UNIVERSITY OF EDUCATION, WINNEBA

MECHANICAL PROPERTIES AND NATURAL DURABILITY ALONG THE STEM OF CLEISTOPHOLIS *PATENS* (NGO NE NKYENE) WOOD AND ITS FEASIBILITY FOR STRUCTURAL USE AND FURNITURE CONSTRUCTION.

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A Dissertation in the Department of CONSTRUCTION AND WOOD TECHNOLOGY EDUCATION, Faculty of TECHNICAL EDUCATION, submitted to the School of Research and Graduate Studies, University of Education, Winneba in partial fulfilment of the requirements for award of the Master of Philosophy

(Wood Science and Technology) Degree.

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DECLARATION

STUDENT'S DECLARATION

I, John Quansah, hereby declare that except for the references to the literature, which have been duly cited herein, this Dissertation is the result of my own field and laboratory work towards the award of Master of Philosophy: Wood Science and Technology under the supervision of Prof. Charles ANTWI-BOASIAKO (Head of the Department of Wood Science and Technology, Faculty of Renewable Natural Resources (FRNR), Kwame Nkrumah University of Science and Technology-Kumasi). I further declare that the research has not been submitted previously, either wholly or partially, for a degree in the University of Education Winneba- Kumasi or elsewhere, except where due acknowledgement has been made in the text.

SIGNATURE…………………………………… DATE…………………………………

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for the supervision of Dissertation as laid down by the University of Education, Winneba.

NAME OF SUPERVISOR: Prof. Charles ANTWI-BOASIAKO

SIGNATURE……………………………. DATE…………………………….

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DEDICATION

I dedicate this work to my dear wife (Christiana Quansah) and Children (Jojo Quansah, Araba Kutuafo Quansah and Ama Kumah Quansah).

ABSTRACT

The over-dependence on the primary timber species has resulted in increased focus on research in the Lesser Used Species (LUS). Cleistopholis *patens* is an LUS commonly found in Sierra Leone and Ghana, yet it is commercially underutilized. This study assessed some physical, mechanical, and natural durability of C. *patens* against termites in comparison with other known commercial species. Three *C. patens* trees, collected from Assin Akropong Forest Reserve near Assin Fosu in the Central Region of Ghana were used for the study. Moisture content along the stem ranged from 12.38 - 13.81 % from butt to top. The basic density Values showed that C. *patens* is a low-density species with a range of 198.7 – 273.2 Kg/m3 from top to butt along the stem. The mean Modulus of Rupture, Modulus of Elasticity, Compression parallel to grain and shear parallel to the grain along the stem (from top to butt) were, 44.58 - 53.92 Nmm-2, 7268 - 8200 Nmm-2, 22.76 - 28.87 Nmm-2 and 5.508 - 7.678 Nmm-2, respectively. The mechanical strength properties values suggest that C. *patens* generally has a low strength for the butt portion and very low strength for the top and middle portions. The mean natural durability (i.e. mass loss) for the various sections along the stem ranged from 87.75 to 100 % (from butt to top) suggesting that C. *patens* is a non-durable timber. Generally, the mean values for the butt portion was significantly different (P < 0.05) from the other portions (middle and top) in all the parameters that were studied. The butt portion of C. *patens* thus have better usability potentials than the top and the middle and must be exploited for various applications such ceiling joist, interior joinery and wall partitioning. However, additional protection with preservative treatment would be required where outdoor applications are necessary. The use of the middle and top portions should be accompanied by preservative treatment in all possible applications (indoor and outdoor purposes).

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ACRONYMS AND ABBREVIATIONS

The following abbreviations and symbols were used in the document:

ASTM	American Society of Testing and Materials
BS	British Standard of Testing Small Clear Samples
Df	Degree of Freedom
FSP	Fibre Saturation Point
P – Value	Probability Value
MC	Moisture Content
MS	Mean Sum of Squares
MOE	Modulus of Elasticity
MOR	Modulus of Rapture
CPG	Compression Parallel to Grain

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Wood resources continue to play an important role in the world, from packaging materials to buildings, to transportation structures. It has been useful to human societies for thousands of years and remains to be seen as one of the most important building materials available (Forest Product Laboratory (FPL), 1999; Kettyle Construction (KCS), 2013; Understandconstruction, 2017). According to FPL (1999) and Tsoumis (2018), archeological discoveries have shown that wood was used by ancient civilizations as a construction material, a substrate for ornate decorative objects, and for providing the final resting place for royalty. These discoveries highlight the unique, long-lasting performance characteristics of wood, as many of these artifacts have survived for thousands of years (FPL, 2010).

Unlike other materials, the characteristics of wood can vary dramatically depending on a lot of factors. For example, the age, type, colour, structure and water content of wood, are all factors that need to be considered before using it for construction purposes (KCS, 2013). If our forests are managed wisely, and we continue to build our intellectual capacity to meet the challenges of evolving human needs and changing wood characteristics, this amazing and exceptionally versatile material would serve the public well for years to come (FPL, 2010).

According to Understand construction (2017), Wood is the perfect example of an environmentally sustainable product; it is biodegradable and renewable, and carries the lowest carbon footprint of any comparable building material. The inherent factors that keep wood in the forefront of raw materials are many and varied, but a chief attribute is its availability in many species, sizes, shapes, and conditions to suit almost every demand (FPL, 2010; Understand construction, 2017). Its malleability, strength, appearance and long life span means that it has well and truly stood the test of time (KCS, 2013). Dry wood has good insulating properties against heat, sound, and electricity. It tends to absorb and dissipate vibrations under some conditions of use, and yet it is an incomparable material for musical instruments (FPL, 2010; Understand construction, 2017).

The grain patterns and colors of wood make it an aesthetically pleasing material, and its appearance may be easily enhanced by stains, varnishes, lacquers, and other finishes (FPL, 2010). However, there has been an intense pressure on the forest by increase in population. The demand for wood has consequently annihilated the ecosystem. According to Science Heathen (SH) (2012), the massive increase in the human population have destroyed majority of the world 's forest in the last 50 years. The incredible scale of this loss has led to significant changes throughout many parts of the world, and in recent years these changes have been accelerating.

According to Ghana Environmental Profile (GEP) (2006), Ghana has one of the stronger economies of sub-Sahara Africa due to its array of natural resources. However, the exploitation of these resources, coupled with the overall lack of environmental awareness, has devastated the country's forests. In less than 50 years, Ghana's primary rainforest has been reduced by 90%, while in the past 15 years (1990-2005), the country lost 1.9 million hectares or 26 % of its forest cover.

The report attributes this tremendous loss of forest to the fact that Subsistence agriculture and cutting for fuel wood is common throughout Ghana and worsening due to a population growth rate approaching 3 %(GEP, 2006).

According to GEP (2006) and Food and Energy security (FES) (2017) illegal logging and gold mining have also proved costly to the country's natural areas. The report continued to recount that forest loss in Ghana has exacerbated droughts and bushfires. In 1997 and 1998, widespread bushfires led the government to step up its anti-bushfire campaign, but the reform had little effect. Desert is encroaching on some deforested lands and soil erosion is rampant. The economic development of Ghana has come at a great cost to its forests and environment. The GEP (2006) report stated that Ghana could earn tens of millions of dollars for reducing its deforestation rate under a carbon-trading initiative proposed by a coalition of developing countries during the discussion at UN climate talks in Nairobi, Kenya.

A report by the Forestry Research Network of Sub-Saharan Africa (FORNESSA, 2010) indicated that efficient utilization of the Lesser Used Species (LUS) would improve sustainability of the tropical timber resources and reduce negative ecological impacts. The use of LUS would help reduce the pressures on the commercially known species such as Milicia excelsa (Odum) and Terminalia superba (Ofram). In Ghana, the use of Cleistopholis patens for structural work, furniture and wood-based products have received no consideration. Lack of knowledge and information has been one of the main obstacles to the successful use of C. patens. They are abundant in secondary forest zones especially in the wet places of Ghana (Hawthorne and Gyakari, 2006). It is therefore appropriate to conduct research into the utilization of C. patens as substitutes to the primary wood species for domestic, commercial and industrial applications.

1.2 Problem Statement

The Ghana timber industry has depended on some few primary species for a very long time for structural and furniture construction. According to the Timber Industry Development Division of the Forestry Commission (FC-TIDD) (2005), export of wood products from the country for the first half of 2005 went up by 10.26% of which Wawa (*Triplochiton scleroxylon*), Mahogany (*Khaya Spp*.), Odum (*M. excelsa*), *Ceiba pentandra*, Teak (*Tectona grandis*), and Sapele (*Entandrophragma cylindricum*) featured prominently in the species exported. A report from the International Tropical Timber Organisation (ITTO) (2014) indicated that Ghana exported a total of 249,846 cubic metres of timber and wood products in the 2014 with the main export species including Wawa (*Triplochiton scleroxylon*), Mahogany (*Khaya Spp*.), Odum (*M. excels*), Teak (*Tectona grandis*), *Ceiba pentandra* and Ofram (*Terminalia superba*).

Naturally, Ghana has about 680 tree species (Hall and Swaine, 1981 as cited by Ofori and Brentuo, 2010). About 126 of these out of 420 tree species reach timber size and therefore are of economic value, to be exploited commercially in the timber industry as raw materials (Ghartey, 1989). The over-dependence on only few primary species, indicating inefficient utilization of timber resources, has several undesirable consequences such as the imminent extinction of those species from the tropical rainforest (Ghana Forestry Department, 1994; Ministry of Lands and Forestry, 1996).

It is certain though, that as the preferred traditional or primary species become more scarce, wood users will start to look more closely at a larger range of species. LUS could potentially solve the problem of over-dependence. However, utilization of LUS depends on the availability of reliable information on their properties and areas of application. Greater utilization of the LUS, such as *C. patens*, is expected not only to increase the output volume and value production per unit forest area, but also to reduce the level of disturbance occurring in the tropical rain forests resulting from the over-utilization of the few primary species. *C. patens* is an LUS which grows rapidly in Sierra Leone and in Ghana (Baker *et al*., 2005). The wood is common and widespread in swamps and disturbed forests from Sierra Leone to Congo (Hawthorne and Gyakari, 2006). It is therefore certain that this species is commonly found but underutilized commercially. Moreover, information on the mechanical properties and durability of C. patens, which is a prerequisite to enhance its uses, is very limited. This research sought to address the issues regarding some physical and mechanical properties as well as natural durability of *C. patens* locally known as ngo ne nkyene', as compared to other primary species of commercial value.

1.3 Aim

1.3.1 Main Objective

To determine some physical, mechanical and natural durability properties of *C. patens* and compare it to other selected commercial species of known properties.

1.3.2 Specific Objectives

- To determine some physical properties (moisture content and basic density) along the stem of *C. patens*.
- To determine some mechanical properties (compression parallel to grain, shear strength and static bending along the stem of *C. patens*.

- To determine the natural durability along the stem of *C. patens* from the base, middle and top.
- To compare the mechanical properties and natural durability of *C. patens* to other selected commercial timber species.

1.4 Research Questions

The following research questions will guide the study:

- How does the compression parallel to grain, shear, and static bending strength vary along the stem of C. patens?
- How durable is C. patens?
- What difference exists in terms of properties between *C. patens* and other selected commercial species whose properties are established and documented?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 General Introduction

According to FAO (2017), the forest area of Ghana is estimated at 9.17 million hectres accounting for about 40% of the total national land. The classification of these forests, based on ecological conditions, puts the Closed Forest Zone area at 8.1342 million hectres and the Transitional Forests at 1.036 million hectres. The Closed Forest Zone is categorized into Evergreen Rainforest, Evergreen Moist Forest and Moist Semi-deciduous Forest. The state of the forest reserves indicates that there is a general increase in forest disturbance from the wetter to the drier forest areas. About 14% of the total permanent forest estates in Ghana are without adequate forest cover. The worse affected areas are the Moist Semi-Deciduous North-west and South-east subtype Forest Zones. These are as a results of both forest fires and logging damage. It is clear, however, that while reserve boundaries have been largely protected and respected, the condition of the reserves within are variable and in many cases deteriorating (FAO, 2017).

One of the most threatened natural forests in the world is the Ghanaian tropical rainforest with an estimated 1.60 million hectares of permanent forest estate depleted (ITTO, 2006). According to news report, Ghana has the highest rate of deforestation, out of 65 nations, apart from Togo and Nigeria (Ghanaweb, 2011).

In Ghana, the reason behind the cutting down of trees is usually for charcoal, pasture for livestock, farms and urban or industrial purposes. The cutting down of trees, both the legal and illegal, are having a drastic effect on the nation, since they do not involve proper afforestation activities. The forest place is left bare, mostly with the notion of waiting for nature to reproduce these trees again, which takes many years to do so (Ghanaweb, 2011). Forest provide a wide range of economic and social benefits to humankind. These include contributions to the overall economy through employment, processing and trade of forest products, energy and investments in the forest sector. They also include the hosting and protection of sites and landscapes of high cultural, spiritual or recreational value. 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 and Appiah, 1998). Maintaining and enhancing the important functions of forests and forest products is an integral part of sustainable forest management (Global Forest Resources Assessment (GFRA), 2005).

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 (Hoadley, 2000).

2.2 Physical Properties of Wood

According to FPL (2010), the versatility of wood is demonstrated by a wide variety of products. This variety is a result of a spectrum of desirable physical characteristics or properties among the many species of wood. Novascotia (2014) asserted that physical properties refer to density and moisture relations that affect its use. Engler (2009) also indicated that the physical properties of a wood species are those that affect its appearance, weight, feel, and smell. Most craftsmen are not especially concerned about feel and smell, since these changes considerably when you apply a finish. However, appearance is paramount. Weight can also be important if the product is meant to be moved or carried (Engler, 2009). Wood, like many natural materials, is hygroscopic; it absorbs moisture from the surrounding environment. Moisture exchange between wood and air depends on the relative humidity and temperature of the air and the current amount of water in the wood. This moisture relationship has an important influence on wood properties and performance (FPL, 2015). This research will consider only two major macroscopic physical properties; moisture content (mc) and density.

2.2.1 Moisture Content

According to FPL (1999), mc of wood is the weight of water in wood expressed as a fraction, usually a percentage, of the weight of oven-dry wood. Weight, shrinkage, strength, and other properties depend upon the mc of wood. In trees, mc can range from about 30% to more than 200% of the weight of wood substance. In softwoods, the mc of sapwood is usually greater than that of heartwood. In hardwoods, the difference in mc between heartwood and sapwood depends on the species as well as many other factors such as the wood ‘s anatomical properties (FPL, 2010).

Desch and Dinwoodie (1996) indicated that wood mc is one of the many variables that affect the performance and utilization of wood. The amount of water present in wood does not only influence its strength, stiffness and mode of failure, but also its dimensions, susceptibility to fungal attack, workability and the ability to accept adhesives and finishes. There is a considerable amount of moisture in the timber of living trees and newly felled logs. The actual amount varies significantly among trees of different species. In most species, there is usually a marked difference in the mc which may vary with height in the tree.

According to Desch and Dinwoodie (1996), water present in wood is in two forms, namely: free water, that is, water present within cell cavities; and bound water, that is, water found in the cell wall. The removal of free water during seasoning has no effect on both the mechanical performance of the wood and its dimensions. Bound water is chemically bonded to the constituents of the cell wall by hydrogen bonding. In most timbers, the wall can hold about 20 to 30% of their dry mass (Desch and Dinwoodie, 1996). As bound water is removed, it affects the physical and mechanical properties of wood; the wood begins to shrink, most strength properties exhibit improved electrical resistance, resistance to decay, better gluing characteristics and nail-holding power, and a continued reduction in density.

2.2.2 Moisture Content Determination

According to Kollmann and Cotê (1968), there are five distinct methods of determining the moisture content of wood: oven-dry method, distillation method, titration method, hygrometric method, and the electric method. When a sample of wood contains a significant amount of volatile constituents or preservatives, the distillation method is usually recommended (Kollmann and Cotê ,1968).

According to Kollmann and Cotê (1968), the distillation method is not suitable for an exact determination of the water content due to its destructive influence on the wood tissues and to inaccuracies in reading. Only trichloroethylene, xylene and toluence are conditionally applicable as distillation liquids.

According to Tavčar *et al,* (2012). The apparatus for the titration method is shown in Fig. 6.26. Since atmospheric humidity must be carefully excluded, all openings for the compensation of pressure must be secured by glass tubes filled with calcium chloride. The method is an idometric titration in which elementary iodine reacts with sulfurdioxide and water to form hydrogen iodide and sulfuric acid: $SO_2 + I_2 + 2H_2O$ $2HI + H_2\ SO_4$

Probably the reaction is more complicated since the solvents pyridine and methanol take part. For a given amount of iodine used in the reaction the amount of water present can be computed with high accuracy according to the stoichiometric conditions. The titration method requires much time (6 hrs) and is rather expensive.

According to Kollmann and Cotê (1968) Hygrometric Methods is much quicker (10 to 15 min.) than the oven-drying or the titration method but not as fast as the electric method. Measurements are restricted to the range between 3 and 20% of moisture content. The instrument consists simply of perforated tube containing a string of hair which changes its length in response to changes in humidity. One end of this hygroscopic element is attached to the tube, the other to a light lever which moves a pointer across a dial scale.

Oven-dry method is the most accurate of all the methods, but is slow and requires samples be cut from the test materials. Moisture is determined using a clear (defect-free) sample that is thick in the direction of the grain and not from the end of the board in order to avoid rapid drying along the grain. Each sample is immediately weighed and is then oven-dried and re-weighed. The moisture content (mc) is calculated using the formula, (Hartley and Merchant, 1995):

$$MC (\%) = (\text{Initial mass} - \text{oven dry mass}) / (\text{oven dry mass}) \times 100$$

2.3 Density

Wood density is the mass of wood per unit volume. It is an important trait for understanding the function and ecology of woody species, as well as estimating stored biomass and carbon content (Chave *et al*, 2009). It is used as an indicator of wood quality, tissue allocation patterns and a predictor of plant performance (Oyomoare and Zanne, 2013). Density is the weight or mass of a unit volume of wood (Encyclopedia Britannica, 2014). According to Haygreen and Bowyer (1996), density and specific gravity are perhaps the most important factors influencing the mechanical properties of timber, for which reason, density became the first wood property to be scientifically investigated. Tsoumis (1991) indicated that density is the best and simplest index of the strength of a clear wood; with increasing density and strength. This is because density is a measure of the amount of cell wall materials contained in a given volume of wood and hence, higher density wood, denotes a larger amount of cell wall available to resist external forces.

According to Shrivastava (1997), in the determination of elasticity and shock resistance properties, density is less correlated. High wood density is associated with thick fibre walls and thus a higher proportion of fibres. Basic density is considered to be attributable to the quality variations in wood (Lindstrom, 1996). Less dense timber species tend to have rapid volumetric growth rate with shorter life-span compared to very dense timber species which grow more slowly with lower mortality rates (Swenson and Equist, 2008). Density represents the single best indicator of the physical and mechanical properties of wood (Panshin and Zeeuw, 1980).

2.3.1 Determination of Density

Oyomoare and Zann (2013) described wood density as an emergent property in the sense that it is determined by the chemical and structural organization of cells, proportion of space or void volume, and mc. MC is an important factor that has to be accounted for when measuring wood density because mass and volume – the components of wood density – change with mc, due to the hygroscopic nature of wood. Wood is used in a wide range of conditions and thus has a wide range of mc values in service. Determining the density of wood (including water) at a given mc, is often necessary for applications such as estimating structural loads or shipping weights (FPL, 2010).

According to Desch and Dinwoodie (1996), some strength properties show a very marked correlation with density; namely compression strength parallel to the grain, bending strength and hardness. They added that the density of a piece of wood is determined not only by the amount of its substance present, but also by the presence of both extractives and moisture. The presence of moisture in wood not only increases the mass of the timber, but also increases the volume. According to ASTM standard D143-94 (2007) the test samples dimensions should be of 20 × 20 × 20 mm for determining basic density. The density is determined using the relation (Desch and Dinwoodie ,1996).

$$\text{Density} = \frac{\text{Mass of wood}}{\text{Volume of wood}}$$

2.4 Mechanical Properties

According to Record (2004), the mechanical properties of wood are its fitness and ability to resist applied or external forces. External force being any force outside of a given piece of material which tends to deform it in any manner. Such properties determine the use of wood for structural and building purposes such as furniture, vehicles, implements and tool handles to mention a few.

The term mechanical or strength properties, as applied to a material such as wood, refers to the ability of wood to carry applied load or forces (Haygreen and Bowyer., 1996). Tsoumis (1991) and FPL, (2014) defined mechanical properties of wood as those properties that enable it to resist various external forces that would change its shape and size and produce deformities. They further stated that such external forces induce internal resistance, called stresses, in the wood, which when exceeding the force of cohesion of the wood element would lead to failure. Resistance involves a number of specific mechanical properties that determine the suitability of different species of timbers for the various purposes for which wood is used (Illston *et al*., 1987; FPL, 2014).

Woods, such as timber constructional materials, have strong mechanical properties that enable it resist applied or external forces. In practice, timber is frequently subjected to a combination of stresses (compressive, bending tensile and shearing), although one usually predominates (Farmer, 1972; Record, 2004). The mechanical properties of wood largely determine the fitness of wood for structural building purposes and there is hardly a single use of wood that does not depend at least to some degree on one or more of strength properties (Kollmann *et al*,1968; Record, 2004).

According to Wood Technology Society (WTS), (2014), the strength properties of wood vary widely, not only by tree species, but also within different specimens of the same species. Haygreen and Bowyer (1996) and WTS (2014), indicated that mechanical properties are usually the most important characteristics of wood products that enable them to be used in structural applications. They further explained that the term strength is often used in general sense to refer to all mechanical properties. Nonetheless, there are many different types of wood strengths that require equal consideration as supported by Record (2004), who listed the following as mechanical properties of wood: stiffness and elasticity, tensile strength, compressive or crushing strength, shearing strength, transverse or bending strength, toughness, hardness, cleavability and resilience. However, bending strengths (Modulus of Elasticity and Modulus of Rupture), compression perpendicular to grain and shear parallel to grain were considered.

2.4.1 Determination of strength properties of timber

According to Dinwoodie (1989), there are two methods employed in the determination of strength properties of wood. These are Service test and Laboratory experiments. The former has the advantage of being carried out under the same condition to which timber is exposed in use. Tsoumis

(1991) indicated that small clear specimens present the possibility of wider sampling and the systematic study of the effects of various factors like moisture content, density, growth ring structure, physical and chemical treatment on mechanical properties, while such effects are difficult to transfer to full size members due to variation of wood structure and the presence of defects. In addition, he explained that when small clear specimens are used, reduction factor must be applied to obtain safe working stresses. Tests on timber of structural sizes are more representative of service conditions but they have the disadvantage of being costly and time consuming since large wood samples are required and

they take a longer time to rupture. According to Test Resources Incorporation (TRI) (2014), the most common reason for testing wood and timber products is to determine their ultimate or breaking strength in tension, compression and flexure. Most wood products that undergo mechanical testing are used in the construction, furniture and common goods manufacturing industries. The measured strength of the wood and timber material will determine if it is an acceptable candidate for a particular application.

2.4.2 Static Bending

According to Ametek (2008), static bend testing is particularly relevant because wood is frequently used in the form of beams where resistance to bending is an important parameter. Wilcox *et al*. (1991) defined bending strength of wood as ―an index of the maximum load a bending member can be expected to support before failing, weighted for the effects of span, width and depth‖. Bending strength results from a combination of all the three primary strengths (compression, shear and tension); they cause flexure or bending in the wood (Panshin and de Zeeuw, 1964). Wikipedia

(2009) indicated that the span is a significant factor in finding the strength and size of a beam as it determines the maximum bending moment and deflection. Loads are applied at the Centre (Shrivastava, 1997; Wikipedia, 2009).

ASTM D143 (2014), states that the lower support anvils of the three-point static bend fixture should be provided with bearing plates and the load should be applied to the Centre of the specimen by a rigid upper block. Furthermore, the static bending test calls for the use of bearing plates on articulating knife edge support rollers. The bearing plate reduces the risk of load concentrations that could deform and damage the specimen, while the articulating knife edge supports allow the plate to accommodate slight twisting in the wood specimen (ASTM D143(2014). It is required that the distance from the support point to the wood specimen mid- plane must not be greater than the specimen depth. Bending loads are applied to the wood beam specimens by a bearing block. Brandon (2014) indicated that the ends of the test specimen are supported on rollers, usually with growth rings horizontal, and a load is applied at the beam centre so that a constant rate of deflection is maintained until the piece fractures. Instruments measure and plot the load (stress) and the deflection (strain) at intervals, as shown in the Figure 2.1.

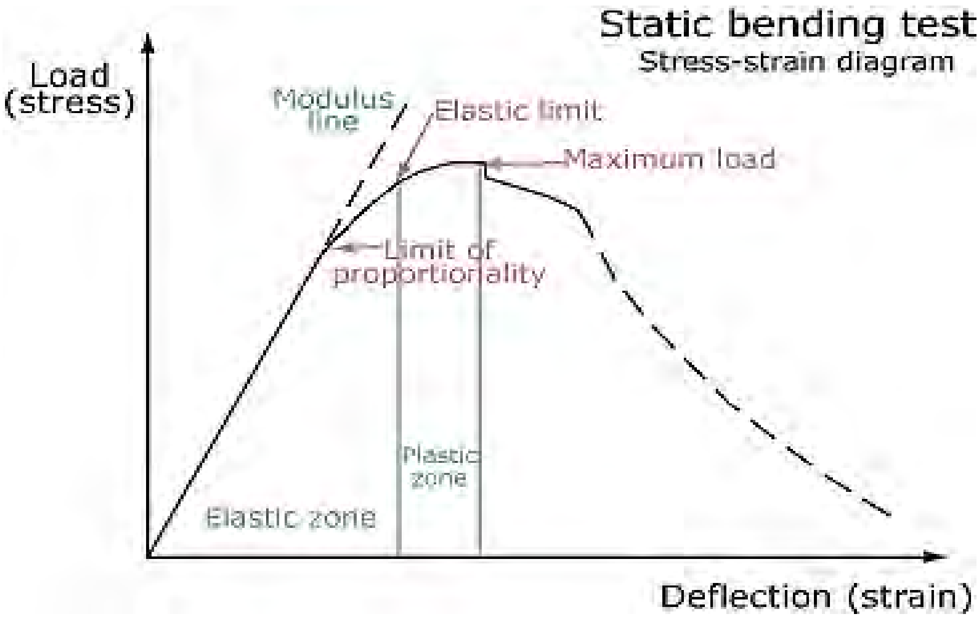

Figure 2.1: The stress-strain relationship of a static bending test

Source: (Brandon, 2014)

Brandon (2014) explained that the vertical axis shows increasing stress and the horizontal axis increasing strain. The first part of the curve is a straight line where the deflection is directly proportional to the load and where, once the load is removed, the beam will return to its original state; that is, it retains its elasticity. With increasing load, a limit point of proportionality is reached after which the increase in amount of deflection is greater than (that is no longer proportional with) the increase in load; but elasticity is still retained until an elastic limit is reached. If stress is further increased, the material loses elasticity and becomes plastic (that is when the load is removed the deformation caused by deflection will be more or less permanent). At the point of maximum load, ultimate load or ultimate strength, the material begins to yield and will fracture unless load is substantially reduced.

2.4.2.1 Modulus of Elasticity

According to WoodworkWeb (2013) the Modulus of Elasticity (MOE) in simplest terms measures a wood's stiffness, and is a good overall indicator of its strength. Technically, it's a measurement of the ratio of stress placed upon the wood compared to the strain deformation that the wood exhibits along its length. MOE is expressed in Nmm-2. This number is given for wood that has been dried to a 12% mc unless otherwise noted (Woodwork Web, 2013). MOE also known as elastic modulus or Young's Modulus, is a measure of how a material or structure will deform or strain when placed under stress (WiseGeek, 2003). Hoadley (2000) specified that MOE can be calculated by choosing any set of values of stress and resulting strain, although the stress and strain values at the proportional limit are conventionally used. The MOE will be determined by the relation BS 373 (1957);

$$MOE = \frac{p/l^3}{4\Delta/bh^3}$$

Where:

p = Load at limit of proportionality (N),

l = length of the test piece (mm)

Δ=Deflection at mid length at limit of proportionality (mm),

b = Breadth of test piece (mm)

h= Depth of test piece (mm).

