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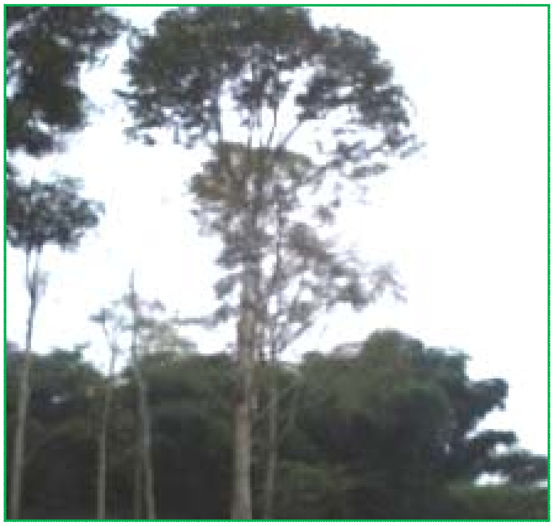
Ministry of Environmental Conservation and Forestry

Forest Department

Study on Wood Anatomical Characters, Physical and Mechanical Properties of Cherry-Bo (Betula alnoides Han.) and Tayok- Khaung-Bin (Taiwania cryptomerioides Hayata)



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ချယ်ရီဘိုနှင့်တရုတ်ခေါင်းပင်၏သစ်အင်္ဂါဗေဒ၊ရုပ်နှင့်အင်အားဆိုင်ရာ ဂုဏ်သတ္တိများအားလေ့လာခြင်း

ချိုချိုမြင့်၊ သုတေသနလက်ထောက်-၂
ဝင်းဦးနိုင်၊ လက်ထောက်သုတေသနအရာရှိ
ကျော်ဝင်းမောင်၊ လက်ထောက်သုတေသနအရာရှိ
နွယ်နွယ်ဝင်း၊သုတေသနလက်ထောက်-၃
သစ်တောသုတေသနဌာန၊ ရေဆင်း

စာတမ်းအကျဉ်းချုပ်

ဤသုတေသနတွင် ချယ်ရီဘိုသစ်(၂)ပင်ကို ရှမ်းပြည်မြောက်ပိုင်း၊ မူဆယ်၊ သဘာဝတောနှင့် တရုတ်ခေါင်းပင်(၁)ပင်ကို ကချင်ပြည်နယ်၊ ဝိုင်းမော်ရှိစိုက်ခင်းမှ စုဆောင်းခဲ့ပါသည်။ ၄င်းသစ်(၂)မျိုး၏ ရုပနှင့်အင်အားဆိုင်ရာ ဂုဏ်သတ္တိများကို ASTM D143-94 (2007) နှင့် BS 373-1957 စံချိန်စံညွှန်း သတ်မှတ်ချက်များနှင့်အညီ ဆောင်ရွက်ခဲ့ပါသည်။ ချယ်ရီဘိုသစ်၏ ရုပနှင့်အင်အားဆိုင်ရာ ဂုဏ်သတ္တိ များသည် သစ်တစ်ပင်မှတစ်ပင်နှင့် သစ်တစ်ပင်တည်းတွင် ပြောင်းလဲမှုရှိကြောင်းတွေ့ရပါသည်။ သို့သော် တရုတ်ခေါင်းပင်၏ ရုပနှင့်အင်အားဆိုင်ရာဂုဏ်သတ္တိ အများစုသည် သစ်တစ်ပင်အတွင်းတွင် သိသိ သာသာ ပြောင်းလဲမှု မရှိကြောင်းတွေ့ရပါသည်။ စမ်းသပ်ရရှိသော ဂုဏ်သတ္တိများအရ ချယ်ရီဘို သစ်သည် မြန်မာ့လူသုံးနည်း သစ်များမှ လေးသောသစ်အချို့နှင့် နှိုင်းယှဉ်နိုင်ပြီး တရုတ်ခေါင်းသစ်ကို ပေါ့သောသစ်များနှင့် နှိုင်းယှဉ်နိုင်ကြောင်း တွေ့ရှိရပါသည်။ သစ်အင်္ဂါဗေဒ လေ့လာချက်အရ ချယ်ရီဘိုသစ်သည် Scalariform perforation များပါရှိသည့် ရှည်လျှားသော Vessel elements များ ပါရှိပြီး တရုတ်ခေါင်းသစ်သည် လုံးဝမပါရှိ ကြောင်းတွေ့ရပါသည်။

Study on Wood Anatomical Characters, Physical and Mechanical Properties of Cherry-Bo (*Betula alnoides* Han.) and Tayok- Khaung-Bin

(*Taiwania cryptomerioides* Hayata)

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Abstract

In this research,two trees of Cherry-Bo (*Betula alnoides* Han.) and one Tayok-Khaung-Bin (*Taiwania cryptomerioides* Hayata) were collected from natural forest of Mu-Se township in Northern Shan State and plantation side of Waingmaw township in Kachin State. Physical and mechanical properties of these two species were conducted in accordance with ASTM D143-94 (2007) and BS 373-1957 standards. Physical and mechanical properties of Cherry-Bo species vary significantly between and within trees. But, almost all of the physical and mechanical properties of Tayok-Khaung-Bin vary not significantly in woodzone. According to investigated properties, Cherry-Bo species is comparable with some LUS heavy wood species and Tayok-Khaung-Bin is comparable with light wood species. According to anatomical study, Cherry-Bo is porous wood containing long vessels with scalariform perforation and Tayok-Khaung-Bin is non-porous wood.

