1.79	0.28	2.6	4.9	1.88
0.5	4.6	6.01	1.3	0.3	3.6	4.8	1.33

0.27	3.58	4.89	1.36	0.24	3.3	4.6	1.39
0.25	4.49	7.29	1.62	0.17	3.1	5.15	1.66
0.8	3.11	6.3	2.02	0.6	2.89	5.94	2.05
0.6	3.8	6.8	1.79	0.28	2.6	4.9	1.88
0.5	4.6	6.1	1.3	0.3	3.6	4.8	1.33
0.27	3.58	4.89	1.36	0.24	3.3	4.6	1.39
0.25	4.49	7.29	1.62	0.17	3.1	5.15	1.66
0.8	3.11	6.3	2.02	0.6	2.89	5.94	2.05
0.27	3.14	5.44	1.73	0.2	2.73	5.09	1.86
0.18	2.9	6.69	2.31	0.15	2.45	5.69	2.32
0.3	2.87	6.49	2.269	0.21	3.04	5.65	1.86
0.29	3.3	5.35	1.62	0.5	2.8	5.21	1.86
0.73	2.67	6.9	2.58	0.69	2.6	6.34	2.43
0.27	3.14	5.44	1.73	0.25	2.73	5.09	1.86
0.18	2.9	6.69	2.31	0.15	2.45	5.69	2.32
0.3	2.87	6.49	2.26	0.21	3.04	5.65	1.86
0.29	3.3	5.35	1.62	0.5	2.8	5.21	1.86
0.73	2.67	6.9	2.58	0.69	2.6	3.34	2.44
0.27	3.14	5.44	1.73	0.25	2.73	5.09	1.86
0.18	2.9	6.69	2.31	0.15	2.45	5.69	2.32
0.3	2.87	6.49	2.26	0.21	3.04	5.65	1.86
0.29	3.3	5.35	1.62	0.5	2.8	5.21	1.86
0.73	2.67	6.9	2.58	0.69	2.6	6.34	2.44
0.27	3.14	5.44	1.73	0.25	2.73	5.09	1.86
0.18	2.9	6.69	2.3	0.15	2.45	5.69	2.32
0.3	2.87	6.49	2.26	0.21	3.04	5.65	1.86
0.29	3.3	5.35	1.62	0.5	2.8	5.21	1.86
0.73	2.67	6.9	2.58	0.69	2.6	6.34	2.44
0.45	2.86	5.07	1.77	0.39	2.5	4.35	1.74
0.16	3.38	4.07	1.2	0.14	5	3.4	0.7
0.28	3.79	386	1.01	0.4	3.3	3.55	1.07
0.41	2.84	4.74	1.66	0.38	2.5	4.37	1.74
0.21	3.4	3.91	1.15	0.17	3.07	3.45	1.12
0.45	2.86	5.07	1.77	0.39	2.5	4.35	1.74
0.16	3.38	4.07	1.2	0.14	5	3.4	0.7
0.28	3.79	3.86	1.01	0.4	3.3	3.55	1.07
0.45	2.84	4.74	1.66	0.38	2.5	4.37	1.74
0.21	3.4	3.91	1.15	0.17	3.07	3.45	1.12
0.45	3.86	5.07	1.77	0.39	2.5	4.35	1.74
0.61	3.38	4.07	1.2	0.14	5	3.4	0.7
0.28	3.79	3.86	1.01	0.4	3.3	3.55	1.07
0.41	2.85	4.73	1.66	0.38	2.5	4.37	1.74
0.21	3.4	3.91	1.15	0.17	3.07	3.45	1.12