2.4.2.2 Modulus of Rupture

According to FPL (2010), Modulus of Rupture (MOR) reflects the maximum load carrying capacity of a member in bending and is proportional to the maximum moment borne by the specimen. Lobo (2014) indicated that MOR is the maximum stress to which a material can be subjected before it breaks. Novascotia(2014) stressed that MOR is a measure of the ultimate strength of wood at the breaking point. Wilcox *et al*. (1991), supports that the MOR is an index of the maximum load a bending member can be expected to support before failing, weighted for the effects of span, width and depth. The MOR in three-point bending can be determined using the Relation (Haygreen *et al*., 1981):

$$\mathrm{MOR} = \frac{3PL}{2bd^2}$$

Where MOR is Modulus of Rupture measured in N/mm²,

P is the maximum load in (N),

L is the span in mm,

b is the width (mm), and d is the depth (mm)

2.4.3 Compression Strength

When a force or load tends to shorten, or crush a wood, there is said to be compressive stress and the strength of wood is said to be compressive strength (Panshin *et al*., 1964). According to Ametek (2008), compression test determines the behavior of materials under crushing loads. The test is carried on a specimen that undergoes compression and deformation at various loads and the result recorded (Shrivastava, 1997). Record (2004) indicated that Compressive stress may be parallel to or perpendicular to the grain. The specimen for the compression-parallel-to-grain test is 2 by 2 mm in cross section and 6 mm long. A crosshead load was applied at a rate of 0.01 mm/s through a ball contact plunger. According to BS 373 (1957) Compressive strength parallel to grain (CPG) was carried out on test pieces of dimension 20 x 20 x 60mm at 12% mc and 20ºC using Instrong Machine. The CPG can be determined by the relation (Haygreen and Bowyer, 1981):

$$\text{CPG} = \frac{P}{A}$$

Where,

A is the cross-sectional area of the piece (mm^2) and

P is the load (N).

2.4.4 Shearing Strength Parallel to Grain

Whenever forces act upon a body in such a way that one portion tends to slide upon another adjacent to it the action is called a shear (Panshin *et al*., 1964; Record, 2004). In wood this shearing action may be: 1) along the grain, or 2) across the grain. A tenon breaking out its mortise is a familiar example of shear along the grain, while the shoving off of the tenon itself would be shear across the grain (Record, 2004). According to Shrivastava (1997), shear strength measures the ability of wood to resist forces that tend to cause one part of the material to slide or slip on another part adjacent to it. Knowledge of shear parallel to the grain is important as is a major cause of failures of woods. The value of shearing stress parallel to the grain is determined by the relation (Dinwoodie and Desch, 1996; Record, 2004);

$$Shear = \frac{P}{A}$$

Where,

P is the maximum load and

A is the cross-sectional area.

2.5 Durability of Wood

According to Wood Solution (WS) (2013), durability is one of the key performance factors used to assess the suitability of a timber species for a specific application. The durability rating of a species is based on the natural ability of the heartwood of that species to resist decay and insect pests including termites. Importers of Specialized Timbers (TIMSPEC, 2013), reported that durability, or more specifically the measure of a timber species durability, is an estimation of how long timber under different external conditions will perform, either with no ground contact (above ground) or tougher partially buried or in contact with the ground. Generally, timbers are grouped into one of four groups: Perishable/Non-durable, Moderately Durable, Durable and Very Durable (Eaton and Hale, 1993: TIMSPEC, 2013). Perishable/Non-durable timbers are only suited to internal usage, where they will always be fully protected from the weather. Moderately Durable timbers are only somewhat durable, and should be avoided for external usage. Durable and Very Durable timbers are well suited for external use, but still have limited in-ground lifespan (Eaton and Hale, 1993: TIMSPEC, 2013).

Natural durability is an inherent ability of timber to resist deterioration by weathering and abrasion (BRE, 1998) or to withstand attack by wood destroying organisms such as bacteria, fungi, insects and marine borers without preservative treatment (Eaton and Hale, 1993). According to American Database of Timber (ASTM D143-94), the degree of resistance to attack by wood destroying fungi and wood destroying insects is determined largely by the extractives formed when sapwood changes into heartwood as the tree grows. Termites are less easily deterred by these extractives (than are fungi) and will attack most species of timber, though slowly in the case of the very durable species. Termites tend to avoid species that have a relatively high silica content because of their abrasive nature. Marine organisms are as well deterred to some extent by high silica content.

Beckwith (1998) indicated that cellulose is the major structural ingredient of wood. It is also the major food of several different insects and decay fungi. Chemicals which are toxic to wood destroyers occur naturally in some trees. Not all of them contain equally effective preservatives though, and they do not occur uniformly throughout a tree. Thus, natural durability is a variable property, even among woods with a reputation for it.

2.5.1 Natural durability

The natural durability of wood is its ability to resist the attacks of foreign organisms that is fungi, insects and marine borers. Although, no wood is entirely immune to attacks of such organisms, a number of them possess superior resistance (Panshin and de Zeeuw, 1980). Given the suitable environmental conditions, many organisms including bacteria, fungi, insects and marine invertebrates can cause severe degradation of wood. Certain types of timber are noted for their marked resistance to bio- deterioration and are commonly used as untreated materials. On the contrary, non-durable timbers generally require preservative treatment if they are to be used in exposed conditions.

Several factors influence the durability of timber. They include wood density, tree age, and growing location. The natural durability of wood depends on species, age, carbohydrate content, moisture content, specific gravity, climate conditions and the type of use (Esenther, 1977). Probably, the most important factor is the presence of toxic substances or extractives formed in the wood during transition from sapwood to heartwood and the type as well as quality of the extractives present which determine the level of durability of the timber concerned (Syofuna *et al*, 2012). Timber species differ considerably in their resistance to insect and fungal attack and even pieces cut from different sections of the same tree often show differences in durability (Ocloo, 1975).

Natural durability is an important property to consider when assessing the suitability of timber for use. It is important when the timber is to be used outdoors. Where it is likely to become damp, or in certain indoors situation where there is the risk of moisture penetration and condensation. Naturally durable timber is generally expensive, slow-growing and less abundant as compared to the non-durable ones (Findlay, 1985). Less durable timbers have been used in certain situations where durable one would have been preferred due to cost and abundance. Where Less durable timbers are to be used, improvement in their utilization have usually been achieved by sorting them out according to their durability class or preferably using them in locations where the utilization of the less durable timbers requires that species be given preservative treatment against bio-degraders.

2.5.2 Classification of Natural Durability

Assigning classes of decay resistance to the various species entailed the use of several criteria. Anon (1993) stipulated that, results of laboratory pure-culture decay tests and field tests are used in assisting durability. In a field test, the soil, temperature and rainfall conditions can vary widely, making the test difficult to compare but laboratory test results are more often uniform since temperature and moisture conditions are closely controlled. In examining field test or in-service performance test results, the aim was to assign resistance rating presumed to be appropriate for exposure conditions common to all test.

In field tests, the time to nominal nature and the relative condition of specimens after a set number of years were used as criteria. In both instances, the wood was classified on the following scales: 1= Very resistant, 2=resistant, 3=moderately and 4=non-resistant or perishable (Anon, 1993). Timber species are usually classified into arbitrary number of classes according to their durability. The classification may be based on the visual rating system as produced by EN 252 (1989) as illustrated in the table 2.1.

Table 2.1: Natural durability classification based on visual rating system

Rating	Extent of deterioration
0	No attack
1	Slight attack
2	Moderate attack
3	Severe attack
4	Failure

Source: EN 252 (1989)

In the classification of the weight loss, different authors have proposed different number of classes. Four classes were proposed by others; very durable, durable, moderately durable and non-durable (Ocloo, 1975) and five classes were proposed by Yanamoto and Hong (1994); Very durable, durable, moderately durable, non-durable and perishable. The classification can as well be based on the percentage mean weight loss as proposed by Eaton and Hale (1993) as shown in the table 2.2.

Table 2.2: Natural durability rating based on percentage mean weight loss against termites.

Weight Loss (%)	Rating
0 - 5	Durable
6 – 10	Moderately durable
11 – 40	Non-durable
41 - 100	Non-durable

Source: Eaton and Hale (1993)

2.5.3 Variation in Durability between Individual Trees

The natural durability of wood of individual trees of the same species may vary within wide limits. Such variability is thought to be largely controlled by genetics, although tree vigor and the soil fertility on which the tree grows can influence fungal resistance of the heartwood (Panshin and de Zeeuw, 1980; Lloyd et. al., 2014). They further reported that several factors influence the durability of wood and these include the species of wood, distribution of heartwood and sapwood, extractive, density, moisture in wood and effect of climate. David (2013) indicated some species of trees are more effective at resisting biological hazards such as fungi and termites than other species. This natural resistance or durability is a function of the type of extractives the tree stores in its heartwood.

2.5.4 Degradation of Wood

According to Thomasson *et al* (2015), wood is subject to degradation by bacteria, fungi, insects, marine borers, and climatic, mechanical, chemical, and thermal factors. Degradation can affect wood of living trees, logs, or products, causing changes in appearance, structure, or chemical composition; these changes range from simple discoloration to alterations that render wood completely useless (Encyclopedia Britannica, 2015). Fortin and Poliquin (1972) explained that, natural resistance of wood refers to its degree of resistance to biological agents only. Different types of symptoms and effects of decay on wood have been identified. They include; weight loss, strength loss, increase permeability, increased electrical conductivity and discoloration, and reduced quality. Microorganisms responsible for the deterioration of plant tissues are essential part of all terrestrial ecosystems and thus the ecosystem cannot function in their absence (Bodig and Jane, 1982).

Morrell (2014) ascertained that despite wood being a highly-integrated matrix of cellulose, hemicellulose, and lignin, which gives wood superior strength properties and a marked resistance to chemical and microbial attack, a variety of organisms and processes are capable of degrading wood. The decay process is continuous, often involving a number of organisms over many years. Wood degrading agents are both biotic and abiotic, and include bacteria, fungi, wood degrading insects, marine borers, heat, strong acids or bases, organic chemicals, mechanical wear, and sunlight (UV degradation) (Kollman and Côté, 1984; Blanchette, 2009).

2.5.4.1 Wood Degradation by Fungi

Fungi are living organism which differs from plants because they do not contain chlorophyll. They are therefore unable to manufacture their own food by photosynthesis and thus obtain their nutrients by attacking plants and animals, breaking them down into soluble forms which can be absorbed by fungi cells (Kollman and Cote, 1984; Mycolog, 2002). Wood rotting fungi cells needs certain requirements in order to function effectively and they include source of food, suitable temperature, oxygen for growth and moisture.

2.5.4.2 Wood Degradation by Insects

According to FAO (1986) and (Zabel and Morrell, 2012) there are three main divisions of wood destroying insects, namely: wood boring beetles, termites and marine borers. From the standpoint of wood utilization, the insects that damage wood can be roughly categorized into those whose attack are confined to wood before it is utilized and those whose damage is mainly restricted to wood in service. Pith flecks, pin-holes and grub holes result from the activities of insects belonging to the first category. Powder post beetles and termites are the most important examples of insect that damage wood in service.

Zabel and Morrell (2012) asserted that relatively few insects actually damage sound, dry wood. Termites, both subterranean termites and dry wood termites, carpenter ants and certain powder post beetles are the primary wood destroying insects. The potential for damage from any of these pests varies by region and climate with more damage in warm, wet climates and generally less in cool, dry climates. All timber at some stage in their life are susceptible to attack by one species or other wood-boring insects, but in practice only a small proportion becomes infested. Infestation may take place in standing trees in woodwork which has been in service for many years or at any intermediate stage depending on the species of insects and wood (Panshin and de Zeeuw, 1970; Zabel and Morrell (2012)).

In certain insects, the timber is consumed by the adult form and the best-known example of this mode of attack are the termites. Few timbers are immune to attack by these voracious eaters and it is rather unfortunate that these insects can survive in the tropics (Illston *et. al.,* 1987). Nearly all insects that cause serious damage to timber belong to the order Coleopterans (beetles) and Isopterans (termites). Insects are second only to decay fungi in the economics loss they cause to lumber and wood in service (Kollman and Cote, 1984).

2.5.4.3 Wood Degradation by Bacteria

According to Hoadley (2000), wood bacteria are microscopic organisms which decay wood. Areas that are very hot in the day or very cold seem to be harmful to bacteria that decompose wood. Wood however decays most quickly in moist, warm regions where bacteria reproduce. According to Encyclopedia Britannica (2015), Bacteria are considered to be the cause of discolorations in the form of darker-coloured heartwood in living trees (a phenomenon called wet wood in fir and black heartwood in hybrid poplars). The colour lightens on exposure to air, and the properties of the wood are not seriously affected. Bacteria also appear during prolonged storage of wood in water, including seawater (e.g., in the case of old sunken ships).

2.5.4.4 Deterioration Caused by Termites

Termites or white ants are important wood-boring insects which decay wood. They are found in virtually all parts of the world except the Arctic and Antarctic regions (Kollman and Cote, 1968; Zabel and Morrell (2012). There are about 5000 species of termites belonging to five families of the order Isopteran. The discovery of a termite infestation can be alarming as these insects may seriously weaken or destroy any timber they feed on. However, it should be recognized that termites play an important role in the breakdown and recycling of dead wood and other plants debris and that only about 30 species cause damage of economic significance to timber in service (FAO, 1986; Noble et. al., 2009). Termites are among the few insects capable of utilizing cellulose as source of food. Since cellulose is the major constituent of most plant tissues it follows that most of plants and plants products are likely to be susceptible to termite damage, under normal conditions termites of one sort or another feed upon the roots or stems of grasses, living trees, dry wood or decaying vegetable matter.

According to Kollman and Cote (1984) and Orkin (2015), termites are soft-bodied, social insects, which feed on cellulose although the gastric juices of most species do not contain celluloses. The presence of cellulose-digesting protozoa in their hind gut enables them to utilize wood as food. Termites are, however, vulnerable to high temperatures and oxygen pressures which would kill protozoa. They further indicated that considerable evidence of interrelationship between termites and fungi in the wood may be the termites 'main source of nitrogen. Termites are social insects in that they have an organized structure in a colony with a king, queen and various castes, each of which have a specialized function. Each caste has its own characteristics (Orkin, 2015).

2.5.4.4.1 Types of Termites

2.5.4.4.1.1 Subterranean Termites

According to Kamble (1991), and Orkin (2015), subterranean termites live in colonies in the ground, and are specially grouped as workers, reproductive and soldiers. They usually enter the wood from the ground or through shelter tubes they construct to reach the wood. These termites use the wood both as shelter and to obtain cellulose, their main source of food. To protect themselves from outside environment, they live entirely within the wood once a colony is established. Termites attack sound wood but prefer a wood that has already been degraded by fungi.

2.5.4.4.1.2 Dry wood Termites

According to Haygreen and Bowyer (1996), dry wood termites can enter exposed wood above the ground directly from the air; and once they gain access, they can live in wood with low mc as low as 5 or 6%. They further indicated that it is difficult to isolate buildings from contact with these insects. Wood structures in areas subject to dry wood termites require regular inspection to examine all cracks and exposed wood are caulked or painted and that ventilation is screened to prevent termites from coming in contact with unpainted.

Dry wood termites can live within furniture and in the wood behind walls, creating elaborate systems of tunnels. Dry wood termite infestations are oftentimes not recognized until they are widespread and require professional treatment. They however stated that it is possible to identify a dry wood termite infestation by loose piles of pellets, known as frass, which appear near where feeding is happening. Dry woods are less cold tolerant and are more commonly found in the southern U.S (Orkin, 2015).

2.6 General Background of Cleistopholis patens

C. patens is a forest tree that can grow up to 35m tall with a trunk diameter of 150-200cm (Irvin, 1961; Hamilton, 1991 and Barker *et al*, 2005). The bole branchless for up to 10-20m, usually straight grain, cylindrical and slender (Barker *et al*, 2005). The tree is from the Family Annonaceae, Genus Cleistopholis hence, and species Cleistopholis patens. The tree is known in the Ghanaian local Asante dialect as ―Ngo ne Nkyene‖ (Translated Oil and Salt Tree). The name ―Ngo ne Nkyene (Oil and Salt Tree) is attributed to the red juice obtained from it which resembles palm oil and tastes like salt. Its regenerative potential is better in swamp forest than in non-swamp (Barker *et al*., 2005). *C. patens* is widely distributed from Senegal westward to Uganda, southward to DR Congo and Cabinda (Angola). The bole is slender, cylindrical and straight, the timber is straight-grained, light-colored, and a bit woolly textured. It is easily cut and finishes smoothly. The wood generally has properties like those of balsa (Ochromaa sp. Malvaceae) (Burkill and Dalziel, 1985). The tree serves as food for chimpanzees in Sonson in Bodengo Forest Reserve in Uganda (Hamilton, 1991). In Liberia, tree trunks are used to float heavy timber. In Nigeria, the tree is used in making canoes, carving, musical instruments and toys, pulp and paper (Burkill, and Dalziel, 1985). The fibrous nature of the tree bark is used in making mats, baskets, cordage and walls for huts.

Various parts of the tree also yield several medicinal benefits such as the use of the seeds and bark in the treatment of malaria and measles, especially in Uganda, where the bark is crushed and used for the treatment. The seeds when roasted and grounded are likewise applied against headaches. The extracts of its bark by the method of decoction is applied in the treatment of stomach-aches, diarrhoea, tuberculosis, bronchitis and hepatitis. The pulp from the bark is also applied against swellings, oedema and whitlow; likewise, the sap is used to treat headaches by nose dripping and rickets in children by rubbing. The ashes of the tree are beneficial as a preservative for foods and use as fuel (Baker *et al*., 2005).

2.6.1 Botanical Description of *C. patens* and Distribution

C. patens are a small to medium-sized tree capable of growing up to 20-30 m in height. The bole of the tree is 10–20 m in height, branchless and usually straight. It is cylindrical and slender. Its 'diameter ranges from 80 to 90 cm, sometimes slightly fluted at the base whiles the bark surface is smooth, shallowly fissured, greyish white to grey, with a strongly fibrous inner bark, peelable in long strips, white to pale orange-brown and scented. The tree is crowned with horizontal branches drooping at the tips and often has twigs with small ridges, glabrous (Barker *et al*., 2005). *C. patens* have a better regeneration potential in swamp forest than in the non-swamp (Baker *et al*., 2005). It grows rapidly most especially in Sierra Leone, where a 7-year-old tree reaches a height of 13 m and a bole diameter of over 20 cm, whereas in Ghana the same height and diameter have been reached on 4-year-old logging tracks. In Guinea, trees have been reported to start fruiting within 5 years of planting. In Côte d 'Ivoire and Ghana, ripe fruits occur between the months of August to November. In Uganda, rotten food materials of dead *C. patens* trees are an important food source for chimpanzees as they extract its juice by chewing (Barker *et al*., 2005).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area and Collection of *C. patens* samples

Plate 3.1: District map of Assin North. Source: **Ghana Statistical Services (2010).**

Three matured and healthy *C. patens* trees were randomly selected from Assin Akropong Forest Reserve near Assin Fosu in the Central Region of Ghana. Assin Fosu has a tropical climate with two main seasons in the country; the dry and wet seasons, the average temperature and rainfall are 26.0°C and 1538mm respectively. The driest month is August (Ghana Meteorological Agency, 2016). The greatest amount of precipitation occurs in June, with an average of 250mm and the warmest month of the year is March, with an average temperature of 27.0°C. The lowest average temperatures in the year occur in August, around 24.3°C. The difference in precipitation between the driest month and the wettest month is 219 mm. The variation in temperature throughout the year is 2.7 °C (Ghana Meteorological Agency, 2016).

The *C. patens* trees aged between 40-42years according to personnel of the Forestry Services Division. Their stem lengths were 20m, 25m and 30m respectively and their diameters at breast height (1.3m) were 0.65, 0.70 and 0.75m respectively. The boles were axially divided into three sections: 3.3m of the base portion from the ground, 9.3m of the middle portion and 12.3m of the crown portion from the ground. They were transported to the Wood Workshop of the Department of Wood Science and Technology, Kwame Nkrumah University of Science and Technology (KNUST) and further broken down for air drying.

3.2 Preparation of Test Samples for Experimentation

The air-dried samples were further processed from the three portions of the bole into appropriate dimensions (Table 3.1) corresponding to the various tests (that is natural durability, density, moisture content, compression parallel to the grain, MOE, MOR and shear strength) were then obtained from defect-free samples.

Table 3.1: Sample sizes and the number of replicates used for Physical, Mechanical Properties and Natural Durability Tests Per Portion of each *C. patens*.

Type of Test	Sample Size (mm)	Part of Stem Used			Total
		Base	Middle	Top	
MC	20×20×20	15	15	15	45
Density	20×20×20	15	15	15	45
Compression Parallel to Grain	20×20×60	30	30	30	90
MOE and MOR	20×20×300	30	30	30	90
Shear Strength	50×50×50	30	30	30	90
Durability	500×50×25	16	16	16	48

3.4 Physical properties test of *C. patens*

Physical properties investigated were MC and basic density according to ASTM D143 -94 (2007)

3.4.1 Moisture content of *C. patens*

The samples for MC measuring 20×20×20mm were determined using the oven-dry method (Panshin *et al*., 1980). The samples were weighed and oven-dried for 24 hours at 103±2°C, cooled in desiccators until constant weight were attained. Fifteen samples were used each from the base, middle and top. MC of the samples was expressed as percentage of oven dry weight of the wood (Hartley and Merchant, 1995):

$$MC\ (\%) = \frac{(w1 - w0)}{w0} \times 100$$

Where,

W1= initial weight of samples (g) and

W0= oven-dry weight of samples (g).

3.4.2 Basic Density of *C. patens*

The test samples from the butt, middle and top were cut into the dimensions of 20 × 20 × 20 mm (ASTM D143 -94 (2007). In all, 45 samples were prepared along the stem. Wood samples were soaked in water for 72 hours to ensure that their MC was above the Fiber Saturation Point (FSP). The dimensions for each sample was measured with a digital caliper to the nearest 0.001mm. The samples were then oven-dried at 103 ± 2ºC for 24 hours and weighed using the digital weighing scale. They were re-dried at 2 hour intervals until no difference in weight was recorded. The basic density was determined by the Relation ASTM D143 -94 (2007):

$$\rho = \frac{\text{Oven dry mass}}{\text{Saturated volume}}$$

Where, ρ is density (g/cm³).

3.5 Mechanical Properties of *C. patens*

Determination of mechanical properties of *C. patens* was carried out at FORIG using BS 373 (1957).

3.5.1 MOR and MOE of *C. patens*

The test procedure for MOR and MOE involved the determination of the maximum load required to cause rupture using small clear wood specimens (BS 373, 1957). A laboratory table with two metal supports solidly mounted by means of screws was used for the experiment. A rectangular-shaped metal was hanged at the midpoint of the specimen and a hook with a circular base was hanged on the metal. The test specimen was placed on the supports, maintaining a length of 10mm at both ends of the support. Weights were placed on the specimen until failure and the maximum load that caused failure of the test samples were recorded. The MOR was determined by the relation (Haygreen *et al*., 1981):

$$\text{MOR} = \frac{3PL}{2bd^2}$$

Where,

MOR is Modulus of Rupture measured in N/mm²,

P is the maximum load in (N),

L is the span in mm,

b is the width (mm) and

d is the depth (mm).

The Modulus of Elasticity (MOE) in three-point bending was also determined by the relation (Bektas *et al*., 2002);

$$MOE = \frac{p/l^3}{4\Delta/bh^3}$$

Where:

p = Load at limit of proportionality (N),

l = length of the test piece (mm)

Δ=Deflection at mid length at limit of proportionality (mm),

b = Breadth of test piece (mm)

h= Depth of test piece (mm).

3.5.2 Shear Strength parallel to the Grain

Wood samples were placed in a shear machine and a load applied parallel to its grains until its failure. The maximum load that caused the failure was recorded (BS 373, 1957). Shear strength (pW) was computed (Haygreen and Bowyer, 1981):

$$pW= \frac{pmax}{b.l}$$

Where,

pmax = the maximum load (N),

b = the thickness of the piece (mm) and

l = the length.

3.5.3 Compressive Strength parallel to the Grain

A crosshead load was applied at a rate of 0.01 mm/s through a ball contact plunger. The compressive strength parallel to the grain of each piece was calculated by the relation (Haygreen and Bowyer, 1981):

$$pW = \frac{pmax}{b.l}$$

Where,

pmax = the maximum load (N),

b = the thickness of the piece (mm) and

l = the length.

3.6 Field Test of *C. patens* for Durability

Test samples (500×50×25mm) were prepared and labeled appropriately for easy identification. They were air-dried to 16-18% mc. The weights of the various replicates were measured and recorded using an electronic balance. The MC of extra samples were determined using the oven-dry method.

Decay resistance, of the stakes and the controls (*C. pentandra*), was determined at the Durability Test Site of the Department of Wood Science and Technology at the Faculty of Renewable Natural Resources (FRNR) Demonstration Farm of KNUST. The site is dominantly colonized by subterranean termites. The test site was prepared, and stakes were inserted such that one-third of their lengths was buried in the ground and 50 cm apart from each other (Figure 3.1) using Completely Randomized Design (CRD) according to EN 252 (1989) and Antwi-Bosiako and Pitman (2009) (Appendix C). The initial weights of the samples were corrected using the formula;

$$\text{CODW} = \frac{100 \times Fresh\ weight\ of\ samples}{100 + MC\ of\ samples}$$

Where CODW is corrected oven dry weight

Regular inspection of the stakes was made once every month for the assessment of deteriorating features. The test samples were left in the field for 6 months after which debris was brushed off the stakes. Visual durability rating was carried out at the pathology laboratory for the assessment of damage using EN 252 (1989) rating scale (Table 3.2). Their weights were recorded and dried with an oven to constant MC. The constant weights were recorded as weights after field test and the percentage mass loss was determined using the formula;

$$\text{Weight Loss} = \frac{CODW - FW}{FW} \times 100$$

Where FW is final weight

Percentage mass losses of samples were determined as an indication of durability using the process of mean weight loss rating. The extent of damage caused by the termite to the wood was rated according to the scale proposed by Eaton and Hale (1993) (Table 3.3).

Table 3.2: Natural durability classification based on EN 252 (1989) visual rating system

Rating	Extent of deterioration
0	No attack
1	Slight attack
2	Moderate attack
3	Severe attack
4	Failure

Source: EN 252 (1989)

Table 3.3: Natural durability rating based on percentage mean weight loss against termites

Weight Loss (%)	Rating
0 - 5	Very durable
6 – 10	Durable
11 – 40	Moderately durable
41 - 100	Non-durable

Source: Eaton and Hale (1993)

Plate 3.2: Inserted *C. patens* and *C. pentandra* (control) stakes from the test field in a 16 x 12 grid, 50 cm apart.

CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

This chapter presents the results of the study in Tables and Figures. Mean values were used and statistical analysis of the data is also presented in tables.

4.2 Physical Properties along the axial portions of *C. patens*

4.2.1 Moisture Content (MC)

Moisture content along the axial stem portions of each of the three *C. patens* decreased from top to butt. For the first *C. patens* (*C. patens* 1), MC decreased as: top (13.81%) > mid (13.52%) > butt (12.38%) (Figure 4.1). For the second *C. patens* (*C. patens* 2), MC decreased as: top (13.76%) > mid (13.31%) > butt (12.19%) (Figure 4.1). For the third *C. patens* (*C. patens* 3), MC decreased as: top (13.94%) > mid (13.38%) > butt (12.43%) (Figure 4.1). There was no significant difference between the three *C. patens* as well as the interaction between the three *C. patens* and the axial stem portions ($p>0.05$) (Table 4.1). However, significant differences were observed between the axial positions of the *C. patens* ($p<0.05$) (Table 4.1). Tukey's multiple comparison test also revealed no significant difference ($p>0.05$) in MC between the axial sections of the three *C. patens* (Appendix B1).

Average MC of the various portions of the three *C. patens* ranged from 12.33% for the butt to 13.83 % for the top. The top portion recorded the greatest mean MC (13.83%) followed by the middle (13.4%) and the butt (12.33 %) (Figure 4.2). From ANOVA (Table 4.2), the difference in the mean MC for the various stem portions was significant ($p<0.05$). However, Tukey's multiple comparison test revealed no significant difference ($p>0.05$) in MC between the top and the middle and between the middle and bottom parts of the stem (Appendix A1).