Key words: ***Betula alnoides* Han.*, Taiwania cryptomerioides* Hayata,Physical and mechanical properties, Anatomical study, Porous wood, Non-porous wood.**

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1. Introduction

In Myanmar, natural forest resources occupy 48.3% or about 31,773,000 ha of the total land area. In these forests, a lot of florae enjoy growing, their number being 4157. Of these, about 2088 trees, big and small can be assumed to be able to produce timber. The number of big trees amount to 1347, of which a small number of timber-producing species can be considered economically important. Because of a high demand for timber consumption for increased population, extension of construction and installation of wood based industries, the amount of commercial timber production decreases.

As Myanmar forests are diverse and rich in species already known, among the species, many species are still left for testing the utilization- oriented properties. Of those species, Cherry-bo (*Betula alnoides* Han.) and Tayok- khaung -bin (*Taiwania cryptomerioides* Hayata.) are untested until now to assess their suitability for proper uses.

Cherry-bo can grow abundantly in hilly region and especially can be found in Mu- Se district of the northern Shan State. The authors found it growing in Kut-khaing Township and Mu-Se Township. The stocking per hectare of this species with diameter ≥90 cm at breast height in

Kut-khaing Township and diameter≥30 cm at breast height in Mu- Se Township are as follows:

Mu-Se township – 150 trees/ ha

Kut-khaing township – 75 trees/ ha

The information on growing stock mentioned above is supplied by Survey teams of Forest Department, Mu- Se district. The stocking of Cherry- bo should be regarded as plentiful in those areas because many species such as Thit- ya, Lauk- ya, Thitmagyi, Yethaphan, Doe-New, Taungthapyay and Swedaw grow. Some bamboo species are also found in the district.

The timber is generally used in large scale in the area of occurrence and the volume available is pretty large, yet the properties of this species have never been investigated before. Thus, with the intension of exploring a better and efficient use of this timber species, physical and mechanical properties were investigated as a first step. Later on if conditions are favourable its drying behavior, treatability and other properties would be tested by the respective researchers of the Forest Research Institute in Yezin.

And also, Tayok-khaung-bin grows in the northern part of Myanmar and widely well known as Chinese coffin wood. It can be found in 1,000 m above sea level in Myitkyina district of Kachin State. It is a valuable, large and tall tree, producing relatively large volume of wood. The timber is extremely good for making a range of high quality products but the species has become threatened in recent years due to logging and habitat loss. Therefore, keeping the assumption in mind that the information on the properties will promote the utilization of Cherry- bo and Tayok-khaung- bin, their anatomical, physical and mechanical properties were tested.

2. Literature Review

Cherry-bo (***Betula alnoides***) belongs to the family of Betulaceae. It attains a height of about 30 meters and 2 meters in girth, It has many names varying among regions. Kachin called it wild cherry, Layam and Shan- phom; Palaung called it Halahigh and Chinese called it Hondauksho. In China, small flat sticks were cut from sawn timber and then dried in steam kiln and used for parquet (Mu-Se district forest department, 2010).

Tayok-khaung-bin **(*Taiwania cryptomerioides*)** belongs to the family of *Taxodiaceae. Taiwania* is known as the Chinese Coffin tree. It can grow to 80 m high and 3 metres across. It is found as an emergent species in forest at mid to high elevations. It is one of the world tallest trees, and also of great economic and cultural importance to people living in local communities. The species is native to Asia, growing in the mountains of central Taiwan. It also occurs in mainland China (Guizhou, Habei, Sichuan, Yunnan); Myanmar and Viet Nam. The timber of *Taiwania* is extremely easy to work, light, durable and pleasantly scented (Global Tree Campaign 2008).

It is necessary to investigate basic wood properties for exploration of end- uses of a wood species. These properties comprise anatomy, durability, treatability, seasoning behaviors, physical and mechanical properties and workability. All these properties are important for efficient utilization of timber species.

In wood utilization, basic information on various aspects of wood is inevitably important for efficient utilization of log (Salang et. al., 1996). Shrinkage and swellings 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 equipment 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 (Tamolang et. al., 1995).These properties are of great importance in construction timber in classifying 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 use of those species that have been sporadically used, and for information that may be useful at one time.

