Khulna University
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Title: Determination of physical and mechanical properties of Nalita (*Trema orientalies*)

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Programme: Bachelor of Science in Forestry

Determination of Physical and mechanical Properties of Nalita *(Trema orientalies)*

Family- Cannabaceae

PROJECT REPORT

Submitted in partial fulfillment of the requirements For the B.Sc (Honors) degree of Forestry from Forestry and Wood Technology

Submitted by:
Puja Saha
Examination Roll No: 130542
Session: 2012-2013

January, 2018

Forestry and Wood Technology Discipline
Life Science School,
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"Determination of Physical and Mechanical Properties of Nalita (*Trema orientalies*)"

PROJECT THESIS
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Puja Saha
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This dissertation has been prepared for the partial fulfillment of the requirements of Four (4) years professional B. Sc. (Hons.) degree in Forestry from Forestry and Wood Technology Discipline, Khulna University, Khulna, Bangladesh.

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Declaration

This is to certify that project work entitled "**Determination of Physical and Mechanical Properties of *Trema orientalis*" (Family- Cannabaceae)**"has been carried out by **Puja Saha**, Examination Roll No.: 130542. The author completed these research activities in the Forestry and Wood Technology Discipline, Khulna University, Khulna, Bangladesh. The above project work or any part of this work has not been submitted in anywhere for the award of any degree without the permission of the author.

Puja Saha

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Signature of Supervisor

Prof. Md. Obaidullah Hannan

Signature of Candidate

Puja Saha

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Puja Saha

The Author

Abstract

The physical and mechanical properties of Nalita (*Trema orientalis)* are determined as per specifications of ASTM. *Trema orientalis* falls under the moderate density group. *Trema orientalis* is categorized as wood having moderate strength group. The green density and oven dry density are 508.65 kg/m^3 and 374.48 kg/m^3. The percentage of longitudinal, redial and tangential shrinkage of *Trema orientalis* are 0.33, 3.34 and 4.57 respectively. Specific gravity of the test specimens *Trema orientalis* wood based on green weight and oven dry weight are 0.51 and 0.38 respectively. The average moisture content percentage of *Trema orientalis* is 48.36%. In respect of mechanical properties the fiber stress at elastic limit (Bending test) for *Trema orientalis* is 9478.81 N/mm^2. The modulus of rupture at maximum load is 72.03 N/mm^2. Almost all the strength properties of this species is observed to be lower than those of teak (*Tectona grandis*) , the standard wood species in determining relative suitability for use.

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CHAPTER ONE

INTRODUCTION

1.1 Description of the species

Trema orientalis is native to primarily tropical zones in Africa, Asia and Australia. This tree is a fast growing species found in previously disturbed areas and on forest margins. It is a pioneer species that can grow on poor soil and can be used to regenerate forest areas by providing shade and protection to saplings offorest hardwoods (http://www.worldagroforestry.org/). The local name of *Trema orientalis* in Bangladesh is Nalita or Jiban. This species is widely distributed through a range of altitudes in higher rainfall areas. It prefers sites on well-drained and exposed soils. It is a shrub or small to medium size tree and its height varies depending on the location and climatic conditions. It can grow 11m to 18 m high in forest regions (http://www.worldagroforestry.org/). It is whitish or off-white or whitish brown wood. It is fine-grained, soft, light and low durability. This species grows best in a sunny position, requires a well drained, sandy soil (http://ecocrop.fao.org/ecocrop/srv/en/home).

It is used in manufacturing panel products, poles and drumstick. An appropriate tropical hardwood for paper and pulp production. Paper made from *Trema orientalis* has good tensile strength and folding endurance (http://www.worldagroforestry.org/). The tree can provide plenty of firewood and excellent charcoal which is even suitable for making gunpowder and fireworks (Manandhar. N. P. 2002).It is widely planted for soil reclamation in southern Asia (Huxley. A. 1992).

As a structural material, wood has high strength per unit weight and is easily shaped and fastened. It is convenient energy source and major cheap souuirces of cellulose it may derivatives for chemical industries. The color patterns texture of wood are often pleasing, leading to uses for many decorated purposes. Wood is available in a wide range of textures, colors, densities and chemical composition supporting wide range of important uses. Physical properties are important in selecting wood for numerous uses, such as musical instruments, decorative surfaces, insulating media etc.

Mechanical properties of wood are indicate the ability of wood to resist various types of external forces, static and dynamic, which may act on it. Mechanical properties are very much important in case of constructional and structural purposes timber. The properties not only vary with species, with reference to the nature of their fiber structure but also with the moisture content, temperature and defects of wood. Sometimes the properties vary with reference to the varying conditions of growth.

1.2 Rationale of study

The wood of *Trema orientalis* has limited use in our country. The wood of *Trema orientalis* is middle class wood. The physical and mechanical properties of *Trema orientalis* of wood should know for using it widely. Due to the lack of property knowledge of this wood, the wood of this species are not being used properly. It is, therefore, essential that both physical and mechanical properties be determined in order to furnish the basic information for their effective utilization. So I am interested to study the physical and mechanical properties of the wood of *Trema orientalis.*

1.3 Objectives

The specific objectives of this study are as the following

1. To know the physical properties of the wood of *Trema orientalis*.
2. To know the mechanical properties of the wood of *Trema orientalis*.

CHAPTER TWO
REVIEW OF LITERATURE

I. Sarwar Jahan *et. al.*, (2009) conducted a study titled, "Effect of different locations on the morphological, chemical, pulping and papermaking properties of *Trema orientalis* (Nalita)". The findings of the study are the chemical compositions and fiber morphology of stem and branch samples from *Trema orientalis* at three different sites planted in Bangladesh in which a large difference between the stem and branch samples was observed. The stem samples have consistently higher cellulose and lower lignin content, and longer fibers than the branch samples in all sites. *T. orientalis* from the Dhaka and Rajbari region had higher cellulose content and longer fiber length, resulting in higher pulp yield and better paper making properties. The *T. Orientalis* pulp from Rajbari region also showed the best bleachability.