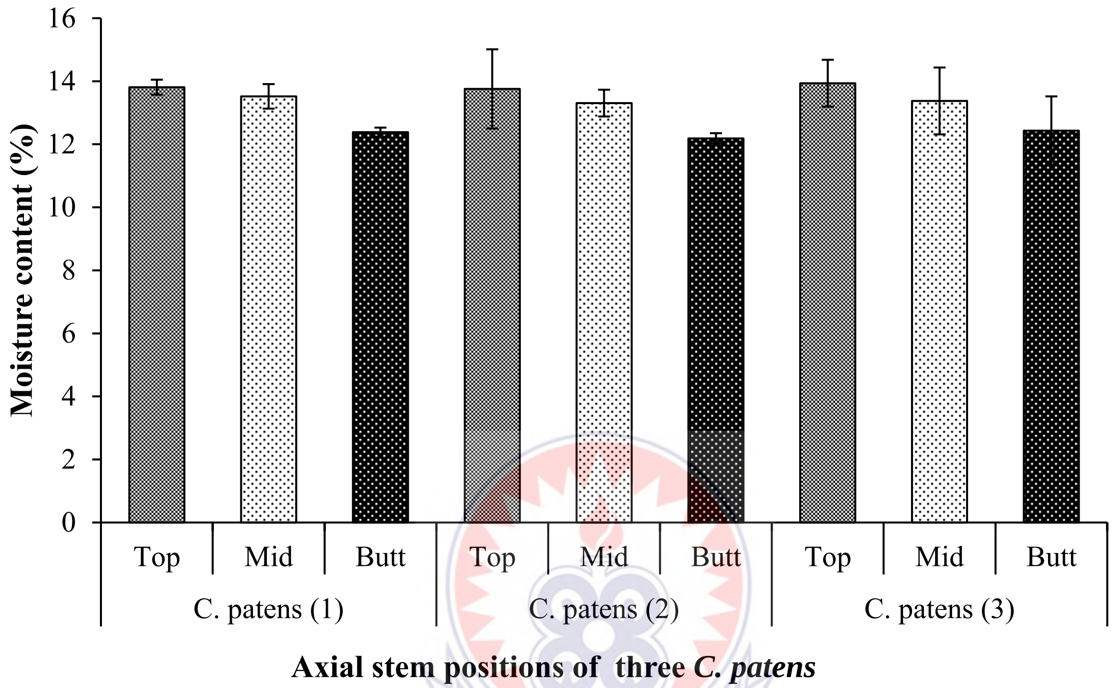

Figure 4.1: Moisture content along the stems of three *C. patens*

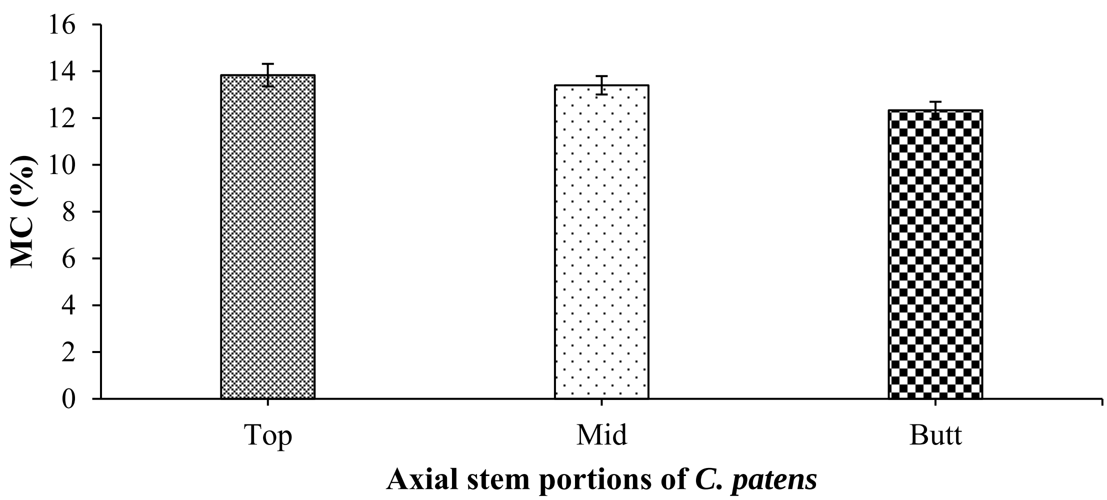

Figure 4.2: Average Moisture content along the stem of *C. patens*.

Table 4.1: ANOVA for Moisture content along the stems of the three *C. patens*

Source of Variation	SS	DF	MS	F (DFn, DFd)	P-value
Interaction	0.3541	4	0.08852	F (4, 126) = 0.01089	0.9998
Row Factor	0.7718	2	0.3859	F (2, 126) = 0.04748	0.9536
Column Factor	53.66	2	26.83	F (2, 126) = 3.301	0.0401
Residual	1024	126	8.128		

Table 4.2: ANOVA for Average Moisture content along the stems of *C. patens*

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	53.6578	2	26.8289	3.454306	0.034495	3.064761
Within Groups	1025.218	132	7.7668			
Total	1078.875	134				

4.2.2 Basic Density

Basic density decreased from butt to top along the axial stem portions of each of the three *C. patens*. For *C. patens* (1), *C. patens* (2) and *C. patens* (3) basic density decreased as: butt (273.2kg/m^3, 291.47kg/m^3, 288.86kg/m^3 respectively) > mid (227.91kg/m^3, 230.18kg/m^3 respectively) > top (198.57kg/m^3, 200.43kg/m^3, 188.41 kg/m^3 respectively) (Figure 4.3). There was no significant difference between the three *C. patens* and interaction between the three *C. patens* and the axial stem portions ($p>0.05$) (Table 4.3). However, significant differences were observed between the axial positions of the *C. patens* ($p<0.05$) (Table 4.3). Tukey's multiple comparison post hoc test also revealed significant differences in the basic density amongst some of the of the axial sections of the three *C. patens* including, *C. patens* (1) top and *C. patens* (1) butt (Appendix B2).

The mean basic density of the various sections of the three *C. patens* showed a decreasing trend from the butt to the top (Figure 4.4). It decreased as: butt (284.5 kg/m^3 > mid (231.91 kg/m^3) > top (195.81 kg/m^3). From ANOVA, there was significant differences for the mean basic density of the various stem sections ($p<0.05$) (Table 4.4). Tukey's multiple comparison post hoc test also revealed significant differences between the various stem sections (Appendix A2).

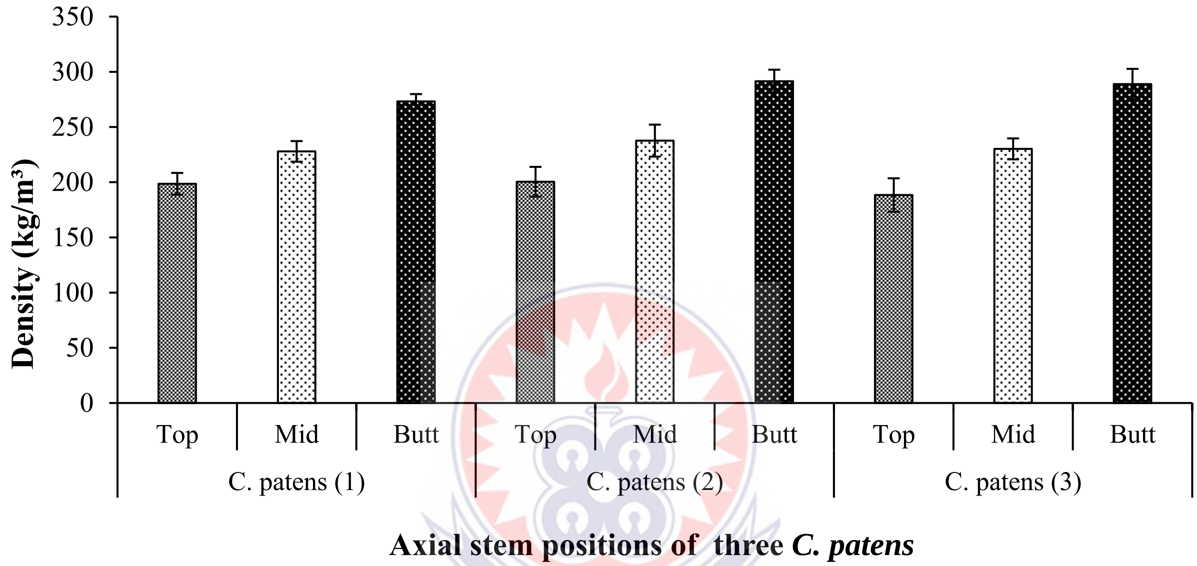

Figure 4.3: Basic density along the stems of three *C. patens*

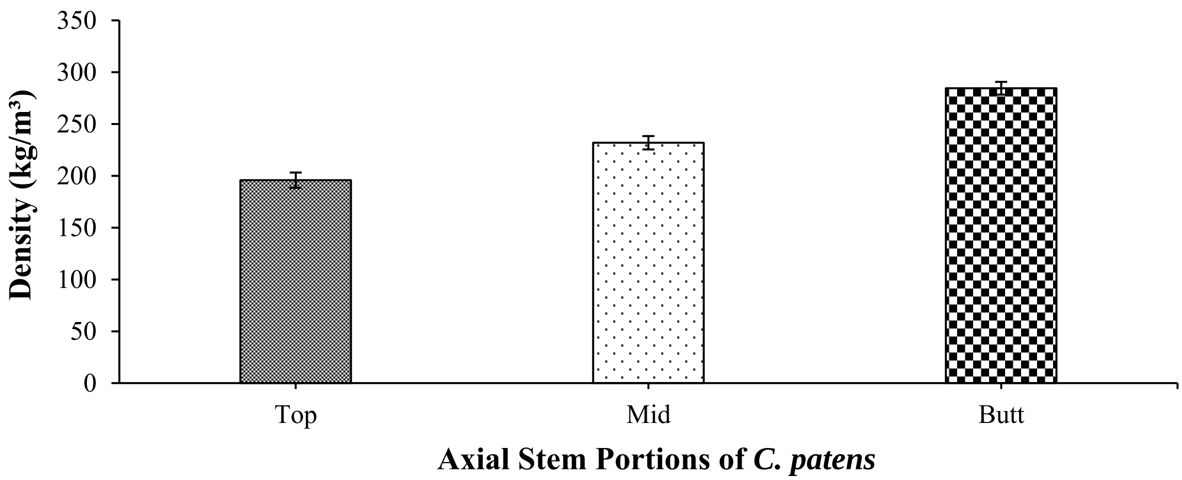

Figure 4.4: Average Density along the stems of *C. patens*

Table 4.3: ANOVA for Basic density along the stems of three *C. patens*

Sources of Variation	SS	DF	MS	F (DFn, DFd)	P value
Interaction	2563	4	640.8	F (4, 126) = 0.3102	P=0.8707
Row Factor	2401	2	1201	F (2, 126) = 0.5812	P=0.5607
Column Factor	179080	2	89540	F (2, 126) = 43.34	P<0.0001
Residual	260288	126	2066		

Table 4.4: ANOVA for Average density along the stems of *C. patens*

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	179079.576	2	89539.78822	44.5585	1.63E-15	3.064761
Within Groups	265252.488	132	2009.488546			
Total	444332.064	134				

4.3 Mechanical properties along the axial portions of *C. patens*

4.3.1 Modulus of Rupture

MOR decreased from butt to top along the axial stem portions of each of the three *C. patens*. For *C. patens* (1), *C. patens* (2) and *C. patens* (3) MOR decreased as: butt (53.617 N/mm^2, 55.509 N/mm^2, 56.053 N/mm^2 respectively) > mid (46.853 5 N/mm^2, 51.473 N/mm^2, 48.617 N/mm^2 respectively) > top (44.582 N/mm^2, 46.182 N/mm^2, 43.616 N/mm^2 respectively) (Figure 4.5). There was significant difference between the three *C. patens* as well as between their axial stem portions (p<0.05) (Table 4.5). However, no significant differences were observed between the interactions of the axial positions of the *C. patens* and three *C. patens* (p>0.05) (Table 4.5). However, Tukey's multiple comparison post hoc test also revealed significant differences in the basic density amongst some of the of the axial sections of the three *C. patens* including, *C. patens* (2) top and *C. patens* (3) mid (Appendix B3).

Combined, there was a decreasing trend in MOR from the butt to the top of the tree (Figure 4.6). The butt portion recorded a mean MOR of 55.06 N/mm^2, followed by the middle portion (46.98 N/mm^2) and the top (44.69 N/mm^2) (Figure 4.6). According to ANOVA, there was significant differences in MOR for the various stem sections ($p<0.05$) (Table 4.6). Tukey's multiple comparison post hoc test also revealed significant differences between in MOR of the various stem sections (Appendix A3).

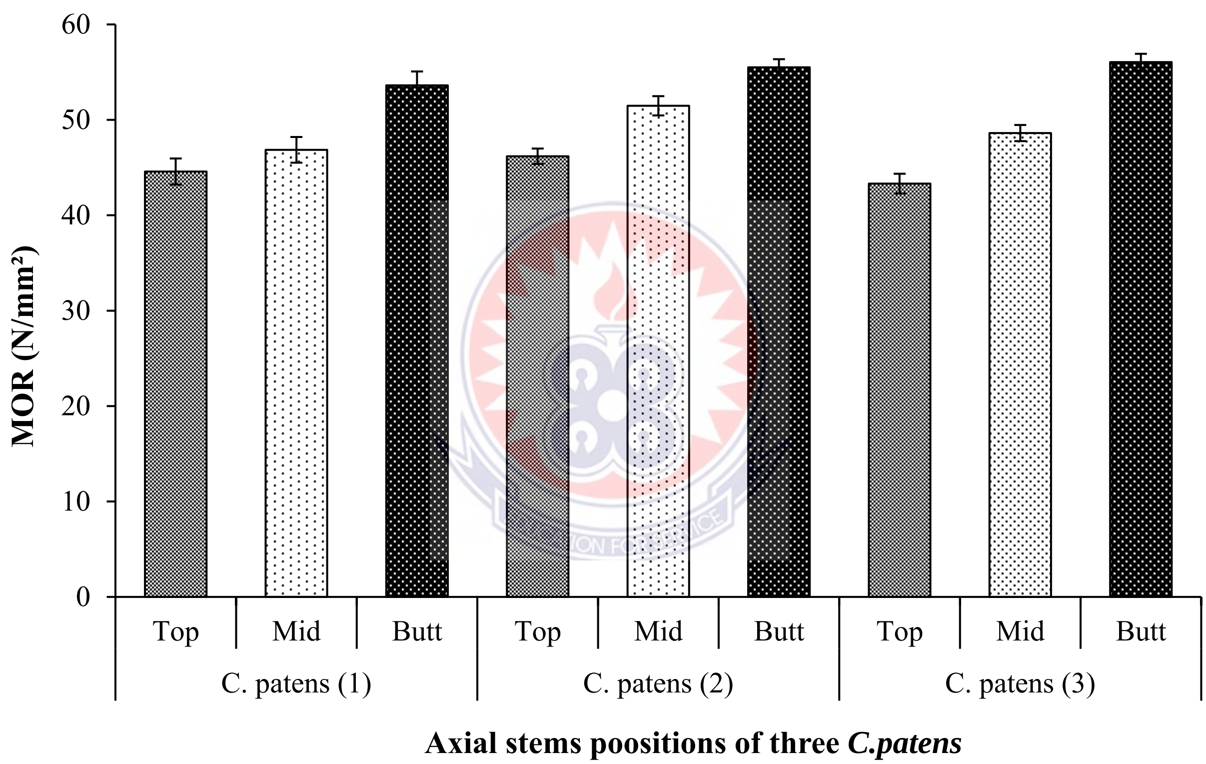

Figure 4.5: Modulus of Rupture along the stems of three *C. patens*

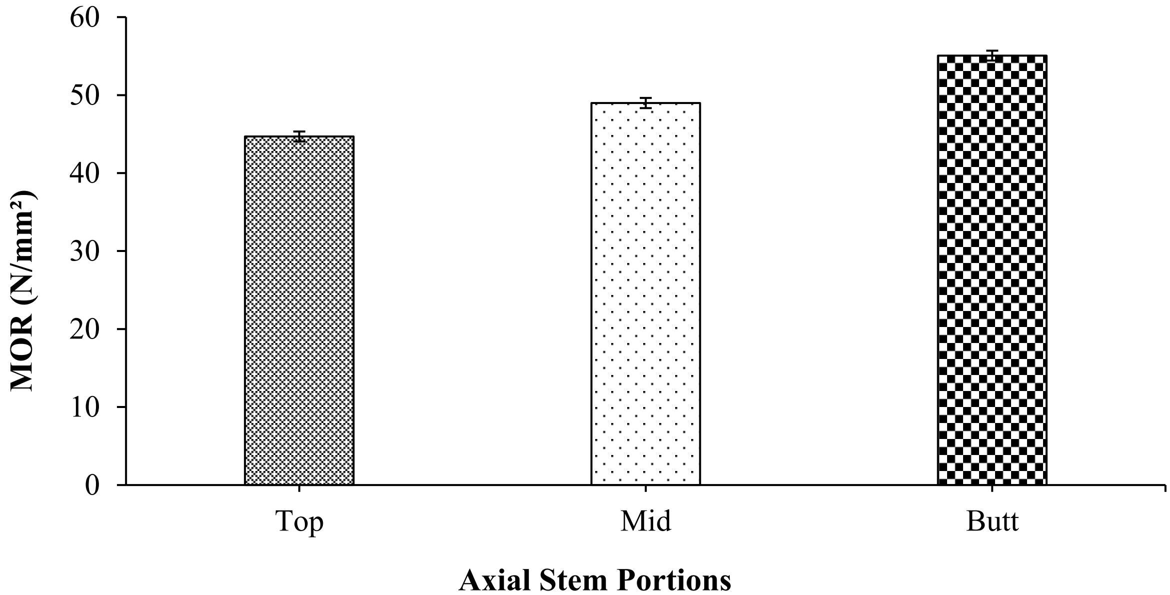

Figure 4.6: Average Modulus of Rupture along the stems of *C. patens*

Table 4.5: ANOVA for Modulus of Rupture along the stems of three *C. patens*

Source of Variation	SS	DF	MS	F (DFn, DFd)	P value
Interaction	210.6	4	52.65	F (4, 261) = 1.472	0.2111
Row Factor	337.4	2	168.7	F (2, 261) = 4.717	0.0097
Column Factor	4884	2	2442	F (2, 261) = 68.27	<0.0001
Residual	9336	261	35.77		

Table 4.6: ANOVA for Average Modulus of Rupture of *C. patens*

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4883.906	2	2441.953	65.96564	5.24E-24	3.029597
Within Groups	9883.957	267	37.01856			
Total	14767.86	269				

4.3.2 Modulus of Elasticity

MOE decreased from butt to top along the axial stem portions of each of the three *C. patens*. For *C. patens* (1), *C. patens* (2) and *C. patens* (3) MOE decreased as: butt (8200.30 N/mm^2, 8289.30 N/mm^2, 8201.10 N/mm^2 respectively) > mid (7555.93 N/mm^2, 7575.30 N/mm^2, 7575.87 N/mm^2 respectively) > top (7268.33 N/mm^2, 7273.80 N/mm^2, 7186 N/mm^2 respectively) (Figure 4.7). There was significant difference in the MOE of the axial stem portions of the three *C. patens* ($p<0.05$) (Table 4.7). However, there were no significant differences between the interactions of the axial positions of the *C. patens* and between the three *C. patens* ($p>0.05$) (Table 4.7). According to Tukey's multiple comparison post hoc test also revealed significant differences in the basic density amongst some of the of the axial sections of the three *C. patens* including, *C. patens* (2) butt and *C. patens* (3) top (Appendix B4).

The average MOE along the stem of the trees decreased from butt to top. The butt portion recorded a mean value of 8230.233 N/mm^2 followed by the middle portion of 7569.03 N/mm^2, and the top with 7242.11 N/mm^2 (Figure 4.8). There was a significant difference in MOE ($p<0.05$) for the various sections of the tree (Table 4.8). Tukey's multiple comparison test however indicated no significant difference in MOE between the top and middle stem sections (Appendix A4).

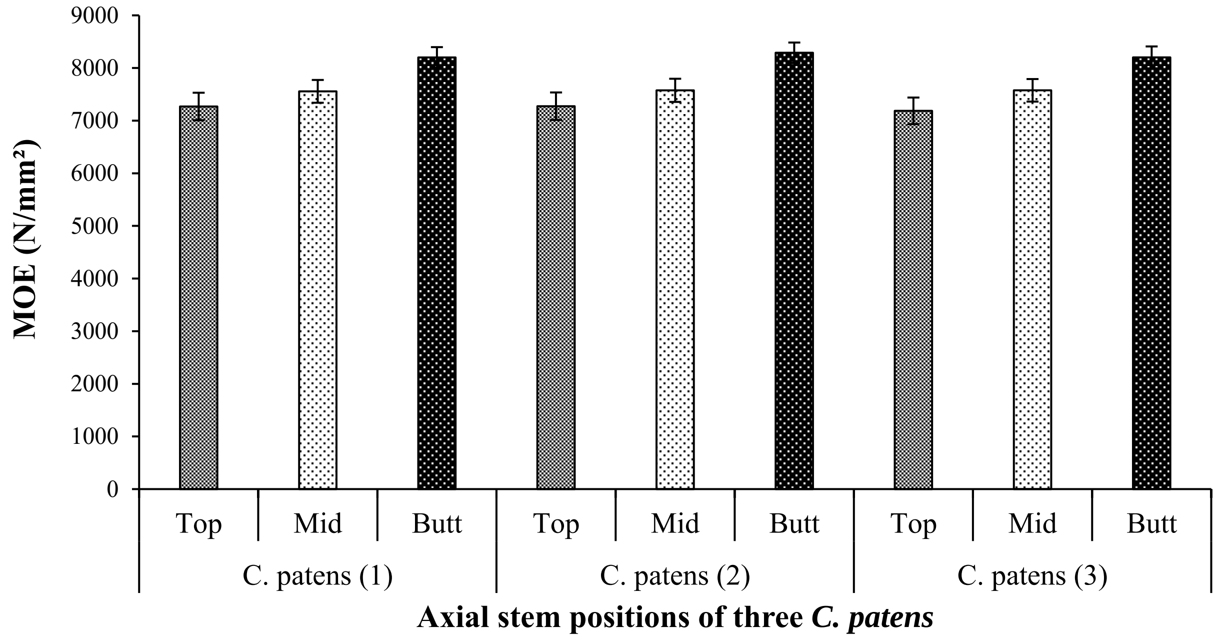

Figure 4.7: Modulus of Elasticity along the stems of three *C. patens*

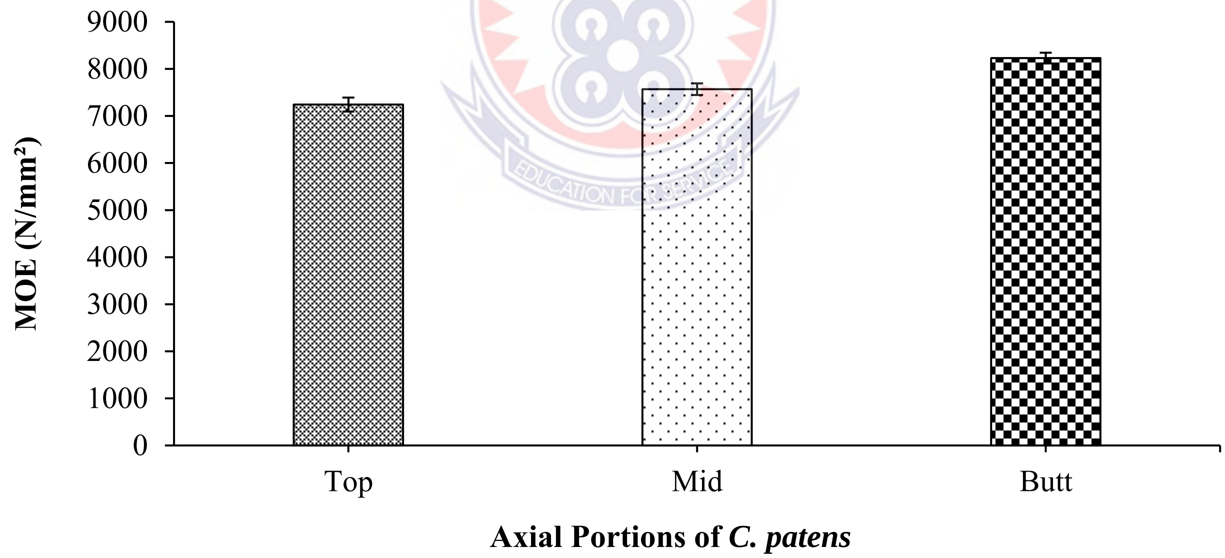

Figure 4.8: Average Modulus of Rupture along the stem of *C. patens*

Table 4.7: ANOVA for Modulus of Elasticity along the stems of three *C. patens*

Source of Variation	SS	DF	MS	F (DFn, DFd)	P value
Interaction	151480	4	37870	F (4, 261) = 0.02464	0.9988
Row Factor	158431	2	79216	F (2, 261) = 0.05154	0.9498
Column Factor	45566153	2	22783077	F (2, 261) = 14.82	<0.0001
Residual	401125012	261	1536877		

Table 4.8: ANOVA for Average Modulus of Elasticity along the stems of *C. patens*

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	45566153	2	22783077	15.15334	5.84E-07	3.029597
Within Groups	4.01E+08	267	1503502			
Total	4.47E+08	269				

4.3.3 Shear strength (parallel to the grain)

Shear strength decreased from butt to top along the axial stem portions of each of the three *C. patens*. For *C. patens* (1), *C. patens* (2) and *C. patens* (3) shear strength decreased as: butt (7.654 N/mm^2, 7.2010 N/mm^2, 7.824 N/mm^2 respectively) > mid (6.3343 N/mm^2, 6.1915 N/mm^2, 6.6202 N/mm^2 respectively) > top (5.5076 N/mm^2, 5.4825 N/mm^2, 5.1996 N/mm^2 respectively) (Figure 4.9). There was significant difference in shear strength along the axial stem portions of the three *C. patens* ($p<0.05$) (Table 4.9). However, there were no significant differences between the interactions of the axial positions of the *C. patens* and between the three *C. patens* ($p>0.05$) (Table 4.9). Tukey's multiple comparison post hoc test also revealed significant differences in the shear strength amongst some of the axial sections of the three *C. patens* including, *C. patens* (1) butt and *C. patens* (1) middle, as well as *C. patens* (1) top and *C. patens* (2) butt (Appendix B5). Figure 4.10 indicates a decreasing trend in the average shear strength from the butt the top of the *C. patens*.

Mean values of 7.560 N/mm^2, 6.382 N/mm^2 and 5.397 N/mm^2 were recorded for the butt, middle and top portions, respectively. Thus, the butt and top recorded the greatest and least shear strengths respectively. There was a significant difference in MOE ($p<0.05$) for the various sections of the tree (Table 4.10). Tukey's multiple comparison test also indicated significant difference in MOE between the stem sections (Appendix A5).