The variation of density and moisture content and other mechanical properties should affect the quality of sawn timber, seasoning of timber, preservation processes, working properties, mechanical properties and final product quality (Salang et. al, 1996). The variation in mechanical properties will affect the use of species for construction and furniture making. The variability in properties can be used for wood products (USDA,1999). Thus, the variation of physical and mechanical properties among logs and species affects choice of log and species for specific utilization.

In this study, the variation in physical and mechanical properties of Cherry–bo and Tayok-khaung–bin species grown in Myanmar was investigated in order to provide the information on the wood quality variation for specifying and classifying the utilization of species.

The objective of this study is:

(1) to investigate the physical and mechanical properties of the species,

(2) to promote the utilization potential of *Betula alnoides* and *Taiwania cryptomerioides*

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

(4) to share knowledge on the utilization potential of these species with local people from those area.

3. Materials and Methods

3.1 Materials

Two Cherry-bo trees of marketable size were collected from natural forests of Mu-Se township in the northern Shan State while one Tayok-khaung-bin was collected from plantation site of Waingmaw township in Kachin State. The trees were authenticated from the herbarium material. The measurements of the sample trees are as below:

Table 1: Girth at breast height and bole length of Cherry–bo and Tayok-khaung-bin

Local Name	Scientific name	GBH	Bole Length
		(cm)	(m)
Cherry-bo	*Betula alnoides* Han.	137	3.5
		134	3.5
Tayok- khaung-bin	*Taiwania cryptomerioides* Hayata	69	2.5

3.2 Methods

Sample trees were tested for wood anatomical structures, shrinkage, density, specific gravity, moisture content, modulus of rupture, modulus of elasticity, axial compression strength, side compression strength and Janka hardness. Physical properties were investigated following ASTM D143-94 (2007) while strength properties were conducted in accordance with BS 373-1957.

3.2.1 Method for anatomical study

For anatomical observation, three sample blocks in transverse, tangential longitudinal and radial longitudinal sections were cut and boiled with water for softening. After boiling, these are immersed in equal solution of 50% glycerine and alcohol in order to more easily cut on sliding microtome. The wood slices of each three sections were cut into 25 – 30 µm thickness and stained in safranin over night. The staining wood slices were dehydrated and mounted on slide to prepare microslide for observation of anatomical studies. Wood samples were also macerated to observe individual elements of woods. The cell dimensions were measured from wood sections on microslide and maceration, and at 50 times randomly for each dimension. The photomicrographs for anatomical characteristics of two species studied were presented in this paper.

3.2.2 Wood Anatomical characteristics of Cherry-bo (*Betula alnoides* Han.)

(i) Macroscopic characteristics of the wood

Growth ring distinct, ring width 4.932 mm to 20.775 mm; sapwood yellowish white; heartwood light brown; odour and taste not distinct; fine texture; straight grained.

(ii) Microscopic characteristics of the wood

Diffuse porous wood; pores frequency moderately few to moderately numerous, mean of pores frequency 10 (range 6 - 15 / mm^2), average solitary pores 59% (range 42% - 85%); pores solitary or as radial pore multiples of 2 – 3 (mostly 2), circular or oval in cross section; pores very small to medium – sized; mean tangential diameter 97.72 µm (range 41 – 153.75 µm); vessel elements moderately short to very long, mean length 835.72 µm (range 297.25 – 1455.50 µm) long; perforation plates scalariform; end wall of vessel elements is oblique, trancate or tailed at one end; intervessel pits alternate to scalariform, elliptical, mean tangential diameter 5 µm (range 3.70 – 6.25 µm). Ray vessels pitting alternate, oval or elliptical in shape, mean tangential diameter 4 µm (range 2.5 – 5 µm). Gums deposits present, tyloses absent. Fibers libriform, very short to moderately long, mean length 1136.95 µm (range 533 - 1845 µm), mean width 25.96 µm (range 17.50 – 42.50 µm), mean fiber walled thickness 3.86 µm (range 2.50 – 7.50 µm), mean lumen width 18.25 µm (range 7.50 – 32.50 µm); `thin walled, septate, simple, slit-like. Axial parenchyma is very sparse. Rays homocellular; consisting of exclusively procumbent cells; uniseriate to multiseriate; mean per mm tangential 10 (range 7 – 13 per mm), normally space to fairly close; mean width of uniseriate 5.69 µm (range 2.50 – 10 µm), extremely fine to very fine, mean height 132.74 µm (range 41 – 379.21 µm), extremely low to rather low, 1 – 3 cells wide and 2 – 12 cells high; mean width of multiseriate rays 40.31 µm (range 20.50 – 61.50 µm), very fine to medium – sized, mean height 267.87 µm (range 71.75 – 635.50 µm), very low to moderately height, 6 – 31 cells high; ray vessels pitting alternate, oval or elliptical in shape, mean tangential diameter 4 µm (range 2.5 – 5 µm). dark reddish – brown gum deposits present, crystal bodies absent; tyloses absent. Parenchyma sparse, some ray parenchyma contains reddish brown gum deposits.