II. Rawshan *et. al.*, (2013) conducted a study titled, "Reinforcing potential of jute pulp with *Trema orientalis* (nalita) pulp". The findings of the study are two morphologically different pulps, a long-fiber jute pulp from a soda-AQ process and a short-fiber *Trema orientalis* pulp from a kraft process, were evaluated and compared for their reinforcing potential. *T. orientalis* pulp needed less beating energy than jute pulp at the same drainage resistance. Addition of jute fiber pulp to the *T. orientals* pulp increased tear strength. Sheet density of pulp blends was increased with the increase of beating degree of both pulps and the proportion of *T. orientalis* pulp. Tensile index and burst index of blended pulp were increased when the beating degree and proportion of *T. orientalis* pulp increased.

III. Jahan *et. al.*, (2013) conducted a study titled, "Effect of tree age on the cellulose structure of Nalita wood (*Trema orientalis*)". The findings of the study are the change of crystalline structure of Nalita cellulose with tree age has been studied using X-ray diffraction and FT-IR spectroscopy. The proportion of crystallinity and crystal size were increased with tree age. FT-IR spectroscopy showed that the Nalita cellulose was a monoclinic unit cell structure (I_{β}). The proportion of crystallinity and crystal size of the 30-month-old Nalita wood was higher as compared to aspen wood. The degree of polymerization (DP) of Nalita cellulose of different ages has also been studied. The DP of cellulose increased with tree age. The DP of Nalita cellulose was lower than that of aspen cellulose. The percentage of glucose in Nalita wood increased with tree age.

IV. Chowdhury *et. al.*, (2006) conducted a study titled, "Effect of different locations on the morphological, chemical, pulping and papermaking properties of *Trema orientalis* (Nalita)". The findings of the study are the chemical compositions and fiber morphology of stem and branch samples from *Trema orientalis* at three different sites planted in Bangladesh were determined and their pulping, bleaching and the resulting pulp properties were investigated. A large difference between the stem and branch samples was observed. The stem samples have consistently higher α-cellulose and lower lignin content, and longer fibers than the branch samples in all sites. *T. orientalis* from the Dhaka and Rajbari region had higher α-cellulose content and longer fiber length, resulting in higher pulp yield and better papermaking properties. The *T. orientalis* pulp from Rajbari region also showed the best bleachability.

V. Mun *et. al.*, (2010) conducted a study titled, "Characteristics of Dioxane Lignin Isolated at Different Ages of Nalita Wood (*Trema orientalis*)". The findings of the study are Nalita (*Trema orientalis*) is one of the fastest growing trees in the tropical countries. The structural characteristics of lignin isolated at different ages of Nalita wood (*Trema orientalis*) by acidolytic dioxane method were examined by UV, FTIR, ^{1}H-NMR and ^{13}C-NMR spectroscopy, alkaline nitrobenzene oxidation, molecular weight determination, elemental and methoxyl analysis. The data were compared with aspen lignin. The structural analysis revealed that Nalita wood lignin is syringyl-guaiacyl type. The methoxyl content in Nalita wood lignin was lower than aspen lignin. The C_9 formulas for 30-months-old Nalita was $C_9H_{9.31}O_{3.13}(OCH_3)_{1.27}$, whereas that of aspen was $C_9H_{8.94}O_{3.15}(OCH_3)_{1.47}$. The weight average molecular weight of Nalita wood lignin was decreased from 36,500 to 25,500 with increasing tree age from 12 to 30 months, whereas weight average molecular weight of aspen was 20,000. Both alcoholic and phenolic hydroxyl group in Nalita wood lignin is lower than aspen lignin.

VI. Jahan *et. al.*, (2009) conducted a study titled, "Prospect of *Trema orientalis* as a pulping raw material in Bangladesh". The findings of the study are the pulp and paper industry in Bangladesh is looking for new raw materials with high productivity perhectare. Currently, bamboo and Gmelinaarborea are the main pulping raw materials for the pulp and paper industry of the country. *Trema orientalis* is one of the fastest growing woods in the tropical region. This paper reviews the literature on the topic, in particular, related to the chemical, morphological and physical properties of *T. orientalis* and its suitability for pulping. In addition, the advantages and disadvantages of various pulping processes proposed in the literature were critically analyzed. It was concluded that *T. orientalis* is a potential pulp wood for the Bangladesh pulp and paper industry.

VII. Patrick *et. al.*, (2010) conducted a study titled, "Contribution to Chemical Study of Stem and Branches of *Trema orientalis* and *Leucaena leucocephala*". The findings of the study are the use of timber in techniques of soil aggradation helps to preserve the environment by recycling sub products and residues from forestry. However, the nature of timber conditions the degradation process. The present study aimed at characterizing and comparing the chemical characteristics of wood branches, and stems of *Trema orientalis* and *Leucaena leucocephala*. By modified lignin Klason, high amounts of lignin were found in the branches than in the trunk of *Trema*, contradicting the results observed for *Leucaena*. Cellulose concentration, obtained from Kurschner and Hoffner was higher in the branches and lower in the trunk of *Leucaena* than in *Trema*. Moreover, ash contents were higher in the branches than in the trunk. C:N and lignin: N ratios, with N values significantly higher in the branches, were higher in wood trunk than in branches. Moreover, all *Trema* ratios were higher than those found in *Leucaena*. However, branches lignin/N ratio, naturally weaker, would predict a more rapid decomposition of their lignocellulose material once on the ground. Overall, pyrolysis GC-MS of branches and stems identified compounds derived mainly from lignin, followed by polysaccharides.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Determination of Physical properties

3.1.1 Collection of Test Specimens

The materials for the tests were collected from Rupsha, Khulna. 1m bolts were collected from the tree keeping the breast-height (1.3 m above ground level) position of the tree at the center of the bolts. All the bolts were fairly straight and free from natural defects. Both ends of the bolts were wrapped with polythene sheets to cheek excessive evaporation of moisture and consequent checking.

3.1.2 Preparation of the Sample

The specimens for determination of moisture content, specific gravity, density were prepared in the from of 1inch × 1inch × 1inch and determination of shrinkage and swelling were prepared in the form of 3 inch × 1inch × 1inch according to ASTM standards. Ten samples were taken from that tree for more accurate result.

The specimens for bending test study was in the form of 12 inch × 1 inch × 1 inch and that was taken for the testing Modulus of Rupture (MOR) and Modulus of Elasticity (MOE). For both tests the sample were taken parallel and smooth. After preparation of all samples were smoothened by using sander.