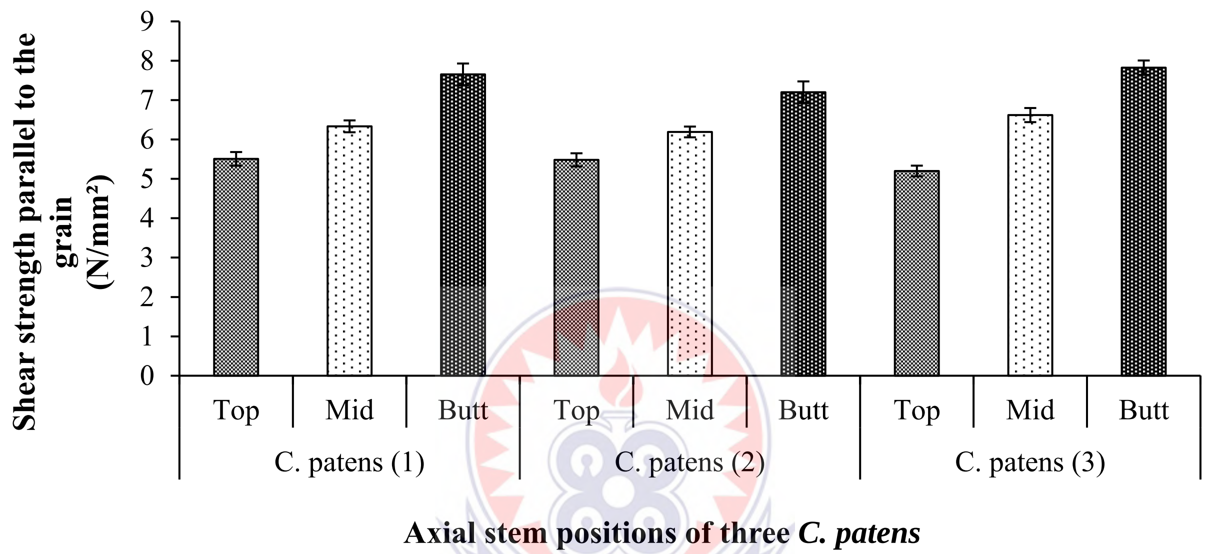

Figure 4.9: Shear strength (parallel to grain) along the stems of three *C. patens*

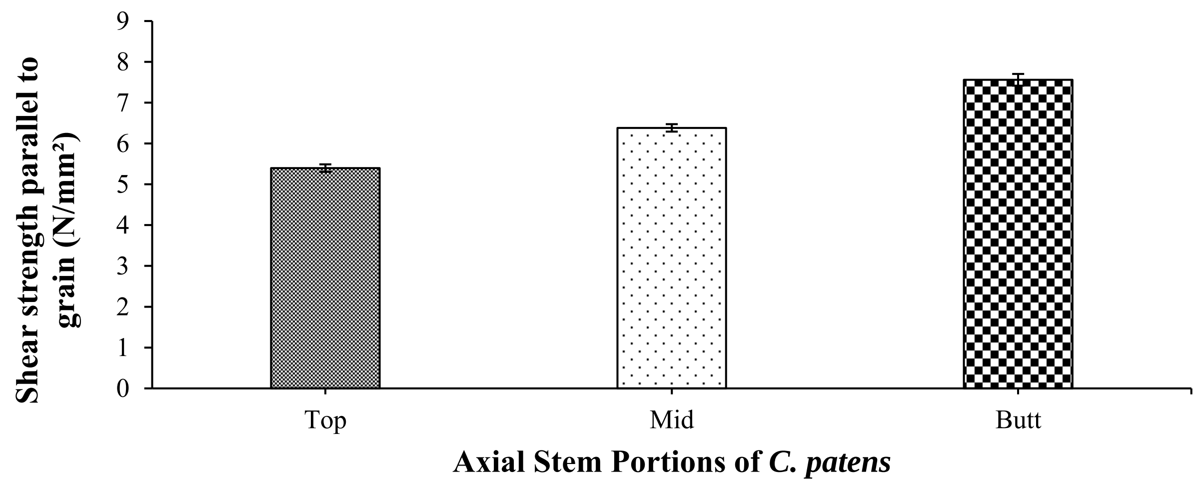

Figure 4.10: Average Shear strength (parallel to grain) along the stems of *C. patens*

Table 4.9: ANOVA for shear strength along the stems of three *C. patens*

Source of Variation	SS	DF	MS	F (DFn, DFd)	P value
Interaction	7.506	4	1.877	F (4, 261) = 1.682	0.1546
Row Factor	3.327	2	1.663	F (2, 261) = 1.491	0.2271
Column Factor	211.1	2	105.6	F (2, 261) = 94.59	<0.0001
Residual	291.2	261	1.116		

Table 4.10: ANOVA for Average Shear strength (parallel to grain) along the stems of *C. patens*

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	211.1	2	105.5503	93.29804	1.88E-31	3.029597
Within Groups	302.06	267	1.131324			
Total	513.16	269				

4.3.4 Compression strength Parallel to the Grain

Compression strength parallel to the grain decreased from butt to top along the axial stem portions of each of the three *C. patens*. For *C. patens* (1), *C. patens* (2) and *C. patens* (3) compression strength parallel to grain decreased as: butt (28.872 N/mm^2, 29.809 N/mm^2, 28.029 N/mm^2 respectively) > mid (26.142 N/mm^2, 25.838 N/mm^2, 23.626 N/mm^2 respectively) > top (24.445 N/mm^2, 23.548 N/mm^2, 21.718 N/mm^2 respectively) (Figure 4.9). There was significant difference in compression strength of the three *C. patens* and along the axial stem portions of the three *C. patens* ($p<0.05$) (Table 4.11). However, there were no significant differences between the interactions of the axial positions of the three *C. patens* ($p>0.05$) (Table 4.11). Tukey's multiple comparison post hoc test revealed significant differences in the compression strength amongst some of the of the axial sections of the three *C. patens* including, *C. patens* (1) top and *C. patens* (1) butt as well as *C. patens* (1) butt and *C. patens* (3) top (Appendix B5).

Combined, the compression strength of *C. patens* decreased from butt to top as: Butt (28.903 N/mm^2) > mid (25.202 N/mm^2) > top (23.237 N/mm^2) (Figure 4.12). There was significant difference in compression strength along the axial stem sections of *C. patens* ($p<0.05$) (Table 4.12). Tukey's multiple comparison post hoc analysis further indicated significant differences between mean compression strength of the various axial stem portions (Appendix A6).

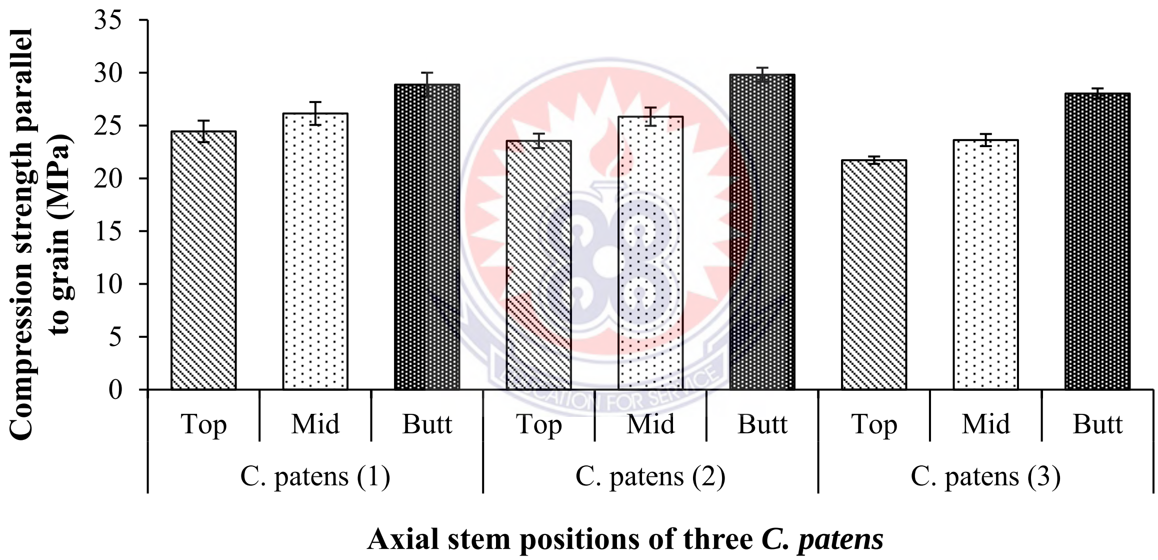

Figure 4.11: Compression strength parallel to the grain along the stems of three *C. patens*

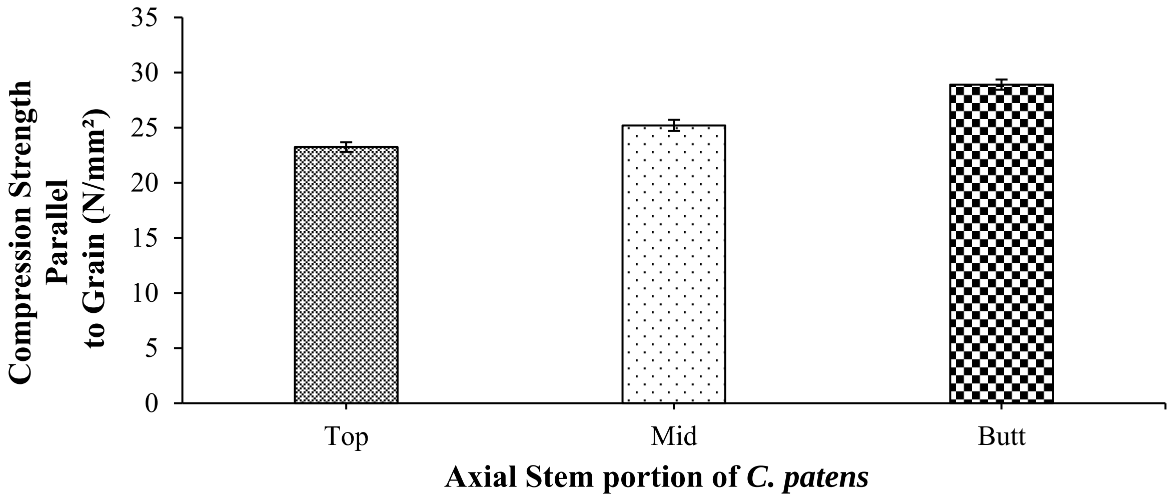

Figure 4.12: Average Compression strength (parallel to grain) along the stems of *C. patens.*

Table 4.11: ANOVA for Compression strength along the stems of three *C. patens*

Source of Variation	SS	DF	MS	F (DFn, DFd)	P value
Interaction	39.93	4	9.983	F (4, 261) = 0.513	0.7262
Row Factor	236.7	2	118.3	F (2, 261) = 6.082	0.0026
Column Factor	1490	2	744.9	F (2, 261) = 38.28	<0.0001
Residual	5079	261	19.46		

Table 4.12: ANOVA for Average Compression Strength (parallel to grain) along the stems of *C. patens*

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1489.889	2	744.9443	37.14038	5.87E-15	3.029597
Within Groups	5355.361	267	20.05753			
Total	6845.249	269				

4.4. Natural Durability of *C. patens*

4.4.1. Percentage mass loss of various portions of *C. patens* and *C. pentandra*

The top stem section of each *C. patens* and *C. pentandra* (control) all recorded 100% mass loss (Figure 4.13). For the other sections, mass loss decreased for *C. patens* (1), *C. patens* (2) and *C. patens* (3) decreased as: mid (98.38%, 97.25%, 96.56% respectively) > butt (87.75%, 87.56%, 86% respectively) (Figure 4.13). There was significant difference in the percentage mass loss of the three *C.* ($p<0.05$) (Table 4.13). However, there were no significant differences between the interactions of the axial positions of the three *C. patens* as well as between the three *C. patens* ($p>0.05$) (Table 4.13).

Average of the three *C. patens* showed an increasing trend in mass loss from the butt to the top of the *C. patens* (Figure 4.14). The butt portion recorded the greatest mass loss of 87.75%, followed by the middle (98.38%) and the top (100%) with the control (*C. pentandra*) also recording 100% (Figure 4.14).

The differences in the mean percentage weight loss for the various sections of *C. patens* and the *C. pentandra* was significant ($p<0.05$) (Table 4.14). However, Tukey's multiple comparison post hoc analysis indicated no significant differences in percentage mass loss between top and middle stem portions of *C. patens*, top stem portion of *C. patens* and *C. pentandra* (control) as well as between the middle stem portion of *C. patens* and *C. pentandra* (Appendix A7).

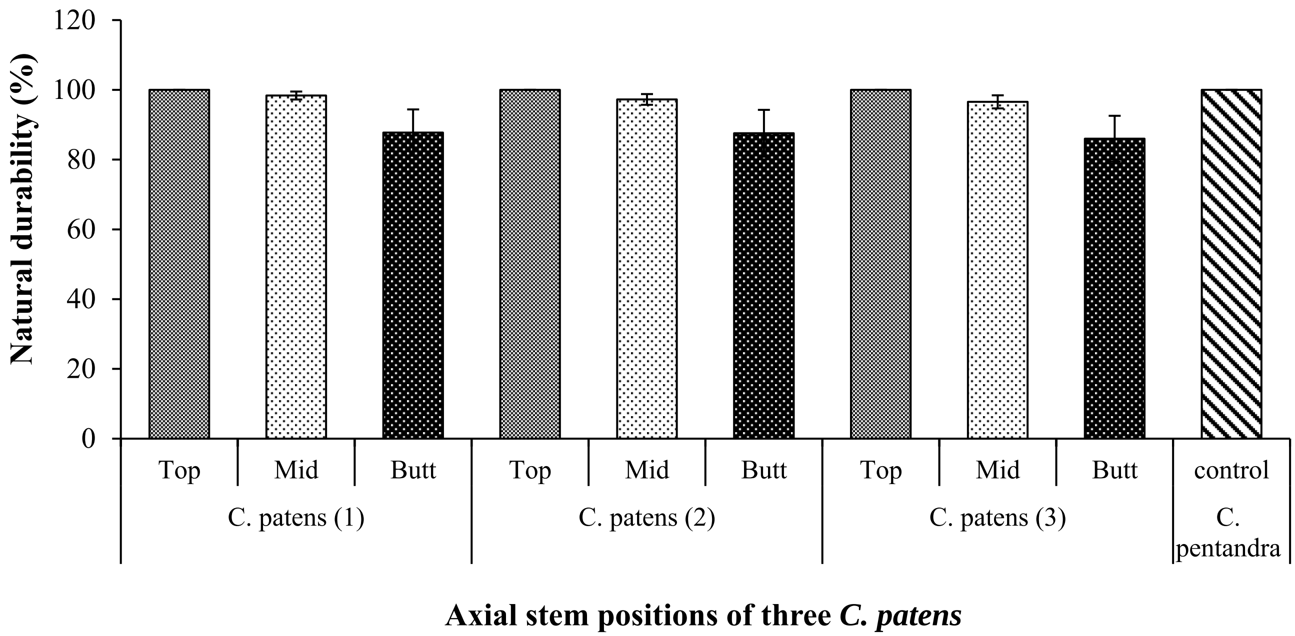

Figure 4.13: Natural durability along the stems of three *C. patens* and *C. pentandra*

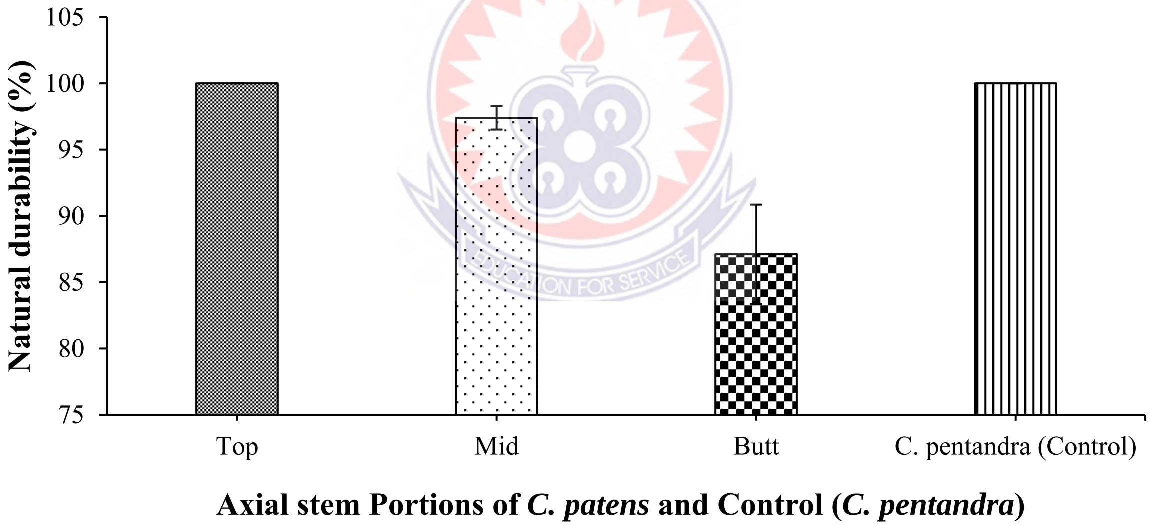

Figure 4.14: Average Natural durability of the various stems portions of *C. patens*.

Table 4.13: ANOVA for Natural durability along the stems of three *C. patens* and *C. pentandra*

Source of variation	SS	DF	MS	F (DFn, DFd)	P value
Interaction	1138	6	189.6	F (6, 180) = 1.021	0.4134
Row Factor	995.6	3	331.9	F (3, 180) = 1.786	0.1514
Column Factor	3348	2	1674	F (2, 180) = 9.01	0.0002
Residual	33444	180	185.8		

Table 4.14: ANOVA for Average Natural durability along the stems of *C. patens* and control (*C. pentandra*)

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5425	3	1808.35	10.1483	3.15E-06	2.652646
Within Groups	33500	188	178.191			
Total	38925	191				

4.4.2. Visual durability rating

For *C. patens* (1), *C. patens* (2) and *C. patens* (3) visual durability ratings decreased as: top (4,4,4) > mid (3.999, 3.993, 3.998 respectively) > butt (3.921, 3.952 and 3.958 respectively) (Table 4.15). There was significant difference in the visual durability ratings along the axial stem sections of the three *C. patens* ($p<0.05$) (Table 4.17). However, there were no significant differences between the interactions of the axial positions of the three *C. patens* as well as between the three *C. patens* ($p>0.05$) (Table 4.17).

For the average of the axial stem sections of the three *C. patens*, the butt and the middle had a mean of 3.943 and 3.997 respectively while both the top of *C. patens* and *C. pentandra* scored 4.0

(Table 4.16). Thus, all the sections along the stem recorded an approximate mean score of 4.0 which corresponds to Failure according to EN 252 (1989) rating for visual durability.

Table 4.15: Visual durability ratings along the stems of three *C. patens* and *C. pentandra*

C. patens	Mean Visual Rating of the Axial Stem Sections (0-4)			Interpretation
	Butt	Mid	Top	
1	3.921	3.999	4	Failure
2	3.951	3.993	4	Failure
3	3.958	3.998	4	Failure
C. pentandra (Control)	4	4	4	Failure

Table 4.16: Average Visual durability rating along the stems of *C. patens* and the control (*C. pentandra*)

Stem section	Mean visual rating (0 - 4)	Interpretation
Butt	3.943	Failure
Middle	3.997	Failure
Top	4.000	Failure
Control (*C. petandra*)	4.000	Failure

From ANOVA, there was no significant difference between the visual rating scores for the various portions of the stem of *C. patens* and *C. pentandra* ($p > 0.05$) (Table 4.9).

Table 4. 17: ANOVA for Visual durability rating along the stems of three *C. patens* and *C. pentandra*

Source of variation	SS	DF	MS	F (DFn, DFd)	P value
Interaction	0.03305	6	0.005508	F (6, 180) = 1.41	0.2130
Row Factor	0.01794	3	0.005979	F (3, 180) = 1.53	0.2082
Column Factor	0.0728	2	0.0364	F (2, 180) = 9.317	0.0001
Residual	0.7032	180	0.003907		

Table 4. 18: ANOVA for Average visual rating along the stems of *C. patens* and the control (*C. pentandra*)

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.108981	3	0.036327	9.632325	6.03E-06	2.652646
Within Groups	0.709015	188	0.003771			
Total	0.817995	191				

CHAPTER FIVE

5.0 DISCUSSION

5.1 Introduction

The discussions have been presented on the physical properties (MC and basic density), mechanical properties (MOR, MOE, Compressive strength parallel to the grain, shear strength) and the natural durability (% weight loss) of *C. patens* that were determined.

5.2 Physical Properties along the axial stem portions of *C. patens*

Physical properties of wood play a significant role to indicate the probable behavior of their strength properties. Various researchers have indicated that physical properties including density, MC, shrinkage and texture influence the domestic and commercial utilization of wood (Killmann, 1983; Cassidy and Aston, 2007; Ayarkwa, 2009). Thus, each physical property has an influence on wood performance. The results of two physical properties, MC and basic density, are discussed below.

5.2.1 Moisture Content (MC)

According to Desch and Dinwoodie (1996), the MC of wood is one of the many variables that affect the performance and utilization of wood. MC along the axial portions of the three *C. patens* ranged from the butt of *C. patens* (2) (12.185%) to the top of *C. patens* (3) (13.936%) (Figure 4.1). Averagely, MC increased with increasing height with the butt recording the least (12.33%) and the top recording the highest (13.83%) (Figure 4.2). MC varies from one portion to another within the same piece of wood (Wood Floor Online, 2009). According to Reeb (1995), substantial moisture gradient can occur in the same log as well as in different logs of the same wood species of the same growing environments. The findings of this research with varying MC at different portions (butt, middle and crown) thus confirm that % MC varies along the same tree. Since wood utilization is influenced by its mc (Nurfaizah *et al*., 2014), varying mc along the stem indicates that the different portions of *C. patens* may be considered for different applications such as roofing, wall portioning, fencing and pallets. The difference in MC along the stem of *C. patens* could be attributed to the differences in the distribution of active cells along it. According to Nurfaizah *et al*. (2014), increasing mc with increasing height of wood is influenced by the number of active cells, where there are greater number of active cells in the sapwood compared with the heartwood. Thus, the butt with greater proportion of heartwood and relatively lower active cells in sapwood recorded a significantly lower MC than the middle and the top.

Usability and strength of wood have been related to its MC by various researchers (Nurfaizah *et al*., 2014; Desch, 1996; USDA, 1999). Barrett *et al* (1975) indicated that bending and strength properties of small clear samples of wood increase with decreasing MC. The butt portion of *C. patens* recorded the least MC which was significantly different ($p < 0.05$) from the middle and the top (Appendix B1). This suggests that its butt portion may be considered for applications involving bending and other strength properties compared to the middle and the top. However, the amount of moisture present in wood does not only influence its strength, stiffness and mode of failure, but also its dimensional stability, susceptibility to fungal attack, workability and the ability to accept adhesives and finishes (Desch and Dinwoodie, 1996). This further indicates that the butt portion with a relatively low MC may be easy to work with, perform better when in service and provide better appealing end products than at the middle and top.

5.2.2 Basic density

Density is used as an indicator of wood quality, tissue allocation patterns and a predictor of plant performance (Oyomoare and Zanne, 2013). Hayreen and Bowyer (1996) also stressed that density and specific gravity are perhaps the most important factors influencing the mechanical properties of timber. The basic density along the axial portions of the three *C. patens* ranged from the top of *C. patens* (3) (188.409 kg/m^3) to the mid of *C. patens* (3) (230.183 kg/m^3) (Figure 4.3). Combined, the mean densities of 284.51 kg/m^3, 231.91 kg/m^3 and 195.81 kg/m^3 were recorded for the butt, middle and top portions of *C. patens* respectively (Figure 4.2). The butt portion had a significantly higher mean density than the middle and the top ($p<0.05$) (Appendix B2). Wood density varies between and within species, and also shows within-tree variability such as axial, radial and within growth ring variation (Panshin and Zeeuw, 1980; Zobel and van Buijtenen, 1989; Saranpaa, 2003). The differences in density along the various portions of *C. patens* thus contribute to the knowledge that wood density within the same log can vary at different portions of the log. Wood density is considered an indicator of its strength, where higher density denotes greater strength (Tsoumis, 1991; Panshin and Zeeuw, 1980). This indicates that the butt portion of *C. patens* may be useful in applications requiring greater strength such as for roofing and flooring compared to the middle and the top as it recorded a significantly higher density.

The decreasing trend of density from the butt to the top agrees with what is reported by several other researchers. In a study involving *Pterygota macrocarpa,* Ayarkwa (1998) also reported of mean densities of 670 kg/m^3, 640 kg/m^3 and 620 kg/m^3 for the butt, middle and top respectively. Zziwa *et al*. (2012) also testified to the same trend of variation in density along the stem in a study of *Artocarpus heterophylllus.* According to Harwald and Olesen (1987), wood has a high density at the butt portion due to more extractive deposits, high proportion of cells and the support provided by the basal portion to the wood. Tsoumis (1992) also indicated that wood density is influenced by differences in the concentration of extractives and the chemical composition of the cell wall. The decrease in density from butt to top in *C. patens* could be attributed to variation in the distribution of extractives along the stem. Stod *et al*. (2016) explained that the decrease in density from the butt to the top of scots pine (*Pinus sylvestris L.)* is also due to more matured wood at the butt whereas the top is mainly made up of juvenile wood. According to Ishengoma *et al*. (1992), juvenile wood is significantly lower in density than mature wood and hence the reduction in density away from the butt end. The highest density at the butt portion of *C. patens* could also be due to accumulation of matured wood cells at the base which is replaced by juvenile wood moving towards the top with a corresponding low density.

The difference in mean density for the butt and the other portions (middle and top) of *C. patens* was significant ($p<0.05$) (Appendix B2). The mean densities for the various portions including the butt, however, are low compared to *Alstonia boonei,* 410 – 450 kg/m^3 (Agyeman, 2014), *Pterygota macrocarpa*, 620 – 670 kg/m^3 (Ayarkwa, 1998), *Cola nitida,* 577.82 - 653.75 kg/m^3 (Effah *et al*., 2013), and *Funtumia elastic*, 497.9 kg/m^3 - 501.3 kg/m^3 (Effah *et al*., 2013). With mean densities of 195.81 kg/m^3 – 284.51 kg/m^3 along the stem, *C. patens* could be classified as a low-density wood (FAO, 1985; Owoyemi and Olaniran, 2014; Racero *et al*., 2015). Low density woods are also graded as soft woods according to FAO, (1985). *C. patens* might thus be considered for applications that do not require excessive loading such as industrial and domestic woodware, fencing, flooring, carving, ceiling, formwork in making columns and lintels as well as wall paneling.

5.3 Mechanical Properties along the axial stem portions of *C. patens*

According to Record (2004), the mechanical properties of wood are its fitness and ability to resist applied or external forces. Haygreen and Bowyer (1996) and Wood Technology Society (WTS) (2004), also indicated that mechanical properties are usually the most important characteristics of wood products that enable it to be used in structural applications. Mechanical properties of wood species must thus be ascertained in addition to other properties such as physical and chemical to establish their usability. In this section, static bending (MOR and MOE), compression parallel to the grain and shear strength parallel to grain are discussed.

5.3.1 Modulus of Rupture (MOR)

MOR gives an indication of the amount of load needed to cause failure (Hoyle, 1989). MOR along the axial portions of the three *C. patens* ranged from the top of *C. patens* (3) (43.316 N/mm^2) to the butt of *C. patens* (3) (56.053 N/mm^2) (Figure 4.5). The mean MOR for the butt, middle and top at 12% MC were 55.06 N/mm^2, 49.98 N/mm^2 and 44.69 N/mm^2 respectively (Figure 4.6). The results show a decrease in MOR from the butt to top of the tree (decreasing with height). This implies that the butt sustained the highest load (force) to cause failure compared to the middle and top, indicating a greater strength in bending at the butt. The mean MOR for the butt was significantly different ($p<0.05$) from the middle and the Top (Appendix B3). Thus, for applications where MOR is important, the butt portion of *C. patens* might be suitable compared to the middle and the top portions. However, from the values of density recorded for the various portions in this study (Figure 4.2), *C. patens* would be considered a low-density and soft timber and might be useful in non-load bearing applications (FAO, 1985; Owoyemi and Olaniran, 2014).

MOR, like most of the other strength properties, is strongly related with density of wood (Rowell, 2005; Hoadley, 2000) and other factors such as juvenile and/or matured wood as well as location and type of species (Stod *et al*., 2016; Zelalem *et al*., 2014). Farmer (1972) indicated that the greater the density, the greater the strength properties such as MOR. This confirms the observed decrease in MOR of *C. patens* from butt to top of the wood; as the density decreased along the wood from the butt to the top (Figure 4.2), MOR also decreased in a similar pattern. In a study conducted by Agyemang (2014) in *Alstonia boonei*, similar results were reported where the butt recorded 31.183 N/mm², the middle 28.617 N/mm², and the top 27.378 N/mm². He likewise attributed the decrease in MOR, from butt to top, to decrease in density from the butt to top of the wood. Zelalem *et al*., (2014) also recorded 63.61 N/mm² for the butt, 47.55 N/mm² for middle and 43.14 N/mm² for top in a study conducted on the influence of physical and mechanical properties on the quality of wood produced from *Pinus patula* tree, which also indicated a decreasing trend from the butt to the top. They also attributed this to the presence of mature wood at the bottom which decreases to the top of the tree height.

According to Ishengoma and Gillah (1992), core wood or juvenile wood is significantly lower in density than mature wood and hence the reduction in density away from the butt end. In the current study, a relatively bigger value of MOR was observed at the bottom of the log and the values recorded are almost in agreement with these works by Agyemang (2014) and Zelalem *et al*., (2014).

The strength of *C. patens* along the stem on the basis of MOR at 12% MC is comparatively lower than all the ten lesser used species in Ghana studied by Ofori *et al*. (2009), *Lophira alata* (Kaku)

(188.4 N/mm²), *Cynometra ananta* (Ananta) (139.9 N/mm²), *Strombosia glaucescens* (Afina) (148.2 N/mm²), *Celtis mildbraedii* (129.8 N/mm²), *Nauclea diderrichii* (Kusia) (109.6 N/mm²), *Celtis zenkeri*, (124.7 N/mm²), *Piptadeniastrum africanum* (Dahoma) (109.6 N/mm²), *Nesogordonia papaverifera* (Danta) (117.4 N/mm²), *Combretodendron africanum* (Essia) (103.7 N/mm²) and *Sterculia rhinopetala* (Wawabima) (110.8 N/mm²). While the butt portion of *C. patens* could be classified as of low strength in terms of its MOR (55.06 N/mm²), the middle and top portions (49.98 N/mm² and 44.69 N/mm² respectively) may be rated very low in accordance with Farmer's (1972) rating (very low: < 50 N/mm²; low: 50 - 85 N/mm²).