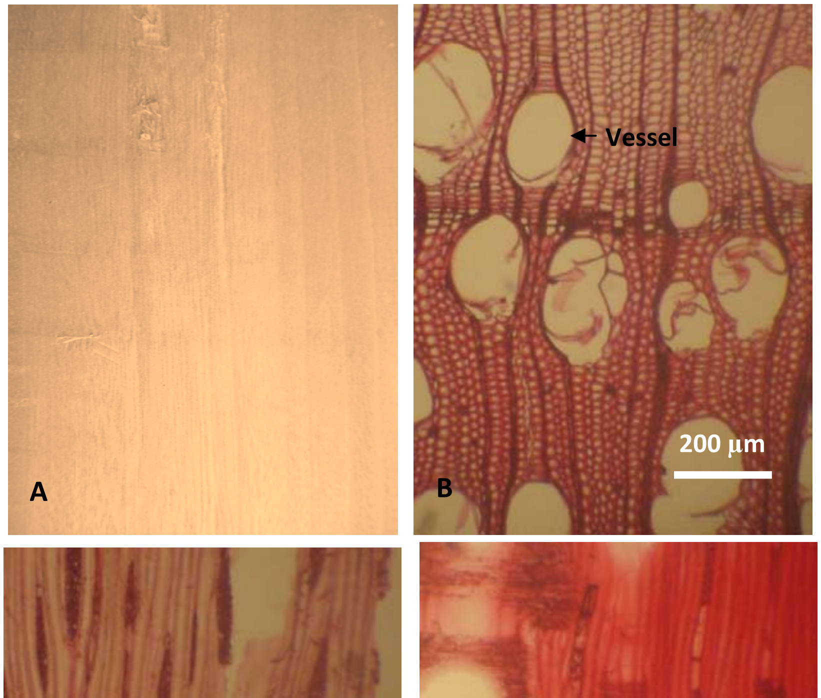


Figure 1. Wood anatomical features of Cherry-bo (*Betula alnoides* Han.)

A. Wood as seen
B. Transverse section showing solitary vessel and vessel grouping and distinct growth ring.
C. Tangential longitudinal section showing uniseriate rays and multiseriate rays.
D. Radial longitudinal section showing rays and scalariform perforation

3.2.3 Wood Anatomical characteristics of Tayok-khaung-bin (*Taiwania cryptomerioides* Hayata.)

(i) Macroscopic characteristics of the wood

Growth ring distinct, ring width 5.283 mm to 29.398 mm; sapwood and heartwood undistinguished, yellowish – white; purgent odour; fine texture; straight grained.

(ii) Microscopic characteristics of the wood

Nonporous wood, sharp transition from early wood to latewood. Resin canal is absent. Longitudinal parenchyma sparse and often apparently wanting. Mostly uniseriate ray cells, mean of tangentially 14 , (range 12 – 19); mean height 296.57 µm(range 30.75 – 1281.25 µm).

In earlywood, mean length of tracheids 1864.24 µm (range 461.25 – 3331.25 µm), mean width 46.95µm (range 27.50- 62.50 µm), mean walled thickness 3.66 µm (range 2.50 – 5 µm). cupressoid pits on radial wall of tracheids in early wood;

In latewood, mean length of tracheids 1946.36 µm (range 973.25 – 2870 µm), mean width 36.75 µm (range 12.50 – 57.50 µm), mean walled thickness 4.60 µm (range 2.50 – 10 µm). piceoid pits on radial wall of trachied in late wood.

