PRELIMINARY STUDY ON PHYSICAL AND MECHANICAL PROPERTIES OF YINMA (*CHUKRASIA VELUTINA*)

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ABSTRACTS

Chukrasia velutina (Yinma) is a deciduous medium to large species, which can produce timber of large size suitable for from furniture up to constructions. It is somewhat smaller than *Chukrasia tabularis* (Yinma). In Southeast Asia and India, both C. *velutina* and C. *tabularis* are used for various uses such as furniture making, windows and light flooring. In Myanmar, Chukrasia tabularis is well-known and used for some constructions. But, C. *velutina* is not well known. Its physical and mechanical properties are not known and its uses are limited. Thus, with the objectives of the promotion of its uses, and studying the variability of wood properties, physical and mechanical properties of five sample trees were investigated. Almost all physical properties vary significantly between and within trees. It is not true to all mechanical properties. Only some mechanical properties vary significantly within and between trees. According to the investigated properties, *Chukrasia velutina* is a good timber in term of its strength. However, its shrinkage is somewhat high, asking for proper drying before putting it into uses.

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1. INTRODUCTION

Myanmar Forest Department has identified roughly 474 tree species. These species are classified into five groups. Less-than 50 species are accepted commercially important. Most of them are lesser-used timber species. Because of a high demand for timber consumption for increased population, extension of construction and installation of wood-based industries, and a reduced amount of commercial timber production, an impulse for utilization of the lesser-used timber species has been made since 1980s by investigation on their utilization-orientated technological properties.

With an attempt for promotion of the uses of Myanmar lesser-used timber species, from 1997 to 2000, 54 lesser-used timber species has been tested for anatomical, physical and mechanical properties, durability, preservation and seasoning behaviors in the project "Introducing Myanmar Lesser-used Timber Species to the World Market".

As Myanmar Forests are diverse and rich in species, many species are still left for testing the utilization-oriented properties. *Chukrasia velutina* (Yinma) is one of the species untested. Yinma is a species that can grow abundantly in dry deciduous forests. The authors see it growing in Yezin, where the investigation on the physical and mechanical properties is conducted. Yinma trees in the campus of FRI were planted in 1980 - 1985. They are about 18-20 years old at the time of felling and testing. The selected sample trees attain an average bole length of 10 m and an average diameter of 45 cm. Thus, it can be said that Yinma are somewhat fast-growing species.

Thus, keeping the assumption in mind that the information on the properties will promote the utilization of Yinma, the exploration on the properties was conducted and the promise on end-uses was suggested. In addition, the variability of the properties was discussed in this paper.

2. LITERATURE REVIEW

It is necessary to investigate basic wood properties for exploration of end-uses of a wood species. These properties comprise in anatomy, durability, treatability, seasoning behaviors, physical and mechanical properties, and workability. These properties all are important for efficient utilization of log. The study of anatomy gives information on the size of pores, tracheids, fibers, thickness of cell wall; the study of durability states how long a given kind of timber lasts outdoor, and the study of treatability indicates which species are difficult to absorb the chemicals; and the study of seasoning can recommend the seasoning methods for the species with the least drying defects in a shortest possible time.

However, it is impossible to put a timber species to suitable end-uses without its physical and mechanical properties. In wood utilization, basic information on various aspects of wood is inevitably important for efficient utilization of log (Salang et. al., 1996). Shrinkage and swelling are physical properties of wood. This shrinkage and swelling can result in warping, checking, splitting, and loosening tool handles, gaps in strip flooring, or performance problems that can detract from the usefulness of the wood products (USDA, 1999). Therefore, these phenomena must be understood and considered when they can affect a product in which wood is used. Density and specific gravity are the indicative of mechanical properties of the same wood. They can be assessed with simple equipments in a short time.

Strength or mechanical properties of wood are qualities that indicate its ability to resist applied external forces. They are very important criteria in determining the relative suitability of different wood species for various uses (F. B Tamolang et. al., 1995). These properties are of great importance in construction timber in classifing strength as beams, strength as posts, columns, strength as tool handles, and strength as sleepers. Timber species are grouped according to these properties. Thus, it is kept in mind that at least physical and mechanical properties of a timber species should be investigated for clarifying its utility and promoting the uses of those species that have been sporadically used, and for information that may be useful at one time.

Wood properties vary considerably between and within species. Even pieces of the same tree show variation. Variability or variation in properties is common to all material (USDA, 1999). The variation of density and moisture content should affect the quality of sawn timber, seasoning of timber, preservation processes, working properties, mechanical properties and final products quality (Salang et. al., 1996). Thus, the number of trees should be enough to cover the variability of properties between trees and the number specimens should be taken enough from each tree. Moreover, there is variability in wood properties between sapwood and heartwood in the same tree and thus, the number specimens should be enough from both sapwood and heartwood.

Thus, the objective of this study is:

(i) to afford reliable data for wood entrepreneurs, interest groups, scholars, ect. for the locality from where the sample trees were collected,

(ii) to promote the use of *Chuckrasia velutina,*

(iii) to investigate the variation trends in physical and mechanical properties of the species, and

(iv) to develop and sustain wood-based industries.

If lesser-used species including *Chukrasia velutina* can be used to an some wider extent, it is hoped that

(i) the natural forests can be better improved by preserving the valuable species and by making *Chukrasia velutina* plantations, and

(ii) timber supply can be increased to counterbalance the increasingly high demand.

3. MATERIAL AND METHODOLOGY

3.1. Material

Chukrasia velutina is selected for the following reasons.

(i) It can give large-sized lumber after conversion.

(ii) Its physical and mechanical properties have never been tested.

Yinma belongs to the family Meliaceae. Meliaceae consists of many genera such as Aglaia, Amoora, Azadirachta, Cedrela, Chisocheton, Chukrasia, Cipadessa, Dysoxylum, Heynea, Lansium, Melia, Munronia, Sandoricum, Soymida, Swietenia,Turraea, Walsura and Xylocarpus. The family consists of shrubs, small trees and trees. It can be found that Genus Chukrasia consists of two species as far as the Forest Department has identified. They are *Chukrasia tabularis* A.Juss. and *C. velutina* Roem. These two species are vernacularly called Yinma.

Chukrasia velutina is widely distributed throughout Myanmar. It can be distinguished from *Chkrasia tabularis* by the velvety undersurface of its leaflets. The tree is rather small and the wood, though good, is harder and less decorative than that of *Chukrasia tabularis*.

During the fieldwork, girth at breast height (GBH), clear bole length, crown length, stump length of sample trees are measured.

Table (1) Girth at breast height, bole length, crown length, stump height of Yinma sample trees

Sr. No	GBH	Bole	Crown	Stump	Remark
	(cm)	(m)	(m)	(cm)	
1	149.86	8.23	12.80	23	
2	132.08	8.23	13.11	18	
3	116.84	13.10	10.06	25	
4	132.08	5.79	6.71	13	* Crown Break
5	160.02	9.45	12.50	36	
Average	138.18	8.96	11.04	23	

According to the results, the sample trees attain an average girth of 138.18 cm (diameter 44 cm) and an average bole length of 9 m. The crown can be 11 m long. The ring number ranges from 19 to 25. Their age is around 20.

3.2. Methodology

Two standards were used for investigation of physical and mechanical properties of the species: B.S. 373: 1957 for testing mechanical properties and ASTM 143-52 for testing physical properties. In case of physical properties, there is a deviation in size of specimen from the standards.

3.2.1. Physical properties

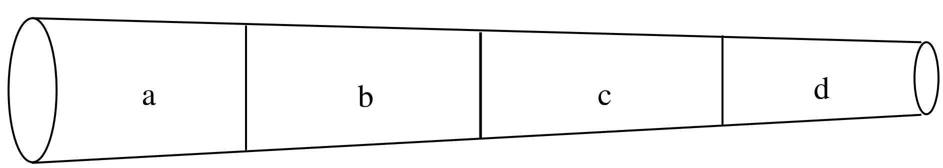

Fig. 1: Sketch showing four bolts of each sample tree

Each sample tree was cut into four bolts, each 3 m long. From the base of each bolt, three disks were cut for preparation of specimens for determination of physical properties.

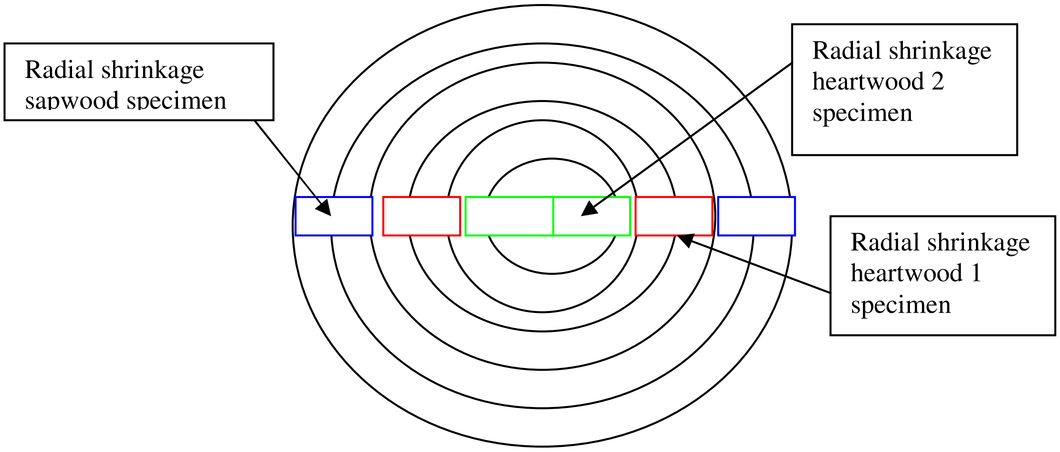

Fig. 2: Sketch showing method of preparation of specimens for determination of radial shrinkage.

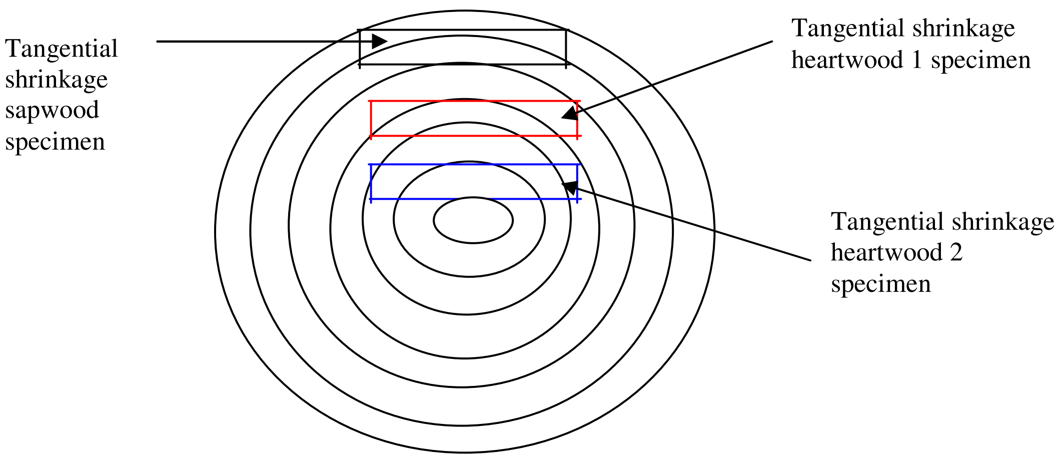

Fig. 3: Sketch showing method of preparation of specimens for determination of tangential shrinkage

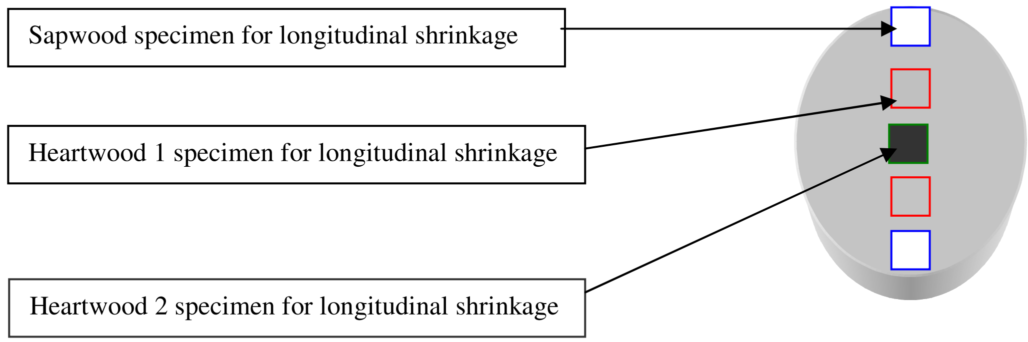

Fig. 4: Sketch showing method of preparation of specimens for determination of longitudinal shrinkage

The number and size of specimens is as follows.

Table (2) Number and size of specimens in physical tests

Sr. No.	Test	Size of Specimen (mm)	No. of Specimens		
			Heartwood 2	Heartwood 1	Sapwood
1	Radial shrinkage	25 x 25 x 50	6	6	6
2	Tangential shrinkage	25 x 25 x 50	6	6	6
3	Longitudinal shrinkage	25 x 25 x 80	6	6	6
4	Volumetric shrinkage, Specific gravity	25 x 25 x 80	6	6	6

3.2.2. Mechanical properties

The bolts from which the three disks were cut, was used for preparation of sticks required for mechanical tests. The size of the sticks was 1" x 1" x 8', and they were matched for green and dry tests. Selection and numbering for the tests were followed the designations in ASTM. The sticks for green test were stored under damp sawdust. Then, they were planed on four surfaces to get the required dimensions of 2 cm x 2 cm in cross section. They were soaked again until they were tested.

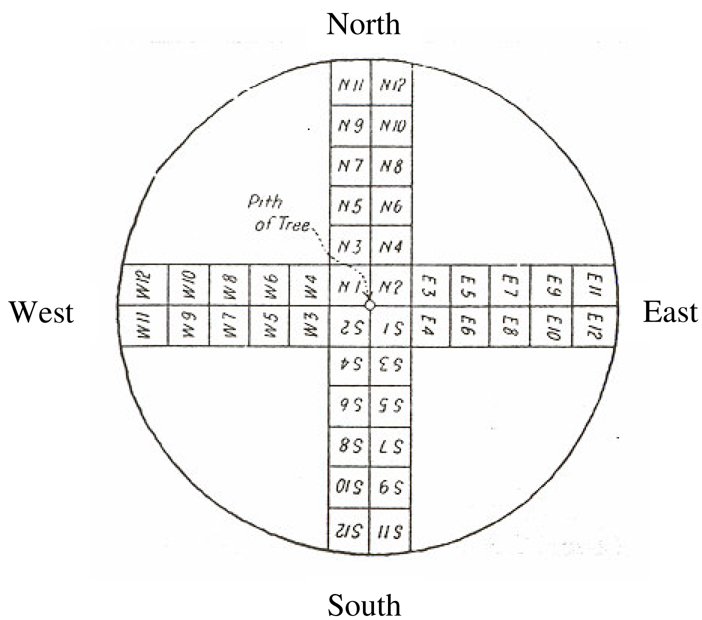

Fig. 5: Sketch showing method of cutting up the bolt and marking the sticks. (from ASTM Designation: D 143-52)

The sticks for dry test were piled so as to have a space of about 1" on each side of each stick to permit circulation of air. In order to prevent from direct sunshine, rain and moisture from the ground, they were stacked under a shed with the use of dry stickers and concrete brick and dry lumber as foundations.