Since *C. patens* will generally fail under higher load due to its low to very low MOR strength, it may be useful in non-load bearing applications such as furniture, poles and wooden containers. The butt portion may however, be considered for structural applications that does not require substantial amount of loading such as light work construction work example interior partition, wall paneling and flooring. Moreover, the MOR for *C. patens* was better than *Alstonia boonei* (31.183 – 27.378 N/mm² from butt to top) (Agyemang, 2014) and similar to *Pinus patula* (63.61 N/mm², 47.55 N/mm² and 43.14 N/mm2 for butt, middle and top respectively) (Zelalem *et al*., 2014). This suggest that *C. patens* could be put to the same uses as *Pinus patula* and other similar species.

The wood industry need to consider possible ways of using it in Ghana such as for furniture or furniture components, boxes and crates, flooring, plywood, particleboard, laminated wood, light construction, exterior and interior joinery, and interior paneling. This will help to ease the pressure on the primary species which is currently over-exploited.

5.3.2 Modulus of Elasticity (MOE)

Kumar (2004) reported that, an important element of wood quality is its ―stiffness or MOE. The end-use of wood material, especially for structural timber is strongly related to MOE. MOE along the axial portions of the three *C. patens* ranged from the top of *C. patens* (3) (7186 N/mm^2) to the top of *C. patens* (2) (8289.30 N/mm^2) (Figure 4.7). Figure 4.8 show the average MOE of the *C. patens* 8230.23 N/mm², 7569.03 N/mm² and 7242.71 N/mm², for the butt, middle and top respectively, that is a decrease from butt to top. Zelalem *et al*. (2014) observed a similar trend in *Pinus patula* tree, with a decrease in MOE from the butt to the top (7193.31 N/mm², 6344.86 N/mm² and 5922.00 N/mm²) respectively. Schneider *et al*. (1991) reported that mechanical properties and basic density varies along the tree height from the butt to the top. Haygreen and Bowyer (1989) also stated that MOE varies linearly with basic density or specific gravity. The results for *C. patens* with decreasing values for both MOE and density from tree butt to top support these findings. Other important factors that influence the stiffness (MOE) of timber are its micro-fibril angle, anatomical properties such as knots, fiber length and spiral grain as well as some environmental factors such as moisture and temperature (Hoadley, 2000; Huang *et al*., 2003).

This current study also revealed a significant difference in MOE along the stem of *C. patens* ($p<0.05$) (Appendix B4), but not between the butt and middle portions. Thus, the butt and middle portions of *C. patens* might be used for similar applications with respect to MOE. The MOE of *C. patens* may be regarded as low with all the sections recording < 9000 N/mm^2 according to TEDB (1994) and Upton and Attah (2003). The strength of *C. patens* based on MOE at 12% MC was also lower compared to all the ten lesser used Ghanaian species studied by Ofori *et al*., (2009). The reported MOE for the ten species were: *Lophira alata* (Kaku) (17,622 N/mm²), *Cynometra ananta*

(Ananta) (14,439 N/mm²), *Strombosia glaucescens* (Afina) (13,355 N/mm²), *Celtis mildbraedii* (12, 545 N/mm²), *Nauclea diderrichii* (Kusia) (11,708 N/mm²), *Celtis zenkeri*, (11,916 N/mm²), *Piptadeniastrum africanum* (Dahoma) (10,897 N/mm²), *Nesogordonia papaverifera* (Danta) (10,363 N/mm²), *Combretodendron africanum* (Essia) (9,739 N/mm²) and *Sterculia rhinopetala* (Wawabima) (10,394 N/mm²).

Thus, while *C. patens* may generally deform under high stress, the butt portion may be used in applications where relatively low stress is involved since it recorded a comparatively better MOE (8230.23 N/mm²,), which is quite close to (Essia) (9,739 N/mm²) (Ofori *et al*., (2009) and relatively better than *Pinus patula* (7193.31 -5922.00 N/mm², from butt to top) (Zelalem *et al*., 2014). It should therefore be explored for use as an alternative material to the primary species in applications such as pallets, tool handles, furniture, sporting goods, boxes, crates, veneer, plywood, hardboard, particle board.

5.3.3 Shear parallel to the grain of wood

According to Shrivastava (1997) shear strength measures the ability of wood to resist forces that tend to cause one part of the material to slide or slip on another part adjacent to it. Shear strength parallel to the grain along the axial portions of the three *C. patens* ranged from the top of *C. patens* (3) (5.1996 N/mm^2) to the butt of *C. patens* (3) (7.824 N/mm^2) (Figure 4.9). The combined average shear strength along the trunk of *C. patens* showed a similar decreasing trend from the butt to the top. The butt sustained a shear force of 7.56 N/mm², the middle recorded 6.38 N/mm² and top 5.40 N/mm² (Figure 4.10). The butt portion recorded a significantly greater shear strength (Appendix

B5) indicating a better resistance to shear forces in structural applications. This variation in shear force along the tree height from the butt to top agrees with the works by Kollman and Côté (1968) and Panshin and de Zeeuw (1970). This may be due to the fact that the butt log of the same tree has more matured wood compared to the top log which consists mainly of juvenile wood (Panshin and deZeeuw, 1970; Zobel *et al*., 1972). Density also plays a critical role in the mechanical properties (Schneider *et al*., 1991; Hoadley, 2000; Rowell, 2005; Ofori *et al*., 2009) and could contribute to the observed trend in shear for *C. patens*. Density also decreased from butt to top across the stem similar to shear parallel to the grain.

The values of shear strength along the tree height was lower than that of *Pterygota macrocarpa* reported by Ayarkwa (1998) where the butt recorded 10.99 N/mm^2 followed by the middle (10.62 N/mm^2) and the top (9.73 N/mm^2), and some Ghanaian species such as Dahoma, Essia and Wawabima which recorded shear strength of 20.4 N/mm^2, 19.2 N/mm^2 and 15.1 N/mm^2 respectively (Ofori *et al.,* 2009). The current research with low shear strength values indicate that the tendency for *C. patens* to slide on another member when in service is high. This must be taken into consideration before it is joined together in service and the necessary precautionary measures must be taken to prevent possible failure. It could also be used in applications that does not involve sliding of members such as exterior and interior joinery, and interior paneling.

5.3.4 Compression strength parallel to the Grain of *C. patens*

Compressive strength parallel to the grain (CPG) is an indication of the crushability of wood sample under load (Kollman and Côté, 1984; Gupta, 1985). Compression strength parallel to the grain along the axial portions of the three *C. patens* ranged from the top of *C. patens* (3) (21.718 MPa) to the butt of *C. patens* (2) (29.809 MPa) (Figure 4.11). Figure 4.12 shows the combined average of the compression strength parallel to the grain that the butt portion sustained compressive force of 28.90 N/mm², followed by the middle (25.20 N/mm²) and the top (23.24 N/mm²), indicating a decreasing trend from butt to top. The decrease agrees with the works of several researchers. Zelalem *et al*., (2014) reported the same trend for both dry and green *Pinus patula*, and in *Pterygota macrocarpa* by Ayarkwa (1998). The decrease in Compressive Strength from butt to top may be due to the accumulation of more matured wood at the butt than at the top, which mainly consists of juvenile wood (Panshin and de Zeeuw, 1970; Zobel *et al*. (2003). The reduction in strength properties within the axial position in a tree may also be due to mechanical factors. From the mechanical point of view, the trunk of a growing tree is considered a cantilever. Under the influence of weight and wind acting on the crown, greater stress develops at the base resulting in the formation of wood of greater strength and density (Tsoumis, 1991). The decreasing trend in density from butt to top recorded for *C. patens* (Figure 4.2) might also be a contributing factor for the observed trend of Compressive Strength along its stem (Schneider *et al*., 1991; Hoadley, 2000; Rowell, 2005).

The Compressive Strength values for the various portions of *C. patens* (Figure 4.6) were lower compared to 66.12 -51.60 N/mm² recorded for *Pterygota macrocarpa* and 64.71 - 40.00N/mm² recorded for *Pinus patula.* According to the system of classification used by Zobel *et al.* (2003), the butt portion of *C. patens* could be classified as having a low compression strength parallel to the grain (19.71 – 29.42 N/mm^2) with the middle and the top being of a very low strength (<19.614 N/mm2). Like the other strength properties, MOR and MOE, CPG of *C. patens* is comparatively lower than all the ten lesser used species in Ghana investigated by Ofori *et al*. (2009). Their values were: *Lophira alata* (Kaku) (91.9 N/mm²), *Cynometra ananta* (Ananta) (74.1 N/mm²), Strombosia *glaucescens* (Afina) (68.9 N/mm²), *Celtis mildbraedii* (62.1 N/mm²), *Nauclea diderrichii*

(Kusia) (57.8 N/mm²), Celtis zenkeri, (59.4 N/mm²), *Piptadeniastrum africanum* (Dahoma) (54.2 N/mm²), *Nesogordonia papaverifera* (Danta) (57.5 N/mm²), *Combretodendron africanum* (Essia) (53.3 N/mm²), and *Sterculia rhinopetala* (Wawabima) (53.5 N/mm²). Even though the CPG for *C. patens* from this study suggest that it may perform poorly under crushing load, the butt portion could be considered for applications that does not involve excessive loading such as wall paneling, wooden cases and furniture since it recorded a comparatively better CPG.

5.4 Natural Durability

According to the Wood Works Information Sheet (2011), the natural durability properties of wood make it resistant to factors such as corrosive salts, dilute acids and sea air and thus makes it suitable for applications such as cooling towers and industrial buildings over steel and concrete. However, wood in service is especially prone to threats of fungal invasion and insect attack with time if factors such as contact with water are not properly managed. The natural resistance of wood to biological agents such as termites is therefore very critical in its selection for various applications. After several months of field exposure to termite attack, the natural durability of *C. patens* was determined using the percentage weight loss and the scale of natural durability rating (based on weight loss) according to Eaton and Hale (1993).

From the study, natural durability along the axial portions of the three *C. patens* ranged from the butt of *C. patens* (3) (86%) to the top of all the *C. patens* and *C. pentandra* (100%) (Figure 4.13). All the three portions as well as the control (*C. pentandra*) were not resistant to termite attack. Average percentage mass loss along the axial stem sections *of C. patens* and *C. pentandra* had the butt portion recording a percentage weight loss of 87.10% followed by the middle and top portions

97.40% and 100%, respectively (Figure 4.14). According to the scale of natural durability rating (mass loss) used for the study, the three portions of *C. patens* as well as the control (*C. pentandra*) were non-durable with mass loses greater than 41% (Table 3.3). This was confirmed by the visual durability rating where scores for all the samples along the stem (Table 4.16) correspond to failure according to EN 252 (1989) rating. However, the butt portion with a relatively low mass loss (87.75%) (Figure 4.16) and a comparatively lower visual rating score (3.947) (Table 4.16) makes it a preferred portion for applications where *C. patens* is required. According to Burkill (1985), the tree is used for canoes, carving, musical instruments and toys in Nigeria. The butt portion must thus be targeted for these and other applications since it recorded a better mass loss and might offer a measure of natural resistance to bio-degraders and thus prolong the lifespan of such products.

Although no portion of the log was resistant to bio-degradation (termite attack), there appeared a slight variation in the percentage weight loss values in the three sections (Figure 4.7) which were also significantly different ($p<0.05$) (Table 4.14). According to Scheffer and Morrell (1998) and Antwi-Boasiako (2004) variation in decay resistance of wood is possible and can be observed among tree species, among individual trees and within individual trees. They also indicated that the resistance of wood increase significantly from the top to the bottom of the stem. The slight variation in the natural durability of *C. patens* from this study adds up to that knowledge. From Figure 4.2, the density decreased from butt to top, similar to the percentage weight loss. According to (Scheffer and Morrell, 1998), density does not appreciably affect decay resistance and according to Antwi-Boasiako and Pitman (2009), density has little influence on durability and that good correlation between the two does not always exist for a number of species.

However, other researchers have observed positive correction between density and natural durability (Wong *et al*., 1993; Yamamoto and Hong, 1994). According to Owoyeni and Olaniran (2014), resistance of wood species varies with its density, and thus density seems to affect the natural resistance, although higher density does not necessarily suggest complete resistance since no wood is absolutely invulnerable to termite attack (Antwi-Boasiako and Pitman, 2009). Several researchers have also reported on wood extractives as the key factor for natural durability (Syafii, 1987; Scheffer and Morrell, 1998; Taylor *et al*., 2003; Antwi-Boasiako and Pitman, 2009) while lignin as well is considered one of the factors that influence natural durability of many durable tropical species (Syafii *et al*., 1988 a,b). According to Antwi-Boasiako and Pitman (2009), extractives contribute significantly to variation in density along the stem of each timber. Thus, the butt portion being denser is most likely associated with greater extractive content making it slightly resistant followed by the middle and the top, respectively.

The present work suggests that *C. patens*, might be a non-durable species, with percentage mass losses along the stem (86-100%) (Figure 4.14), which fall within the recommended range for non-durable wood (41% and 100%) (Table 3.2), based on the scale of natural durability rating proposed by Eaton and Hale (1993). The visual durability rating with a score of approximately 4.0 along the stem (Table 4.16), which indicates failure of the test samples against bio-degraders (EN 252, 1989) further confirms *C. patens* as a non- durable wood. It may thus be considered for interior applications or additional protection such as preservative treatment should be employed before using it for outdoor purposes. Even though the current research indicates that the tree is non-durable, it also has some advantages. Baker *et al*. (2005) reported that it grows rapidly reaching a height of 13 m and a bole diameter of more than 20 cm in only 4 years in Ghana. According to

Lemmens (2012), it has good sawing, planning, nailing and finishing abilities. *C. patens* therefore has the potential to augment the primary wood species which has become over-dependent in Ghana (Ghana Forestry Department, 1994; Ministry of Lands and Forestry, 1996; Forest Products Inspection Bureau, 1996; Ayarkwa, 2009) to avert the possible undesirable consequences to the economy and the wood Industry. Utilization of *C. patens*, especially the butt portion, for joinery, door frames, drums, floats and canoes, furniture, boxes, crates, veneer, plywood, hardboard, particle board, wood-wool and pulpwood, is therefore recommended to the wood industry players in Ghana. Effort must also be directed at improving the lifespan of the wood in service to encourage its utilization in various applications especially for outdoor purposes. This may enhance Ghana's foreign income through export and reduce the pressure on the few primary species.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the results of the study, the following conclusions are made:

- Mean MC along the stem ranged from 12.38 - 13.81 % (from butt to top) and basic density was 284.51, 231.91 and 195.81 Kg/m^3 for the butt, middle and top respectively. Thus the butt portion has the least MC and the highest density. ($p < 0.05$) (Appendix B1 and B2). This indicates that *C. patens* is a low-density species, but the butt portion may be easy to work with, provide aesthetically appealing end products (due to its comparatively low MC) and perform relatively well in applications involving bending and other strength properties.

- The ranges of mean MOR, MOE, Compression parallel to grain and shear parallel to the grain along the stem were: 44.69-55.06 N/mm^2, 7242.71- 8230.23 Nmm^2, 23.24 - 28.90 N/mm^2 and 5.40 - 7.56 N/mm^2 respectively. The mean mechanical strength values indicate that *C. patens* belong to a very low and/or low strength category of timber species with the butt section being stronger than at the middle and top sections.

- Mass loss (with very high mean values of 87.10, 97.40 and 100% for the butt, middle and top sections respectively) along the stem indicates that *C. patens* could fit in the non-durable timber species bracket. The butt portion, however, appears relatively durable compared to the middle and top.

- The density and mechanical properties of *C. patens* were comparatively lower, while the MC and natural durability were higher than some species previously studied such as *Lophira alata, Cynometra ananta and Celtis zenkeri*. They were however, similar to *Pinus patula and Alstonia boonei.* The butt portion of *C. patens* was better than the middle and top in all the parameters investigated and could be more useful in various applications.

6.2 Recommendations

1. Due to the very low density and mechanical strength properties of *C. patens,* it should be used in non-load bearing applications such as fencing, carving, kitchen stool, sporting goods, plywood, hardboard, particle board, laminated wood, exterior and interior joinery, and interior paneling.

2. Since *C. patens* is a non-durable timber, it should be considered for interior applications such as ceiling joints, wall paneling and flooring or it could be protected with preservative chemicals before using it for outdoor purposes if practicable.

3. Where it is necessary to use *C. patens* for furniture or similar purposes, the butt section should be considered since it had a relatively better physical and mechanical properties as well as natural durability.

4. Since *C. patens* grows rapidly in Ghana and the mechanical properties were similar to that of *Pinus patula* which is already being used in some applications such as board manufacturing, and furniture as well as paper and pulp production, it should be considered for use in applications such as board manufacturing, paper and pulp production as well as pallets, tool handles, veneers, boxes and crates to reduce the pressure on the over-dependent primary species.

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APPENDICES

APPENDIX A1: Tukey's multiple comparison test for Moisture content of *C. patens*

Number of families	1							
Number of comparisons per family	3							
Alpha	0.05							
Tukey's multiple comparisons test	**Mean Diff.**	**95% CI of diff.**	**Significant?**	**Summary**	**Adjusted P Value**			
Top vs. Mid	0.434	-0.959 to 1.83	No	ns	0.7411	A-B		
Top vs. Butt	1.5	0.108 to 2.89	Yes	*	0.0314	A-C		
Mid vs. Butt	1.07	-0.326 to 2.46	No	ns	0.1685	B-C		
Test details	**Mean 1**	**Mean 2**	**Mean Diff.**	**SE of diff.**	**n1**	**n2**	**q**	**DF**
Top vs. Mid	13.8	13.4	0.434	0.588	45	45	1.04	132
Top vs. Butt	13.8	12.3	1.5	0.588	45	45	3.61	132
Mid vs. Butt	13.4	12.3	1.07	0.588	45	45	2.57	132

APPENDIX A2: Tukey's multiple comparison test for Basic density of *C. patens*

Number of families	1							
Number of comparisons per family	3							
Alpha	0.05							
Tukey's multiple comparisons test	**Mean Diff.**	**95% CI of diff.**	**Significant?**	**Summary**	**Adjusted P Value**			
Top vs. Mid	-36.1	-58.5 to -13.7	Yes	***	0.0006	A-B		
Top vs. Butt	-88.7	-111 to -66.3	Yes	****	<0.0001	A-C		
Mid vs. Butt	-52.6	-75 to -30.2	Yes	****	<0.0001	B-C		
Test details	**Mean 1**	**Mean 2**	**Mean Diff.**	**SE of diff.**	**n1**	**n2**	**q**	**DF**
Top vs. Mid	196	232	-36.1	9.45	45	45	5.4	132
Top vs. Butt	196	285	-88.7	9.45	45	45	13.3	132
Mid vs. Butt	232	285	-52.6	9.45	45	45	7.87	132

APPENDIX A3: Tukey's multiple comparison test for MOR of *C. patens*

Number of families	1							
Number of comparisons per family	3							
Alpha	0.05							
Tukey's multiple comparisons test	**Mean Diff.**	**95% CI of diff.**	**Significant?**	**Summary**	**Adjusted P Value**			
Top vs. Mid	-4.29	-6.43 to -2.15	Yes	****	<0.0001	A-B		
Top vs. Butt	-10.4	-12.5 to -8.23	Yes	****	<0.0001	A-C		
Mid vs. Butt	-6.08	-8.21 to -3.94	Yes	****	<0.0001	B-C		
Test details	**Mean 1**	**Mean 2**	**Mean Diff.**	**SE of diff.**	**n1**	**n2**	**q**	**DF**
Top vs. Mid	44.7	49	-4.29	0.907	90	90	6.69	267
Top vs. Butt	44.7	55.1	-10.4	0.907	90	90	16.2	267
Mid vs. Butt	49	55.1	-6.08	0.907	90	90	9.48	267

APPENDIX A4: Tukey's multiple comparison test for MOE of *C. patens*

Number of families	1							
Number of comparisons per family	3							
Alpha	0.05							
Tukey's multiple comparisons test	**Mean Diff.**	**95% CI of diff.**	**Significant?**	**Summary**	**Adjusted P Value**			
Top vs. Mid	-326	-757 to 104	No	ns	0.1765	A-B		
Top vs. Butt	-988	-1418 to -557	Yes	****	<0.0001	A-C		
Mid vs. Butt	-661	-1092 to -230	Yes	**	0.0010	B-C		
Test details	**Mean 1**	**Mean 2**	**Mean Diff.**	**SE of diff.**	**n1**	**n2**	**q**	**DF**
Top vs. Mid	7243	7569	-326	183	90	90	2.52	267
Top vs. Butt	7243	8230	-988	183	90	90	7.64	267
Mid vs. Butt	7569	8230	-661	183	90	90	5.12	267

APPENDIX A5: Tukey's multiple comparison test for Shear strength of *C. patens*

Number of families	1							
Number of comparisons per family	3							
Alpha	0.05							
Tukey's multiple comparisons test	**Mean Diff.**	**95% CI of diff.**	**Significant?**	**Summary**	**Adjusted P Value**			
Top vs. Mid	-0.985	-1.36 to -0.612	Yes	****	<0.0001	A-B		
Top vs. Butt	-2.16	-2.54 to -1.79	Yes	****	<0.0001	A-C		
Mid vs. Butt	-1.18	-1.55 to -0.804	Yes	****	<0.0001	B-C		
Test details	**Mean 1**	**Mean 2**	**Mean Diff.**	**SE of diff.**	**n1**	**n2**	**q**	**DF**
Top vs. Mid	5.4	6.38	-0.985	0.159	90	90	8.79	267
Top vs. Butt	5.4	7.56	-2.16	0.159	90	90	19.3	267
Mid vs. Butt	6.38	7.56	-1.18	0.159	90	90	10.5	267

APPENDIX A6: Tukey's multiple comparison test for Compression strength of *C. patens*

Number of families	1							
Number of comparisons per family	3							
Alpha	0.05							
Tukey's multiple comparisons test	**Mean Diff.**	**95% CI of diff.**	**Significant?**	**Summary**	**Adjusted P Value**			
Top vs. Mid	-1.96	-3.54 to -0.391	Yes	**	0.0099	A-B		
Top vs. Butt	-5.67	-7.24 to -4.09	Yes	****	<0.0001	A-C		
Mid vs. Butt	-3.7	-5.27 to -2.13	Yes	****	<0.0001	B-C		
Test details	**Mean 1**	**Mean 2**	**Mean Diff.**	**SE of diff.**	**n1**	**n2**	**q**	**DF**
Top vs. Mid	23.2	25.2	-1.96	0.668	90	90	4.16	267
Top vs. Butt	23.2	28.9	-5.67	0.668	90	90	12	267
Mid vs. Butt	25.2	28.9	-3.7	0.668	90	90	7.84	267

APPENDIX A7: Tukey's multiple comparison test for Natural durability (mass loss) of *C. patens* and *C. pentandra*

Number of families	1							
Number of comparisons per family	6							
Alpha	0.05							
Tukey's multiple comparisons test	**Mean Diff.**	**95% CI of diff.**	**Significant?**	**Summary**	**Adjusted P Value**			
Top vs. mid	2.6	-4.46 to 9.67	No	ns	0.7747	A-B		
Top vs. Butt	12.9	5.83 to 20	Yes	****	<0.0001	A-C		
Top vs. Control	0	-7.06 to 7.06	No	ns	>0.9999	A-D		
mid vs. Butt	10.3	3.23 to 17.4	Yes	**	0.0012	B-C		
mid vs. Control	-2.6	-9.67 to 4.46	No	ns	0.7747	B-D		
Butt vs. Control	-12.9	-20 to -5.83	Yes	****	<0.0001	C-D		
Test details	**Mean 1**	**Mean 2**	**Mean Diff.**	**SE of diff.**	**n1**	**n2**	**q**	**DF**
Top vs. mid	100	97.4	2.6	2.72	48	48	1.35	188
Top vs. Butt	100	87.1	12.9	2.72	48	48	6.69	188
Top vs. Control	100	100	0	2.72	48	48	0	188
mid vs. Butt	97.4	87.1	10.3	2.72	48	48	5.34	188
mid vs. Control	97.4	100	-2.6	2.72	48	48	1.35	188
Butt vs. Control	87.1	100	-12.9	2.72	48	48	6.69	188

APPENDIX A8: Tukey's multiple comparison test for Visual durability ratings of *C. patens* and *C. pentandra*

Number of families	**1**							
Number of comparisons per family	6							
Alpha	0.05							
Tukey's multiple comparisons test	**Mean Diff.**	**95% CI of diff.**	**Sig.?**	**Summary**	**Adjusted P Value**			
top vs. middle	0.00333	-0.0292 to 0.0358	No	ns	0.9934	A-B		
top vs. base	0.056	0.0235 to 0.0885	Yes	****	<0.0001	A-C		
top vs. control	0	-0.0325 to 0.0325	No	ns	>0.9999	A-D		
middle vs. base	0.0527	0.0202 to 0.0852	Yes	***	0.0002	B-C		
middle vs. control	-0.0033	-0.0358 to 0.0292	No	ns	0.9934	B-D		
base vs. control	-0.056	-0.0885 to -0.0235	Yes	****	<0.0001	C-D		
Test details	**Mean 1**	**Mean 2**	**Mean Diff.**	**SE of diff.**	**n1**	**n2**	**q**	**DF**
top vs. middle	4	4	0.00333	0.0125	48	48	0.376	188
top vs. base	4	3.94	0.056	0.0125	48	48	6.32	188
top vs. control	4	4	0	0.0125	48	48	0	188
middle vs. base	4	3.94	0.0527	0.0125	48	48	5.95	188
middle vs. control	4	4	-0.00333	0.0125	48	48	0.376	188
base vs. control	3.94	4	-0.056	0.0125	48	48	6.32	188

APPENDIX B1: Tukey's multiple comparison test for Moisture content along the axial stem sections of the three *C. patens*.