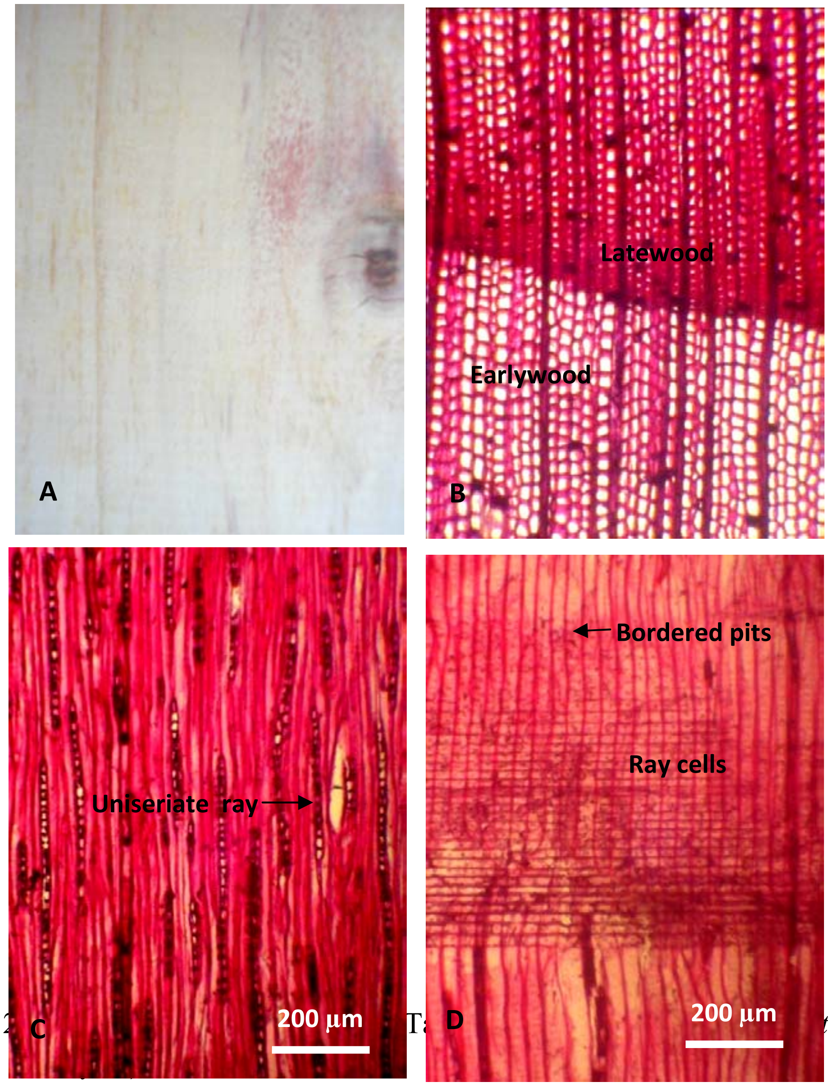


Figure T *tomerioides*

A. Wood as seen
B. Transverse section showing dermacation of earlywood and latewood.
C. Tangential longitudinal section showing uniseriate rays
D. Radial longitudinal section showing rays and bordered pits in tracheids.

3.2.4. Physical and Mechanical properties

Three disks, each about 80 mm thick were cut from the base of each log. They were used for preparation of specimens for testing radial, tangential, longitudinal and volumetric shrinkage, density and specific gravity.

Three kinds of specimens were prepared from each disk: sapwood specimens, heartwood specimens and juvenile specimens (Here: sapwood means the wood near the bark, juvenile the wood near the pith and heartwood the wood between the two wood zones). The rest parts of the logs were used for mechanical tests.

Table 2 : Number and size of specimens for physical tests

Sr. No.	Test	Size of specimen (mm^3)	No. of Specimens		
			Juvenile	Heartwood	Sapwood
1	Radial shrinkage	25x25x50	6	6	6
2	Tangential shrinkage	25x25x50	6	6	6
3	Longitudinal shrinkage	25x25x100	6	6	6
4	Volumetric shrinkage, Specific gravity	25x25x100	6	6	6

Table 3: Number and size of specimens for mechanical tests

Sr. No.	Test	Size of specimen (mm^3)	No. of specimens/ tree
1	Static Bending	20x20x300	36
2	Compression parallel to grain	20x20x60	36
3	Compression perpendicular to grain	20x20x60	36
4	Hardness	20x20x60	36

3. 2. 5 Testing procedures

After preparation of specimens for testing physical properties, they were sanded and cleaned to remove loose materials so that they could not affect the moisture content. They were weighed and measured for determination of shrinkage and moisture while green and data were recorded. Then they were air-dried. When the specimens had attained constant weights, were measured and data recorded. They were then oven-dried at a temperature of 103±2˚C. On attaining constant weights, they were measured and data recorded again. For determination of specific gravity, the volume was determined by water displacement method. For mechanical properties, green and air-dry tests were conducted according to the designations in BS standards.

The tests and calculated properties are:

(1) Physical properties

a) Density

b) Specific gravity

c) Radial shrinkage
d) Tangential shrinkage
e) Longitudinal shrinkage
f) Volumetric shrinkage
g) Moisture content

(2) Mechanical properties

a) Static bending
  a.a) Modulus of elasticity (MOE)
  a.b) Modulus of rupture (MOR)
  a.c) Fiber stress at proportional limit (FS@PL)
b) Compression parallel to grain
  b.a) Maximum crushing strength (MCS)
  b.b) Fiber stress at proportional limit (FS@PL)
c) Compression Perpendicular to grain
  c.a) Fiber stress at proportional limit (FS@PL)
d) Hardness
  d.a) Radial
  d.b) Tangential
  d.c) Longitudinal or end

4. Data analysis

In this research, the minimum, maximum, mean and standard deviation of physical and mechanical properties were calculated. Analysis of variance (ANOVA) was performed to examine the variability of wood properties between trees and within trees.