3.1.3 Determination of Physical Properties

Lengths of tangential, longitudinal and radial surface were measured using slide caliper having venire constant 0.01cm. Weight of each test specimen (green) was measured in air using electric balance and the data were recorded.

3.1.4 Moisture Content

The amount of water in wood is normally expressed as percentage of oven dry weight of the wood. Moisture content was measured in oven dry method. For the measurement of moisture content of the samples, the samples were weighted by an electric balance in testing condition and the values were recorded. Then the same samples were weighted in oven dry condition following the same procedure. The moisture content of the samples were worked out following the formula stated below,

$$MC(\%) = \{(W_w - W_o) \times 100\} / W_o$$

Where,

W_w = Weight of samples in testing condition

W_o = Weight of samples in oven dry condition

MC = Moisture Content

3.1.5 Shrinkage

Shrinkage and its accompanying effects of warping, checking and splitting constitute woods most troublesome physical properties. Shrinkage of wood is the change in dimensions i.e. reduction due to changes i.e. losses of its moisture content. The reduction in size is expressed as percentage of the original green dimension, depending upon whether linear shrinkage is being measured. The terms longitudinal, tangential and radial shrinkage are used to describe the linear shrinkage in the respective reference direction. Shrinkage in three linear direction was evaluated as percentage of dimensional changes from green condition to oven dry condition on drying for 24hrs to a constant weight at a temperature 0f 103°C±2°C. The dimensions were measured both in green and oven dry condition with a slide caliper and weight was taken on an electric balance.

For the calculation of radial, tangential and longitudinal shrinkage of the specimens the following formula was followed,

$$S = \{(G_d - O_{dd}) \times 100\} / G_d$$

Where,

S = Shrinkage percentage

G_d = Green dimension

O_{dd} = Oven dry dimension

3.1.6 Density

Wood density and wood specific gravity both indicate the amount of actual wood substance present in a unit volume of wood. Wood density is not a simple characteristic. It is affected by the cell wall thickness, the cell diameter, the early to late wood ratio and the chemical content of the wood. Basic density was determined by water displacement method.

The following formula was used to calculate the density of wood,

$$D = m / (b_1 \times b_2 \times t)$$

Where,

m= mass of the sample

b_1= length of the sample

b_2= width of the sample

t= thickness of the sample

D= Density.

3.1.7 Swelling

The dimensional changes that accompany with swelling of wood is major sources of both visual and structural problems in furniture. Swelling occurs as the wood changes moisture content in response to daily as well as seasonal changes in the relative humidity of the atmosphere, i.e., when the air is humid, wood adsorbs moisture and swells; when the air is dry, wood loses moisture.

The formula used to determine swelling is-

$$S = \{(t_2 - t_1)/t_1\} \times 100$$

Where,

S= Swelling (%)

t_2= thickness of sample after immersion

t_1= thickness of sample before immersion in water

3.2 Determination of Mechanical properties

3.2.1 Determination of bending test

This test (static bending) was carried out by Universal Testing Machine (UTM) in Akij Particle Board Mills Ltd. Mechanical properties were evaluated in accordance with the specification of ASTM (Anon., 1971). The load was applied to the piston of the cage at a rate of 0.01 mm/s as suggested by Desch and Dinwoodie (1980). All the samples were tested by applying load perpendicular to the grain. The test was carried on until maximum load was reached and final failure was observed.

Modulus of Elasticity (MOE) was calculated from the following equation,

$$MOE = P'L^3/4\Delta bd^3$$

Where,

MOE = is the modulus of elasticity in bending, in N/mm^2

P' = is the load, in N at the limit of proportionality

L = is the span, in mm

Δ = is the deflection, in mm at the limit of proportionality

b = is the width, in mm

d = is the depth, in mm

And the Modulus of Rupture (MOR) was measured by using the following formula, (Desch and Dinwoodie, 1996).

$$MOR = 3PL/2bd^2$$

Where,

MOR = Modulus of rupture in N/mm^2

P= maximum load in N

L = is the span, in mm

b = is the width, in mm

d = is the depth, in mm

CHAPTER FOUR

RESULTS AND DISCUSSION

Results

The results of the tests on the physical and mechanical properties of *Trema orientalis* are presented in table 1 and table 2. Individual strength values were computed from data collected from seven different tests. The strength properties of Chittagong teak was recommended as the standard for Bangladesh to which all other timber species may be compared in determining their relative suitability for various purposes.

4.1 Physical Properties

4.1.1 Surface Appearance and Grain Directions

Trema orientalis is an interlocked grained and coarse textured wood. Its sapwood is whitish or off-white in color on freshly cut surface. Its heartwood is light brown color.

4.1.2 Moisture Content

The average moisture content of the specimens of *Trema orientalis* at the test was 48.36%

4.1.3 Shrinkage

The percentage of longitudinal, radial and tangential shrinkage of *Trema orientalis* wood was 0.33%, 3.34% and 4.57% respectively.

4.1.4 Specific Gravity

Specific gravity of the test specimens of *Trema orientalis* wood based on oven dry weight and green weight of sample was 0.38 and 0.51 respectively.

4.1.5 Density

Density of the test specimens of *Trema orientalis* wood based on weight of oven dry sample and volume after soaking into water. By calculating density of sample found that Green Density 508.65 kg/m^3 And Dry Density 374.48 kg/m^3.

4.1.6 Swelling

Swelling of the test specimens of *Trema orientalis* wood based on weight of oven dry sample and weight after soaking into water. By calculating swelling of sample found that radial and tangential swellings are 2.76 & 4.16 and 3.37 & 4.90 respectively.

Table-1: Determination of physical properties

Serial No.	Name of Species	Density kg/m³		Specific gravity		Moisture content (%)	Shrinkage (%)			Swelling (%)		
		Green Density	Dry Density	Volume at test	Volume at OD		Longitudinal	Radial	Tangential	Longitudinal	Radial	Tangential
1	*Trema orientalis*	508.65	374.48	0.50	0.38	48.36	0.33	3.34	4.57	0.31 (24hrs)	2.75 (24hrs)	4.16 (24hrs)
2										0.36 (48hrs)	3.37 (48hrs)	4.9 (48hrs)

Shrinkage determination:

The amount of shrinkage is affected by the amount of moisture lost by wood when its moisture content fluctuates between the oven dry state and fiber saturation point. The relationship is linear and applied in tangential, radial and longitudinal direction and therefore to volumetric changes (Tsoumis, 1991). Radial, tangential and longitudinal shrinkage of *Trema orientalis* are shown in Table-1 and Fig-1.