The size of specimens in mechanical tests is as follows.

Table (3) Size of specimens in mechanical tests

Sr. No.	Tests	Size (cm)
1	Static bending	20 x 20 x 300
2	Compression parallel to grain	20 x 20 x 80
3	Compression perpendicular to grain	20 x 20 x 60
4	Hardness	20 x 20 x 60

From the above tests, the following properties were calculated:

(1) Static bending
- (a) Fiber stress at proportional limit (FS@PL)
- (b) Modulus of rupture (MOR)
- (c) Modulus of elasticity (MOE)

(2) Compression parallel to grain
- (a) Fiber stress at proportional limit (FS@PL)
- (b) Maximum crushing strength

(3) Compression perpendicular to grain
- (a) Fiber stress at proportional limit (FS@PL)

(4) Hardness
- (a) Radial
- (b) Tangential
- (c) End

4. DATA ANALYSIS

In this research, the influence of two factors on physical and mechanical properties has been analysed for a single tree: Wood zones in horizontal direction and Tree height in vertical direction.

Factor A:	Wood zones with three levels of source of variation	: h1 (Heartwood 1) : h2 (Heartwood 2) : s (Sapwood)
Factor B:	Tree height with four levels of sources of variation	: a (3 m long bolt-base) : b (3 m long bolt-middle 1) : c (3 m long bolt-middle 2) : d (3 m long bolt-top)

The amount of repetition = 6 specimens per wood zone.

The experimental design was a completely randomized two-factorial model:

$$Yijk = \mu + Ai + Bj + (AB)ij + \varepsilon ijk$$

Where,

Yijk	=	Value of variable Y due to the effect of the i^{th} level of wood zones and j^{th} level of tree height at k^{th} repetition.
μ	=	Mean value of expectation of variable Y
Ai	=	Influence of i^{th} level of wood zones
Bj	=	Influence of j^{th} level of tree height
(AB)ij	=	Influence of interaction between i^{th} level of wood zones and j^{th} level of tree height
εijk	=	Experimental error

However, for a species, the influence of three factors as sources of variation of properties has been analysed: Trees, Tree heights and Wood zones. The third factor C was added to the above model.

Factor C: Trees with 5 levels of source of variation

The experimental design was a completely randomized three-factorial model.

$$Yijkl = \mu + Ai + Bj + Ck + (AB)ij + (AC)ik + (BC)jk + (ABC)ijk + \varepsilon ijkl$$

where

Yijkl	=	Value of variable Y due to the effect of the i^{th} level of wood zones, j^{th} level of tree height and k^{th} level of tree at l^{th} repetition
μ	=	Mean value of expectation of variable Y
Ai	=	Influence of i^{th} level of wood zones
Bj	=	Influence of j^{th} level of tree height
Ck	=	Influence of k^{th} tree
(AB)ij	=	Influence of interaction between i^{th} level of wood zones and j^{th} level of tree height
(AC)ik	=	Influence of interaction between i^{th} level of wood zones and k^{th} level of tree height
(BC)jk	=	Influence of interaction between j^{th} level of tree height and k^{th} level of tree height

(ABC)ijk = Influence of interaction among i^{th} level of wood zones, j^{th} level of tree height, and k^{th} level of trees

If the influence of mentioned factors and their interactions was significant, the test of significant difference was conducted according to Tukey's test.

5. RESULTS AND DISCUSSION

Physical and mechanical properties of Yinma (*Chukrasia velutina*) were tested in this research. Physical properties include radial, tangential, longitudinal and volumetric shrinkage, moisture content, specific gravity and density. From radial and tangential shrinkage, dimensional stability and total transverse shrinkage were computed. From the shrinkage-moisture relation curve, fiber saturation point was estimated.

Mechanical properties include static bending test, endwise compression test, sidewise compression test, and hardness test. From these tests, the related properties were computed.

5.1. Physical Properties

5.1.1. Radial shrinkage

As wood is an anisotropic material, it shrinks not equally in three directions: radial, tangential and longitudinal. Wood shrinks most in the direction of annual growth rings (tangentially), about half as much across the rings (radially) and only slightly along the grain (longitudinally) (USDA, 1999).

This unequal shrinkage may cause degradation of wood products. Degradation may result from a simple reduction of dimension, anisotropy, or differential shrinkage in the mass of the wood under the influence of differences in the distribution of moisture or density. And thus, various defects may develop, such as opening, change of cross-sectional shape, warping, casehardening, honeycombing, collapse and loosened grain. Thus, the shrinkage in all directions must be understood, and species with lesser or small shrinkage is desirable in practical uses.

Table (4) Radial shrinkage of Yinma from green to oven-dry conditions

Tree	R_SH% Means	R_SH% N	R_SH% Std.Dev.	R_SH% CV%	R_SH% 95% confid. Limit
1	4.664	68	0.423	9	0.102
2	4.270	71	0.628	15	0.147
3	4.640	68	0.715	15	0.172
4	4.602	57	0.618	13	0.164
5	4.315	63	0.992	23	0.248
Average	4.498	5	0.190	4	0.236

Note: R_SH means "radial shrinkage from green to oven-dry conditions".

The average radial shrinkage of Yinma from green to oven-dry conditions is from 4.262% to 4.734% at 95% probability level. The minimum and maximum are 4.270 % and 4.664 %. The shrinkage is somewhat high so that proper drying is necessary before uses. There are significant variations in radial shrinkage between and within trees. Within trees, the significant variations are found with height, but it is difficult to define the trend i.e. it is increasing or decreasing with height. In most trees, the greatest shrinkage is in section a: the base bolt, which has the highest density.

In horizontal direction, every tree shows significant variations in wood zones. Sapwood (the wood near bark) shrinks most, heartwood 2 (the wood near pith) less and the heartwood 1 (the wood between sapwood and heartwood 2) least in almost all trees. Thus, heartwood 1 is desirable for uses in comparison with heartwood 2 or sapwood.

5.1.2. Tangential shrinkage

The average total tangential shrinkage ranges from 7.617% to 8.736% at a risk of 5 It is not very high and is about twice as great as the radial shrinkage (right angle to the growth rings). Normally, tangential shrinkage of ≤ 7 is desirable for most uses. The coefficients of variation are lower than 15%, and so the results are reliable.

It is found that tangential shrinkage shows significant variations between trees. %. The minimum and maximum tree means are 7.572% and 8.669%. That is why, it is necessary to collect enough sample trees for determination of tangential shrinkage.

Table (5) Tangential shrinkage from green to oven-dry conditions

Tree	T_SH% Means	T_SH% N	T_SH% Std.Dev.	T_SH% CV%	T_SH% 95% confid. Limit
1	7.572	70	0.845	11	0.200
2	8.669	72	1.045	12	0.244
3	8.259	70	0.807	10	0.191
4	8.507	61	1.126	13	0.286
5	7.875	72	0.826	10	0.193
Average	8.176	5	0.451	6	0.560

Note: T_SH means "tangential shrinkage from green to oven-dry conditions".

Moreover, within trees are significant variations in tangential shrinkage. Vertically, the trend of variation could not be defined exactly. Some trees show a decreasing trend with height (trees 1, 2, and 3) and some trees an increasing trend (trees 4, 5). Horizontally, the variation trend in tangential shrinkage is definite: the shrinkage in sapwood is the highest, in heartwood 1 the least and in heartwood 2 between the two others.

Thus, it is advisable that the heartwood 1 without sapwood or juvenile wood should be used for some applications as it shrinks the least.

5.1.3. Longitudinal shrinkage

It is the shrinkage along the grain of wood. The longitudinal shrinkage of Yinma wood is from 0.080 % to 0.251% from green to oven-dry conditions. The shrinkage is so small in comparison with radial and tangential shrinkage that it can be ignored. The shrinkage varies significantly between trees but not within trees. The longitudinal shrinkage does not change significantly with height and with distances from the pith. However, the shrinkage is the greatest in a base bolt and is decreasing with height.

It is note-worthy that there were some specimens, which became longer than before, resulting in elongation instead of shortening. It is believed that green specimens will become shorter after oven drying. It is not always true in all directions (radial, tangential and longitudinal). The elongation may be accounted for by the existence of internal stresses that may result from seasoning (Ivanov, 1962). In fact, longitudinal shrinkage is not in a direct ratio to the moisture content, but seems to depend on the size of the fibril angle. The smaller the angle, the greater the longitudinal shrinkage is observed to become.

Table (6) Longitudinal shrinkage from green to oven-dry conditions

Trees	LONG_SH% Means	LONG_SH% N	LONG_SH% Std.Dev.	LONG_SH% CV%	LONG_SH% 95% confid. Limit
1	0.105	72	0.103	97	0.024
2	0.199	66	0.169	85	0.041
3	0.095	71	0.084	89	0.020
4	0.165	54	0.141	85	0.038
5	0.262	42	0.162	62	0.050
Average	0.165	5	0.069	42	0.086

Note: LONG_SH means "longitudinal shrinkage from green to oven-dry conditions"

5.1.4. Volumetric shrinkage

It is the reduction in total dimension of wood after removal of bound water below fiber saturation point (Anon, 1997). The volumetric shrinkage of Yinma ranges from 12.450% to 15.685% at 95% probability level and is grouped into moderately high (Class IV). In cases of high stability requirement, the users can avoid such timber, or timber should be used after being specially seasoned.

Table (7) Volumetric shrinkage from green to oven-dry conditions

Trees	VS% Means	VS% N	VS% Std.Dev.	VS% CV%	VS% 95%confid. Limit
1	13.324	67	2.321	17.4	0.561512
2	16.362	57	2.047	12.5	0.542283
3	13.679	70	1.094	8.0	0.258818
4	13.762	64	1.772	12.9	0.438521
5	13.212	66	1.627	12.3	0.396476
Average	14.068	5	1.303	9.3	1.617629

Note: VS means "volumetric shrinkage from green to oven-dry conditions".

There are significant variations in the volumetric shrinkage between trees. Thus, enough sample trees are necessary to present the reliable data.

Within trees, the volumetric shrinkage varies significantly with height and with distances from the pith. Vertically, the basal portion has the highest shrinkage in most sample trees and in the upper portions, it is difficult to define the trend. Volumetric shrinkage increases markedly from ground level to breast height, but does not vary much in the upper level (Panshin et. al, 1980). In this case, it seems to decrease with height, but it is not pronounced.

Horizontally, sapwood shrinks most and heartwood 1 least in almost all sample trees. The trend is not increasing or decreasing with distances from the pith. Neither sapwood near the bark nor the heartwood 2 near the pith is as good as heartwood 1.

5.1.5. Dimensional stability

It is the ratio of tangential shrinkage to radial shrinkage. It is also called the coefficient between tangential and radial shrinkage. The wood having a low ratio is best suited for use (Panshin et.al, 1980). Those timbers, which have dimensional stability less than or equal to 2.0 and dimensional changes i.e. radial shrinkage and tangential shrinkage less than or equal to 3.5 and 7% are found to be suitable for making high quality wood products (Kyi, 2000). The dimensional stability of Yinma is 1.82 and can be said low. However, radial and tangential shrinkage are high. Thus, it would not be the best timber for high quality wood products.

5.1.6. Density

The density of Yinma wood is from 1072 to 1149 kg/m^3 at green condition, from 740 to 800 kg/m^3 at oven-dry condition and from 799 to 859 kg/m^3 at 95% probability level. It is a heavy wood species.

Density shows significant variations between and within trees. Thus, in order to represent the species, the number of trees tested should be enough.

Vertically, oven-dry density seems to decrease with height. In the vertical direction, there is a tendency for reduction of density with tree heights (Tsoumis, 1991). In medium to high density wood species, density decreases with stem heights (Kuroda, 1982). Yinma seems to follow the trend.

Horizontally, oven-dry density is the highest in sapwood, the least in heartwood 2 (juvenile wood) and medium in heartwood 1. In hardwoods, density was found to decrease with distance from pith (Tsoumis, 1991). Again, medium to high density species show the increasing trend in density with distance from the pith and decreasing towards the bark (Kuroda, 1982). It can be found that the density of Yinma is an increasing trend with distance from the pith.

5.1.7. Basic specific gravity

It is the ratio of the oven-dry weight of wood to its green volume. The basic specific gravity of Yinma ranges from 0.635 to 0.687 at 95% probability level. The species can be grouped into "moderately high"(Anon, 1997). This property is an important parameter in determining a good approximation of the latent strength of a particular species in the absence of actual strength test results. It is also useful in estimating charcoal and pulp yields, gluing, nail holding and shrinkage characteristics of a given wood species.

Table (8) Basic specific gravity (Oven-dry weight/ green volume)

Trees	B_SPGR Means	B_SPGR N	B_SPGR Std.Dev.	B_SPGR CV%	B_SPGR 95% confid. Limit
1	0.670	65	0.040	6	0.010
2	0.655	57	0.055	8	0.015
3	0.638	70	0.057	9	0.014
4	0.650	64	0.031	5	0.008
5	0.693	66	0.070	10	0.017
Average	0.661	5	0.021	3	0.026

Note: B_SPGR means "basic specific gravity".

It is found that the basic specific gravity varies between and within species. Within trees, it is the highest in the base portion, and it is not definite in the upper level. It increases with distances from the pith.

5.1.8. Moisture content

The green moisture content of Yinma is from 58.3 to 75.7% at 95% probability level. It shows significant variations between and within trees. Within trees, the significant variation exists in vertical and horizontal directions. In vertical direction, the trend of variation is not definite. It seems to increase from the pith to the bark.

Table (9) Green moisture content of Yinma sample trees

Trees	MC% Means	MC% N	MC% Std.Dev.	MC% CV%	MC% 95% confid. Limit
1	63.8	212	9	15	1.3
2	78.3	225	10	13	1.3
3	67.3	261	8	12	1.0
4	66.2	185	7	11	1.0
5	59.2	258	7	11	0.8
Average	67.0	5	7	10	8.7

Note: MC means "moisture content".

5.1.9. Fiber saturation point

Fiber saturation point is an important criterion in wood utilization. The removal of moisture from the wood above this point causes no change in volume and dimensions and shrinkage does not occur. Below this point, the water from the cell walls of the wood is removed, and shrinkage occurs and mechanical properties undergo changes. Thus, the fiber saturation point is estimated for Yinma from moisture-shrinkage relationship.