5. Results and Discussion

5.1 Wood anatomical characteristics of Cherry-bo and Tayok- khaung-bin

The anatomical structure of wood of *Betula alnoides* and *Taiwania cryptomerioides* is quite different because these two species are not totally related each other. *Betula alnoides* is angiosperm and *Taiwania* is gymnosperm. Angiosperm wood is called hard wood and is formed by cell elements including vessel, fibers, ray parenchyma and axial parenchyma. Gymnosperm wood is known as soft wood and constructed by tracheids and ray parenchyma cells. Wood of *Betula alnoides* is diffuse porous and consists of very small to medium–sized pores with moderately few to moderately numerous frequency. Fibers are very short to moderately long, non-septate and thin – walled. Rays are homogeneous and uniserate to tetraseriate. Uniseriate rays are extremely fine to very fine and 2 – 12 cells high. Multiseriate rays are very fine to medium sized and 6 – 31 cells high. Reddish – brown gum deposits are found in the ray cells. Axial parenchyma cells distribute in very sparse among the fibers. The wood of *Taiwania cryptomerioides* lack the resin canal. The sharp transition from early wood to late wood is found. The piceoid pits are observed on radial wall of tracheids in late wood and cupressoide pits in early wood. Rays contain only parenchyma and are mostly uniseriate.

According to result of growth ring measurement wood formation produces minimum growth ring width of about 5 mm and maximum growth ring width over 20 mm per year in these two species.

5.2. Physical properties of Cherry-bo

The physical properties of Cherry-bo are presented in table (1).

Table (1).Physical Properties of Cherry-bo

Property	Minimum	Maximum	Mean	Standard deviation
Green MC%	39.11	62.15	49.60	6.07
Basic specific gravity	0.418	0.694	0.568	0.085
Specific gravity12%	0.447	0.780	0.626	0.103
Basic density (kg/m^3)	418	694	568	85
Density (12%) (kg/m^3)	502	874	701	115
Oven-dry density (kg/m3)	457	810	647	109
Shrinkage (green to air dry):				
Radial (%)	2.00	3.96	3.15	0.51
Tangential (%)	3.25	5.32	4.47	0.69
Longitudinal (%)	0.05	0.46	0.22	0.11
Volumetric (%)	4.53	8.76	7.16	1.26
Shrinkage (green to oven-dry):				
Radial (%)	3.34	6.61	5.25	0.85
Tangential (%)	5.42	8.87	7.45	1.16
Longitudinal (%)	0.07	0.77	0.37	0.18
Volumetric (%)	7.56	14.59	11.92	2.11

The average moisture content of Cherry-bo is 49.60%. The minimum and maximum moisture content are 39.11% and 62.15%.

The basic specific gravity of Cherry-bo ranges from 0.418 to 0.694 and the mean basic specific gravity is 0.568. It is higher than those of Pyinma (0.529), Kokko (0.538), Myaukthwethe (0.549) and Binga (0.554), but lower than those of Zaungbale (0.597), Kyun (*Tectona grandis*) (0.598), Hnaw (0.601), Chinyok (0.601), Lein (0.644), Nabe (0.672),Thabye (0.674) and Taungokshit (0.691). It is comparable with the basic specific gravity of Pyaukseik (0.567), Thingadu (0.561), and Taungthayet (0.558) (Table 2). So, it is a heavy wood species.

The mean basic and oven-dry density are 568 kg/m^3 and 647 kg/m^3,repectively, while the mean density of Cherry-bo at 12% moisture content is 701kg/m^3.

Table (2) Basic specific gravity of Cherry-bo and some other lesser used timber species

Local name	Scientific Name	Basic Specific Gravity
Cherry-bo	*Betula alnoides*	0.568
Pyinma	*Lagerstroemia speciosa*	0.529
Kokko	*Albizzia lebbek*	0.538
Myaukthwethe	*Myristica angustifolia*	0.549
Binga	*Mitragyna rotundifolia*	0.554
Taungthayet	*Swintonia floribunda*	0.558
Thingadu	*Parashorea stellata*	0.561
Pyaukseik	*Holoptelea integrifolia*	0.567
Tawthayet	*Mangifera indica*	0.582
Seikche	*Bridelia retusa*	0.583
Leza	*Lagerstroemia tomentosa*	0.583
Zaungbale	*Lagerstroemia villosa*	0.597
Hnaw	*Adina cordifolia*	0.601
Chinyok	*Garuga pinnata*	0.601
Lein	*Terminalia pyrifolia*	0.644
Nabe	*Lannea coromandelica*	0.672
Thabye	*Eugenia spp.*	0.674
Taungokshit	*Elaeocarpus spp.*	0.691

The averages of wood shrinkage from green to air- dry condition are 3.15% and 4.47% for the radial and tangential directions, respectively. The corresponding values from green to oven dry are 5.25% and 7.45%. It shrinkage is comparable with that of black cherry (3.7% and 7.1% from green to oven dry).