Number of families	1				
Number of comparisons per family	36				
Alpha	0.05				
Tukey's multiple comparisons test	**Mean Diff.**	**95.00% CI of diff.**	**Sig.?**	**Summary**	**Adjusted P Value**
C. patens (1):Top vs. C. patens (1):Mid	0.29	-2.996 to 3.576	No	ns	>0.9999
C. patens (1):Top vs. C. patens (1):Butt	1.425	-1.861 to 4.711	No	ns	0.9072
C. patens (1):Top vs. C. patens (2):Top	0.05317	-3.233 to 3.339	No	ns	>0.9999

C. patens (1):Top vs. C. patens (2):Mid	0.5034	-2.782 to 3.789	No	ns	>0.9999
C. patens (1):Top vs. C. patens (2):Butt	1.625	-1.661 to 4.91	No	ns	0.8240
C. patens (1):Top vs. C. patens (3):Top	-0.1266	-3.413 to 3.159	No	ns	>0.9999
C. patens (1):Top vs. C. patens (3):Mid	0.4347	-2.851 to 3.721	No	ns	>0.9999
C. patens (1):Top vs. C. patens (3):Butt	1.378	-1.908 to 4.664	No	ns	0.9224
C. patens (1):Mid vs. C. patens (1):Butt	1.135	-2.151 to 4.421	No	ns	0.9746
C. patens (1):Mid vs. C. patens (2):Top	-0.2368	-3.523 to 3.049	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (2):Mid	0.2134	-3.072 to 3.499	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (2):Butt	1.335	-1.951 to 4.62	No	ns	0.9348
C. patens (1):Mid vs. C. patens (3):Top	-0.4166	-3.703 to 2.869	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (3):Mid	0.1447	-3.141 to 3.431	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (3):Butt	1.088	-2.198 to 4.374	No	ns	0.9805
C. patens (1):Butt vs. C. patens (2):Top	-1.372	-4.658 to 1.914	No	ns	0.9242
C. patens (1):Butt vs. C. patens (2):Mid	-0.9219	-4.208 to 2.364	No	ns	0.9934
C. patens (1):Butt vs. C. patens (2):Butt	0.1992	-3.087 to 3.485	No	ns	>0.9999
C. patens (1):Butt vs. C. patens (3):Top	-1.552	-4.838 to 1.734	No	ns	0.8578
C. patens (1):Butt vs. C. patens (3):Mid	-0.9906	-4.277 to 2.295	No	ns	0.9893
C. patens (1):Butt vs. C. patens (3):Butt	-0.04736	-3.333 to 3.239	No	ns	>0.9999
C. patens (2):Top vs. C. patens (2):Mid	0.4503	-2.836 to 3.736	No	ns	>0.9999
C. patens (2):Top vs. C. patens (2):Butt	1.571	-1.714 to 4.857	No	ns	0.8492
C. patens (2):Top vs. C. patens (3):Top	-0.1798	-3.466 to 3.106	No	ns	>0.9999
C. patens (2):Top vs. C. patens (3):Mid	0.3815	-2.904 to 3.667	No	ns	>0.9999
C. patens (2):Top vs. C. patens (3):Butt	1.325	-1.961 to 4.611	No	ns	0.9374

C. patens (2):Mid vs. C. patens (2):Butt	1.121	-2.165 to 4.407	No	ns	0.9765			
C. patens (2):Mid vs. C. patens (3):Top	-0.6301	-3.916 to 2.656	No	ns	0.9996			
C. patens (2):Mid vs. C. patens (3):Mid	-0.06875	-3.355 to 3.217	No	ns	>0.9999			
C. patens (2):Mid vs. C. patens (3):Butt	0.8745	-2.411 to 4.16	No	ns	0.9954			
C. patens (2):Butt vs. C. patens (3):Top	-1.751	-5.037 to 1.535	No	ns	0.7562			
C. patens (2):Butt vs. C. patens (3):Mid	-1.19	-4.476 to 2.096	No	ns	0.9663			
C. patens (2):Butt vs. C. patens (3):Butt	-0.2466	-3.532 to 3.039	No	ns	>0.9999			
C. patens (3):Top vs. C. patens (3):Mid	0.5613	-2.725 to 3.847	No	ns	0.9998			
C. patens (3):Top vs. C. patens (3):Butt	1.505	-1.781 to 4.79	No	ns	0.8778			
C. patens (3):Mid vs. C. patens (3):Butt	0.9433	-2.343 to 4.229	No	ns	0.9923			
Test details	**Mean 1**	**Mean 2**	**Mean Diff.**	**SE of diff.**	**N1**	**N2**	**q**	**DF**
C. patens (1):Top vs. C. patens (1):Mid	13.81	13.52	0.29	1.041	15	15	0.394	126
C. patens (1):Top vs. C. patens (1):Butt	13.81	12.38	1.425	1.041	15	15	1.936	126
C. patens (1):Top vs. C. patens (2):Top	13.81	13.76	0.05317	1.041	15	15	0.07224	126
C. patens (1):Top vs. C. patens (2):Mid	13.81	13.31	0.5034	1.041	15	15	0.6839	126
C. patens (1):Top vs. C. patens (2):Butt	13.81	12.19	1.625	1.041	15	15	2.207	126
C. patens (1):Top vs. C. patens (3):Top	13.81	13.94	-0.1266	1.041	15	15	0.172	126
C. patens (1):Top vs. C. patens (3):Mid	13.81	13.38	0.4347	1.041	15	15	0.5905	126
C. patens (1):Top vs. C. patens (3):Butt	13.81	12.43	1.378	1.041	15	15	1.872	126
C. patens (1):Mid vs. C. patens (1):Butt	13.52	12.38	1.135	1.041	15	15	1.542	126
C. patens (1):Mid vs. C. patens (2):Top	13.52	13.76	-0.2368	1.041	15	15	0.3217	126
C. patens (1):Mid vs. C. patens (2):Mid	13.52	13.31	0.2134	1.041	15	15	0.29	126
C. patens (1):Mid vs. C. patens (2):Butt	13.52	12.19	1.335	1.041	15	15	1.813	126

C. patens (1):Mid vs. C. patens (3):Top	13.52	13.94	-0.4166	1.041	15	15	0.566	126
C. patens (1):Mid vs. C. patens (3):Mid	13.52	13.38	0.1447	1.041	15	15	0.1966	126
C. patens (1):Mid vs. C. patens (3):Butt	13.52	12.43	1.088	1.041	15	15	1.478	126
C. patens (1):Butt vs. C. patens (2):Top	12.38	13.76	-1.372	1.041	15	15	1.864	126
C. patens (1):Butt vs. C. patens (2):Mid	12.38	13.31	-0.9219	1.041	15	15	1.252	126
C. patens (1):Butt vs. C. patens (2):Butt	12.38	12.19	0.1992	1.041	15	15	0.2707	126
C. patens (1):Butt vs. C. patens (3):Top	12.38	13.94	-1.552	1.041	15	15	2.108	126
C. patens (1):Butt vs. C. patens (3):Mid	12.38	13.38	-0.9906	1.041	15	15	1.346	126
C. patens (1):Butt vs. C. patens (3):Butt	12.38	12.43	-0.04736	1.041	15	15	0.06434	126
C. patens (2):Top vs. C. patens (2):Mid	13.76	13.31	0.4503	1.041	15	15	0.6117	126
C. patens (2):Top vs. C. patens (2):Butt	13.76	12.19	1.571	1.041	15	15	2.135	126
C. patens (2):Top vs. C. patens (3):Top	13.76	13.94	-0.1798	1.041	15	15	0.2443	126
C. patens (2):Top vs. C. patens (3):Mid	13.76	13.38	0.3815	1.041	15	15	0.5183	126
C. patens (2):Top vs. C. patens (3):Butt	13.76	12.43	1.325	1.041	15	15	1.8	126
C. patens (2):Mid vs. C. patens (2):Butt	13.31	12.19	1.121	1.041	15	15	1.523	126
C. patens (2):Mid vs. C. patens (3):Top	13.31	13.94	-0.6301	1.041	15	15	0.856	126
C. patens (2):Mid vs. C. patens (3):Mid	13.31	13.38	-0.06875	1.041	15	15	0.0934	126
C. patens (2):Mid vs. C. patens (3):Butt	13.31	12.43	0.8745	1.041	15	15	1.188	126
C. patens (2):Butt vs. C. patens (3):Top	12.19	13.94	-1.751	1.041	15	15	2.379	126
C. patens (2):Butt vs. C. patens (3):Mid	12.19	13.38	-1.19	1.041	15	15	1.616	126
C. patens (2):Butt vs. C. patens (3):Butt	12.19	12.43	-0.2466	1.041	15	15	0.335	126
C. patens (3):Top vs. C. patens (3):Mid	13.94	13.38	0.5613	1.041	15	15	0.7626	126
C. patens (3):Top vs. C. patens (3):Butt	13.94	12.43	1.505	1.041	15	15	2.044	126

C. patens (3):Mid vs. C. patens (3):Butt	13.38	12.43	0.9433	1.041	15	15	1.281	126

APPENDIX B2: Tukey's multiple comparison test for Basic density along the axial stem sections of the three *C. patens*.

Number of families	1				
Number of comparisons per family	36				
Alpha	0.05				
Tukey's multiple comparisons test	**Mean Diff.**	**95.00% CI of diff.**	**Sig.?**	**Summary**	**Adjusted P Value**
C. patens (1):Top vs. C. patens (1):Mid	-29.34	-81.72 to 23.05	No	ns	0.7031
C. patens (1):Top vs. C. patens (1):Butt	-74.63	-127 to -22.24	Yes	***	0.0005
C. patens (1):Top vs. C. patens (2):Top	-1.86	-54.24 to 50.53	No	ns	>0.9999
C. patens (1):Top vs. C. patens (2):Mid	-39.08	-91.46 to 13.31	No	ns	0.3184
C. patens (1):Top vs. C. patens (2):Butt	-92.89	-145.3 to -40.51	Yes	****	<0.0001
C. patens (1):Top vs. C. patens (3):Top	10.16	-42.22 to 62.55	No	ns	0.9995
C. patens (1):Top vs. C. patens (3):Mid	-31.61	-83.99 to 20.78	No	ns	0.6119
C. patens (1):Top vs. C. patens (3):Butt	-90.29	-142.7 to -37.9	Yes	****	<0.0001
C. patens (1):Mid vs. C. patens (1):Butt	-45.29	-97.68 to 7.094	No	ns	0.1484
C. patens (1):Mid vs. C. patens (2):Top	27.48	-24.91 to 79.86	No	ns	0.7719
C. patens (1):Mid vs. C. patens (2):Mid	-9.742	-62.13 to 42.64	No	ns	0.9996
C. patens (1):Mid vs. C. patens (2):Butt	-63.56	-115.9 to -11.17	Yes	**	0.0061
C. patens (1):Mid vs. C. patens (3):Top	39.5	-12.89 to 91.89	No	ns	0.3041
C. patens (1):Mid vs. C. patens (3):Mid	-2.274	-54.66 to 50.11	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (3):Butt	-60.95	-113.3 to -8.567	Yes	*	0.0103

C. patens (1):Butt vs. C. patens (2):Top	72.77	20.38 to 125.2	Yes	***	0.0008
C. patens (1):Butt vs. C. patens (2):Mid	35.55	-16.84 to 87.93	No	ns	0.4500
C. patens (1):Butt vs. C. patens (2):Butt	-18.27	-70.65 to 34.12	No	ns	0.9732
C. patens (1):Butt vs. C. patens (3):Top	84.79	32.41 to 137.2	Yes	****	<0.0001
C. patens (1):Butt vs. C. patens (3):Mid	43.02	-9.368 to 95.4	No	ns	0.2005
C. patens (1):Butt vs. C. patens (3):Butt	-15.66	-68.05 to 36.72	No	ns	0.9899
C. patens (2):Top vs. C. patens (2):Mid	-37.22	-89.6 to 15.17	No	ns	0.3852
C. patens (2):Top vs. C. patens (2):Butt	-91.03	-143.4 to -38.65	Yes	****	<0.0001
C. patens (2):Top vs. C. patens (3):Top	12.02	-40.36 to 64.41	No	ns	0.9984
C. patens (2):Top vs. C. patens (3):Mid	-29.75	-82.14 to 22.64	No	ns	0.6870
C. patens (2):Top vs. C. patens (3):Butt	-88.43	-140.8 to -36.04	Yes	****	<0.0001
C. patens (2):Mid vs. C. patens (2):Butt	-53.82	-106.2 to -1.432	Yes	*	0.0391
C. patens (2):Mid vs. C. patens (3):Top	49.24	-3.144 to 101.6	No	ns	0.0831
C. patens (2):Mid vs. C. patens (3):Mid	7.468	-44.92 to 59.85	No	ns	>0.9999
C. patens (2):Mid vs. C. patens (3):Butt	-51.21	-103.6 to 1.175	No	ns	0.0608
C. patens (2):Butt vs. C. patens (3):Top	103.1	50.67 to 155.4	Yes	****	<0.0001
C. patens (2):Butt vs. C. patens (3):Mid	61.28	8.9 to 113.7	Yes	**	0.0097
C. patens (2):Butt vs. C. patens (3):Butt	2.606	-49.78 to 54.99	No	ns	>0.9999
C. patens (3):Top vs. C. patens (3):Mid	-41.77	-94.16 to 10.61	No	ns	0.2340
C. patens (3):Top vs. C. patens (3):Butt	-100.5	-152.8 to -48.07	Yes	****	<0.0001
C. patens (3):Mid vs. C. patens (3):Butt	-58.68	-111.1 to -6.293	Yes	*	0.0161

Test details	**Mean 1**	**Mean 2**	**Mean Diff.**	**SE of diff.**	**N1**	**N2**	**q**	**DF**
C. patens (1):Top vs. C. patens (1):Mid	198.6	227.9	-29.34	16.6	15	15	2.5	126

C. patens (1):Top vs. C. patens (1):Butt	198.6	273.2	-74.63	16.6	15	15	6.359	126
C. patens (1):Top vs. C. patens (2):Top	198.6	200.4	-1.86	16.6	15	15	0.1585	126
C. patens (1):Top vs. C. patens (2):Mid	198.6	237.7	-39.08	16.6	15	15	3.33	126
C. patens (1):Top vs. C. patens (2):Butt	198.6	291.5	-92.89	16.6	15	15	7.916	126
C. patens (1):Top vs. C. patens (3):Top	198.6	188.4	10.16	16.6	15	15	0.8661	126
C. patens (1):Top vs. C. patens (3):Mid	198.6	230.2	-31.61	16.6	15	15	2.694	126
C. patens (1):Top vs. C. patens (3):Butt	198.6	288.9	-90.29	16.6	15	15	7.694	126
C. patens (1):Mid vs. C. patens (1):Butt	227.9	273.2	-45.29	16.6	15	15	3.859	126
C. patens (1):Mid vs. C. patens (2):Top	227.9	200.4	27.48	16.6	15	15	2.341	126
C. patens (1):Mid vs. C. patens (2):Mid	227.9	237.7	-9.742	16.6	15	15	0.8301	126
C. patens (1):Mid vs. C. patens (2):Butt	227.9	291.5	-63.56	16.6	15	15	5.416	126
C. patens (1):Mid vs. C. patens (3):Top	227.9	188.4	39.5	16.6	15	15	3.366	126
C. patens (1):Mid vs. C. patens (3):Mid	227.9	230.2	-2.274	16.6	15	15	0.1937	126
C. patens (1):Mid vs. C. patens (3):Butt	227.9	288.9	-60.95	16.6	15	15	5.194	126
C. patens (1):Butt vs. C. patens (2):Top	273.2	200.4	72.77	16.6	15	15	6.201	126
C. patens (1):Butt vs. C. patens (2):Mid	273.2	237.7	35.55	16.6	15	15	3.029	126
C. patens (1):Butt vs. C. patens (2):Butt	273.2	291.5	-18.27	16.6	15	15	1.557	126
C. patens (1):Butt vs. C. patens (3):Top	273.2	188.4	84.79	16.6	15	15	7.225	126
C. patens (1):Butt vs. C. patens (3):Mid	273.2	230.2	43.02	16.6	15	15	3.666	126
C. patens (1):Butt vs. C. patens (3):Butt	273.2	288.9	-15.66	16.6	15	15	1.335	126
C. patens (2):Top vs. C. patens (2):Mid	200.4	237.7	-37.22	16.6	15	15	3.171	126
C. patens (2):Top vs. C. patens (2):Butt	200.4	291.5	-91.03	16.6	15	15	7.757	126
C. patens (2):Top vs. C. patens (3):Top	200.4	188.4	12.02	16.6	15	15	1.025	126

C. patens (2):Top vs. C. patens (3):Mid	200.4	230.2	-29.75	16.6	15	15	2.535	126
C. patens (2):Top vs. C. patens (3):Butt	200.4	288.9	-88.43	16.6	15	15	7.535	126
C. patens (2):Mid vs. C. patens (2):Butt	237.7	291.5	-53.82	16.6	15	15	4.586	126
C. patens (2):Mid vs. C. patens (3):Top	237.7	188.4	49.24	16.6	15	15	4.196	126
C. patens (2):Mid vs. C. patens (3):Mid	237.7	230.2	7.468	16.6	15	15	0.6364	126
C. patens (2):Mid vs. C. patens (3):Butt	237.7	288.9	-51.21	16.6	15	15	4.364	126
C. patens (2):Butt vs. C. patens (3):Top	291.5	188.4	103.1	16.6	15	15	8.782	126
C. patens (2):Butt vs. C. patens (3):Mid	291.5	230.2	61.28	16.6	15	15	5.222	126
C. patens (2):Butt vs. C. patens (3):Butt	291.5	288.9	2.606	16.6	15	15	0.2221	126
C. patens (3):Top vs. C. patens (3):Mid	188.4	230.2	-41.77	16.6	15	15	3.56	126
C. patens (3):Top vs. C. patens (3):Butt	188.4	288.9	-100.5	16.6	15	15	8.56	126
C. patens (3):Mid vs. C. patens (3):Butt	230.2	288.9	-58.68	16.6	15	15	5	126

APPENDIX B3: Tukey's multiple comparison test for Modulus of Rupture along the axial stem sections of the three *C. patens*.

Number of families	1				
Number of comparisons per family	36				
Alpha	0.05				
Tukey's multiple comparisons test	**Mean Diff.**	**95.00% CI of diff.**	**Sig.?**	**Summary**	**Adjusted P Value**
C. patens (1):Top vs. C. patens (1):Mid	-2.274	-7.104 to 2.557	No	ns	0.8674
C. patens (1):Top vs. C. patens (1):Butt	-9.035	-13.87 to -4.205	Yes	****	<0.0001
C. patens (1):Top vs. C. patens (2):Top	-1.6	-6.43 to 3.23	No	ns	0.9820
C. patens (1):Top vs. C. patens (2):Mid	-6.893	-11.72 to -2.063	Yes	***	0.0004

C. patens (1):Top vs. C. patens (2):Butt	-10.93	-15.76 to -6.097	Yes	****	<0.0001
C. patens (1):Top vs. C. patens (3):Top	1.266	-3.565 to 6.096	No	ns	0.9962
C. patens (1):Top vs. C. patens (3):Mid	-4.035	-8.865 to 0.7954	No	ns	0.1863
C. patens (1):Top vs. C. patens (3):Butt	-11.47	-16.3 to -6.641	Yes	****	<0.0001
C. patens (1):Mid vs. C. patens (1):Butt	-6.761	-11.59 to -1.931	Yes	***	0.0006
C. patens (1):Mid vs. C. patens (2):Top	0.6737	-4.157 to 5.504	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (2):Mid	-4.62	-9.45 to 0.2107	No	ns	0.0733
C. patens (1):Mid vs. C. patens (2):Butt	-8.654	-13.48 to -3.823	Yes	****	<0.0001
C. patens (1):Mid vs. C. patens (3):Top	3.539	-1.291 to 8.37	No	ns	0.3508
C. patens (1):Mid vs. C. patens (3):Mid	-1.761	-6.592 to 3.069	No	ns	0.9674
C. patens (1):Mid vs. C. patens (3):Butt	-9.198	-14.03 to -4.368	Yes	****	<0.0001
C. patens (1):Butt vs. C. patens (2):Top	7.435	2.605 to 12.27	Yes	****	<0.0001
C. patens (1):Butt vs. C. patens (2):Mid	2.142	-2.689 to 6.972	No	ns	0.9020
C. patens (1):Butt vs. C. patens (2):Butt	-1.892	-6.723 to 2.938	No	ns	0.9503
C. patens (1):Butt vs. C. patens (3):Top	10.3	5.47 to 15.13	Yes	****	<0.0001
C. patens (1):Butt vs. C. patens (3):Mid	5	0.1696 to 9.83	Yes	*	0.0362
C. patens (1):Butt vs. C. patens (3):Butt	-2.437	-7.267 to 2.394	No	ns	0.8161
C. patens (2):Top vs. C. patens (2):Mid	-5.293	-10.12 to -0.4629	Yes	*	0.0200
C. patens (2):Top vs. C. patens (2):Butt	-9.327	-14.16 to -4.497	Yes	****	<0.0001
C. patens (2):Top vs. C. patens (3):Top	2.866	-1.965 to 7.696	No	ns	0.6448
C. patens (2):Top vs. C. patens (3):Mid	-2.435	-7.265 to 2.395	No	ns	0.8166
C. patens (2):Top vs. C. patens (3):Butt	-9.872	-14.7 to -5.041	Yes	****	<0.0001
C. patens (2):Mid vs. C. patens (2):Butt	-4.034	-8.864 to 0.7964	No	ns	0.1865

C. patens (2):Mid vs. C. patens (3):Top	8.159	3.329 to 12.99	Yes	****	<0.0001
C. patens (2):Mid vs. C. patens (3):Mid	2.858	-1.972 to 7.689	No	ns	0.6480
C. patens (2):Mid vs. C. patens (3):Butt	-4.578	-9.409 to 0.2521	No	ns	0.0788
C. patens (2):Butt vs. C. patens (3):Top	12.19	7.363 to 17.02	Yes	****	<0.0001
C. patens (2):Butt vs. C. patens (3):Mid	6.892	2.062 to 11.72	Yes	***	0.0004
C. patens (2):Butt vs. C. patens (3):Butt	-0.5443	-5.375 to 4.286	No	ns	>0.9999
C. patens (3):Top vs. C. patens (3):Mid	-5.301	-10.13 to -0.4703	Yes	*	0.0197
C. patens (3):Top vs. C. patens (3):Butt	-12.74	-17.57 to -7.907	Yes	****	<0.0001
C. patens (3):Mid vs. C. patens (3):Butt	-7.437	-12.27 to -2.606	Yes	****	<0.0001

Test details	**Mean 1**	**Mean 2**	**Mean Diff.**	**SE of diff.**	**N1**	**N2**	**q**	**DF**
C. patens (1):Top vs. C. patens (1):Mid	44.58	46.86	-2.274	1.544	30	30	2.082	261
C. patens (1):Top vs. C. patens (1):Butt	44.58	53.62	-9.035	1.544	30	30	8.274	261
C. patens (1):Top vs. C. patens (2):Top	44.58	46.18	-1.6	1.544	30	30	1.465	261
C. patens (1):Top vs. C. patens (2):Mid	44.58	51.48	-6.893	1.544	30	30	6.313	261
C. patens (1):Top vs. C. patens (2):Butt	44.58	55.51	-10.93	1.544	30	30	10.01	261
C. patens (1):Top vs. C. patens (3):Top	44.58	43.32	1.266	1.544	30	30	1.159	261
C. patens (1):Top vs. C. patens (3):Mid	44.58	48.62	-4.035	1.544	30	30	3.695	261
C. patens (1):Top vs. C. patens (3):Butt	44.58	56.05	-11.47	1.544	30	30	10.51	261
C. patens (1):Mid vs. C. patens (1):Butt	46.86	53.62	-6.761	1.544	30	30	6.192	261
C. patens (1):Mid vs. C. patens (2):Top	46.86	46.18	0.6737	1.544	30	30	0.6169	261
C. patens (1):Mid vs. C. patens (2):Mid	46.86	51.48	-4.62	1.544	30	30	4.231	261
C. patens (1):Mid vs. C. patens (2):Butt	46.86	55.51	-8.654	1.544	30	30	7.925	261
C. patens (1):Mid vs. C. patens (3):Top	46.86	43.32	3.539	1.544	30	30	3.241	261

C. patens (1):Mid vs. C. patens (3):Mid	46.86	48.62	-1.761	1.544	30	30	1.613	261
C. patens (1):Mid vs. C. patens (3):Butt	46.86	56.05	-9.198	1.544	30	30	8.424	261
C. patens (1):Butt vs. C. patens (2):Top	53.62	46.18	7.435	1.544	30	30	6.809	261
C. patens (1):Butt vs. C. patens (2):Mid	53.62	51.48	2.142	1.544	30	30	1.961	261
C. patens (1):Butt vs. C. patens (2):Butt	53.62	55.51	-1.892	1.544	30	30	1.733	261
C. patens (1):Butt vs. C. patens (3):Top	53.62	43.32	10.3	1.544	30	30	9.433	261
C. patens (1):Butt vs. C. patens (3):Mid	53.62	48.62	5	1.544	30	30	4.579	261
C. patens (1):Butt vs. C. patens (3):Butt	53.62	56.05	-2.437	1.544	30	30	2.232	261
C. patens (2):Top vs. C. patens (2):Mid	46.18	51.48	-5.293	1.544	30	30	4.848	261
C. patens (2):Top vs. C. patens (2):Butt	46.18	55.51	-9.327	1.544	30	30	8.542	261
C. patens (2):Top vs. C. patens (3):Top	46.18	43.32	2.866	1.544	30	30	2.624	261
C. patens (2):Top vs. C. patens (3):Mid	46.18	48.62	-2.435	1.544	30	30	2.23	261
C. patens (2):Top vs. C. patens (3):Butt	46.18	56.05	-9.872	1.544	30	30	9.041	261
C. patens (2):Mid vs. C. patens (2):Butt	51.48	55.51	-4.034	1.544	30	30	3.694	261
C. patens (2):Mid vs. C. patens (3):Top	51.48	43.32	8.159	1.544	30	30	7.472	261
C. patens (2):Mid vs. C. patens (3):Mid	51.48	48.62	2.858	1.544	30	30	2.618	261
C. patens (2):Mid vs. C. patens (3):Butt	51.48	56.05	-4.578	1.544	30	30	4.193	261
C. patens (2):Butt vs. C. patens (3):Top	55.51	43.32	12.19	1.544	30	30	11.17	261
C. patens (2):Butt vs. C. patens (3):Mid	55.51	48.62	6.892	1.544	30	30	6.312	261
C. patens (2):Butt vs. C. patens (3):Butt	55.51	56.05	-0.5443	1.544	30	30	0.4985	261
C. patens (3):Top vs. C. patens (3):Mid	43.32	48.62	-5.301	1.544	30	30	4.854	261
C. patens (3):Top vs. C. patens (3):Butt	43.32	56.05	-12.74	1.544	30	30	11.66	261
C. patens (3):Mid vs. C. patens (3):Butt	48.62	56.05	-7.437	1.544	30	30	6.811	261

APPENDIX B4: Tukey's multiple comparison test for Modulus of Elasticity along the axial stem sections of the three *C. patens*.