The estimated fiber saturation point is 23% for heartwood 1 and heartwood 2 and about 21% for sapwood.

5.2. Mechanical Properties

These properties are taken into consideration in the use of wood where strength is essential. Depending on the properties, a given wood is put into uses as beams, posts, sleepers, floors, etc.

5.2.1. Static bending

The properties from the static bending play an important role in the uses of wood as beams.

5.2.1.1. Modulus of rupture

It reflects the maximum load-carrying capacity of a member in bending. It is an accepted criterion of strength, although it is not a true stress because the formula by which it is computed is valid only to the elastic limit.

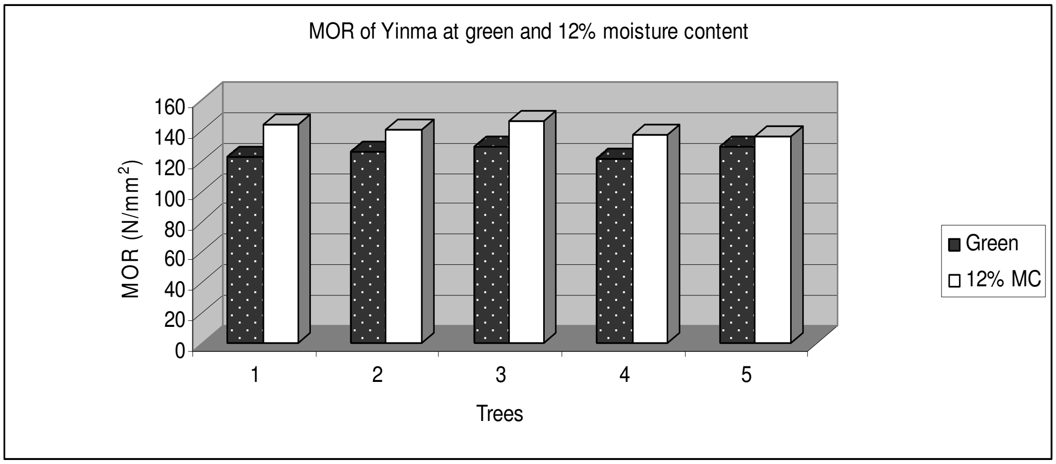

Fig. 6: Graph showing modulus of rupture at green and 12% moisture conditions

The modulus of rupture of Yinma is from 120 to 130 N/mm^2 at green condition and from 136 to 146 N/mm^2 at 12 % moisture content at 95% probability level. The property shows no significant variation between trees at green and air-dried conditions. Within trees, the property has significant variations only in horizontal direction i.e. significant variation due to different wood zones. The significance holds true for both green and air-dried conditions. Sapwood has the highest value and heartwood 2 the lowest.

5.2.1.2.Fiber stress at proportional limit (FS@PL)

It is a stress set up in a specimen by loading it to the proportional limit. It is the maximum stress to which the material can be subjected under a given type of load without being permanently deformed.

The fiber stress at proportional limit of Yinma ranges from 76 to 88 N/mm^2 at green and from 83 to 95 N/mm^2 at 12% moisture content at 95% probability level. In green condition, there is no significant variation in fiber stress at proportional limit between and within trees. In air-dried state, the property shows significant variations between and within trees.

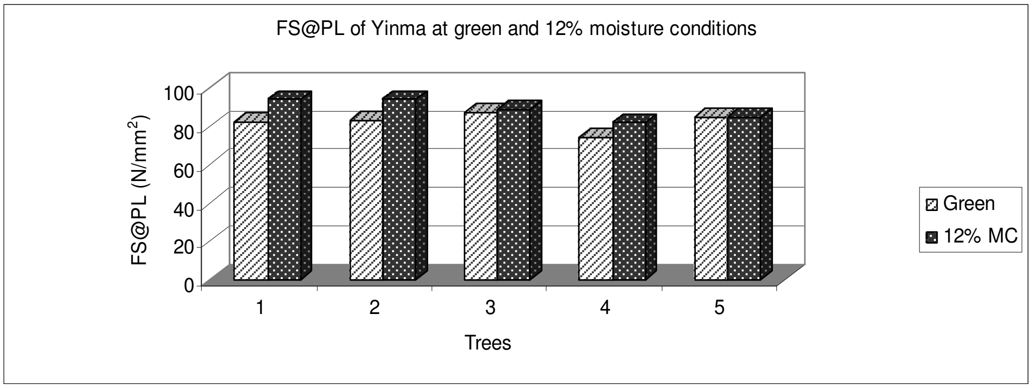

Fig. 7: Graph showing fiber stress at proportional limit (FS@PL) at green and 12% moisture conditions

5.2.1.3.Modulus of elasticity

It is the measure of stiffness of the wood. It is a value indicative of stiffness, not of strength and is applied only to conditions within the proportional limit. A high modulus of elasticity indicates a stiff wood.

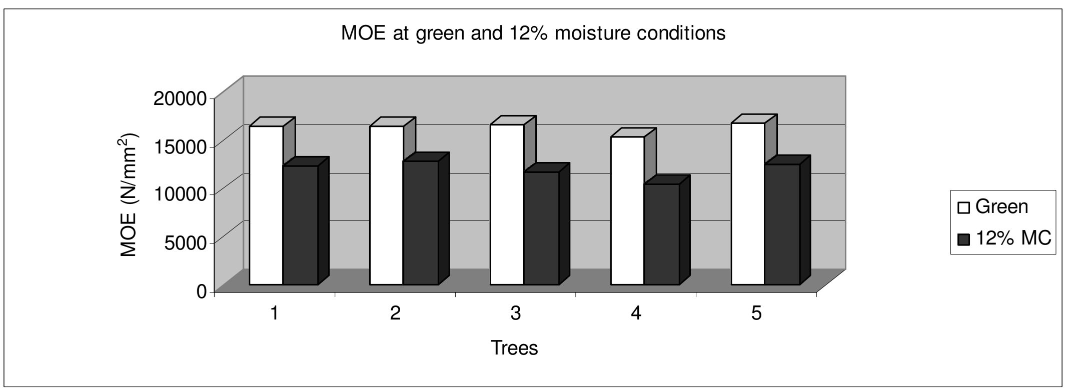

Fig. 8: Graph showing modulus of elasticity (MOE) at green and 12% moisture conditions

The modulus of elasticity of Yinma ranges from 15800 to 16925 N/mm^2 at green and from 10910 to 13100 N/mm^2 at 12% moisture condition at 95% probability level. It can be seen that air-dried Yinma wood is not as stiff as green one. This observation is strange that wood properties increase after removing moisture below fiber saturation point.

There are significant variations in the modulus of elasticity between and within trees. Within trees, significant variations exist only in wood zones.

5.2.2. Compression parallel to grain

The compression parallel to grain is involved in many uses of wood as posts, columns, and props. Short columns with unsupported length less than eleven times the least dimension have the full compressive strength of the material.

5.2.2.1. Maximum crushing strength

It is the maximum stress sustained by a compression parallel-to-grain specimen. The maximum crushing strength of Yinma is from 29 to 37 N/mm^2 at green and from 52 to 60 N/mm^2 at 12% moisture conditions at 95% probability level.

The maximum crushing strength of Yinma varies significantly between trees at both green and air-dried (Adjusted to 12% moisture content) conditions. Within trees, significant variation is valid for horizontal direction only at green state. There is no significant variation in the maximum crushing strength with height.

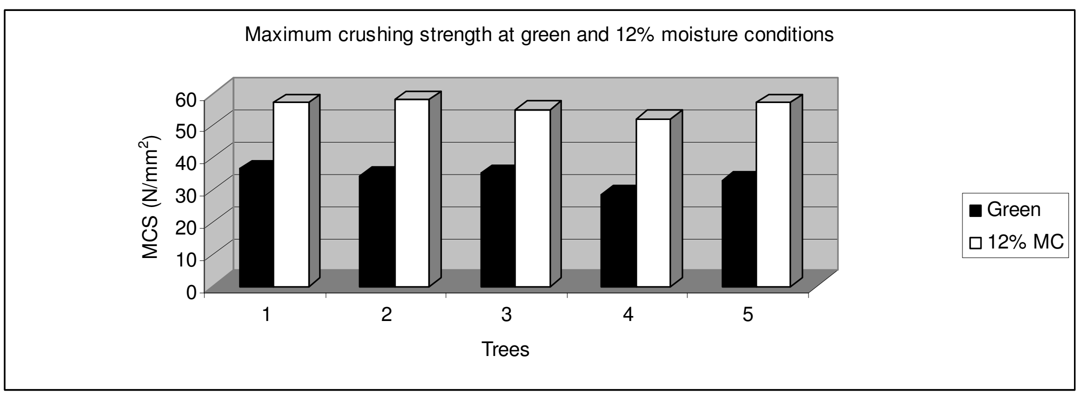

Fig. 9: Graph showing maximum crushing strength at green and 12% moisture conditions

5.2.2.2.Fiber stress at proportional limit

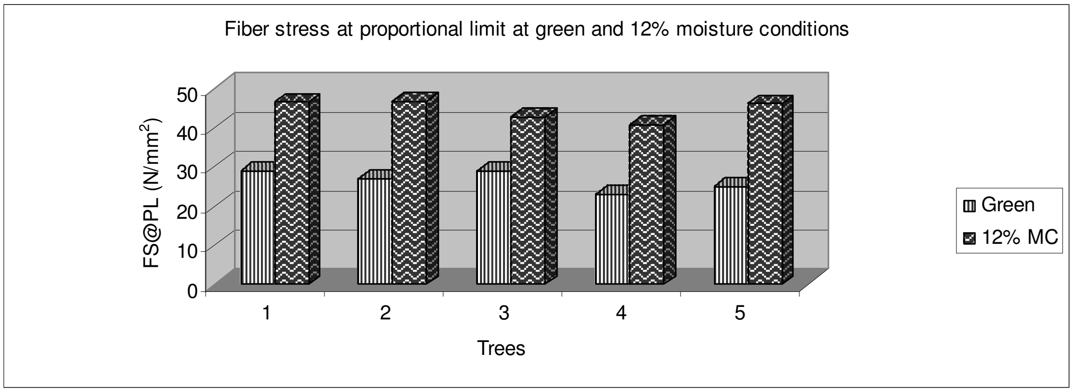

Fig. 10: Graph showing fiber stress at proportional limit at green and 12% moisture conditions

The fiber stress at proportional limit ranges from 24 to 28 N/mm^2 at green and from 41 to 49 N/mm^2 at 12% moisture content at 95% probability level.

Significant variations are observed between trees at green and air-dried conditions. At air-dried condition, there is no significant variation within trees although heartwood 2 has the least values in horizontal direction. In vertical direction, the trend of variation is not definite.

At green condition, the significant variation exists in horizontal direction within trees. Green heartwood 2 has lesser fiber stress than sapwood or heartwood 1 in all sample trees. Every sample tree shows that sapwood has the greatest value in the property. As in air-dried condition, the trend of variation could not be defined in vertical direction.

5.2.3. Compression perpendicular to grain

From the test, only one property is computed: Fiber stress at proportional limit. It is one of the properties, which are taken into considerations in the uses of wood as railway sleepers. The fiber stress at proportional limit of Yinma ranges from 11 to 13 N/mm^2 at green and from 12 to 14 N/mm^2 at 12% moisture content at 95% probability level.

The significant variation in the fiber stress at proportional limit exists between and within trees in air-dried condition. Within trees, the significant variation is valid for horizontal variation. There is no significant variation between and within trees at green state.

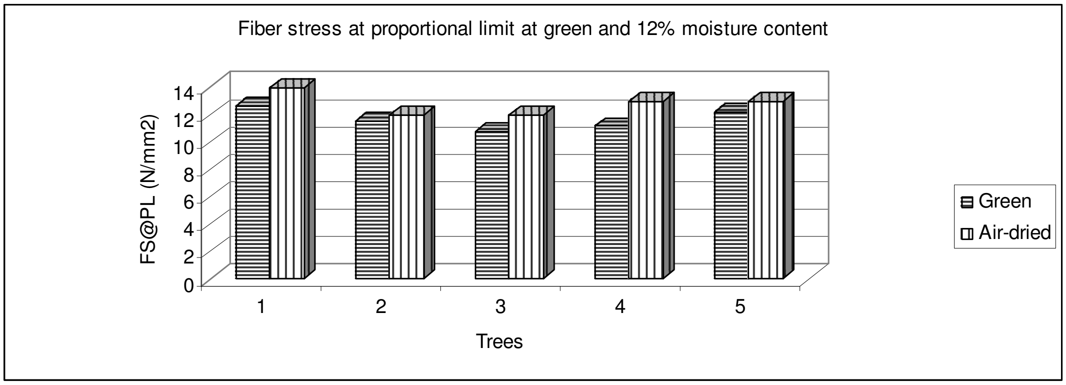

Fig. 11: Graph showing fiber stress at proportional limit at green and 12% moisture conditions

5.2.4. Hardness

It is the resistance of wood to indentation. The property is important for the uses of wood as floors, paving blocks, bearings and rollers.

The hardness of green Yinma is from 2789 to 3199 N in radial direction, from 2741 to 3098 N in tangential direction and from 3537 to 3959 N in grain direction. Air-dried Yinma has a hardness ranging from 3478 to 4151 N in radial direction, from 3117 to 3755 N in tangential direction, and from 5498 to 6099 N in grain direction.

At green and air-dried conditions, there are significant variations within and between trees. Within trees, the significant variations within direction are more pronounced. The end hardness is the highest, and the difference is between radial and tangential hardness is not significant.

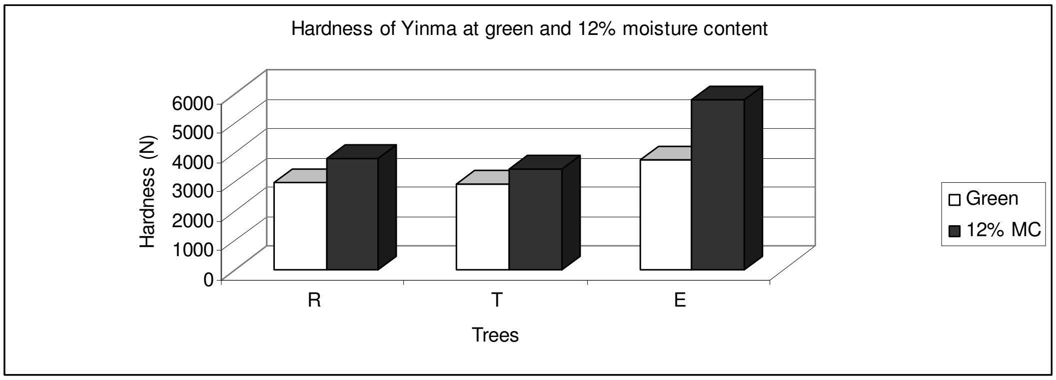

Fig. 12: Graph showing hardness at green and 12% moisture conditions

6. RECOMMENDATIONS

According to the classification for construction purposes adopted in India, two properties are taken in consideration: Modulus of Elasticity (MOE) and Modulus of Rupture (MOR). Depending on the values of the two properties, three groups are classified as:

Group I	MOE >	12555 N/mm^2
	MOR >	88 N/mm^2
Group II	MOE	9765 to 12555 N/mm^2
	MOR	59 to 88 N/mm^2
Group III	MOE	5580 to 9765 N/mm^2
	MOR	41 to 59 N/mm^2

According to this grouping, Yinma will be in Group II (MOE 12002 N/mm^2 and MOR 141 N/mm^2).