Like other wood species, the longitudinal shrinkage of Cherry-bo is very small. The mean longitudinal shrinkage from green to oven-dry condition is only 0.37%. The difference between the longitudinal and horizontal (radial and tangential) shrinkage is due to the alignment of wood cells (Anonymous 1992). As water is removed from the cell walls, the cells move closer together. Movement in the horizontal is greater than in the longitudinal direction.

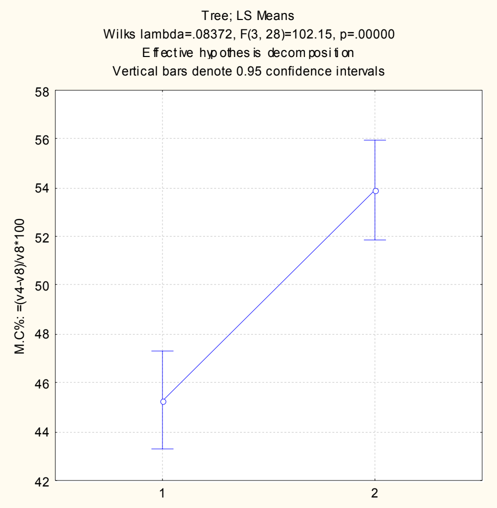
5.2.1. Variation in physical properties of Cherry-bo

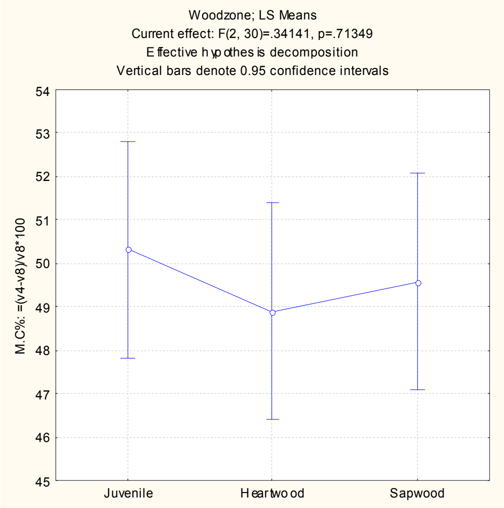
The analysis of variance of the physical properties of Cherry-bo is summarized in table (3). Moisture content, basic specific gravity and shrinkage (R & T) significantly differs between trees. Basic specific gravity and shrinkage are significantly different among woodzones while moisture content is not. The interaction effect is only significantly different for shrinkage (R & T) while the other are not. The mean radial shrinkage of Cherry-bo from green to oven-dry increased from juvenile to sapwood. Similarly, the radial shrinkage from green to air-dry also increased and significantly differed ($p<0.05$) from the juvenile to sapwood.

Table (3) Summary of ANOVA on the physical properties of Cherry- bo

Source of variation	Moisture content	Basic specific gravity	Shrinkage (Green to air-dry)			Shrinkage (Green to oven- dry)		
			R	T	L	R	T	L
Tree	*	*	*	*	ns	*	*	ns
Woodzone	ns	*	*	*	ns	*	*	ns
Tree x Woodzone	ns	ns	*	*	ns	*	*	ns

R=radial; T=tangential; L=longitudinal; *=significant; ns=not significant

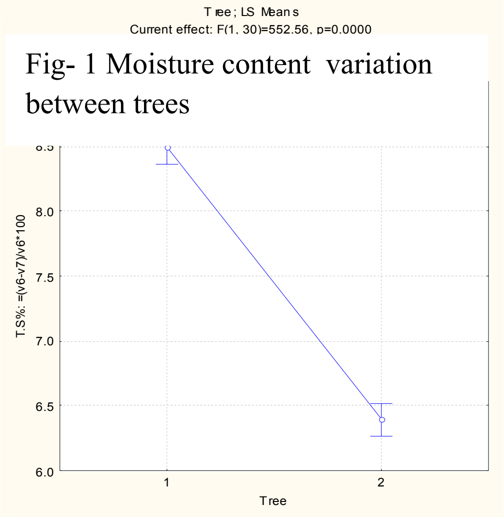


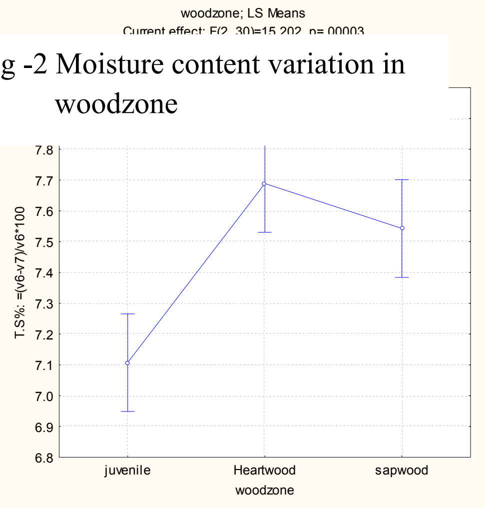


content
n trees

Fig- 1 Moisture content variation between trees

Fig -2 Moisture content variation in woodzone





rinkage variation

Fig-4 Tangential shrinkage variation in woodzone

It is evident that the mean tangential shrinkage of wood from green to oven-dry and from green to air-dry increase significantly from the juvenile wood (nearest the pith) to the sapwood(nearest the bark) and is significantly different ($p<0.05$) between trees.