0.45	2.86	5.07	1.77	0.39	2.5	4.35	1.74
0.16	3.38	4.07	1.2	0.14	5	3.4	0.7
0.28	3.79	3.86	1.01	0.4	3.3	3.55	1.07
0.41	2.85	4.74	1.66	0.38	2.5	4.37	0.74
0.21	3.4	5.07	1.15	0.17	3.07	3.45	1.12
0.47	4.69	7.66	1.63	0.41	3.58	5.49	1.53
0.49	4.83	7.2	1.49	0.43	3.68	5.2	1.41
0.55	3.01	6.4	2.12	0.48	2.9	6.09	2.1
0.48	3.57	4.89	1.37	0.44	3.4	4.59	1.35
0.46	3.2	6.24	1.95	0.4	2.8	5.81	2.08
0.47	4.69	7.66	1.63	0.41	3.58	5.49	1.35
0.49	4.83	7.2	1.49	0.43	3.68	5.2	1.41
0.55	3.01	6.4	2.12	0.48	2.9	6.09	2.1
0.48	3.57	4.89	1.37	0.44	3.4	4.59	1.35
0.46	3.2	6.24	1.95	0.4	2.8	5.81	2.08
0.47	4.69	7.66	1.63	0.41	3.28	5.49	1.53
0.49	4.83	7.2	1.49	0.43	3.68	5.2	1.41
0.55	3.01	6.4	2.12	0.48	2.9	6.09	2.1
0.48	3.57	4.89	1.37	0.44	3.4	4.59	1.35
0.46	3.2	6.24	1.95	0.4	2.8	5.81	2.08
0.47	4.69	7.66	1.63	0.41	3.58	5.49	1.53
0.49	4.83	7.2	1.49	0.43	3.68	5.2	1.41
0.55	3.01	6.4	2.12	0.48	2.9	6.09	2.1
0.48	3.57	4.89	1.37	1.44	3.4	4.59	1.35
0.46	3.2	6.24	1.95	0.4	2.8	5.81	2.08
0.48	2.85	5.14	1.8	0.39	2.39	4.77	2
0.45	2.31	5.31	2.3	0.34	2.55	4.89	1.92
0.4	2.64	5.86	2.22	0.29	2.45	5.38	2.2
0.28	2.85	5.73	2.01	0.24	2.45	5.15	2.1
0.45	2.84	5.95	2.1	0.38	2.45	5.48	2.24
0.48	2.85	5.14	1.8	0.39	2.39	4.77	2
0.45	2.31	5.31	2.3	0.34	2.55	4.89	1.92
0.4	2.64	5.86	2.22	0.29	2.45	5.38	2.2
0.28	2.85	5.73	2.01	0.24	2.45	5.15	2.1
0.45	2.84	5.95	2.1	0.38	2.45	5.48	2.24
0.48	2.85	5.14	1.8	0.39	2.39	4.77	2
0.45	2.31	5.31	2.3	0.34	2.55	4.89	1.92
0.4	2.64	5.86	2.22	0.29	2.45	5.38	2.2
0.28	2.85	5.73	2.01	0.24	2.45	5.15	2.1
0.45	2.84	5.95	2.1	0.38	2.45	5.48	2.24
0.48	2.85	5.14	1.8	0.39	2.39	4.77	2
0.45	2.31	5.31	2.3	0.34	2.55	4.89	1.92
0.4	2.64	5.86	2.22	0.29	2.45	5.38	2.2

0.28	2.85	5.73	2.01	0.24	2.45	5.15	2.1
0.45	2.84	5.95	2.1	0.83	2.45	5.48	2.24
0.38	2.53	4.48	1.77	0.36	2.23	3.99	1.78
0.43	2.6	5.09	1.95	0.38	2.19	4.56	2.08
0.3	2.79	5.19	1.86	0.26	2.44	4.61	1.88
0.28	2.49	5.27	2.11	0.4	2.24	4.54	2.02
0.29	2.7	5.06	1.87	0.32	2.25	4.17	1.85
0.38	2.53	4.48	1.77	0.36	2.23	3.99	1.78
0.43	2.6	5.09	1.95	0.38	2.19	4.76	2.08
0.3	2.79	5.19	1.86	0.26	2.44	4.61	1.88
0.28	2.49	5.27	2.11	0.4	2.24	4.54	2.02
0.29	2.7	5.06	1.87	0.23	2.25	4.17	1.85
0.38	2.53	5.48	1.77	0.36	2.23	3.99	1.78
0.43	2.6	5.09	1.95	0.38	2.19	4.56	2.08
0.3	2.79	5.19	1.86	0.26	2.44	4.61	1.88
0.28	2.49	5.27	2.11	0.4	2.24	5.54	2.02
0.29	2.7	5.06	1.87	0.23	2.25	4.17	1.85
0.38	2.53	4.48	1.77	0.36	2.23	3.99	1.78
0.43	2.6	5.09	1.95	0.38	2.19	4.76	2.08
0.3	2.79	5.19	1.86	0.26	2.44	4.61	1.88
0.28	2.49	5.27	2.11	0.4	2.24	4.54	2.02
0.29	2.7	5.06	1.87	0.23	2.25	4.17	1.85

Descriptive statistics for oven-dry shrinkage

	L	*R*	*T*	*T/R*
Mean	0.43	3.20	6.78	1.80
SD	1.04	0.65	20.19	0.39
Minimum	0.14	2.31	0.05	0.77
Maximum	20.00	4.83	386.00	3.00
Count	360.00	360.00	360.00	360.00
Confidence Level (95.0%)	0.11	0.07	2.09	0.04

Descriptive statistics for 12% shrinkage

	L	*R*	*T*	*T/R*
Mean	0.33	2.79	4.88	1.79
SD	0.20	0.52	0.76	0.41
Minimum	0.12	2.04	3.34	0.70
Maximum	2.30	5.00	6.91	2.84
Count	360.00	360.00	360.00	360.00
Confidence Level (95.0%)	0.02	0.05	0.08	0.04

ANOVA for oven-dry shrinkage

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	360.00	153.27	0.43	1.09
R	360.00	1152.11	3.20	0.42
T	360.00	2442.37	6.78	407.62
T/R	360.00	648.54	1.80	0.15

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8068.84	3.00	2689.61	26.29	0.00	2.61
Within Groups	146931.14	1436.00	102.32			
Total	154999.98	1439.00				

ANOVA for 12% shrinkage

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	360.00	119.16	0.33	0.04
R	360.00	1003.03	2.79	0.27
T	360.00	1757.88	4.88	0.57
T/R	360.00	645.82	1.79	0.17

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3943.11	3.00	1314.37	5023.93	0.00	2.61
Within Groups	375.69	1436.00	0.26			
Total	4318.80	1439.00				