According to the classification system adopted in Philippines for green timbers, five groups are classified. In this system, modulus of rupture and modulus of elasticity in static bending, maximum crushing strength in endwise compression, fiber stress at proportional limit in sidewise compression, endwise shear strength and toughness are taken in account. For Yinma, shear strength and toughness are not available, and the classification will be done without them. Green Yinma will be in Group II (Moderately high strength). If the maximum crushing strength is not less than the lower limit of the group, Yinma will be in Group I (High strength). Timber species in Group II are suitable for medium-heavy constructions such as heavy-duty furniture and cabinets, medium-grade beams, girders, rafters, chords and purlins, flooring, door panels and frames, paving blocks, boot and shoe lasts, bobbins, spindles sailboat parts, gunstocks, tool handles, wheel shafts and axles, cant hooks and peavies, parquetry, veneer and plywood face, studs for car and truck bodies, airplane construction, sporting equipment like baseball bats, checkerboards and golf clubs, tripods, T-squares and kitchen implements like mortars and pestles.

In five groups classification system proposed by U Soe Tint (1987), three properties (modulus of rupture, modulus of elasticity and maximum crushing strength) are taken in account. According to this classification, Yinma will be in Group IV. It is due to smaller maximum crushing strength. It may be reflected by the fact that the specimens for endwise compression test were soaked for somewhat long duration and they might undergo decaying to some extent.

The specific gravity of Yinma at 12% moisture content is 0.740. It is similar to Kanyaung and In. The basic specific gravity of Yinma is similar to those of Lein, Nabe, Thabye, and Thadi.

The basic specific gravity of Yinma (*Chukrasia velutina*) is higher than those of some lesser-used timber species such as Binga, Chinyok, Hnaw, Kokko, Leza, Pyaukseik, Pyinma, Taungthayet, Tawthayet, Thingadu, Yemane, and Zaungbale. It is less than those of some lesser-used timber species such as Yon, Yinzat, Yinma (*Chuckrasia tabularis*), Yindaik, Thitpayaung, Thitmagyi, Taukkyan, Sit, Petthan, Panga, Myaukchaw, Kyetyo, and Dwani.

It is a moderately high density wood (basic specific gravity 0.661). It is suitable for medium heavy constructions. In building, it should be used as beams, purlins, floors, and rafters. It should not be used as posts, columns, and props because of some weakness in the properties according to the results.

Its shrinkage is somewhat high and is in class "moderately high". If green timber is put into uses, there will be some losses of moisture from the timber, resulting in warping, checking, splitting and loosening of tool handles, gaps in strip flooring, or performance problems that detract from the usefulness of the wood product. Therefore, it is important to use the timber after proper drying. Moreover, it is a moderately refractory timber, which should be converted green and the sawn timber should be dried under cover.

The wood of Chukrasia species is of considerable economic importance in Southeast Asia and India. The major uses are furniture making, turney, doors, windows and light flooring.

The wood takes a very high polish but it is preferable to polish it after allowing the natural colour to develop to a suitable shade. Nailing, screwing and gluing properties are good. It can be peeled and sliced into veneers which can be glued satisfactorily to produce decorative plywood (Kalinganire et. al.,2000).

In India, the *Chukrasia* timber is in high demand for cabinet making, piano cases and decorative boards for various ornamental work. It is also suitable for carving and pulp.

In fact, heartwood is in dark-brown color and has attractive figures. It will be suitable for furniture making if the workability is favourable. However, most carpenters avoid the air-dried Yinma wood because it is very difficult to work after drying. All tests in Malaysia showed that *Chukrasia* wood is difficult or very difficult to saw.

7. CONCLUSION

Yinma (*Chukrasia velutina*) is a good timber in term of strength properties, but its shrinkage is somewhat high. Thus, proper drying will be necessary before putting it into uses. It should be used especially for buildings as beams due to its high bending strength. It would not be suitable for furniture making due to its difficult working properties with hand tools.

Further study on natural durability, treatability, and seasoning behaviors should be conducted. Its availability will be more important from the production point of view.

There is variability in wood properties between and within trees, especially in physical properties. It would be necessary to test sufficient number of sample trees to avoid the variation between trees. Moreover, sufficient number of specimens should be taken from each sample trees from different wood zones to overcome the variation within trees.

Appendix I

Physical and Mechanical Properties of Yinma(*Chukrasia Velutina*)

No	Property	Seasoning	Mean	N (Trees)	Std.Dev	CV%	95% confid. limit
1	Shrinkage (%)						
	(a) Radial	Oven-dry	4.498	5	0.190	4	0.236
		12%	2.699	-	-	-	-
	(b) Tangential	Oven-dry	8.176	5	0.451	6	0.560
		12%	4.906	-	-	-	-
	(c) Longitudinal	Oven-dry	0.165	5	0.069	42	0.086
		12%	0.099	-	-	-	-
	(d) Volumetric	Oven-dry	14.068	5	1.303	9	1.618
		12%	8.441	-	-	-	-
2	Dimensional stability	Oven-dry	1.82	-	-	-	-
3	Density (kg/m^3)	Green	1111	5	31	3	38
		12%	829	5	30	4	27
		Oven-dry	770	5	24	3	30
4	Specific gravity	Green	0.661	5	0.021	3	0.026
		12%	0.740	5	0.027	4	0.034
		Oven-dry	0.770	5	0.024	3	0.087
5	Moisture content	Green	67.0	5	7	10	8.7
6	Fiber saturation point (%)						
	(a) Heartwood 2	23	-	-	-	-	-
	(b) Heartwood 1	23	-	-	-	-	-
	(c) Sapwood	21	-	-	-	-	-
7	Static bending (N/mm^2)						
	(a) FS@PL	Green	82	5	5	6	6
		12%	89	5	5	6	6
	(b) MOR	Green	125	5	4	3	5
		12%	141	5	4	3	5
	(c) MOE	Green	16366	5	558	3	666
		12%	12002	5	913	8	1089
8	Compression parallel to grain						
	(a) FS@PL(N/mm^2)	Green	26	5	2	8	2
		12%	45	5	3	7	4
	(b) MCS (N/mm^2)	Green	33	5	3	9	4
		12%	56	5	3	5	4
10	Compression perpendicular to grain (N/mm^2)						
	(a) FS@PL	Green	12	5	1	9	1
		12%	13	5	1	8	1
11	Hardness (N)						
	(a) Radial	Green	2994	5	165	6	205
		12%	3814	5	271	7	336
	(b) Tangential	Green	2920	5	144	5	179
		12%	3436	5	257	7	319
	(c) End	Green	3748	5	170	5	211
		12%	5799	5	242	4	300

Appendix II

Radial Shrinkage Of Yinma From Green To Oven-Dry Conditions

Table (1) Theresults of significant test of the effect of trees, sections, wood zones and their interaction

1-TREE, 2-SECTION, 3-WOODZONE

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4	2.54650	267	.165098	15.4242	0.000000*
2	3	3.92286	267	.165098	23.7608	0.000000*
3	2	24.35511	267	.165098	147.5191	0.000000*
12	12	1.43226	267	.165098	8.6752	0.000000*
13	8	2.35100	267	.165098	14.2400	0.000000*
23	6	.70639	267	.165098	4.2786	0.000389*
123	24	.39178	267	.165098	2.3730	0.000467*

* means "significantly different at 95% probability level".

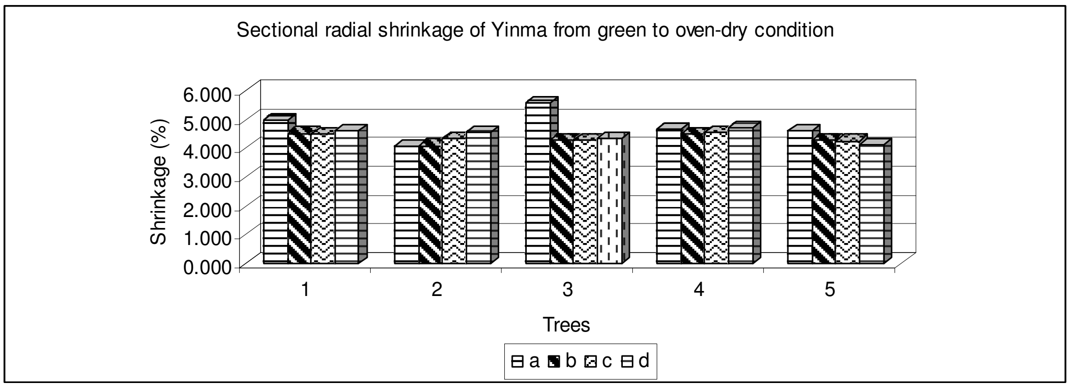

Fig. 1: Graph showing radial shrinkage by sections from green to oven-dry conditions

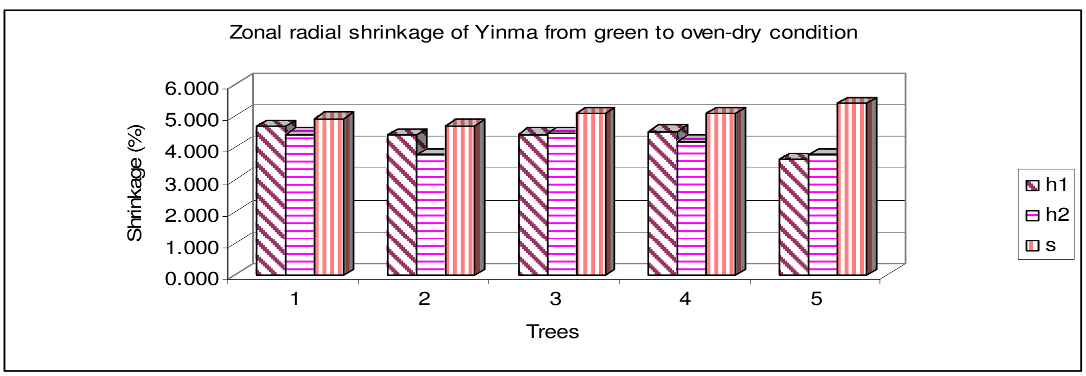

Fig. 2: Graph showing radial shrinkage by wood zones from green to oven-dry conditions

Appendix III

Tangential Shrinkage Of Yinma From Green To Oven-Dry Conditions

Table (1) Results of significant test of the effect of trees, sections, wood zones and their interactions on tangential shrinkage

1-TREE, 2-SECTION, 3-WOODZONE

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4	13.73056	285	.417589	32.88057	.000000*
2	3	10.19807	285	.417589	24.42132	.000000*
3	2	15.36080	285	.417589	36.78449	.000000*
12	12	4.15867	285	.417589	9.95875	.000000*
13	8	3.04012	285	.417589	7.28018	.000000*
23	6	4.12096	285	.417589	9.86845	.000000*
123	24	.96161	285	.417589	2.30276	.000690*

* means "significantly different at 95% probability level".

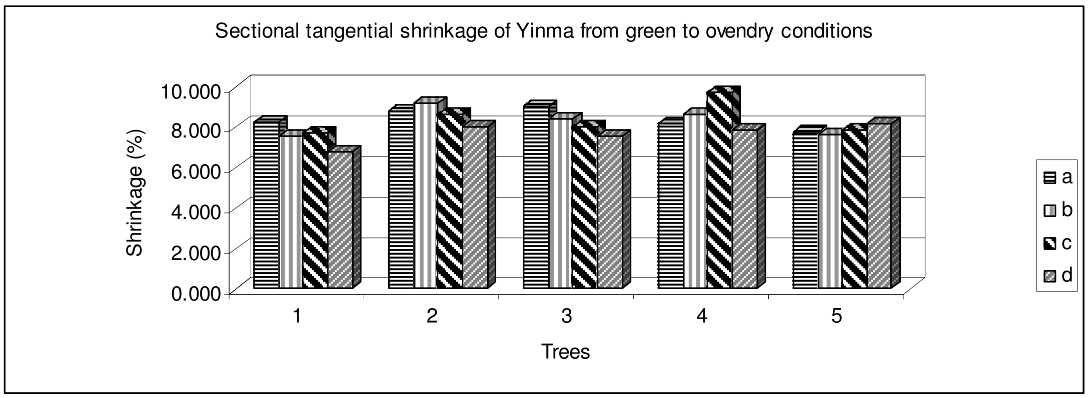

Fig. 2: Graph showing tangential shrinkage by sections from green to oven-dry conditions

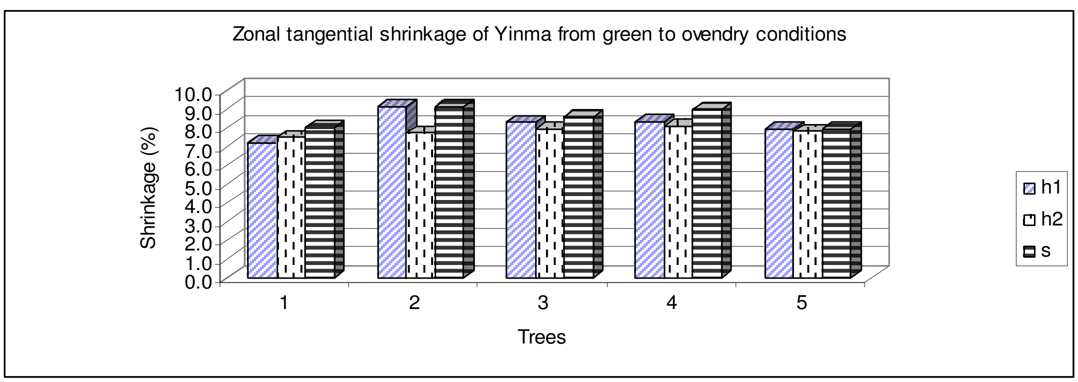

Fig. 3: Graph showing tangential shrinkage by wood zones from green to oven-dry conditions

Appendix IV

Longitudinal Shrinkage Of Yinma From Green To Oven-Dry Conditions

Table (1) Results of significant test of the effect of trees, sections, wood zones and their interaction on longitudinal shrinkage

1-TREE, 2-SECTION, 3-WOODZONE

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4	.250465	245	.016374	15.29672	.000000*
2	3	.021570	245	.016374	1.31735	.269291
3	2	.020460	245	.016374	1.24954	.288456
12	12	.025980	245	.016374	1.58666	.095863
13	8	.020335	245	.016374	1.24192	.275158
23	6	.014168	245	.016374	.86530	.521031
123	24	.019912	245	.016374	1.21608	.228129

* means "significantly different at 95% probability level".