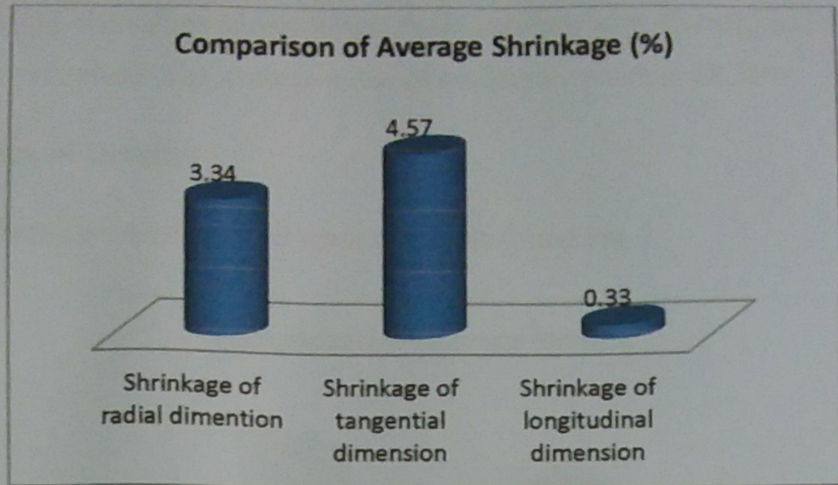

Figure-1: Comparison of Average Shrinkage (%)

Figure-1 showed that, tangential shrinkage was highest than radial and longitudinal shrinkage. Reyes, L. J. (1938) and Tamolang, F. N. (1969) are observed that the radial and tangential shrinkage (green to oven dry) of Philippines *Trema orientalis* was 3.5% and 7.7%.

Moisture Content determination:

The amount of water in wood affects weight, permeability, dimensional stability and strength. Thus the quality wood products are affected by water. Water in green or freshly harvested wood is located in cell wall and cell lumen (Haygreen and Bowyer, 1992). The moisture content of *Trema orientalis* is presented in Table-1 and Fig-2.

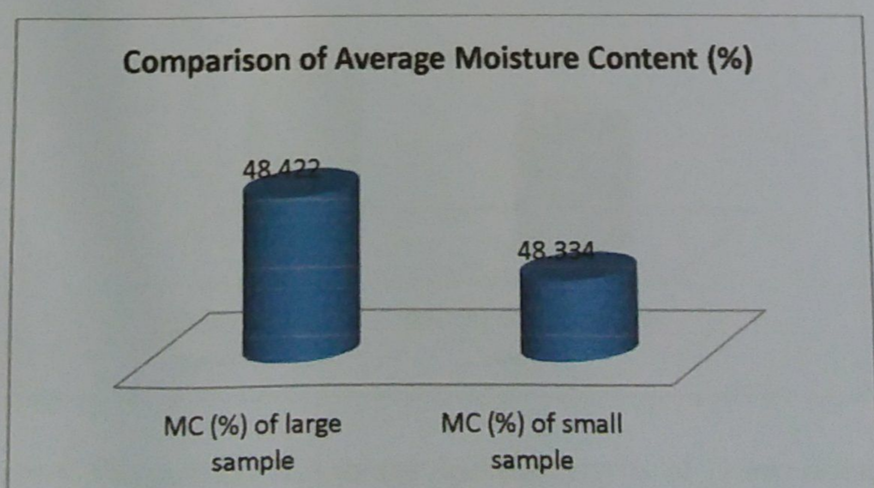

Figure-2: Comparison of Average Moisture Content (%) between large and small sample

It was found that, the values of moisture content between large (3 inch) and small (1 inch) sample were very close. The average value of moisture content is 48.36%.

Determination of Density:

Density of *Trema orientalis* are presented in Table-1 and Fig-3.

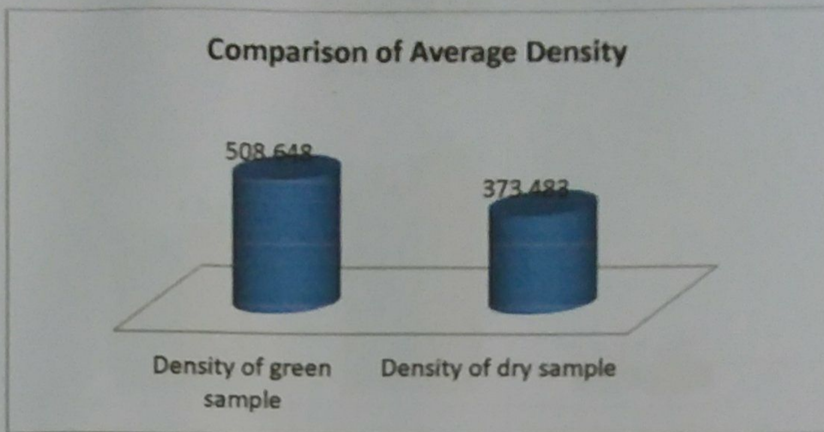

Figure-3: Comparison of Average Density between green and dry sample

It is found that the green density was 508.65kg/m^3 and the dry density was 373.48 kg/m^3. According to Martin Chudnoff (1973), the average basic air dry density of Philippines *Trema orientalis* was 360 lb/ft^3. The average basic density of Nalita was about 0.38 g/cc (M. Sarwar Jahan, Sung Phil Mun).