Number of families	1				
Number of comparisons per family	36				
Alpha	0.05				
Tukey's multiple comparisons test	**Mean Diff.**	**95.00% CI of diff.**	**Sig.?**	**Summary**	**Adjusted P Value**
C. patens (1):Top vs. C. patens (1):Mid	-287.6	-1289 to 713.7	No	ns	0.9929
C. patens (1):Top vs. C. patens (1):Butt	-932	-1933 to 69.29	No	ns	0.0907
C. patens (1):Top vs. C. patens (2):Top	-5.467	-1007 to 995.8	No	ns	>0.9999
C. patens (1):Top vs. C. patens (2):Mid	-307	-1308 to 694.3	No	ns	0.9891
C. patens (1):Top vs. C. patens (2):Butt	-1021	-2022 to -19.71	Yes	*	0.0418
C. patens (1):Top vs. C. patens (3):Top	82.33	-918.9 to 1084	No	ns	>0.9999
C. patens (1):Top vs. C. patens (3):Mid	-307.5	-1309 to 693.7	No	ns	0.9889
C. patens (1):Top vs. C. patens (3):Butt	-932.8	-1934 to 68.49	No	ns	0.0901
C. patens (1):Mid vs. C. patens (1):Butt	-644.4	-1646 to 356.9	No	ns	0.5357
C. patens (1):Mid vs. C. patens (2):Top	282.1	-719.1 to 1283	No	ns	0.9938
C. patens (1):Mid vs. C. patens (2):Mid	-19.37	-1021 to 981.9	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (2):Butt	-733.4	-1735 to 267.9	No	ns	0.3513
C. patens (1):Mid vs. C. patens (3):Top	369.9	-631.3 to 1371	No	ns	0.9647
C. patens (1):Mid vs. C. patens (3):Mid	-19.93	-1021 to 981.3	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (3):Butt	-645.2	-1646 to 356.1	No	ns	0.5339
C. patens (1):Butt vs. C. patens (2):Top	926.5	-74.76 to 1928	No	ns	0.0948

C. patens (1):Butt vs. C. patens (2):Mid	625	-376.3 to 1626	No	ns	0.5779			
C. patens (1):Butt vs. C. patens (2):Butt	-89	-1090 to 912.3	No	ns	>0.9999			
C. patens (1):Butt vs. C. patens (3):Top	1014	13.04 to 2016	Yes	*	0.0444			
C. patens (1):Butt vs. C. patens (3):Mid	624.4	-376.8 to 1626	No	ns	0.5791			
C. patens (1):Butt vs. C. patens (3):Butt	-0.8	-1002 to 1000	No	ns	>0.9999			
C. patens (2):Top vs. C. patens (2):Mid	-301.5	-1303 to 699.8	No	ns	0.9903			
C. patens (2):Top vs. C. patens (2):Butt	-1016	-2017 to -14.24	Yes	*	0.0439			
C. patens (2):Top vs. C. patens (3):Top	87.8	-913.5 to 1089	No	ns	>0.9999			
C. patens (2):Top vs. C. patens (3):Mid	-302.1	-1303 to 699.2	No	ns	0.9902			
C. patens (2):Top vs. C. patens (3):Butt	-927.3	-1929 to 73.96	No	ns	0.0942			
C. patens (2):Mid vs. C. patens (2):Butt	-714	-1715 to 287.3	No	ns	0.3890			
C. patens (2):Mid vs. C. patens (3):Top	389.3	-612 to 1391	No	ns	0.9524			
C. patens (2):Mid vs. C. patens (3):Mid	-0.5667	-1002 to 1001	No	ns	>0.9999			
C. patens (2):Mid vs. C. patens (3):Butt	-625.8	-1627 to 375.5	No	ns	0.5761			
C. patens (2):Butt vs. C. patens (3):Top	1103	102 to 2105	Yes	*	0.0188			
C. patens (2):Butt vs. C. patens (3):Mid	713.4	-287.8 to 1715	No	ns	0.3902			
C. patens (2):Butt vs. C. patens (3):Butt	88.2	-913.1 to 1089	No	ns	>0.9999			
C. patens (3):Top vs. C. patens (3):Mid	-389.9	-1391 to 611.4	No	ns	0.9520			
C. patens (3):Top vs. C. patens (3):Butt	-1015	-2016 to -13.84	Yes	*	0.0441			
C. patens (3):Mid vs. C. patens (3):Butt	-625.2	-1626 to 376	No	ns	0.5774			
Test details	**Mean 1**	**Mean 2**	**Mean Diff.**	**SE of diff.**	**N1**	**N2**	**q**	**DF**
C. patens (1):Top vs. C. patens (1):Mid	7268	7556	-287.6	320.1	30	30	1.271	261
C. patens (1):Top vs. C. patens (1):Butt	7268	8200	-932	320.1	30	30	4.118	261

C. patens (1):Top vs. C. patens (2):Top	7268	7274	-5.467	320.1	30	30	0.02415	261
C. patens (1):Top vs. C. patens (2):Mid	7268	7575	-307	320.1	30	30	1.356	261
C. patens (1):Top vs. C. patens (2):Butt	7268	8289	-1021	320.1	30	30	4.511	261
C. patens (1):Top vs. C. patens (3):Top	7268	7186	82.33	320.1	30	30	0.3638	261
C. patens (1):Top vs. C. patens (3):Mid	7268	7576	-307.5	320.1	30	30	1.359	261
C. patens (1):Top vs. C. patens (3):Butt	7268	8201	-932.8	320.1	30	30	4.121	261
C. patens (1):Mid vs. C. patens (1):Butt	7556	8200	-644.4	320.1	30	30	2.847	261
C. patens (1):Mid vs. C. patens (2):Top	7556	7274	282.1	320.1	30	30	1.247	261
C. patens (1):Mid vs. C. patens (2):Mid	7556	7575	-19.37	320.1	30	30	0.08556	261
C. patens (1):Mid vs. C. patens (2):Butt	7556	8289	-733.4	320.1	30	30	3.24	261
C. patens (1):Mid vs. C. patens (3):Top	7556	7186	369.9	320.1	30	30	1.634	261
C. patens (1):Mid vs. C. patens (3):Mid	7556	7576	-19.93	320.1	30	30	0.08807	261
C. patens (1):Mid vs. C. patens (3):Butt	7556	8201	-645.2	320.1	30	30	2.85	261
C. patens (1):Butt vs. C. patens (2):Top	8200	7274	926.5	320.1	30	30	4.093	261
C. patens (1):Butt vs. C. patens (2):Mid	8200	7575	625	320.1	30	30	2.761	261
C. patens (1):Butt vs. C. patens (2):Butt	8200	8289	-89	320.1	30	30	0.3932	261
C. patens (1):Butt vs. C. patens (3):Top	8200	7186	1014	320.1	30	30	4.481	261
C. patens (1):Butt vs. C. patens (3):Mid	8200	7576	624.4	320.1	30	30	2.759	261
C. patens (1):Butt vs. C. patens (3):Butt	8200	8201	-0.8	320.1	30	30	0.003535	261
C. patens (2):Top vs. C. patens (2):Mid	7274	7575	-301.5	320.1	30	30	1.332	261
C. patens (2):Top vs. C. patens (2):Butt	7274	8289	-1016	320.1	30	30	4.487	261
C. patens (2):Top vs. C. patens (3):Top	7274	7186	87.8	320.1	30	30	0.3879	261
C. patens (2):Top vs. C. patens (3):Mid	7274	7576	-302.1	320.1	30	30	1.335	261

C. patens (2):Top vs. C. patens (3):Butt	7274	8201	-927.3	320.1	30	30	4.097	261
C. patens (2):Mid vs. C. patens (2):Butt	7575	8289	-714	320.1	30	30	3.155	261
C. patens (2):Mid vs. C. patens (3):Top	7575	7186	389.3	320.1	30	30	1.72	261
C. patens (2):Mid vs. C. patens (3):Mid	7575	7576	-0.5667	320.1	30	30	0.002504	261
C. patens (2):Mid vs. C. patens (3):Butt	7575	8201	-625.8	320.1	30	30	2.765	261
C. patens (2):Butt vs. C. patens (3):Top	8289	7186	1103	320.1	30	30	4.875	261
C. patens (2):Butt vs. C. patens (3):Mid	8289	7576	713.4	320.1	30	30	3.152	261
C. patens (2):Butt vs. C. patens (3):Butt	8289	8201	88.2	320.1	30	30	0.3897	261
C. patens (3):Top vs. C. patens (3):Mid	7186	7576	-389.9	320.1	30	30	1.722	261
C. patens (3):Top vs. C. patens (3):Butt	7186	8201	-1015	320.1	30	30	4.485	261
C. patens (3):Mid vs. C. patens (3):Butt	7576	8201	-625.2	320.1	30	30	2.762	261

APPENDIX B5: Tukey's multiple comparison test for the Shear strength along the axial stem sections of the three *C. patens*.

Number of families	1				
Number of comparisons per family	36				
Alpha	0.05				
Tukey's multiple comparisons test	**Mean Diff.**	**95.00% CI of diff.**	**Sig.?**	**Summary**	**Adjusted P Value**
C. patens (1):Top vs. C. patens (1):Mid	-0.8266	-1.68 to 0.02651	No	ns	0.0658
C. patens (1):Top vs. C. patens (1):Butt	-2.147	-3 to -1.293	Yes	****	<0.0001
C. patens (1):Top vs. C. patens (2):Top	0.02513	-0.828 to 0.8783	No	ns	>0.9999
C. patens (1):Top vs. C. patens (2):Mid	-0.6839	-1.537 to 0.1692	No	ns	0.2332
C. patens (1):Top vs. C. patens (2):Butt	-1.693	-2.547 to -0.8403	Yes	****	<0.0001

C. patens (1):Top vs. C. patens (3):Top	0.308	-0.5451 to 1.161	No	ns	0.9693
C. patens (1):Top vs. C. patens (3):Mid	-1.113	-1.966 to -0.2595	Yes	**	0.0019
C. patens (1):Top vs. C. patens (3):Butt	-2.316	-3.169 to -1.463	Yes	****	<0.0001
C. patens (1):Mid vs. C. patens (1):Butt	-1.32	-2.173 to -0.4667	Yes	****	<0.0001
C. patens (1):Mid vs. C. patens (2):Top	0.8518	-0.00138 to 1.705	No	ns	0.0507
C. patens (1):Mid vs. C. patens (2):Mid	0.1427	-0.7104 to 0.9959	No	ns	0.9999
C. patens (1):Mid vs. C. patens (2):Butt	-0.8668	-1.72 to -0.01362	Yes	*	0.0432
C. patens (1):Mid vs. C. patens (3):Top	1.135	0.2815 to 1.988	Yes	**	0.0014
C. patens (1):Mid vs. C. patens (3):Mid	-0.286	-1.139 to 0.5672	No	ns	0.9806
C. patens (1):Mid vs. C. patens (3):Butt	-1.49	-2.343 to -0.6364	Yes	****	<0.0001
C. patens (1):Butt vs. C. patens (2):Top	2.172	1.318 to 3.025	Yes	****	<0.0001
C. patens (1):Butt vs. C. patens (2):Mid	1.463	0.6095 to 2.316	Yes	****	<0.0001
C. patens (1):Butt vs. C. patens (2):Butt	0.4531	-0.4 to 1.306	No	ns	0.7694
C. patens (1):Butt vs. C. patens (3):Top	2.455	1.601 to 3.308	Yes	****	<0.0001
C. patens (1):Butt vs. C. patens (3):Mid	1.034	0.1808 to 1.887	Yes	**	0.0057
C. patens (1):Butt vs. C. patens (3):Butt	-0.1696	-1.023 to 0.6835	No	ns	0.9995
C. patens (2):Top vs. C. patens (2):Mid	-0.709	-1.562 to 0.1441	No	ns	0.1918
C. patens (2):Top vs. C. patens (2):Butt	-1.719	-2.572 to -0.8654	Yes	****	<0.0001
C. patens (2):Top vs. C. patens (3):Top	0.2829	-0.5703 to 1.136	No	ns	0.9819
C. patens (2):Top vs. C. patens (3):Mid	-1.138	-1.991 to -0.2846	Yes	**	0.0013
C. patens (2):Top vs. C. patens (3):Butt	-2.341	-3.194 to -1.488	Yes	****	<0.0001
C. patens (2):Mid vs. C. patens (2):Butt	-1.01	-1.863 to -0.1564	Yes	**	0.0079
C. patens (2):Mid vs. C. patens (3):Top	0.9919	0.1388 to 1.845	Yes	**	0.0099

C. patens (2):Mid vs. C. patens (3):Mid	-0.4287	-1.282 to 0.4244	No	ns	0.8193			
C. patens (2):Mid vs. C. patens (3):Butt	-1.632	-2.485 to -0.7791	Yes	****	<0.0001			
C. patens (2):Butt vs. C. patens (3):Top	2.001	1.148 to 2.855	Yes	****	<0.0001			
C. patens (2):Butt vs. C. patens (3):Mid	0.5808	-0.2723 to 1.434	No	ns	0.4556			
C. patens (2):Butt vs. C. patens (3):Butt	-0.6227	-1.476 to 0.2304	No	ns	0.3561			
C. patens (3):Top vs. C. patens (3):Mid	-1.421	-2.274 to -0.5675	Yes	****	<0.0001			
C. patens (3):Top vs. C. patens (3):Butt	-2.624	-3.477 to -1.771	Yes	****	<0.0001			
C. patens (3):Mid vs. C. patens (3):Butt	-1.204	-2.057 to -0.3504	Yes	***	0.0005			
Test details	**Mean 1**	**Mean 2**	**Mean Diff.**	**SE of diff.**	**N1**	**N2**	**q**	DF
C. patens (1):Top vs. C. patens (1):Mid	5.508	6.334	-0.8266	0.2727	30	30	4.286	261
C. patens (1):Top vs. C. patens (1):Butt	5.508	7.654	-2.147	0.2727	30	30	11.13	261
C. patens (1):Top vs. C. patens (2):Top	5.508	5.483	0.02513	0.2727	30	30	0.1303	261
C. patens (1):Top vs. C. patens (2):Mid	5.508	6.192	-0.6839	0.2727	30	30	3.546	261
C. patens (1):Top vs. C. patens (2):Butt	5.508	7.201	-1.693	0.2727	30	30	8.781	261
C. patens (1):Top vs. C. patens (3):Top	5.508	5.2	0.308	0.2727	30	30	1.597	261
C. patens (1):Top vs. C. patens (3):Mid	5.508	6.62	-1.113	0.2727	30	30	5.769	261
C. patens (1):Top vs. C. patens (3):Butt	5.508	7.824	-2.316	0.2727	30	30	12.01	261
C. patens (1):Mid vs. C. patens (1):Butt	6.334	7.654	-1.32	0.2727	30	30	6.844	261
C. patens (1):Mid vs. C. patens (2):Top	6.334	5.483	0.8518	0.2727	30	30	4.417	261
C. patens (1):Mid vs. C. patens (2):Mid	6.334	6.192	0.1427	0.2727	30	30	0.7401	261
C. patens (1):Mid vs. C. patens (2):Butt	6.334	7.201	-0.8668	0.2727	30	30	4.494	261
C. patens (1):Mid vs. C. patens (3):Top	6.334	5.2	1.135	0.2727	30	30	5.883	261
C. patens (1):Mid vs. C. patens (3):Mid	6.334	6.62	-0.286	0.2727	30	30	1.483	261

C. patens (1):Mid vs. C. patens (3):Butt	6.334	7.824	-1.49	0.2727	30	30	7.723	261
C. patens (1):Butt vs. C. patens (2):Top	7.654	5.483	2.172	0.2727	30	30	11.26	261
C. patens (1):Butt vs. C. patens (2):Mid	7.654	6.192	1.463	0.2727	30	30	7.584	261
C. patens (1):Butt vs. C. patens (2):Butt	7.654	7.201	0.4531	0.2727	30	30	2.349	261
C. patens (1):Butt vs. C. patens (3):Top	7.654	5.2	2.455	0.2727	30	30	12.73	261
C. patens (1):Butt vs. C. patens (3):Mid	7.654	6.62	1.034	0.2727	30	30	5.361	261
C. patens (1):Butt vs. C. patens (3):Butt	7.654	7.824	-0.1696	0.2727	30	30	0.8796	261
C. patens (2):Top vs. C. patens (2):Mid	5.483	6.192	-0.709	0.2727	30	30	3.676	261
C. patens (2):Top vs. C. patens (2):Butt	5.483	7.201	-1.719	0.2727	30	30	8.911	261
C. patens (2):Top vs. C. patens (3):Top	5.483	5.2	0.2829	0.2727	30	30	1.467	261
C. patens (2):Top vs. C. patens (3):Mid	5.483	6.62	-1.138	0.2727	30	30	5.899	261
C. patens (2):Top vs. C. patens (3):Butt	5.483	7.824	-2.341	0.2727	30	30	12.14	261
C. patens (2):Mid vs. C. patens (2):Butt	6.192	7.201	-1.01	0.2727	30	30	5.234	261
C. patens (2):Mid vs. C. patens (3):Top	6.192	5.2	0.9919	0.2727	30	30	5.143	261
C. patens (2):Mid vs. C. patens (3):Mid	6.192	6.62	-0.4287	0.2727	30	30	2.223	261
C. patens (2):Mid vs. C. patens (3):Butt	6.192	7.824	-1.632	0.2727	30	30	8.463	261
C. patens (2):Butt vs. C. patens (3):Top	7.201	5.2	2.001	0.2727	30	30	10.38	261
C. patens (2):Butt vs. C. patens (3):Mid	7.201	6.62	0.5808	0.2727	30	30	3.012	261
C. patens (2):Butt vs. C. patens (3):Butt	7.201	7.824	-0.6227	0.2727	30	30	3.229	261
C. patens (3):Top vs. C. patens (3):Mid	5.2	6.62	-1.421	0.2727	30	30	7.366	261
C. patens (3):Top vs. C. patens (3):Butt	5.2	7.824	-2.624	0.2727	30	30	13.61	261
C. patens (3):Mid vs. C. patens (3):Butt	6.62	7.824	-1.204	0.2727	30	30	6.241	261

APPENDIX B6: Tukey's multiple comparison test for the compression strength along the axial stem sections of the three *C. patens*.

Number of families	1				
Number of comparisons per family	36				
Alpha	0.05				
Tukey's multiple comparisons test	**Mean Diff.**	**95.00% CI of diff.**	**Sig.?**	**Summary**	**Adjusted P Value**
C. patens (1):Top vs. C. patens (1):Mid	-1.697	-5.26 to 1.866	No	ns	0.8595
C. patens (1):Top vs. C. patens (1):Butt	-4.427	-7.99 to -0.8643	Yes	**	0.0040
C. patens (1):Top vs. C. patens (2):Top	0.897	-2.666 to 4.46	No	ns	0.9971
C. patens (1):Top vs. C. patens (2):Mid	-1.393	-4.956 to 2.17	No	ns	0.9508
C. patens (1):Top vs. C. patens (2):Butt	-5.364	-8.926 to -1.801	Yes	***	0.0001
C. patens (1):Top vs. C. patens (3):Top	2.727	-0.8361 to 6.289	No	ns	0.2917
C. patens (1):Top vs. C. patens (3):Mid	0.8193	-2.743 to 4.382	No	ns	0.9985
C. patens (1):Top vs. C. patens (3):Butt	-3.584	-7.146 to -0.02094	Yes	*	0.0474
C. patens (1):Mid vs. C. patens (1):Butt	-2.73	-6.293 to 0.8327	No	ns	0.2901
C. patens (1):Mid vs. C. patens (2):Top	2.594	-0.9687 to 6.157	No	ns	0.3597
C. patens (1):Mid vs. C. patens (2):Mid	0.304	-3.259 to 3.867	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (2):Butt	-3.667	-7.229 to -0.1039	Yes	*	0.0382
C. patens (1):Mid vs. C. patens (3):Top	4.424	0.8609 to 7.986	Yes	**	0.0041
C. patens (1):Mid vs. C. patens (3):Mid	2.516	-1.046 to 6.079	No	ns	0.4027
C. patens (1):Mid vs. C. patens (3):Butt	-1.887	-5.449 to 1.676	No	ns	0.7722
C. patens (1):Butt vs. C. patens (2):Top	5.324	1.761 to 8.887	Yes	***	0.0002
C. patens (1):Butt vs. C. patens (2):Mid	3.034	-0.5287 to 6.597	No	ns	0.1662
C. patens (1):Butt vs. C. patens (2):Butt	-0.9367	-4.499 to 2.626	No	ns	0.9961

C. patens (1):Butt vs. C. patens (3):Top	7.154	3.591 to 10.72	Yes	****	<0.0001			
C. patens (1):Butt vs. C. patens (3):Mid	5.246	1.684 to 8.809	Yes	***	0.0002			
C. patens (1):Butt vs. C. patens (3):Butt	0.8433	-2.719 to 4.406	No	ns	0.9981			
C. patens (2):Top vs. C. patens (2):Mid	-2.29	-5.853 to 1.273	No	ns	0.5374			
C. patens (2):Top vs. C. patens (2):Butt	-6.261	-9.823 to -2.698	Yes	****	<0.0001			
C. patens (2):Top vs. C. patens (3):Top	1.83	-1.733 to 5.392	No	ns	0.8007			
C. patens (2):Top vs. C. patens (3):Mid	-0.07767	-3.64 to 3.485	No	ns	>0.9999			
C. patens (2):Top vs. C. patens (3):Butt	-4.481	-8.043 to -0.9179	Yes	**	0.0034			
C. patens (2):Mid vs. C. patens (2):Butt	-3.971	-7.533 to -0.4079	Yes	*	0.0165			
C. patens (2):Mid vs. C. patens (3):Top	4.12	0.5569 to 7.682	Yes	*	0.0106			
C. patens (2):Mid vs. C. patens (3):Mid	2.212	-1.35 to 5.775	No	ns	0.5850			
C. patens (2):Mid vs. C. patens (3):Butt	-2.191	-5.753 to 1.372	No	ns	0.5982			
C. patens (2):Butt vs. C. patens (3):Top	8.09	4.528 to 11.65	Yes	****	<0.0001			
C. patens (2):Butt vs. C. patens (3):Mid	6.183	2.62 to 9.746	Yes	****	<0.0001			
C. patens (2):Butt vs. C. patens (3):Butt	1.78	-1.783 to 5.343	No	ns	0.8240			
C. patens (3):Top vs. C. patens (3):Mid	-1.907	-5.47 to 1.655	No	ns	0.7615			
C. patens (3):Top vs. C. patens (3):Butt	-6.31	-9.873 to -2.748	Yes	****	<0.0001			
C. patens (3):Mid vs. C. patens (3):Butt	-4.403	-7.966 to -0.8403	Yes	**	0.0044			
Test details	**Mean 1**	**Mean 2**	**Mean Diff.**	**SE of diff.**	**N1**	**N2**	**q**	**DF**
C. patens (1):Top vs. C. patens (1):Mid	24.45	26.14	-1.697	1.139	30	30	2.107	261
C. patens (1):Top vs. C. patens (1):Butt	24.45	28.87	-4.427	1.139	30	30	5.497	261
C. patens (1):Top vs. C. patens (2):Top	24.45	23.55	0.897	1.139	30	30	1.114	261
C. patens (1):Top vs. C. patens (2):Mid	24.45	25.84	-1.393	1.139	30	30	1.73	261

C. patens (1):Top vs. C. patens (2):Butt	24.45	29.81	-5.364	1.139	30	30	6.66	261
C. patens (1):Top vs. C. patens (3):Top	24.45	21.72	2.727	1.139	30	30	3.386	261
C. patens (1):Top vs. C. patens (3):Mid	24.45	23.63	0.8193	1.139	30	30	1.017	261
C. patens (1):Top vs. C. patens (3):Butt	24.45	28.03	-3.584	1.139	30	30	4.45	261
C. patens (1):Mid vs. C. patens (1):Butt	26.14	28.87	-2.73	1.139	30	30	3.39	261
C. patens (1):Mid vs. C. patens (2):Top	26.14	23.55	2.594	1.139	30	30	3.221	261
C. patens (1):Mid vs. C. patens (2):Mid	26.14	25.84	0.304	1.139	30	30	0.3775	261
C. patens (1):Mid vs. C. patens (2):Butt	26.14	29.81	-3.667	1.139	30	30	4.553	261
C. patens (1):Mid vs. C. patens (3):Top	26.14	21.72	4.424	1.139	30	30	5.493	261
C. patens (1):Mid vs. C. patens (3):Mid	26.14	23.63	2.516	1.139	30	30	3.124	261
C. patens (1):Mid vs. C. patens (3):Butt	26.14	28.03	-1.887	1.139	30	30	2.343	261
C. patens (1):Butt vs. C. patens (2):Top	28.87	23.55	5.324	1.139	30	30	6.611	261
C. patens (1):Butt vs. C. patens (2):Mid	28.87	25.84	3.034	1.139	30	30	3.767	261
C. patens (1):Butt vs. C. patens (2):Butt	28.87	29.81	-0.9367	1.139	30	30	1.163	261
C. patens (1):Butt vs. C. patens (3):Top	28.87	21.72	7.154	1.139	30	30	8.882	261
C. patens (1):Butt vs. C. patens (3):Mid	28.87	23.63	5.246	1.139	30	30	6.514	261
C. patens (1):Butt vs. C. patens (3):Butt	28.87	28.03	0.8433	1.139	30	30	1.047	261
C. patens (2):Top vs. C. patens (2):Mid	23.55	25.84	-2.29	1.139	30	30	2.843	261
C. patens (2):Top vs. C. patens (2):Butt	23.55	29.81	-6.261	1.139	30	30	7.774	261
C. patens (2):Top vs. C. patens (3):Top	23.55	21.72	1.83	1.139	30	30	2.272	261
C. patens (2):Top vs. C. patens (3):Mid	23.55	23.63	- 0.07767	1.139	30	30	0.09644	261
C. patens (2):Top vs. C. patens (3):Butt	23.55	28.03	-4.481	1.139	30	30	5.563	261
C. patens (2):Mid vs. C. patens (2):Butt	25.84	29.81	-3.971	1.139	30	30	4.93	261

C. patens (2):Mid vs. C. patens (3):Top	25.84	21.72	4.12	1.139	30	30	5.115	261
C. patens (2):Mid vs. C. patens (3):Mid	25.84	23.63	2.212	1.139	30	30	2.747	261
C. patens (2):Mid vs. C. patens (3):Butt	25.84	28.03	-2.191	1.139	30	30	2.72	261
C. patens (2):Butt vs. C. patens (3):Top	29.81	21.72	8.09	1.139	30	30	10.05	261
C. patens (2):Butt vs. C. patens (3):Mid	29.81	23.63	6.183	1.139	30	30	7.677	261
C. patens (2):Butt vs. C. patens (3):Butt	29.81	28.03	1.78	1.139	30	30	2.21	261
C. patens (3):Top vs. C. patens (3):Mid	21.72	23.63	-1.907	1.139	30	30	2.368	261
C. patens (3):Top vs. C. patens (3):Butt	21.72	28.03	-6.31	1.139	30	30	7.835	261
C. patens (3):Mid vs. C. patens (3):Butt	23.63	28.03	-4.403	1.139	30	30	5.467	261

APPENDIX B7: Tukey's multiple comparison test for Natural durability along the axial stem sections of the three *C. patens*.

Number of families	1				
Number of comparisons per family	66				
Alpha	0.05				
Tukey's multiple comparisons test	**Mean Diff.**	**95.00% CI of diff.**	**Sig.?**	**Summary**	**Adjusted P Value**
C. patens (1):Top vs. C. patens (1):Mid	1.625	-14.33 to 17.58	No	ns	>0.9999
C. patens (1):Top vs. C. patens (1):Butt	12.25	-3.709 to 28.21	No	ns	0.3213
C. patens (1):Top vs. C. patens (2):Top	0	-15.96 to 15.96	No	ns	>0.9999
C. patens (1):Top vs. C. patens (2):Mid	2.75	-13.21 to 18.71	No	ns	>0.9999
C. patens (1):Top vs. C. patens (2):Butt	12.44	-3.522 to 28.4	No	ns	0.2986
C. patens (1):Top vs. C. patens (3):Top	0	-15.96 to 15.96	No	ns	>0.9999
C. patens (1):Top vs. C. patens (3):Mid	3.438	-12.52 to 19.4	No	ns	0.9999

C. patens (1):Top vs. C. patens (3):Butt	14	-1.959 to 29.96	No	ns	0.1481
C. patens (1):Top vs. C. pentandra:Top	0	-15.96 to 15.96	No	ns	>0.9999
C. patens (1):Top vs. C. pentandra:Mid	0	-15.96 to 15.96	No	ns	>0.9999
C. patens (1):Top vs. C. pentandra:Butt	0	-15.96 to 15.96	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (1):Butt	10.63	-5.334 to 26.58	No	ns	0.5485
C. patens (1):Mid vs. C. patens (2):Top	-1.625	-17.58 to 14.33	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (2):Mid	1.125	-14.83 to 17.08	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (2):Butt	10.81	-5.147 to 26.77	No	ns	0.5206
C. patens (1):Mid vs. C. patens (3):Top	-1.625	-17.58 to 14.33	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (3):Mid	1.813	-14.15 to 17.77	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (3):Butt	12.38	-3.584 to 28.33	No	ns	0.3060
C. patens (1):Mid vs. C. pentandra:Top	-1.625	-17.58 to 14.33	No	ns	>0.9999
C. patens (1):Mid vs. C. pentandra:Mid	-1.625	-17.58 to 14.33	No	ns	>0.9999
C. patens (1):Mid vs. C. pentandra:Butt	-1.625	-17.58 to 14.33	No	ns	>0.9999
C. patens (1):Butt vs. C. patens (2):Top	-12.25	-28.21 to 3.709	No	ns	0.3213
C. patens (1):Butt vs. C. patens (2):Mid	-9.5	-25.46 to 6.459	No	ns	0.7121
C. patens (1):Butt vs. C. patens (2):Butt	0.1875	-15.77 to 16.15	No	ns	>0.9999
C. patens (1):Butt vs. C. patens (3):Top	-12.25	-28.21 to 3.709	No	ns	0.3213
C. patens (1):Butt vs. C. patens (3):Mid	-8.813	-24.77 to 7.147	No	ns	0.8001
C. patens (1):Butt vs. C. patens (3):Butt	1.75	-14.21 to 17.71	No	ns	>0.9999
C. patens (1):Butt vs. C. pentandra:Top	-12.25	-28.21 to 3.709	No	ns	0.3213
C. patens (1):Butt vs. C. pentandra:Mid	-12.25	-28.21 to 3.709	No	ns	0.3213
C. patens (1):Butt vs. C. pentandra:Butt	-12.25	-28.21 to 3.709	No	ns	0.3213

C. patens (2):Top vs. C. patens (2):Mid	2.75	-13.21 to 18.71	No	ns	>0.9999
C. patens (2):Top vs. C. patens (2):Butt	12.44	-3.522 to 28.4	No	ns	0.2986
C. patens (2):Top vs. C. patens (3):Top	0	-15.96 to 15.96	No	ns	>0.9999
C. patens (2):Top vs. C. patens (3):Mid	3.438	-12.52 to 19.4	No	ns	0.9999
C. patens (2):Top vs. C. patens (3):Butt	14	-1.959 to 29.96	No	ns	0.1481
C. patens (2):Top vs. C. pentandra:Top	0	-15.96 to 15.96	No	ns	>0.9999
C. patens (2):Top vs. C. pentandra:Mid	0	-15.96 to 15.96	No	ns	>0.9999
C. patens (2):Top vs. C. pentandra:Butt	0	-15.96 to 15.96	No	ns	>0.9999
C. patens (2):Mid vs. C. patens (2):Butt	9.688	-6.272 to 25.65	No	ns	0.6860
C. patens (2):Mid vs. C. patens (3):Top	-2.75	-18.71 to 13.21	No	ns	>0.9999
C. patens (2):Mid vs. C. patens (3):Mid	0.6875	-15.27 to 16.65	No	ns	>0.9999
C. patens (2):Mid vs. C. patens (3):Butt	11.25	-4.709 to 27.21	No	ns	0.4564
C. patens (2):Mid vs. C. pentandra:Top	-2.75	-18.71 to 13.21	No	ns	>0.9999
C. patens (2):Mid vs. C. pentandra:Mid	-2.75	-18.71 to 13.21	No	ns	>0.9999
C. patens (2):Mid vs. C. pentandra:Butt	-2.75	-18.71 to 13.21	No	ns	>0.9999
C. patens (2):Butt vs. C. patens (3):Top	-12.44	-28.4 to 3.522	No	ns	0.2986
C. patens (2):Butt vs. C. patens (3):Mid	-9	-24.96 to 6.959	No	ns	0.7775
C. patens (2):Butt vs. C. patens (3):Butt	1.563	-14.4 to 17.52	No	ns	>0.9999
C. patens (2):Butt vs. C. pentandra:Top	-12.44	-28.4 to 3.522	No	ns	0.2986
C. patens (2):Butt vs. C. pentandra:Mid	-12.44	-28.4 to 3.522	No	ns	0.2986
C. patens (2):Butt vs. C. pentandra:Butt	-12.44	-28.4 to 3.522	No	ns	0.2986
C. patens (3):Top vs. C. patens (3):Mid	3.438	-12.52 to 19.4	No	ns	0.9999
C. patens (3):Top vs. C. patens (3):Butt	14	-1.959 to 29.96	No	ns	0.1481