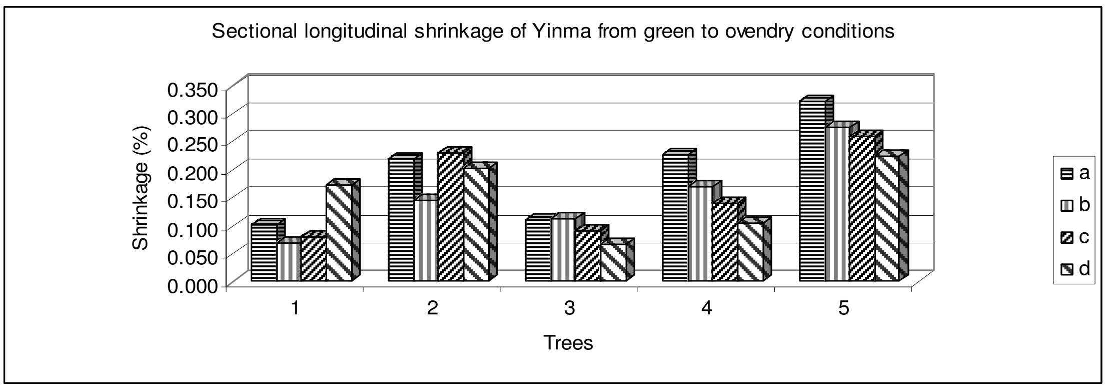

Fig. 1: Graph showing longitudinal shrinkage by sections from green to oven-dry conditions

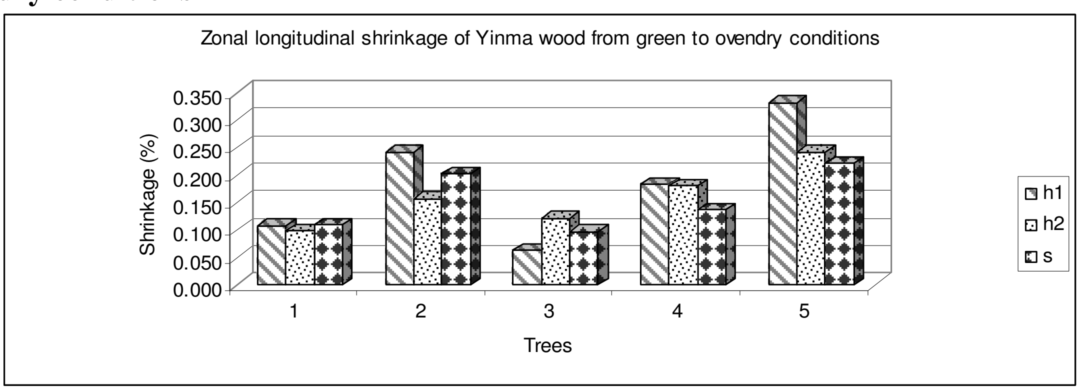

Fig. 2: Graph showing longitudinal shrinkage by wood zones from green to oven-dry conditions

Appendix V

Volumetric Shrinkage Of Yinma From Green To Oven-Dry Conditions

1-TREE, 2-SECTION, 3-WOODZONE

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4	105.3892	262	.887008	118.8143	0.000000*
2	3	54.0665	262	.887008	60.9538	.000000*
3	2	93.9393	262	.887008	105.9058	0.000000*
12	12	24.3772	262	.887008	27.4825	0.000000*
13	8	4.9885	262	.887008	5.6240	.000001*
23	6	5.3082	262	.887008	5.9844	.000007*
123	24	2.4778	262	.887008	2.7934	.000032*

* means "significantly different at 95% probability level".

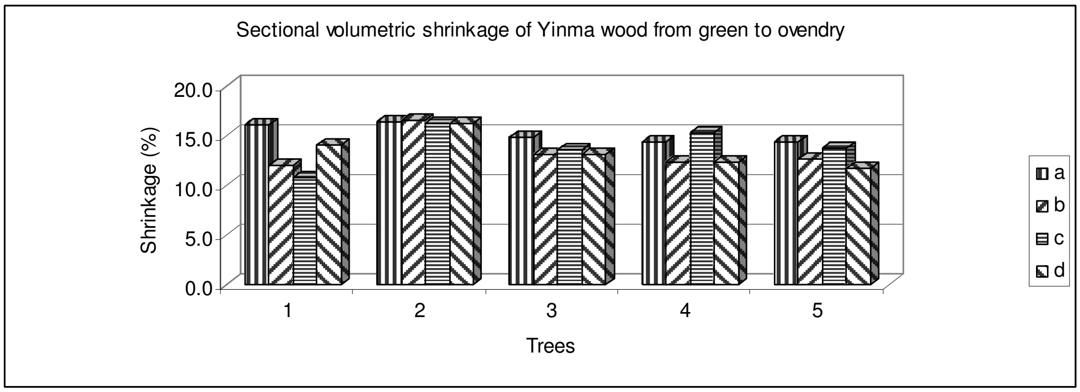

Fig. 1: Graph showing volumetric shrinkage by sections from green to oven-dry conditions

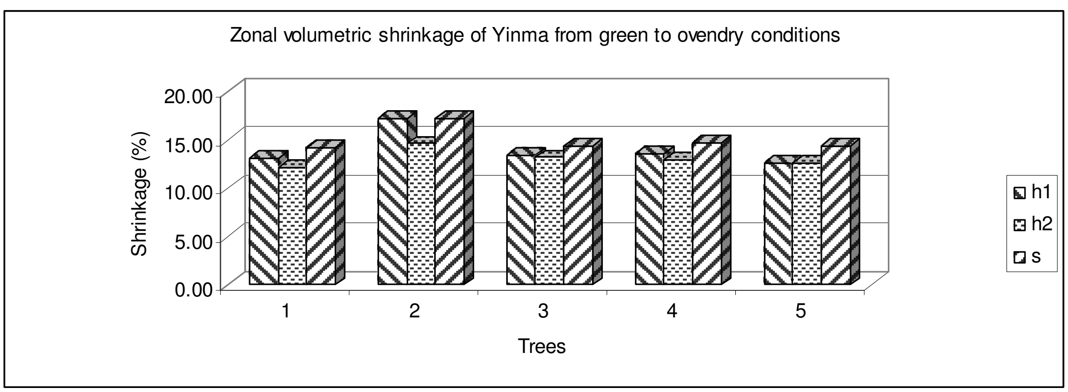

Fig. 2: Graph showing volumetric shrinkage by wood zones from green to oven-dry conditions

Appendix VI

Density At 12% Moisture Content Of Yinma

Table (1) Results of significant test of the effect of trees, sections, wood zones and their interactions on density

1-TREE, 2-SECTION, 3-WOODZONE

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4	58368.6	262	2076.172	28.1136	0.000000*
2	3	29469.4	262	2076.172	14.1941	0.000000*
3	2	268968.3	262	2076.172	129.5500	0.000000*
12	12	13696.0	262	2076.172	6.5968	0.000000*
13	8	18518.8	262	2076.172	8.9197	0.000000*
23	6	12732.6	262	2076.172	6.1327	0.000005*
123	24	3226.9	262	2076.172	1.5542	0.051191

* means "significantly different at 95% probability level".

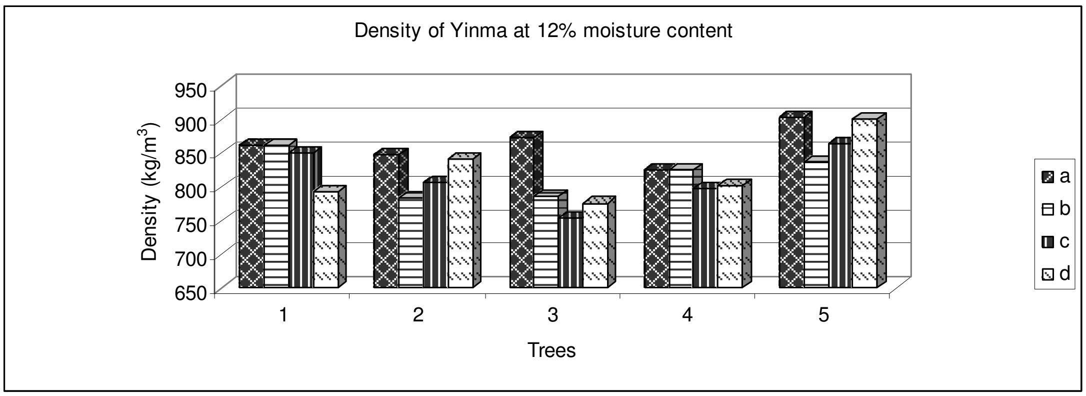

Fig. 1: Graph showing density at 12% moisture content by sections

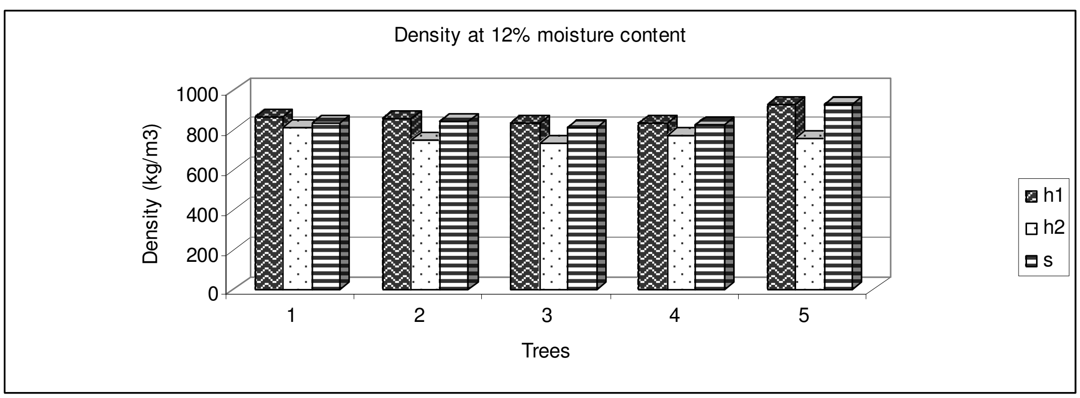

Fig. 2: Graph showing density at 12% moisture content by wood zones

Appendix VII

Basic Specific Gravity Of Yinma

Table (1) Results of significant test of the effects of trees, sections, wood zones and their interactions on basic specific gravity

1-TREE, 2-SECTION, 3-WOODZONE

	df	MS	df	MS		
	Effect	Effect	Error	Error	F	p-level
1	4	.029281	262	.001057	27.6939	.000000*
2	3	.014820	262	.001057	14.0168	.000000*
3	2	.138362	262	.001057	130.8638	0.000000*
12	12	.007018	262	.001057	6.6374	.000000*
13	8	.009330	262	.001057	8.8243	.000000*
23	6	.006561	262	.001057	6.2053	.000004*
123	24	.001668	262	.001057	1.5778	.045541

* means "significantly different at 95% probability level".

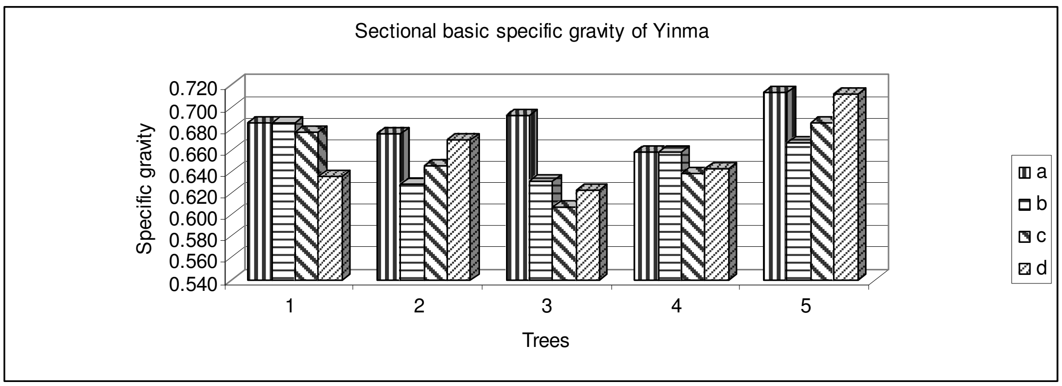

Fig. 1: Graph showing basic specific gravity by sections

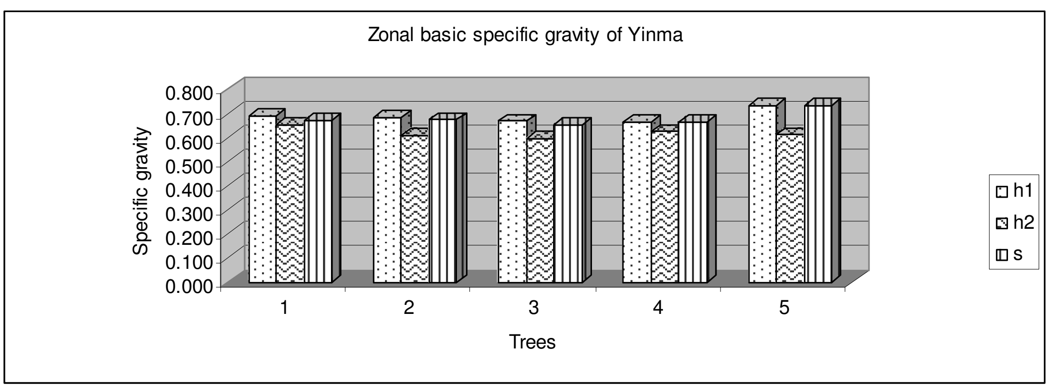

Fig. 2: Graph showing basic specific gravity by wood zones

Appendix VIII

Green Moisture Content Of Yinma

Table (1) Results of significant test of the effects of trees, sections, wood zones, and their interactions on green moisture content

1-TREE, 2-SECTION, 3-WOODZONE

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4	11009.77	959	45.70460	240.8898	0.000000*
2	3	2611.10	959	45.70460	57.1300	0.000000*
3	2	3558.53	959	45.70460	77.8594	0.000000*
12	12	459.02	959	45.70460	10.0431	0.000000*
13	8	314.74	959	45.70460	6.8864	0.000000*
23	6	763.14	959	45.70460	16.6973	0.000000*
123	24	95.22	959	45.70460	2.0835	0.001737*

* means "significantly different at 95% probability level".