Determination of Specific Gravity:

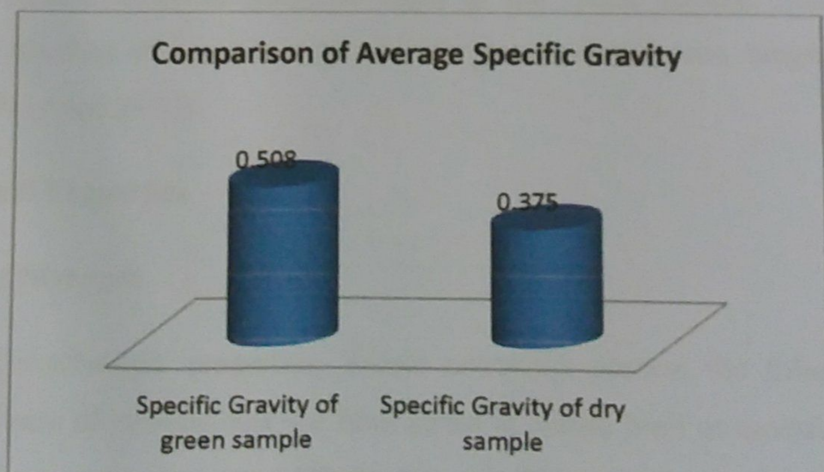

Figure-4: Comparison of Average Specific Gravity of *Trema orientalis*

Figure-4 showed that, the specific gravity of green and dry condition of Nalita was 0.51 and 0.38.The average basic specific gravity of Nalita was about 0.38 (M. Sarwar Jahan, Sung Phil Mun). And other, the average basic air dry specific gravity of Philippines *Trema orientalis* was 0.36(Martin Chudnoff, 1973).

Determination of swelling:

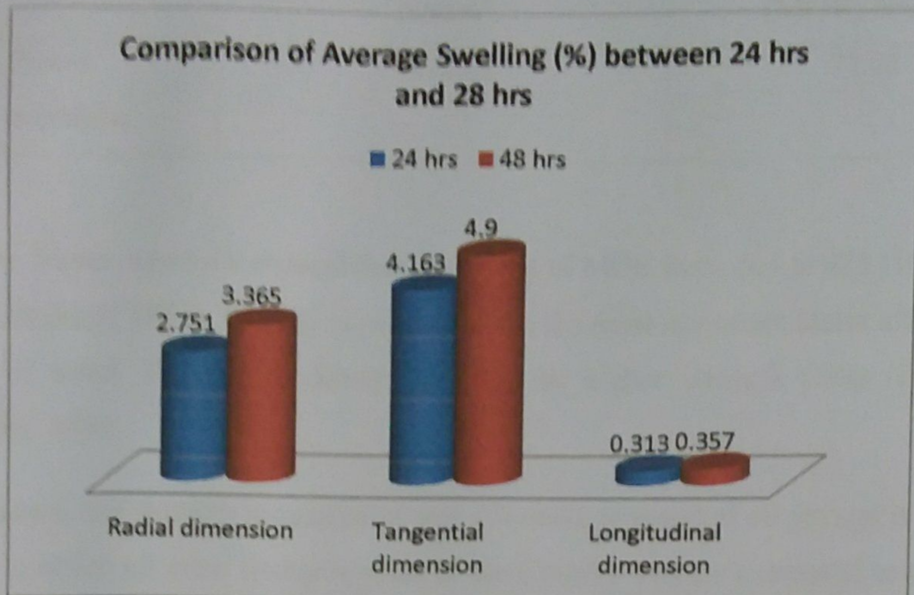

Figure-5: Comparison of Average Swelling (%) between 24 hrs and 48 hrs

Figure-5 showed that, the swelling (%) of *Trema orientalis* after 24hrs and 48hrs immersion in water. The observations of this study the tangential swelling is about two times higher than the radial swelling in Nalita wood and the longitudinal swelling ranged from 0.10 to 0.15%. Panshin and de Zeeuw (1980) stated that the swelling or shrinkage oftangential surface is about twice as more as the radial surface. The longitudinal shrinkage or swelling of wood is negligible for practical purposes, ranging from about 0.10 to 0.30 % (Anon,1970).

4.2 Mechanical Properties

4.2.1 Bending Strength

In respect of mechanical properties, *Trema orientalis* possess the following strength properties. In case of bending test the fiber stress at elastic limit or modulus of elasticity (MOE) for *Trema orientalis* is 9478.81 N/mm^2. The modulus of rupture (MOR) at maximum load 72.03 N/mm^2.

Table-2: Determination of mechanical properties

Serial	Name of Species	Static bending test	
		Modulus of Elasticity (MOE) N/mm²	Modulus of rupture (MOR) N/mm²
	Trema orientalis	9478.81	72.03

Philippine *Trema orientalis* showed that the values of MOE from 765 to 925 (1000lb/in.²) (Martin Chudnoff, 1973). Density is considered as the most important factor affecting the strength of wood. The higher density indicate the higher strength value (Desch and Dinwoodie, 1996).

In Bangladesh, the strength properties of teak (*Tectona grandis*) of 40 yrs age is used as a standard to which all other timber species of the Country may be compared to determine their relative suitability for various purposes (Yakub *et al.*, 1978). Compared to teak, (Isabel *et al.*, 2011) density and shrinkage are lower than teak (relative to teak, the basic density is 607 kg/m^3 and the radial and tangential shrinkage are 3.5% and 5.2%). In case of mechanical properties, the properties are lower than teak (relative to teak, modulus of elasticity is 10684N/mm^2 and modulus of rupture is 141 N/mm^2 (Isabel *et al.*, 2011)).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the data presented in this report, the following information can be concluded:

- The percentage of longitudinal, radial and tangential shrinkage of *Trema orientalis* are 0.33, 3.34 and 4.57 respectively.
- Specific gravity of the test specimens *Trema orientalis* wood based on green weight and oven dry weight are 0.51 and 0.38 respectively.
- The average moisture content percentage of *Trema orientalis* is 48.36 %
- In respect of mechanical properties Modulus of Elasticity (MOE) for *Trema orientalis* is 9478.81 N/mm^2
- The Modulus of Rupture (MOR) at maximum load is 72.03 N/mm^2
- Almost all the strength properties of this species is observed to be lower than those of teak (*Tectona grandis*), the standard wood species in determining relative suitability for use.

5.2 Recommendations

The following recommendation are suggested

- An effective research programs is to be conducted to find out the efficient protection measure against high volumetric shrinkage of wood of this species.
- We should make plantation of this species for timber, fuel wood pulp and paper production and medicinal values.
- It needs more study to find out more effective and economic utilization of the wood of *Trema orientalis*.