C. patens (3):Top vs. C. pentandra:Top	0	-15.96 to 15.96	No	ns	>0.9999
C. patens (3):Top vs. C. pentandra:Mid	0	-15.96 to 15.96	No	ns	>0.9999
C. patens (3):Top vs. C. pentandra:Butt	0	-15.96 to 15.96	No	ns	>0.9999
C. patens (3):Mid vs. C. patens (3):Butt	10.56	-5.397 to 26.52	No	ns	0.5578
C. patens (3):Mid vs. C. pentandra:Top	-3.438	-19.4 to 12.52	No	ns	0.9999
C. patens (3):Mid vs. C. pentandra:Mid	-3.438	-19.4 to 12.52	No	ns	0.9999
C. patens (3):Mid vs. C. pentandra:Butt	-3.438	-19.4 to 12.52	No	ns	0.9999
C. patens (3):Butt vs. C. pentandra:Top	-14	-29.96 to 1.959	No	ns	0.1481
C. patens (3):Butt vs. C. pentandra:Mid	-14	-29.96 to 1.959	No	ns	0.1481
C. patens (3):Butt vs. C. pentandra:Butt	-14	-29.96 to 1.959	No	ns	0.1481
C. pentandra:Top vs. C. pentandra:Mid	0	-15.96 to 15.96	No	ns	>0.9999
C. pentandra:Top vs. C. pentandra:Butt	0	-15.96 to 15.96	No	ns	>0.9999
C. pentandra:Mid vs. C. pentandra:Butt	0	-15.96 to 15.96	No	ns	>0.9999

Test details	**Mean 1**	**Mean 2**	**Mean Diff.**	**SE of diff.**	**N1**	**N2**	**q**	**DF**
C. patens (1):Top vs. C. patens (1):Mid	100	98.38	1.625	4.819	16	16	0.4769	180
C. patens (1):Top vs. C. patens (1):Butt	100	87.75	12.25	4.819	16	16	3.595	180
C. patens (1):Top vs. C. patens (2):Top	100	100	0	4.819	16	16	0	180
C. patens (1):Top vs. C. patens (2):Mid	100	97.25	2.75	4.819	16	16	0.807	180
C. patens (1):Top vs. C. patens (2):Butt	100	87.56	12.44	4.819	16	16	3.65	180
C. patens (1):Top vs. C. patens (3):Top	100	100	0	4.819	16	16	0	180
C. patens (1):Top vs. C. patens (3):Mid	100	96.56	3.438	4.819	16	16	1.009	180
C. patens (1):Top vs. C. patens (3):Butt	100	86	14	4.819	16	16	4.108	180
C. patens (1):Top vs. C. pentandra:Top	100	100	0	4.819	16	16	0	180

C. patens (1):Top vs. C. pentandra:Mid	100	100	0	4.819	16	16	0	180
C. patens (1):Top vs. C. pentandra:Butt	100	100	0	4.819	16	16	0	180
C. patens (1):Mid vs. C. patens (1):Butt	98.38	87.75	10.63	4.819	16	16	3.118	180
C. patens (1):Mid vs. C. patens (2):Top	98.38	100	-1.625	4.819	16	16	0.4769	180
C. patens (1):Mid vs. C. patens (2):Mid	98.38	97.25	1.125	4.819	16	16	0.3301	180
C. patens (1):Mid vs. C. patens (2):Butt	98.38	87.56	10.81	4.819	16	16	3.173	180
C. patens (1):Mid vs. C. patens (3):Top	98.38	100	-1.625	4.819	16	16	0.4769	180
C. patens (1):Mid vs. C. patens (3):Mid	98.38	96.56	1.813	4.819	16	16	0.5319	180
C. patens (1):Mid vs. C. patens (3):Butt	98.38	86	12.38	4.819	16	16	3.631	180
C. patens (1):Mid vs. C. pentandra:Top	98.38	100	-1.625	4.819	16	16	0.4769	180
C. patens (1):Mid vs. C. pentandra:Mid	98.38	100	-1.625	4.819	16	16	0.4769	180
C. patens (1):Mid vs. C. pentandra:Butt	98.38	100	-1.625	4.819	16	16	0.4769	180
C. patens (1):Butt vs. C. patens (2):Top	87.75	100	-12.25	4.819	16	16	3.595	180
C. patens (1):Butt vs. C. patens (2):Mid	87.75	97.25	-9.5	4.819	16	16	2.788	180
C. patens (1):Butt vs. C. patens (2):Butt	87.75	87.56	0.1875	4.819	16	16	0.05502	180
C. patens (1):Butt vs. C. patens (3):Top	87.75	100	-12.25	4.819	16	16	3.595	180
C. patens (1):Butt vs. C. patens (3):Mid	87.75	96.56	-8.813	4.819	16	16	2.586	180
C. patens (1):Butt vs. C. patens (3):Butt	87.75	86	1.75	4.819	16	16	0.5135	180
C. patens (1):Butt vs. C. pentandra:Top	87.75	100	-12.25	4.819	16	16	3.595	180
C. patens (1):Butt vs. C. pentandra:Mid	87.75	100	-12.25	4.819	16	16	3.595	180
C. patens (1):Butt vs. C. pentandra:Butt	87.75	100	-12.25	4.819	16	16	3.595	180
C. patens (2):Top vs. C. patens (2):Mid	100	97.25	2.75	4.819	16	16	0.807	180
C. patens (2):Top vs. C. patens (2):Butt	100	87.56	12.44	4.819	16	16	3.65	180

C. patens (2):Top vs. C. patens (3):Top	100	100	0	4.819	16	16	0	180
C. patens (2):Top vs. C. patens (3):Mid	100	96.56	3.438	4.819	16	16	1.009	180
C. patens (2):Top vs. C. patens (3):Butt	100	86	14	4.819	16	16	4.108	180
C. patens (2):Top vs. C. pentandra:Top	100	100	0	4.819	16	16	0	180
C. patens (2):Top vs. C. pentandra:Mid	100	100	0	4.819	16	16	0	180
C. patens (2):Top vs. C. pentandra:Butt	100	100	0	4.819	16	16	0	180
C. patens (2):Mid vs. C. patens (2):Butt	97.25	87.56	9.688	4.819	16	16	2.843	180
C. patens (2):Mid vs. C. patens (3):Top	97.25	100	-2.75	4.819	16	16	0.807	180
C. patens (2):Mid vs. C. patens (3):Mid	97.25	96.56	0.6875	4.819	16	16	0.2017	180
C. patens (2):Mid vs. C. patens (3):Butt	97.25	86	11.25	4.819	16	16	3.301	180
C. patens (2):Mid vs. C. pentandra:Top	97.25	100	-2.75	4.819	16	16	0.807	180
C. patens (2):Mid vs. C. pentandra:Mid	97.25	100	-2.75	4.819	16	16	0.807	180
C. patens (2):Mid vs. C. pentandra:Butt	97.25	100	-2.75	4.819	16	16	0.807	180
C. patens (2):Butt vs. C. patens (3):Top	87.56	100	-12.44	4.819	16	16	3.65	180
C. patens (2):Butt vs. C. patens (3):Mid	87.56	96.56	-9	4.819	16	16	2.641	180
C. patens (2):Butt vs. C. patens (3):Butt	87.56	86	1.563	4.819	16	16	0.4585	180
C. patens (2):Butt vs. C. pentandra:Top	87.56	100	-12.44	4.819	16	16	3.65	180
C. patens (2):Butt vs. C. pentandra:Mid	87.56	100	-12.44	4.819	16	16	3.65	180
C. patens (2):Butt vs. C. pentandra:Butt	87.56	100	-12.44	4.819	16	16	3.65	180
C. patens (3):Top vs. C. patens (3):Mid	100	96.56	3.438	4.819	16	16	1.009	180
C. patens (3):Top vs. C. patens (3):Butt	100	86	14	4.819	16	16	4.108	180
C. patens (3):Top vs. C. pentandra:Top	100	100	0	4.819	16	16	0	180
C. patens (3):Top vs. C. pentandra:Mid	100	100	0	4.819	16	16	0	180

C. patens (3):Top vs. C. pentandra:Butt	100	100	0	4.819	16	16	0	180
C. patens (3):Mid vs. C. patens (3):Butt	96.56	86	10.56	4.819	16	16	3.1	180
C. patens (3):Mid vs. C. pentandra:Top	96.56	100	-3.438	4.819	16	16	1.009	180
C. patens (3):Mid vs. C. pentandra:Mid	96.56	100	-3.438	4.819	16	16	1.009	180
C. patens (3):Mid vs. C. pentandra:Butt	96.56	100	-3.438	4.819	16	16	1.009	180
C. patens (3):Butt vs. C. pentandra:Top	86	100	-14	4.819	16	16	4.108	180
C. patens (3):Butt vs. C. pentandra:Mid	86	100	-14	4.819	16	16	4.108	180
C. patens (3):Butt vs. C. pentandra:Butt	86	100	-14	4.819	16	16	4.108	180
C. pentandra:Top vs. C. pentandra:Mid	100	100	0	4.819	16	16	0	180
C. pentandra:Top vs. C. pentandra:Butt	100	100	0	4.819	16	16	0	180
C. pentandra:Mid vs. C. pentandra:Butt	100	100	0	4.819	16	16	0	180

APPENDIX B8: Tukey's multiple comparison test for Visual durability rating along the axial stem sections of the three *C. patens*.

Number of families	1				
Number of comparisons per family	66				
Alpha	0.05				
Tukey's multiple comparisons test	**Mean Diff.**	**95.00% CI of diff.**	**Sig.?**	**Summary**	**Adjusted P Value**
C. patens (1):Top vs. C. patens (1):Mid	0.00125	-0.07193 to 0.07443	No	ns	>0.9999
C. patens (1):Top vs. C. patens (1):Butt	0.07875	0.005568 to 0.1519	Yes	*	0.0230
C. patens (1):Top vs. C. patens (2):Top	0	-0.07318 to 0.07318	No	ns	>0.9999
C. patens (1):Top vs. C. patens (2):Mid	0.006875	-0.06631 to 0.08006	No	ns	>0.9999
C. patens (1):Top vs. C. patens (2):Butt	0.04875	-0.02443 to 0.1219	No	ns	0.5475
C. patens (1):Top vs. C. patens (3):Top	0	-0.07318 to 0.07318	No	ns	>0.9999
C. patens (1):Top vs. C. patens (3):Mid	0.001875	-0.07131 to 0.07506	No	ns	>0.9999
C. patens (1):Top vs. C. patens (3):Butt	0.0425	-0.03068 to 0.1157	No	ns	0.7432
C. patens (1):Top vs. C. pentandra:Top	0	-0.07318 to 0.07318	No	ns	>0.9999
C. patens (1):Top vs. C. pentandra:Mid	0	-0.07318 to 0.07318	No	ns	>0.9999
C. patens (1):Top vs. C. pentandra:Butt	0	-0.07318 to 0.07318	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (1):Butt	0.0775	0.004318 to 0.1507	Yes	*	0.0276
C. patens (1):Mid vs. C. patens (2):Top	-0.00125	-0.07443 to 0.07193	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (2):Mid	0.005625	-0.06756 to 0.07881	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (2):Butt	0.0475	-0.02568 to 0.1207	No	ns	0.5882
C. patens (1):Mid vs. C. patens (3):Top	-0.00125	-0.07443 to 0.07193	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (3):Mid	0.000625	-0.07256 to 0.07381	No	ns	>0.9999
C. patens (1):Mid vs. C. patens (3):Butt	0.04125	-0.03193 to 0.1144	No	ns	0.7780

C. patens (1):Mid vs. C. pentandra:Top	-0.00125	-0.07443 to 0.07193	No	ns	>0.9999
C. patens (1):Mid vs. C. pentandra:Mid	-0.00125	-0.07443 to 0.07193	No	ns	>0.9999
C. patens (1):Mid vs. C. pentandra:Butt	-0.00125	-0.07443 to 0.07193	No	ns	>0.9999
C. patens (1):Butt vs. C. patens (2):Top	-0.07875	-0.1519 to -0.005568	Yes	*	0.0230
C. patens (1):Butt vs. C. patens (2):Mid	-0.07187	-0.1451 to 0.001307	No	ns	0.0593
C. patens (1):Butt vs. C. patens (2):Butt	-0.03	-0.1032 to 0.04318	No	ns	0.9698
C. patens (1):Butt vs. C. patens (3):Top	-0.07875	-0.1519 to -0.005568	Yes	*	0.0230
C. patens (1):Butt vs. C. patens (3):Mid	-0.07687	-0.1501 to -0.003693	Yes	*	0.0301
C. patens (1):Butt vs. C. patens (3):Butt	-0.03625	-0.1094 to 0.03693	No	ns	0.8916
C. patens (1):Butt vs. C. pentandra:Top	-0.07875	-0.1519 to -0.005568	Yes	*	0.0230
C. patens (1):Butt vs. C. pentandra:Mid	-0.07875	-0.1519 to -0.005568	Yes	*	0.0230
C. patens (1):Butt vs. C. pentandra:Butt	-0.07875	-0.1519 to -0.005568	Yes	*	0.0230
C. patens (2):Top vs. C. patens (2):Mid	0.006875	-0.06631 to 0.08006	No	ns	>0.9999
C. patens (2):Top vs. C. patens (2):Butt	0.04875	-0.02443 to 0.1219	No	ns	0.5475
C. patens (2):Top vs. C. patens (3):Top	0	-0.07318 to 0.07318	No	ns	>0.9999
C. patens (2):Top vs. C. patens (3):Mid	0.001875	-0.07131 to 0.07506	No	ns	>0.9999
C. patens (2):Top vs. C. patens (3):Butt	0.0425	-0.03068 to 0.1157	No	ns	0.7432
C. patens (2):Top vs. C. pentandra:Top	0	-0.07318 to 0.07318	No	ns	>0.9999
C. patens (2):Top vs. C. pentandra:Mid	0	-0.07318 to 0.07318	No	ns	>0.9999
C. patens (2):Top vs. C. pentandra:Butt	0	-0.07318 to 0.07318	No	ns	>0.9999
C. patens (2):Mid vs. C. patens (2):Butt	0.04188	-0.03131 to 0.1151	No	ns	0.7609
C. patens (2):Mid vs. C. patens (3):Top	-0.006875	-0.08006 to 0.06631	No	ns	>0.9999
C. patens (2):Mid vs. C. patens (3):Mid	-0.005	-0.07818 to 0.06818	No	ns	>0.9999

C. patens (2):Mid vs. C. patens (3):Butt	0.03563	-0.03756 to 0.1088	No	ns	0.9026
C. patens (2):Mid vs. C. pentandra:Top	-0.006875	-0.08006 to 0.06631	No	ns	>0.9999
C. patens (2):Mid vs. C. pentandra:Mid	-0.006875	-0.08006 to 0.06631	No	ns	>0.9999
C. patens (2):Mid vs. C. pentandra:Butt	-0.006875	-0.08006 to 0.06631	No	ns	>0.9999
C. patens (2):Butt vs. C. patens (3):Top	-0.04875	-0.1219 to 0.02443	No	ns	0.5475
C. patens (2):Butt vs. C. patens (3):Mid	-0.04688	-0.1201 to 0.02631	No	ns	0.6084
C. patens (2):Butt vs. C. patens (3):Butt	-0.00625	-0.07943 to 0.06693	No	ns	>0.9999
C. patens (2):Butt vs. C. pentandra:Top	-0.04875	-0.1219 to 0.02443	No	ns	0.5475
C. patens (2):Butt vs. C. pentandra:Mid	-0.04875	-0.1219 to 0.02443	No	ns	0.5475
C. patens (2):Butt vs. C. pentandra:Butt	-0.04875	-0.1219 to 0.02443	No	ns	0.5475
C. patens (3):Top vs. C. patens (3):Mid	0.001875	-0.07131 to 0.07506	No	ns	>0.9999
C. patens (3):Top vs. C. patens (3):Butt	0.0425	-0.03068 to 0.1157	No	ns	0.7432
C. patens (3):Top vs. C. pentandra:Top	0	-0.07318 to 0.07318	No	ns	>0.9999
C. patens (3):Top vs. C. pentandra:Mid	0	-0.07318 to 0.07318	No	ns	>0.9999
C. patens (3):Top vs. C. pentandra:Butt	0	-0.07318 to 0.07318	No	ns	>0.9999
C. patens (3):Mid vs. C. patens (3):Butt	0.04062	-0.03256 to 0.1138	No	ns	0.7945
C. patens (3):Mid vs. C. pentandra:Top	-0.001875	-0.07506 to 0.07131	No	ns	>0.9999
C. patens (3):Mid vs. C. pentandra:Mid	-0.001875	-0.07506 to 0.07131	No	ns	>0.9999
C. patens (3):Mid vs. C. pentandra:Butt	-0.001875	-0.07506 to 0.07131	No	ns	>0.9999
C. patens (3):Butt vs. C. pentandra:Top	-0.0425	-0.1157 to 0.03068	No	ns	0.7432
C. patens (3):Butt vs. C. pentandra:Mid	-0.0425	-0.1157 to 0.03068	No	ns	0.7432
C. patens (3):Butt vs. C. pentandra:Butt	-0.0425	-0.1157 to 0.03068	No	ns	0.7432
C. pentandra:Top vs. C. pentandra:Mid	0	-0.07318 to 0.07318	No	ns	>0.9999

C. pentandra:Top vs. C. pentandra:Butt	0	-0.07318 to 0.07318	No	ns	>0.9999			
C. pentandra:Mid vs. C. pentandra:Butt	0	-0.07318 to 0.07318	No	ns	>0.9999			
Test details	**Mean 1**	**Mean 2**	**Mean Diff.**	**SE of diff.**	**N1**	**N2**	**q**	**DF**
C. patens (1):Top vs. C. patens (1):Mid	4	3.999	0.00125	0.0221	16	16	0.08	180
C. patens (1):Top vs. C. patens (1):Butt	4	3.921	0.07875	0.0221	16	16	5.04	180
C. patens (1):Top vs. C. patens (2):Top	4	4	0	0.0221	16	16	0	180
C. patens (1):Top vs. C. patens (2):Mid	4	3.993	0.006875	0.0221	16	16	0.44	180
C. patens (1):Top vs. C. patens (2):Butt	4	3.951	0.04875	0.0221	16	16	3.12	180
C. patens (1):Top vs. C. patens (3):Top	4	4	0	0.0221	16	16	0	180
C. patens (1):Top vs. C. patens (3):Mid	4	3.998	0.001875	0.0221	16	16	0.12	180
C. patens (1):Top vs. C. patens (3):Butt	4	3.958	0.0425	0.0221	16	16	2.72	180
C. patens (1):Top vs. C. pentandra:Top	4	4	0	0.0221	16	16	0	180
C. patens (1):Top vs. C. pentandra:Mid	4	4	0	0.0221	16	16	0	180
C. patens (1):Top vs. C. pentandra:Butt	4	4	0	0.0221	16	16	0	180
C. patens (1):Mid vs. C. patens (1):Butt	3.999	3.921	0.0775	0.0221	16	16	4.96	180
C. patens (1):Mid vs. C. patens (2):Top	3.999	4	-0.00125	0.0221	16	16	0.08	180
C. patens (1):Mid vs. C. patens (2):Mid	3.999	3.993	0.005625	0.0221	16	16	0.36	180
C. patens (1):Mid vs. C. patens (2):Butt	3.999	3.951	0.0475	0.0221	16	16	3.04	180
C. patens (1):Mid vs. C. patens (3):Top	3.999	4	-0.00125	0.0221	16	16	0.08	180
C. patens (1):Mid vs. C. patens (3):Mid	3.999	3.998	0.000625	0.0221	16	16	0.04	180
C. patens (1):Mid vs. C. patens (3):Butt	3.999	3.958	0.04125	0.0221	16	16	2.64	180
C. patens (1):Mid vs. C. pentandra:Top	3.999	4	-0.00125	0.0221	16	16	0.08	180
C. patens (1):Mid vs. C. pentandra:Mid	3.999	4	-0.00125	0.0221	16	16	0.08	180

C. patens (1):Mid vs. C. pentandra:Butt	3.999	4	-0.00125	0.0221	16	16	0.08	180
C. patens (1):Butt vs. C. patens (2):Top	3.921	4	-0.07875	0.0221	16	16	5.04	180
C. patens (1):Butt vs. C. patens (2):Mid	3.921	3.993	-0.07187	0.0221	16	16	4.6	180
C. patens (1):Butt vs. C. patens (2):Butt	3.921	3.951	-0.03	0.0221	16	16	1.92	180
C. patens (1):Butt vs. C. patens (3):Top	3.921	4	-0.07875	0.0221	16	16	5.04	180
C. patens (1):Butt vs. C. patens (3):Mid	3.921	3.998	-0.07687	0.0221	16	16	4.92	180
C. patens (1):Butt vs. C. patens (3):Butt	3.921	3.958	-0.03625	0.0221	16	16	2.32	180
C. patens (1):Butt vs. C. pentandra:Top	3.921	4	-0.07875	0.0221	16	16	5.04	180
C. patens (1):Butt vs. C. pentandra:Mid	3.921	4	-0.07875	0.0221	16	16	5.04	180
C. patens (1):Butt vs. C. pentandra:Butt	3.921	4	-0.07875	0.0221	16	16	5.04	180
C. patens (2):Top vs. C. patens (2):Mid	4	3.993	0.006875	0.0221	16	16	0.44	180
C. patens (2):Top vs. C. patens (2):Butt	4	3.951	0.04875	0.0221	16	16	3.12	180
C. patens (2):Top vs. C. patens (3):Top	4	4	0	0.0221	16	16	0	180
C. patens (2):Top vs. C. patens (3):Mid	4	3.998	0.001875	0.0221	16	16	0.12	180
C. patens (2):Top vs. C. patens (3):Butt	4	3.958	0.0425	0.0221	16	16	2.72	180
C. patens (2):Top vs. C. pentandra:Top	4	4	0	0.0221	16	16	0	180
C. patens (2):Top vs. C. pentandra:Mid	4	4	0	0.0221	16	16	0	180
C. patens (2):Top vs. C. pentandra:Butt	4	4	0	0.0221	16	16	0	180
C. patens (2):Mid vs. C. patens (2):Butt	3.993	3.951	0.04188	0.0221	16	16	2.68	180
C. patens (2):Mid vs. C. patens (3):Top	3.993	4	-0.006875	0.0221	16	16	0.44	180
C. patens (2):Mid vs. C. patens (3):Mid	3.993	3.998	-0.005	0.0221	16	16	0.32	180
C. patens (2):Mid vs. C. patens (3):Butt	3.993	3.958	0.03563	0.0221	16	16	2.28	180
C. patens (2):Mid vs. C. pentandra:Top	3.993	4	-0.006875	0.0221	16	16	0.44	180

C. patens (2):Mid vs. C. pentandra:Mid	3.993	4	-0.006875	0.0221	16	16	0.44	180
C. patens (2):Mid vs. C. pentandra:Butt	3.993	4	-0.006875	0.0221	16	16	0.44	180
C. patens (2):Butt vs. C. patens (3):Top	3.951	4	-0.04875	0.0221	16	16	3.12	180
C. patens (2):Butt vs. C. patens (3):Mid	3.951	3.998	-0.04688	0.0221	16	16	3	180
C. patens (2):Butt vs. C. patens (3):Butt	3.951	3.958	-0.00625	0.0221	16	16	0.4	180
C. patens (2):Butt vs. C. pentandra:Top	3.951	4	-0.04875	0.0221	16	16	3.12	180
C. patens (2):Butt vs. C. pentandra:Mid	3.951	4	-0.04875	0.0221	16	16	3.12	180
C. patens (2):Butt vs. C. pentandra:Butt	3.951	4	-0.04875	0.0221	16	16	3.12	180
C. patens (3):Top vs. C. patens (3):Mid	4	3.998	0.001875	0.0221	16	16	0.12	180
C. patens (3):Top vs. C. patens (3):Butt	4	3.958	0.0425	0.0221	16	16	2.72	180
C. patens (3):Top vs. C. pentandra:Top	4	4	0	0.0221	16	16	0	180
C. patens (3):Top vs. C. pentandra:Mid	4	4	0	0.0221	16	16	0	180
C. patens (3):Top vs. C. pentandra:Butt	4	4	0	0.0221	16	16	0	180
C. patens (3):Mid vs. C. patens (3):Butt	3.998	3.958	0.04062	0.0221	16	16	2.6	180
C. patens (3):Mid vs. C. pentandra:Top	3.998	4	-0.001875	0.0221	16	16	0.12	180
C. patens (3):Mid vs. C. pentandra:Mid	3.998	4	-0.001875	0.0221	16	16	0.12	180
C. patens (3):Mid vs. C. pentandra:Butt	3.998	4	-0.001875	0.0221	16	16	0.12	180
C. patens (3):Butt vs. C. pentandra:Top	3.958	4	-0.0425	0.0221	16	16	2.72	180
C. patens (3):Butt vs. C. pentandra:Mid	3.958	4	-0.0425	0.0221	16	16	2.72	180
C. patens (3):Butt vs. C. pentandra:Butt	3.958	4	-0.0425	0.0221	16	16	2.72	180
C. pentandra:Top vs. C. pentandra:Mid	4	4	0	0.0221	16	16	0	180
C. pentandra:Top vs. C. pentandra:Butt	4	4	0	0.0221	16	16	0	180
C. pentandra:Mid vs. C. pentandra:Butt	4	4	0	0.0221	16	16	0	180

Appendix C: Completely randomized design table for insertion of *C. patens* and *C. pentandra* stakes in the experimental field

CB14	2T2	CB8	1T9	1T14	2T11	3B8	3M9	2M1	3M4	1T6	CT3
3M10	1T16	3B13	1M1	2B11	3B9	3M12	3B6	1B11	1B7	CT13	1T7
3B4	1B9	3T14	CM10	CB2	1M9	1M3	1B8	2B13	2M13	CB6	3M3
1T8	2T16	1B4	CT4	1T11	2M8	CM7	3M2	CB12	1B6	3T7	1B1
2T7	3T6	3M13	3B2	2B4	3T15	1M12	3M7	1B2	3M5	CB13	CM2
1T10	2M14	CT2	2T3	1T12	2B8	2B1	CM13	2M13	2B15	CT16	2B14
3M14	3M6	3B9	1B13	3M12	2M9	2T8	3M1	CB7	3T13	2T6	1T13
3T4	CM12	2M11	2T1	1T1	1T3	1T4	3B16	CT6	CT7	3B15	1M14
CM5	1B3	3M9	3M16	1M6	2B5	1T15	1B12	2M7	CB4	1B16	2M6
CT14	CM14	3T1	3T5	3M8	CB15	3B1	2M5	1T2	1M10	3T10	CB5
2M15	CM1	CT11	2T12	CT12	2B16	2B6	CB10	1M5	1M15	CM15	2T15
2B10	3M15	2T8	2B3	2B2	2B9	2M16	3T2	CT5	CM3	CT8	2T13
3T16	3B7	1M16	2B7	3B11	2T5	1B14	1M13	CM4	CT1	1M8	3B5
1B10	1B15	1M4	1M1	CT15	CM6	3B12	2T9	CT9	3M11	2T10	CB11
CM8	CT10	2B12	3T3	CB1	1M2	2M4	1T5	CM11	3T11	1M11	2M2
1B5	3T12	3B3	CB9	3B10	3T9	2T14	3B14	CM16	2T4	CB16	2M10