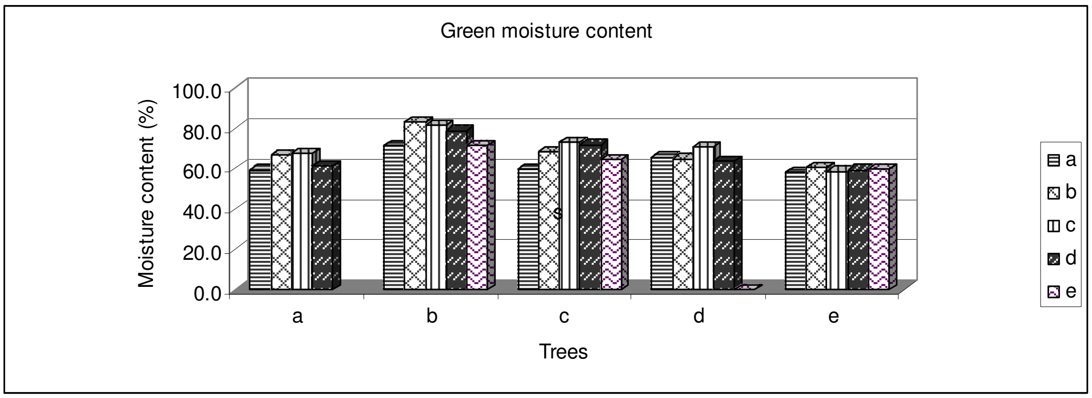

Fig. 1: Graph showing green moisture content of Yinma by sections

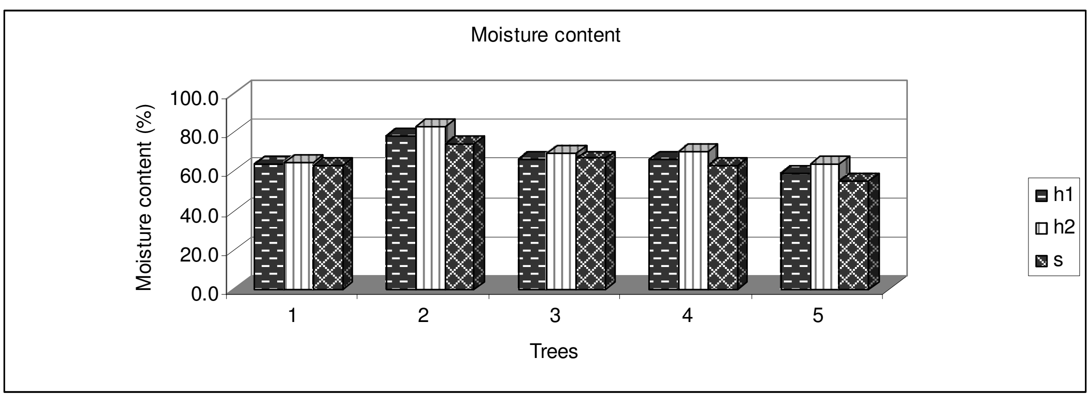

Fig. 2: Graph showing green moisture content of Yinma by wood zones

Appendix IX

Fiber Stress At Proportional Limit In Bending Test (Green)

Table (1) Results of significant test of the effect of trees, sections, wood zones, and their interactions on fiber stress at proportional limit

1-TREE, 2-SECTION, 3-WOODZONE

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4	526.3576	129	236.8731	2.222108	.070137
2	2	67.3639	129	236.8731	.284388	.752945
3	2	550.7711	129	236.8731	2.325174	.101851
12	8	75.6126	129	236.8731	.319212	.957546
13	8	248.0372	129	236.8731	1.047131	.404460
23	4	80.7717	129	236.8731	.340991	.849863

* means "significantly different at 95% probability level".

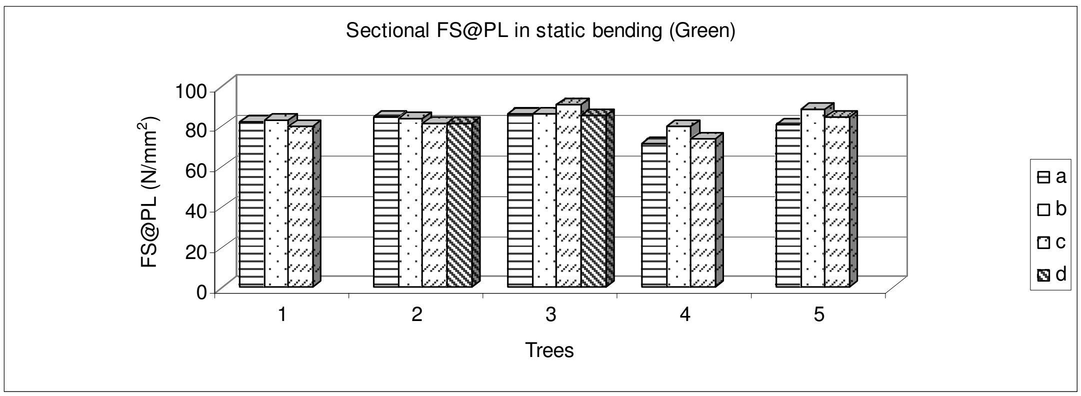

Fig. 1: Graph showing fiber stress at proportional limit in bending by sections (Green)

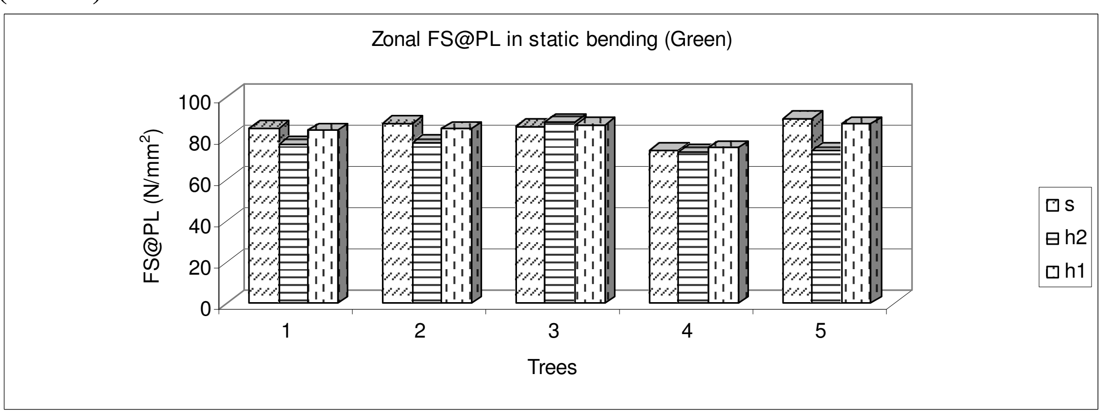

Fig. 1: Graph showing fiber stress at proportional limit in bending by wood zones (Green)

Appendix X

Modulus Of Rupture Of Yinma In Bending (Green)

Table (1) Results of significant test of the effect of trees, sections, wood zones and their interactions on modulus of rupture

1-TREE, 2-SECTION, 3-WOODZONE

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4	286.317	129	363.1910	.788336	.534769
2	2	1.846	129	363.1910	.005084	.994929
3	2	1769.947	129	363.1910	4.873324	.009113*
12	8	238.791	129	363.1910	.657479	.727911
13	8	257.341	129	363.1910	.708557	.683564
23	4	114.790	129	363.1910	.316060	.866816
123	16	178.328	129	363.1910	.491003	.947868

* means "significantly different at 95% probabilitylevel"

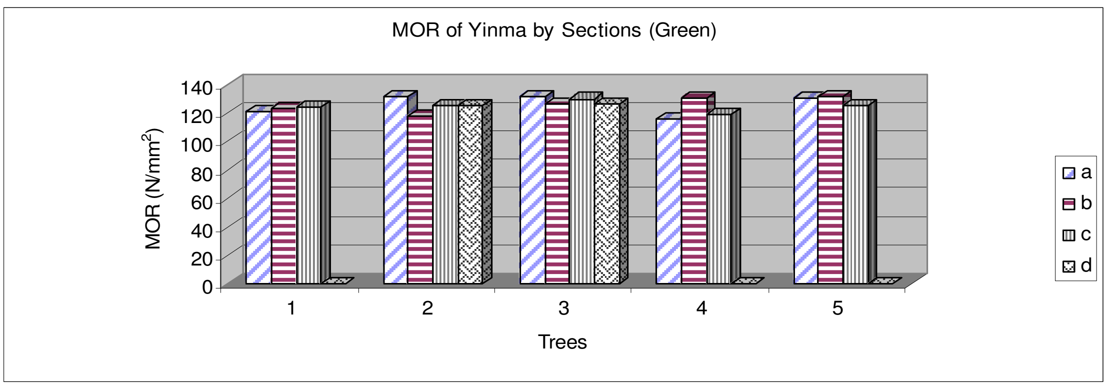

Fig. 1: Graph showing modulus of rupture in bending by sections (Green)

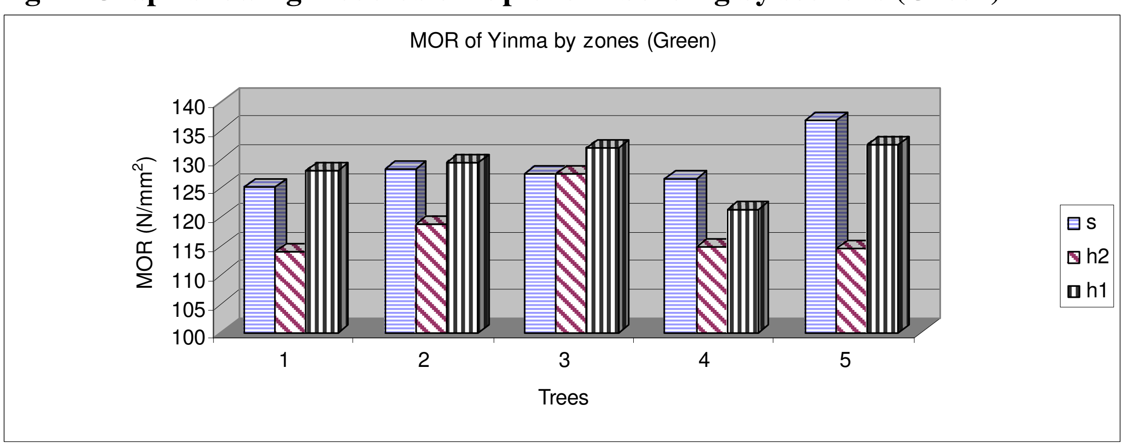

Fig. 2: Graph showing modulus of rupture in bending by wood zones (Green)

Appendix XI

Modulus Of Elasticity In Bending (Green)

Table (1) Results of significant test of the effect of trees, sections, wood zones, and their interactions

1-TREE, 2-SECTION, 3-WOODZONE

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4	6135695	129	9260642	.662556	.619121
2	2	3312365.	129	9260642	.357682	.699987
3	2	34806580	129	9260642	3.758549	.025910*
12	8	6107160	129	9260642	.659475	.726194
13	8	13600368	129	9260642	1.468620	.174829
23	4	2226430.	129	9260642	.240419	.914981
123	16	5932500.	129	9260642	.640614	.845547

* means "significantly different at 95% probability level".

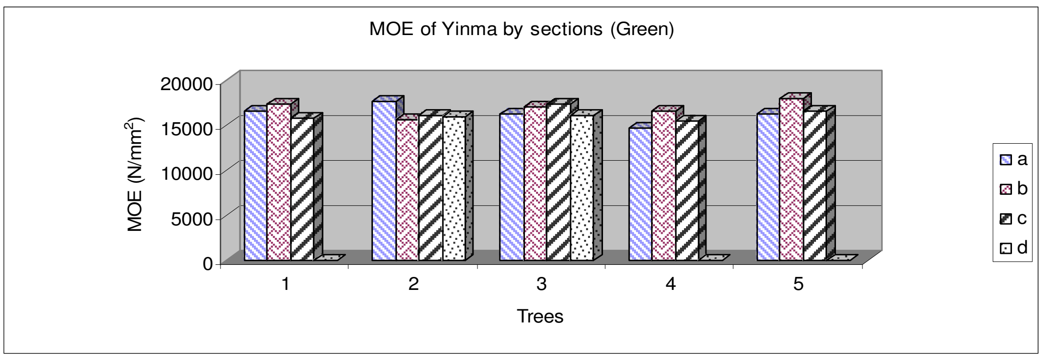

Fig. 1: Graph showing modulus of elasticity in bending by sections (Green)

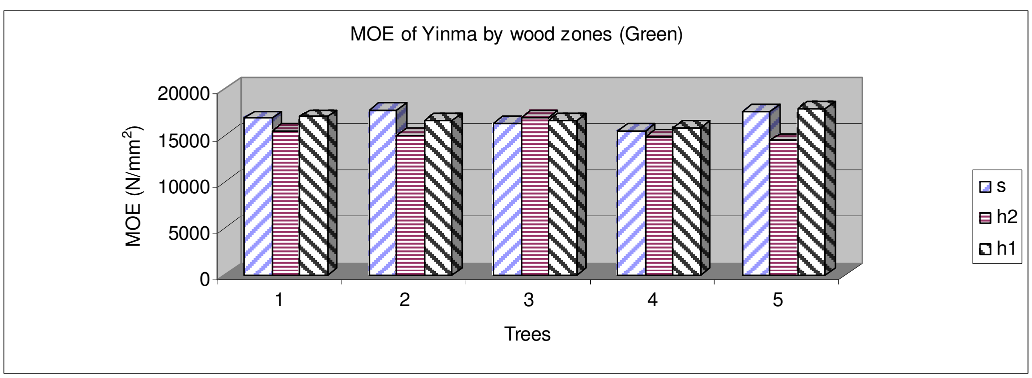

Fig. 2: Graph showing modulus of elasticity in bending by wood zones (Green)

Appendix XII

Maximum Crushing Strength In Endwise Compression (Green)

Table (1) Results of significant test of the effect of trees, sections, wood zones and their interactions on maximum crushing strength in endwise compression

1-TREE, 2-SECTION, 3-WOODZONE

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4	173.1533	90	34.06581	5.082905	.000972*
2	2	.8904	90	34.06581	.026137	.974209
3	2	310.8072	90	34.06581	9.123728	.000247*
12	8	22.9049	90	34.06581	.672373	.714520
13	8	34.5095	90	34.06581	1.013024	.432072
23	4	19.8211	90	34.06581	.581846	.676560
123	16	45.7392	90	34.06581	1.342671	.189772

* means "significantly different at 95% probability level".