CHAPTER SIX

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Dimension of Green Sample

Sample	Readial-1 (mm)	Readial-2 (mm)	Readial-3 (mm)	Average of radial	Tangential-1(mm)	Tangential-2 (mm)	Average of Tangential	Longitudinal (mm)	Weight (Kg)
1	22.89	23.34		23.11	22.33	22.47	22.4	72.31	0.017
	23.01	23.57		23.29	21.96	22.10	22.03	72.36	
	23.18	23.65		23.41	21.72	21.95	21.83	72.46	
Average	23.03	23.52		23.27	22	22.17	22.08	72.38	0.017
2	23.23	21.68		22.45	21.49	22.93	22.21	71.99	0.018
	23.34	21.74		22.54	21.56	23.16	22.36	72.06	
	23.51	21.88		22.69	21.83	23.27	22.55	72.13	
Average	23.36	21.77		22.56	21.63	23.12	22.37	72.06	0.018
3	22.91	22.91		22.91	21.45	21.40	21.42	72.88	0.019
	22.81	22.82		22.81	21.30	21.41	21.35	72.69	
	22.72	22.96		22.84	21.04	21.75	21.39	72.56	
Average	22.81	22.9		22.85	21.26	21.52	21.39	72.71	0.019
4	22.45	22.66		22.55	21.66	21.79	21.72	74.52	0.019
	23.00	23.04		23.02	21.72	21.54	21.63	74.70	
	22.98	23.44		23.21	21.94	21.77	21.85	74.12	
Average	22.81	23.05		22.93	21.77	21.7	21.73	74.45	0.019
5	21.81	23.64		22.72	23.62	21.68	22.65	73.67	0.020
	22.24	23.68		22.96	23.76	21.89	22.82	73.98	
	22.41	23.62		23.01	23.50	21.82	22.66	74.12	
Average	22.15	23.65		22.9	23.63	21.8	22.71	73.92	0.02
6	23.66	22.07		22.86	23.60	21.77	22.68	73.18	0.019
	23.74	22.12		22.93	23.87	21.80	22.83	73.46	
	23.07	21.81		22.44	23.20	21.82	22.51	72.74	
Average	23.49	22		22.74	23.56	21.8	22.68	73.13	0.019
7	22.20	22.74		22.47	22.78	21.80	22.29	73.55	0.019
	22.63	22.58		22.60	22.45	22.18	22.31	74.12	
	23.35	22.28		22.81	21.96	22.97	22.46	74.38	
Average	22.73	22.53		22.63	22.4	22.32	22.36	74.02	0.019
8	23.03	22.61	22.54	22.72	22.93		22.93	73.67	0.021
	23.54	22.53	23.21	23.09	22.95		22.95	73.92	
	23.60	22.76	23.43	23.26	23.00		23	72.93	
Average	23.39	22.63	23.06	23.03	22.96		22.96	73.51	0.021
9	22.72	22.57		22.64	22.77	22.36	22.56	74.12	0.019
	22.80	22.56		22.68	22.21	22.13	22.17	74.29	
	22.86	22.76		22.81	21.80	21.57	21.68	73.88	
Average	22.79	22.63		22.71	22.26	22.02	22.14	74.1	0.019
10	22.86	22.66	23.52	23.01	23.58		23.58	74.69	0.020
	22.42	22.36	23.35	22.71	23.18		23.18	75.27	
	21.75	21.91	23.40	22.35	22.85		22.85	74.89	
Average	22.34	22.31	23.42	22.69	23.2		23.2	74.95	0.02

Dimension of Oven Dry Sample

Sample	Readial-1 (mm)	Readial-2 (mm)	Readial-3 (mm)	Average of radial	Tangential-1(mm)	Tangential-2 (mm)	Average of Tangential	Longitudinal (mm)	Weight (Kg)
1	22.20	22.69							
	22.24	23.15		22.44	21.24	21.08	21.16	71.91	0.011
	21.71	23.46		22.79	21.29	21.04	21.16	72.10	
Avg	22.05	23.17		22.58	20.72	20.69	20.70	72.34	
2	22.81	20.80		22.61	21.08	20.94	21.01	72.12	
	23.15	20.93		21.80	20.18	22.19	21.28	71.31	0.012
	23.28	20.89		22.04	20.50	22.48	21.49	72.00	
Avg	23.08	20.87		22.08	20.72	21.95	21.33	71.88	
3	22.20	22.42		21.97	20.53	22.21	21.37	71.73	
	22.13	22.29		22.31	20.55	20.43	20.49	72.35	0.012
	21.95	22.45		22.21	20.44	20.16	20.3	72.60	
Avg.	22.09	22.39		22.2	20.08	20.18	20.13	71.59	
				22.24	20.36	20.26	20.31	72.18	
4	21.66	21.45		21.55	20.59	21.13	20.86	74.24	0.013
	22.20	21.95		22.07	20.54	20.79	20.66	75.11	
	21.80	22.42		22.11	20.66	20.81	20.73	73.44	
Avg.	21.89	21.94		21.91	20.6	20.91	20.75	74.26	
5	21.28	23.05		22.16	22.75	20.79	21.77	73.51	0.013
	21.08	23.19		22.13	22.90	20.68	21.79	73.70	
	20.61	23.31		21.96	22.98	20.47	21.72	74.09	
Avg.	20.99	23.18		22.08	22.88	20.65	21.76	73.77	
6	23.21	21.20		22.20	22.80	20.54	21.67	72.74	0.013
	23.26	21.09		22.17	22.99	20.38	21.68	73.32	
	22.57	20.68		21.62	22.52	20.48	21.5	72.89	
Avg.	23.01	20.99		22	22.77	20.47	21.62	72.98	
7	21.62	21.69		21.65	21.55	21.05	21.3	73.42	0.013
	22.27	21.64		21.95	21.27	21.73	21.5	73.96	
	22.97	21.35		22.16	20.79	22.41	21.6	74.18	
Avg.	22.29	21.56		21.92	21.2	21.73	21.4	73.85	
8	22.35	22.07	21.58	22	21.82		21.82	73.39	0.015
	20.90	21.63	22.65	21.72	21.76		21.76	73.55	
	23.08	21.91	22.76	22.58	21.77		21.77	72.81	
Avg.	22.11	21.87	22.33	22.10	21.78		21.78	73.25	

	21.81	22.25		22.03	20.59	20.48	20.53	74.00	0.013
9	21.80	22.11		21.95	21.05	20.89	20.97	74.07	
	21.81	21.71		21.76	22.04	21.48	21.76	73.76	
Avg.	21.81	22.02		21.91	21.23	20.95	21.09	73.94	
10	22.46	21.94	22.63	22.34	22.60		22.6	74.38	0.014
	21.22	21.53	22.89	21.88	22.11		22.11	75.01	
	20.90	21.19	22.71	21.6	22.08		22.08	74.76	
Avg.	21.53	21.55	22.74	21.94	22.26		22.26	74.72	