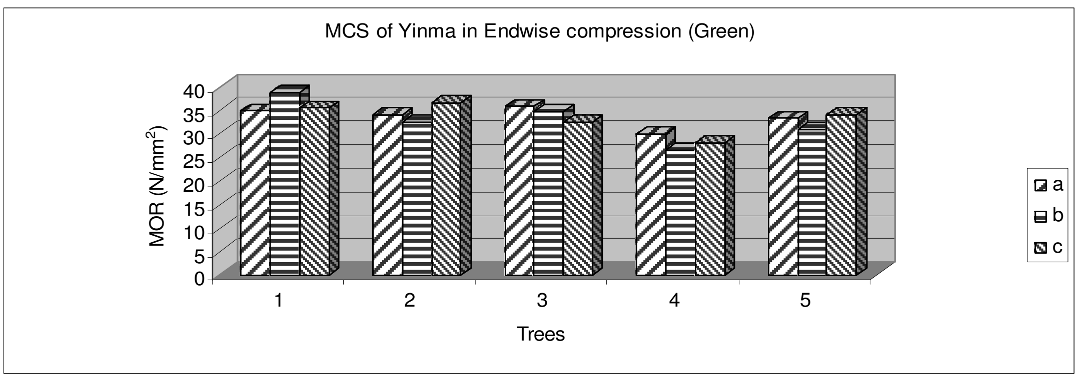

Fig. 1: Graph showing maximum crushing strength in endwise compression by sections

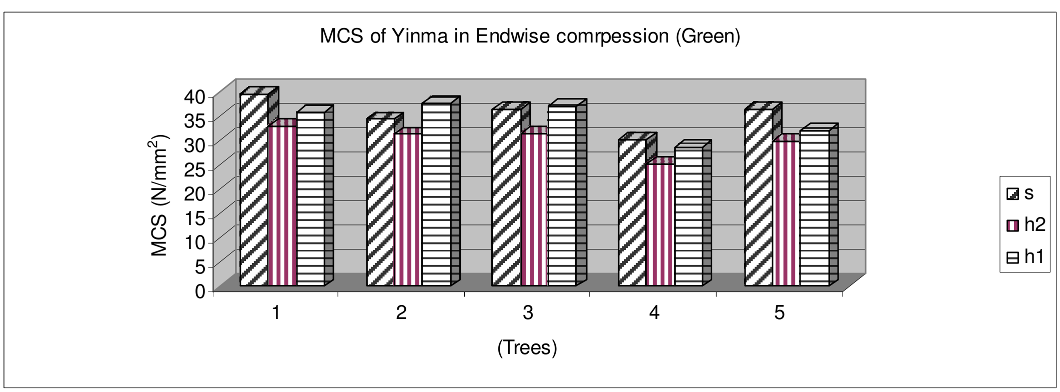

Fig. 2: Graph showing maximum crushing strength in endwise compression by wood zones

Appendix XIII

Fiber Stress At Proportional Limit In Sidewise Compression (Green)

Table (1) Results of significant test of the effect of trees, sections, wood zones, and their interactions on fiber stress at proportional limit

Appendix XIV

Hardness (Green)

Table (1) Results of significant test of the effect of trees, sections, wood zones and their interactions on hardness

1-TREE, 2-SECTION, 3-DIRECT

	df	MS	df	MS		
	Effect	Effect	Error	Error	F	p-level
1	4	4493051	1107	539221.8	8.3325	0.000001*
2	2	1565584.	1107	539221.8	2.9034	0.055253
3	2	65822308	1107	539221.8	122.0691	0.000000*
12	8	2106050.	1107	539221.8	3.9057	0.000147*
13	8	479338.	1107	539221.8	.8889	0.525028
23	4	133077.	1107	539221.8	.2468	0.911666
123	16	203429.	1107	539221.8	.3773	0.987459

* means "significantly different at 95% probability level".

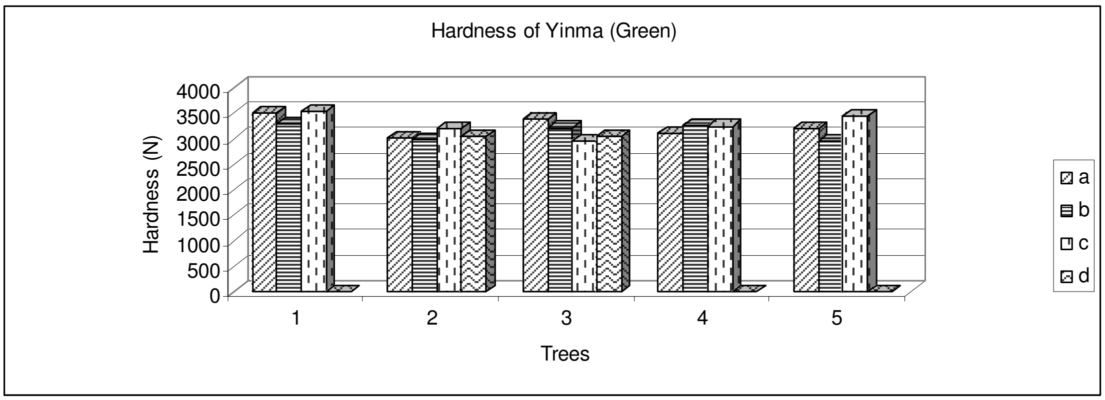

Fig. 1: Graph showing hardness by sections

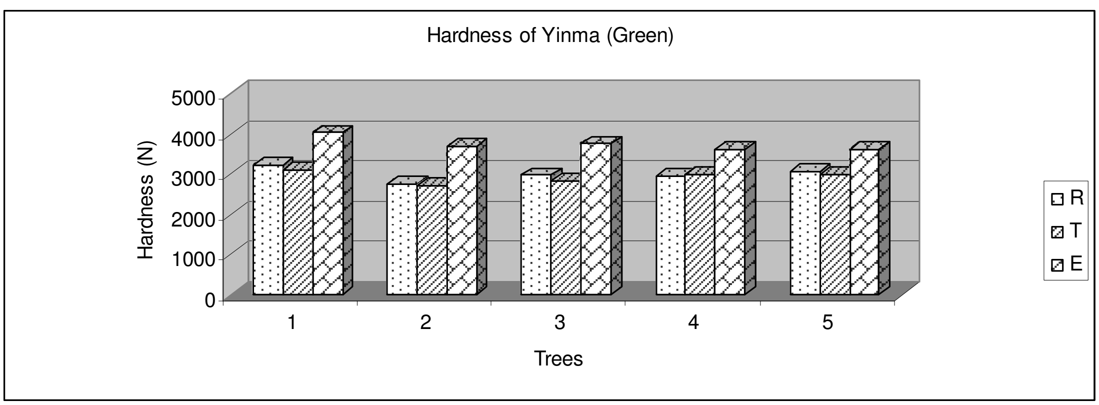

Fig. 2: Graph showing hardness by directions

Appendix XV

Modulus Of Rupture In Bending At 12% Moisture Content

Table (1) Results of significant test of the effect of trees, sections, wood zones, and their interactions on modulus of rupture in bending

1-TREE, 2-SECTION, 3-WOODZONE

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4	400.697	125	265.5398	1.50899	.203556
2	2	160.886	125	265.5398	.60588	.547188
3	2	3691.422	125	265.5398	13.90158	.000004*
12	8	342.598	125	265.5398	1.29020	.254490
13	8	172.831	125	265.5398	.65087	.733537
23	4	292.594	125	265.5398	1.10188	.358731
123	16	254.938	125	265.5398	.96007	.504059

* means "significantly different at 95% probability level".

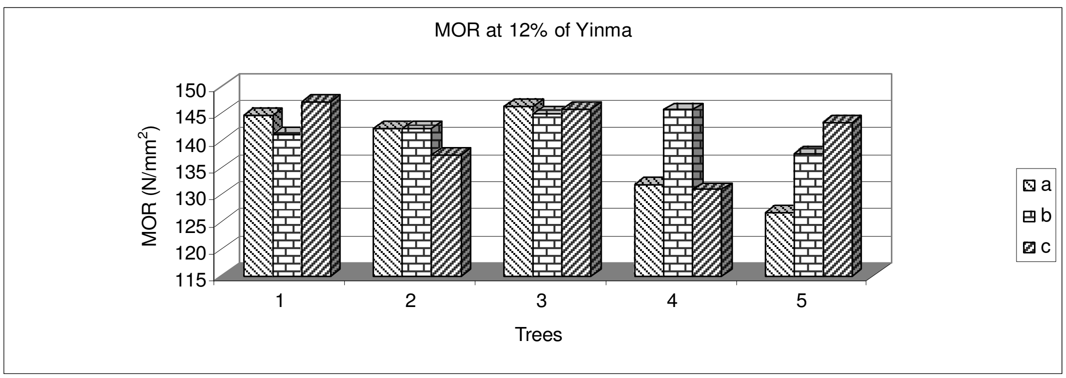

Fig. 1: Graph showing modulus of rupture at 12% moisture content in bending by sections

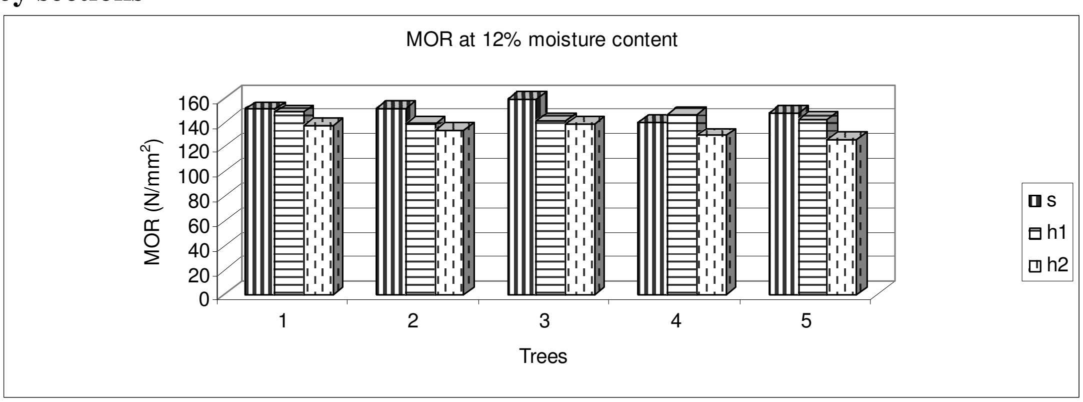

Fig. 2: Graph showing modulus of rupture at 12% moisture content in bending by wood zones

Appendix XVI

Modulus Of Elasticity At 12% Moisture Content In Bending

Table (1) Results of significant test of the effect of trees, sections, wood zones, and their interactions on modulus of elasticity.

1-TREE, 2-SECTION, 3-WOODZONE

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4	20261990	125	1674690.	12.09895	.000000*
2	2	4262140.	125	1674690.	2.54503	.082531
3	2	18156026	125	1674690.	10.84142	.000046*
12	8	1089578	125	1674690.	.65061	.733754
13	8	1367452.	125	1674690.	.81654	.589353
23	4	787946.	125	1674690.	.47050	.757295
123	16	753676.	125	1674690.	.45004	.965070

* means "significantly different at 95% probability level".

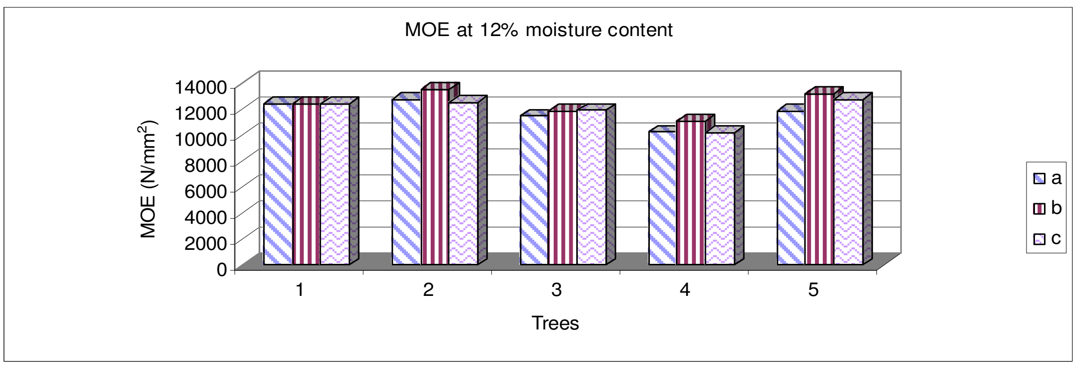

Fig. 1: Graph showing modulus of elasticity at 12% moisture content in bending by sections

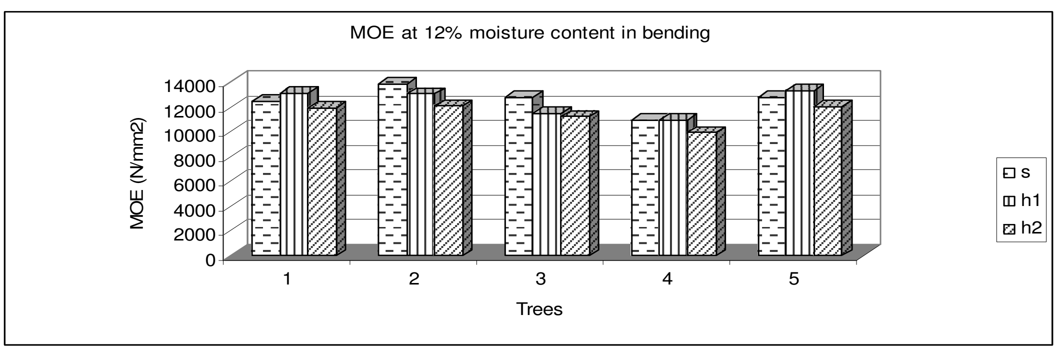

Fig. 2: Graph showing modulus of elasticity at 12% moisture content in bending by wood zones

Appendix XVII

Maximum Crushing Strength At 12% Moisture Content In Endwise Compression

Table (1) Results of significant test of the effect of trees, sections, woodzones and their interactions

1-TREE, 2-SECTION, 3-WOODZONE

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4	219.5500	138	41.10374	5.341363	.000498*
2	2	3.9820	138	41.10374	.096878	.907728
3	2	111.2152	138	41.10374	2.705719	.070368
12	8	43.9492	138	41.10374	1.069227	.388256
13	8	62.9167	138	41.10374	1.530680	.151918
23	4	38.1900	138	41.10374	.929113	.449041
123	16	28.1891	138	41.10374	.685803	.804206

* means "significantly different at 95% probability level".