Swelling of Oven Dry Sample after 24 hours

Sample	Readial-1 (mm)	Readial -2 (mm)	Readial -3 (mm)	Tangential -1(mm)	Tangential -2 (mm)	Longitudinal (mm)	Weight (Kg)
1	22.85	22.82		22.19	22.29	72.37	
	22.88	23.65		21.92	22.01	72.16	0.019
	22.63	23.78		21.94	22.04	72.68	
Average	22.79	23.42		22.02	22.11	72.4	0.019
2	23.20	21.64		21.71	22.67	71.76	
	23.44	21.74		21.68	22.96	71.92	0.018
	23.57	22.01		21.98	22.58	71.54	
Average	23.40	21.8		21.79	22.74	71.74	0.018
3	22.31	22.83		21.06	21.41	72.86	
	22.55	22.69		21.25	21.38	72.80	0.019
	22.72	22.86		21.64	21.81	72.60	
Average	22.52	22.79		21.32	21.53	72.75	0.019
4	22.12	22.53		21.40	21.47	74.17	
	22.70	22.66		21.35	21.18	74.52	0.020
	22.77	23.09		21.56	21.54	74.73	
Average	22.53	22.76		21.44	21.4	74.47	0.02
5	21.42	23.44		23.52	21.72	73.57	
	21.94	23.45		23.51	21.75	74.08	0.020
	22.42	23.50		23.49	22.04	74.39	
Average	21.92	23.46		23.51	21.84	74.01	0.02
6	23.47	22.10		23.28	21.81	73.08	
	23.53	21.85		23.61	21.50	73.38	0.020
	22.94	21.35		23.11	21.74	73.32	
Average	23.31	21.77		23.33	21.68	73.26	0.02
7	22.14	22.39		22.55	21.91	73.52	
	22.60	22.26		22.30	22.26	74.51	0.020
	23.27	22.35		22.25	23.09	74.34	
Average	22.67	22.33		22.37	22.42	74.12	0.02
8	22.82	22.70	22.36	22.57		73.64	

	23.33	22.22	22.77	22.59		73.75	0.022
	23.63	22.74	23.33	23.00		72.92	
Average	23.26	22.55	22.82	22.72		73.43	0.022
9	22.64	22.72		21.45	21.06	74.14	
	22.58	22.52		21.74	21.70	73.85	0.020
	22.86	22.37		22.59	22.34	73.92	
Average	22.69	22.54		21.93	21.7	73.97	0.02
10	22.85	22.61	23.32	23.43		74.66	
	21.75	22.06	23.22	22.86		75.21	0.021
	21.58	22.04	23.42	22.75		74.92	
Average	22.06	22.24	23.32	23.01		74.93	0.021

Swelling of Oven Dry Sample after 48 hours

Sample	Readial-1 (mm)	Readia l-2 (mm)	Readia l-3 (mm)	Tangentia l-1(mm)	Tangentia l-2 (mm)	Longitudi nal (mm)	Weight (Kg)
	23.01	23.1		22.28	22.46	72.21	
1	22.99	23.53		22.12	22.25	72.12	0.021
	23.19	23.7		21.97	22.24	72.96	
Average	23.06	23.44		22.12	22.32	72.43	0.021
	23.63	21.77		21.96	22.73	71.94	
2	23.52	21.88		21.77	23.13	71.72	0.021
	23.37	21.94		21.92	22.95	71.76	
Average	23.506	21.86		21.88	22.94	71.81	0.021
	22.6	22.89		21.19	21.41	72.6	
3	22.68	22.82		21.47	21.61	72.87	0.021
	22.94	22.88		21.63	22	72.5	
Average	22.74	22.86		21.43	21.67	72.66	0.021
	22.35	22.43		21.28	21.49	75	
4	22.79	22.9		21.52	21.37	75.16	0.023
	22.6	23.25		21.74	21.62	74.5	
Average	22.58	22.86		21.51	21.49	74.89	0.023
	22.5	23.53		23.58	22.28	73.94	
5	22.14	23.64		23.69	22.04	74.42	0.023
	21.69	23.54		23.85	21.73	74.09	
Average	22.11	23.57		23.71	22.02	74.15	0.023
	23.64	22.15		23.65	21.97	73.68	
6	23.83	21.94		23.81	21.78	73.1	0.021
	23.89	21.68		23.17	21.85	72.71	
Average	23.78	21.92		23.54	21.87	73.16	0.021
	22.13	22.59		22.7	21.96	74.55	
7	22.74	22.45		22.56	22.4	73.54	0.022
	23.37	22.39		22.16	23.18	73.55	
Average	22.74	22.48		22.47	22.51	73.88	0.022
	22.95	22.7	22.49	22.79		73.97	
8	23.46	22.38	23.01	22.86		73.28	0.021
	23.51	22.92	23.41	23.05		73.08	

Average	23.30	22.67	22.97	22.9		73.44	0.021
	22.79	22.77		21.6	21.59	73.79	
9	22.72	22.62		22.05	21.94	73.94	0.022
	22.94	22.26		22.74	22.38	74.23	
Average	22.81	22.55		22.13	21.97	73.99	0.022
	22.93	22.69	23.56	23.57		74.74	
10	22.01	22.27	23.42	23.11		74.92	0.024
	21.95	22.27	23.23	22.86		75.34	
Average	22.29	22.41	23.4	23.18		75	0.024

Shrinkage determination

Radial dimension of green sample (mm)	Radial dimension of oven dry sample (mm)	Shrinkage of radial dimension (%)	Tangential dimension of Green sample (mm)	Tangential dimension of oven Dry sample (mm)	Shrinkage of tangential dimension (%)	Longitudinal dimension of Green sample (mm)	Longitudinal dimension of oven dry sample (mm)	Shrinkage of longitudinal dimension (%)
1	23.28	22.61	2.86	22.09	21.01	4.87	72.38	72.12
2	22.57	21.98	2.61	22.38	21.37	4.49	72.06	71.73
3	22.86	22.24	2.69	21.39	20.31	5.05	72.71	72.18
4	22.93	21.92	4.43	21.74	20.76	4.51	74.45	74.26
5	22.9	22.09	3.56	22.72	21.77	4.18	73.92	73.77
6	22.75	22	3.28	22.68	21.62	4.67	73.13	72.98
7	22.63	21.93	3.12	22.36	21.47	4.00	74.02	73.85
8	23.03	22.10	4.02	22.96	21.78	5.14	73.51	73.25
9	22.71	21.92	3.5	22.14	21.09	4.74	74.1	73.94
10	22.69	21.94	3.30	23.2	22.26	4.05	74.95	74.72
Avg.	**22.83**	**22.07**	**3.337**	**22.36**	**21.34**	**4.57**	**73.52**	**73.28**

Moisture Content determination of Large Sample (3 inch*1 inch*1 inch)

Sample	Green weight (kg)	Oven Dry weight (kg)	Moisture Content (%)

1	0.017	0.011	54.55
2	0.018	0.012	50
3	0.019	0.012	58.33
4	0.019	0.013	46.15
5	0.02	0.013	53.85
6	0.019	0.013	46.16
7	0.019	0.013	46.16
8	0.021	0.015	40
9	0.019	0.013	46.16
10	0.02	0.014	42.86

Moisture Content determination of Small Sample (1 inch*1 inch*1 inch)

Sample	Green weight (kg)	Oven Dry weight (kg)	Moisture Content (%)
1	0.005	0.004	25
2	0.005	0.004	25
3	0.006	0.003	100
4	0.005	0.004	25
5	0.005	0.003	66.67
6	0.004	0.003	33.33
7	0.005	0.003	66.67
8	0.005	0.003	66.67
9	0.005	0.004	25
10	0.006	0.004	50

Determination of Density and Specific Gravity of Green Sample

Sample	Radial	Tangential	Longitudinal	Volume (m^3)	Weight (Kg)	Density (Kg/m^3)	Secific Gravity
1	23.28	22.09	72.38	3.72E-05	0.017	456.92	0.46
2	22.57	22.38	72.06	3.64E-05	0.018	494.74	0.49

3	22.86	21.39	72.71	3.55E-05	0.019	534.52	0.53
4	22.93	21.735	74.45	3.71E-05	0.019	512.07	0.51
5	22.9	22.715	73.92	3.85E-05	0.02	520.14	0.52
6	22.745	22.68	73.13	3.77E-05	0.019	503.65	0.50
7	22.63	22.36	74.02	3.75E-05	0.019	507.28	0.51
8	23.03	22.96	73.51	3.89E-05	0.021	540.27	0.54
9	22.71	22.14	74.1	3.73E-05	0.019	509.97	0.51
10	22.69	23.2	74.95	3.95E-05	0.02	506.92	0.51

Determination of Density and Specific Gravity of Dry Sample

Sample	Radial	Tangential	Longitudinal	Volume (m^3)	Weight (Kg)	Density (Kg/m^3)	Secific Gravity
1	22.61	21.01	72.12	3.43E-05	0.011	321.08	0.32
2	21.98	21.37	71.73	3.37E-05	0.012	356.24	0.36
3	22.24	20.31	72.18	3.26E-05	0.012	368.06	0.37
4	21.92	20.76	74.26	3.38E-05	0.013	384.88	0.39
5	22.09	21.77	73.77	3.55E-05	0.013	366.61	0.37
6	22	21.62	72.98	3.47E-05	0.013	374.51	0.38
7	21.93	21.47	73.85	3.48E-05	0.013	374.04	0.37
8	22.10	21.78	73.25	3.53E-05	0.015	425.37	0.43
9	21.92	21.09	73.94	3.42E-05	0.013	380.40	0.38
10	21.94	22.26	74.72	3.65E-05	0.014	383.64	0.38

Determination of swelling of *Trema orientalis* after 24 hours

Sample	Radial Dimension after immersion (mm)	Radial Dimension before immersion (mm)	Swelling (%)	Tangential Dimension after immersion (mm)	Tangential Dimension before immersion (mm)	Swelling (%)	Longitudinal Dimension after immersion (mm)	Longitudinal Dimension before immersion (mm)	Swelling (%)
1	23.10	22.61	2.19	22.07	21.01	5.02	72.4	72.12	0.39
2	22.60	21.98	2.85	22.27	21.37	4.19	71.74	71.73	0.01
3	22.66	22.24	1.88	21.43	20.31	5.49	72.75	72.18	0.79

4	22.65	21.92	3.33	21.42	20.76	3.20	74.47	74.26	0.29
5	22.69	22.09	2.75	22.68	21.77	4.18	74.01	73.77	0.33
6	22.54	22	2.46	22.51	21.62	4.09	73.26	72.98	0.38
7	22.5	21.93	2.62	22.40	21.47	4.33	74.12	73.85	0.37
8	22.88	22.10	3.50	22.72	21.78	4.32	73.43	73.25	0.25
9	22.62	21.92	3.20	21.82	21.09	3.44	73.97	73.94	0.04
10	22.54	21.94	2.73	23.01	22.26	3.37	74.93	74.72	0.28

Determination of swelling of *Tremaorientalis*after 48 hours

Sample	Radial Dimension after immersion (mm)	Radial Dimension before immersion (mm)	Swelling (%)	Tangential Dimension after immersion (mm)	Tangential Dimension before immersion,mm	Swelling (%)	Longitudinal Dimension after immersion (mm)	Longitudinal Dimension before immersion (mm)	Swelling (%)
1	23.25	22.61	2.84	22.22	21.01	5.76	72.43	72.12	0.43
2	22.68	21.98	3.22	22.41	21.37	4.87	71.81	71.73	0.11
3	22.8	22.24	2.52	21.55	20.31	6.11	72.66	72.18	0.67
4	22.72	21.92	3.68	21.5	20.76	3.59	74.89	74.26	0.85
5	22.84	22.09	3.42	22.87	21.77	5.05	74.15	73.77	0.52
6	22.86	22	3.88	22.71	21.62	5.02	73.16	72.98	0.25
7	22.61	21.93	3.13	22.49	21.47	4.78	73.88	73.85	0.04
8	22.98	22.10	3.98	22.9	21.78	5.14	73.44	73.25	0.26
9	22.68	21.92	3.51	22.05	21.09	4.55	73.99	73.94	0.07
10	22.70	21.94	3.47	23.18	22.26	4.13	75	74.72	0.37