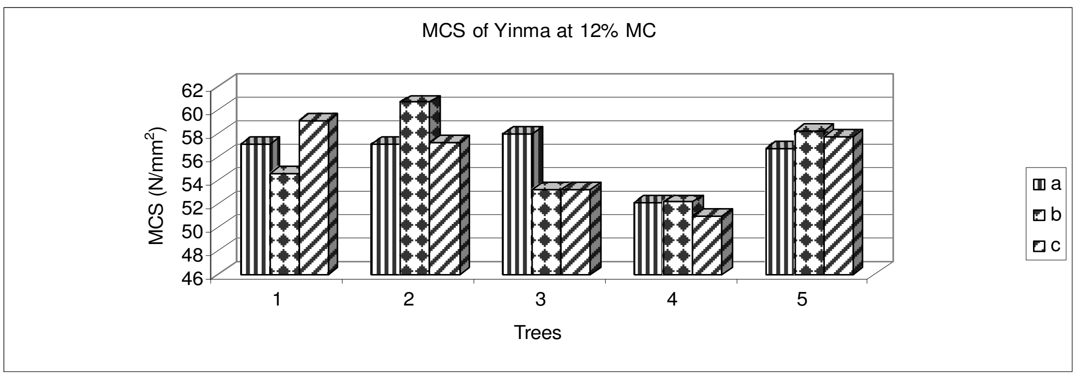

Fig. 1: Graph showing maximum crushing strength at 12% moisture content by sections

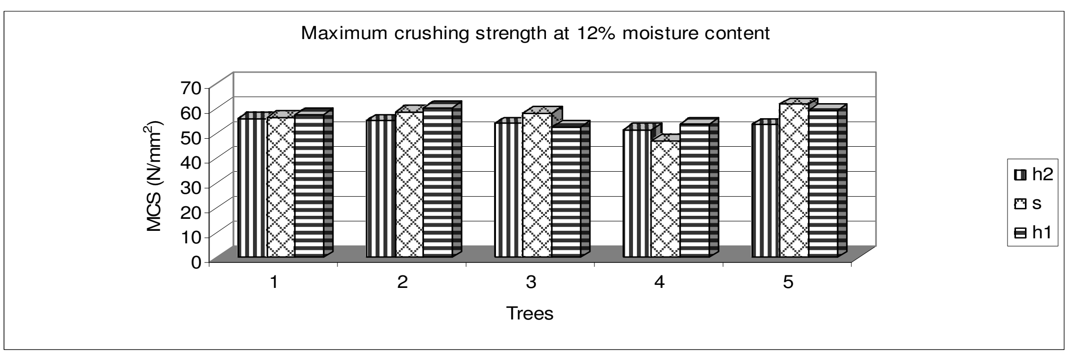

Fig. 2: Graph showing maximum crushing strength at 12% moisture content by wood zones

Appendix XVIII

Fiber Stress At Proportional Limit At 12% Moisture Content In Sidewise Compression

Table (1) Results of significant test of the effect of trees, sections, wood zones and their interactions on fiber stress at proportional limit

1-TREE, 2-SECTION, 3-WOODZONE

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4	16.42563	105	6.268754	2.620238	.039033*
2	2	8.45290	105	6.268754	1.348417	.264109
3	2	38.49715	105	6.268754	6.141117	.003004*
12	8	5.80908	105	6.268754	.926672	.497781
13	8	2.51666	105	6.268754	.401461	.917491
23	4	8.56032	105	6.268754	1.365553	.250925
123	16	9.15569	105	6.268754	1.460528	.128851

* means "significantly different at 95% probability level".

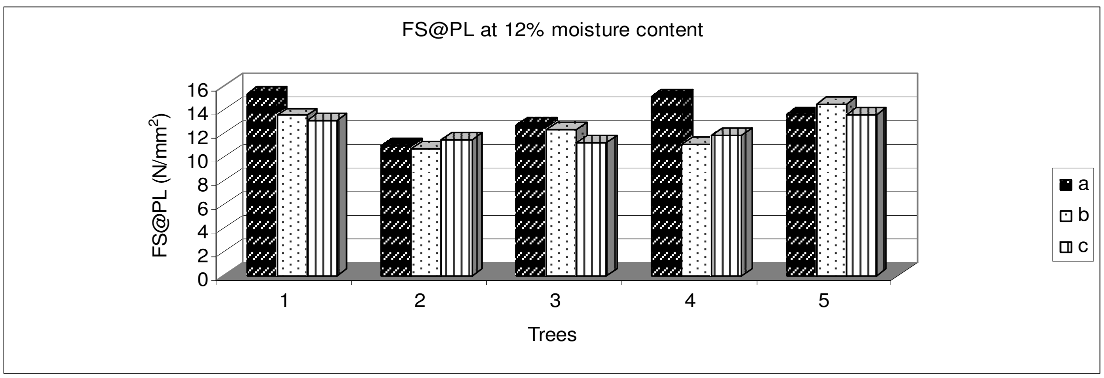

Fig. 1: Graph showing fiber stress at proportional limit at 12% moisture content by sections

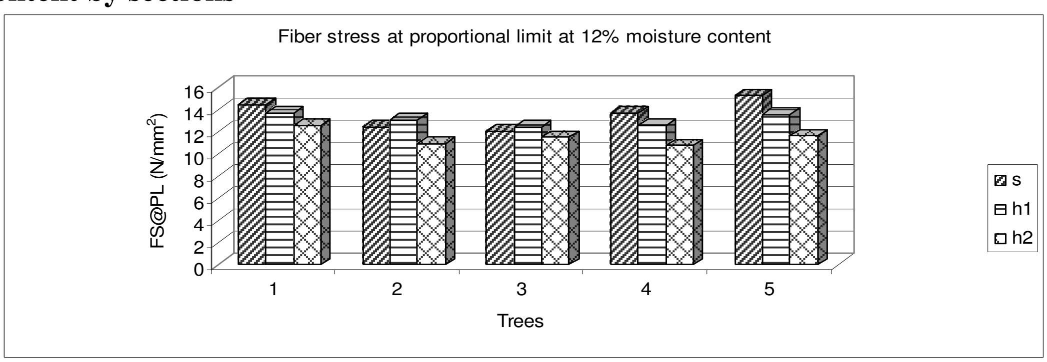

Fig. 2: Graph showing fiber stress at proportional limit at 12% moisture content by wood zones

Appendix XIX

Hardness At 12% Moisture Content

Table (1) Results of significant test of the effect of trees, sections, wood zones and their interactions on hardness at 12% moisture content

1-TREE, 2-SECTION, 3-DIRECT

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4	13643614	927	731693.7	18.6466	.000000*
2	2	1347920.	927	731693.7	1.8422	.159049
3	2	398461408	927	731693.7	544.5741	0.000000*
12	8	3670151.	927	731693.7	5.0160	.000004*
13	8	662883.	927	731693.7	.9060	.510677
23	4	400573.	927	731693.7	.5475	.700931
123	16	166410.	927	731693.7	.2274	.999376

* means "significantly different at 95% probability level".

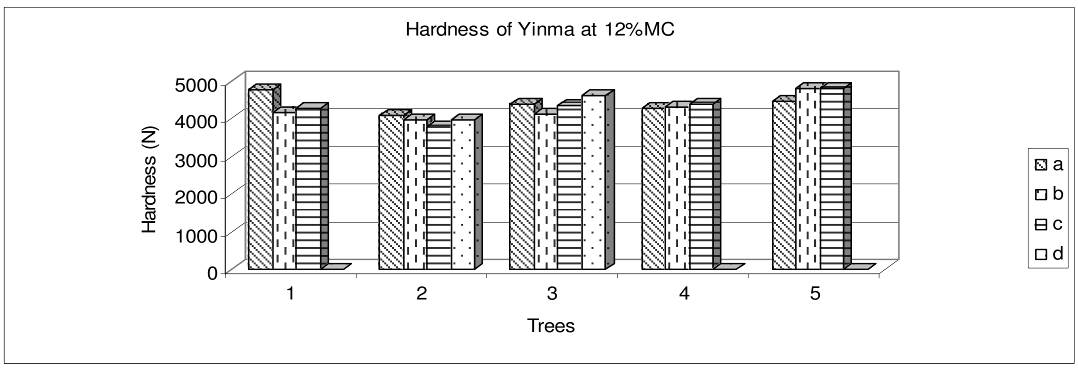

Fig. 1: Graph showing hardness at 12% moisture content by sections

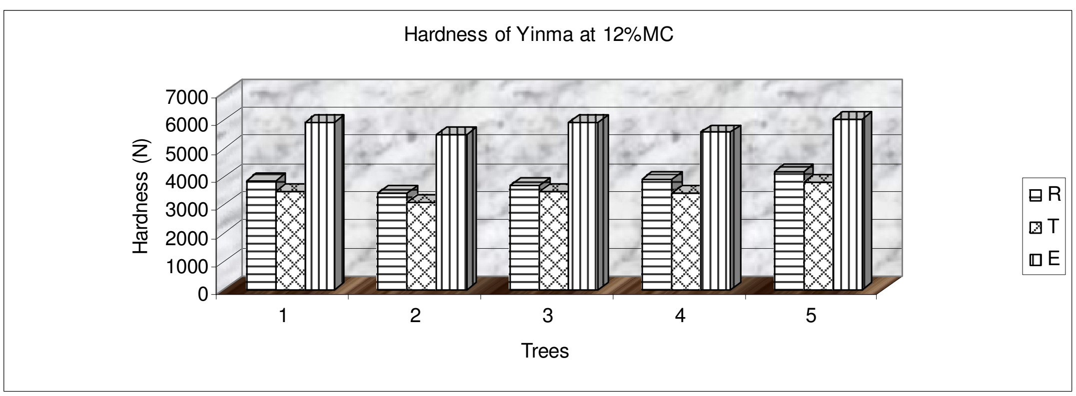

Fig. 2: Graph showing hardness at 12% moisture content by directions

Appendix XX

Comparision of physical properties of Leza and Pyaukseik with those of some Myanma commercial timber species

No	Species	Moisture Content	Specific Gravity	Density	Radial Shrinkage	Tangential Shrinkage	Dimensional Stability
		(%)	-	(kg/m3)	(%)	(%)	-
1	Leza	94.0	0.553	1075	4.7	6.9	1.46
		12.0	0.606	679	2.8	4.1	1.46
2	Pyaukseik	67.5	0.580	964	4.6	7.6	1.66
		12.0	0.639	715	2.8	4.6	1.66
3	Binga*	58.4	0.553	881	3.8	7.3	1.92
		12.0	0.606	679			
4	Hnaw*	81.4	0.583	1058	2.8	5.6	2.00
		12.0	0.643	720			
5	In*	50.3	0.726	1090	4.4	9.1	2.07
		12.0	0.821	919			
6	Kanyin-ni*	65.7	0.655	1090	4.2	8.9	2.12
		12.0	0.731	819			
7	Teak*	51.8	0.598	913	2.3	4.2	1.83
		12.0	0.661	740			
8	Padauk*	43.8	0.752	1074	3.4	5.1	1.50
		12.0	0.854	957			
9	Pyinkado*	48.6	0.779	1154	3.3	6.7	2.03
		12.0	0.889	996			
10	Pyinma*	118.1	0.518	1122	4.4	6.8	1.55
		12.0	0.564	632			
11	Taukkyan*	53.5	0.707	1090	4.8	7.1	1.48
		12.0	0.797	892			
12	Taungthayet*	58.5	0.551	865	3.2	6.0	1.88
		12.0	0.604	676			
13	Thadi*	43.7	0.710	1072	5.5	8.9	1.62
		12.0	0.800	896			
14	Thingan*	73.9	0.637	1106	3.4	6.5	1.91
		12.0	0.709	794			
15	Thinkadu*	70.7	0.589	1010	4.2	9.8	2.33
		12.0	0.650	728			
16	Zaungbale*	39.1	0.610	974	4.2	7.6	1.81
		12.0	0.676	757			

*Data source: Physical and mechanical properties of some Myanma Timbers (Kyi, 1993)

Appendix XXI

Comparison of mechanical properties of Leza and Pyaukseik with those of some Myanma commercial timber species

No.	Species	Moisture Content (%)	Static Bending (N/mm^2)			Compression Parallel to grain (N/mm^2)		Compression Perpendicular to grain (N/mm^2)	Hardness (N)		
			FS@PL	MOR	MOE	FS@PL	MCS	FS@PL	Radial	Tang-ential	End
1	Leza	94.0	54	74	12035	24	31	9.0	4493	4374	5286
		12.0	71	105	14375	38	47	12.0	5478	5399	6614
2	Pyaukseik	67.5	42	73	9366	25	32	8.7	4354	4474	5203
		12.0	64	95	12108	34	45	10.7	5583	5260	8059
3	Binga*	58.4	44	73	9170	28	36	6.8	4781	4693	5467
		12.0	55	100	11229	41	54	9.7	5277	5686	7250
4	Hnaw*	81.4	39	65	8377	27	34	7.5	4713	4889	5575
		12.0	45	79	9429	29	46	10.3	5199	5780	6449
5	In*	50.3	48	80	12093	25	39	8.4	6310	6310	6467
		12.0	69	124	15546	33	68	8.7	8510	8243	9066
6	Kanyin-ni*	65.7	48	76	13928	27	40	6.6	4536	4487	4713
		12.0	62	118	16155	29	60	9.2	6559	6041	6377
7	Padauk*	43.8	65	110	13080	38	57	13.6	8936	9220	9220
		12.0	90	145	14464	54	77	19.7	9742	9811	9404
8	Pyinkado*	48.6	66	107	15617	44	55	11.7	8554	8514	8113
		12.0	71	132	16851	45	71	13.8	9213	10151	8611
9	Pyinma*	118.1	38	59	8860	23	29	8.5	4889	4821	4801
		12.0	37	78	9837	30	40	7.7	4256	4300	5258
10	Taukkyan*	53.5	48	78	11459	27	39	8.8	6849	6535	6447
		12.0	68	111	13457	36	61	12.6	9385	9819	10268
11	Taungthayet*	58.5	32	59	11294	20	28	3.9	3331	3263	3351
		12.0	46	84	13210	26	43	6.5	3912	3984	4887
12	Teak*	51.8	49	79	11535	28	40	7.3	4644	4576	4066
		12.0	69	103	13011	41	60	10.7	5234	5183	5018
13	Thadi*	43.7	47	84	10873	20	35	9.3	7642	7309	7319
		12.0	62	117	13135	30	57	15.9	8882	8904	9652
14	Thingan*	73.9	55	79	10432	33	43	10.5	6084	6045	5889
		12.0	60	95	11551	35	46	10.8	6218	6797	7142
15	Thinkadu*	70.7	44	70	13204	27	38	6.4	3929	4047	3684
		12.0	62	101	15284	39	56	6.8	4805	5397	4308
16	Zaungbale*	39.1	45	79	12239	24	34	5.6	4703	4909	5369
		12.0	69	114	14823	38	66	8.7	5804	5793	7630

*Data source: Physical and mechanical properties of some Myanma Timbers (Kyi, 1993).

Data at 12% moisture content are originally given at air-dry (Different moisture contents). For ease of comparison they are converted into 12% moisture content.

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