The mean basic specific gravity is significantly affect between trees and also significantly affect among woodzone. The mean basic specific gravity increase from juvenile to sapwood. The interaction between trees and woodzone is also not significant.

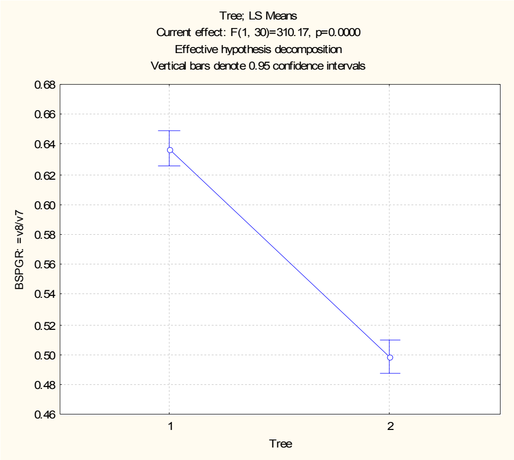


Fig-5 Basic specific gravity variation between trees

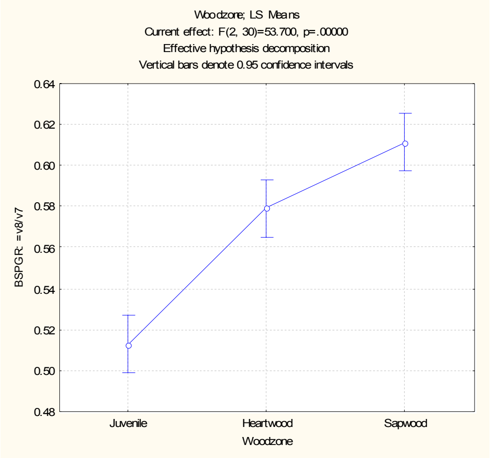


Fig-6 Basic specific gravity variation in woodzone

5.3 Mechanical Properties of Cherry-bo

The maximum, minimum, mean and standard deviation of mechanical test results at 12% moisture content are shown in table (4). The strength properties of Cherry-bo are comparable to those of some other lesser used timber species in table (5). At 12% moisture content condition, modulus of rupture ranges from 65.53N/mm^2 to 174.90 N/mm^2.The mean modulus of rupture value is 111.58 N/mm^2.The average value for modulus of elasticity is 11243 N/mm^2. In compression parallel to grain, the mean maximum strength is 44.20 N/mm^2.These values are higher than Binga, Chinyok, Pyinma, and Thitswele. but are lower than Dwani, Lein, Myaukchaw, Nabe, Pethan, Taungokshit, Thande, Yinma and Yinzat (Table 5).The mean value for fiber stress at proportional limit in compression perpendicular to grain is 10.68 N/mm^2.The average values for radial, tangential and end hardness are 2.18 (kN), 2.08 (kN) and 3.93(kN) respectively.

Table (4) Mechanical Properties of Cherry-bo at 12% moisture content

Property	Min	Max	Mean	Std.Dev
Static Bending				
MOR(N/mm^2)	66	175	112	26.12
MOE(N/mm^2)	5855	18016	11243	3023
Compression Parallel				
MCS(N/mm^2)	26.15	65.26	44.20	10.26
Compression Perpendicular				
FS@PL(N/mm^2)	5.69	16.54	10.68	2.97
Hardness(kN)				
Radial	0.68	3.73	2.18	0.83
Tangential	0.76	3.83	2.06	0.77
End	2.22	6.11	3.93	1.09

MOR=modulus of rupture, MOE=modulus of elasticity, MCS= maximum crushing strength, FS@PL=fiber stress at proportional limit,

Table (5) Comparison of Mechanical Properties of Cherry-bo and some other LUS Species

Local Name	Scientific Name	MOR (N/mm^2)	MOE (N/mm^2)	MCS (N/mm^2)

Cherry-bo	*Betula alnoides*	112	11243	44
Binga	*Mitragyna rotundifolia*	82	11053	42
Chinyok	*Garuga pinnata*	84	10963	44
Dwani	*Eriolaena candollei*	123	15445	53
Lein	*Terminalia pyrifolia*	129	19203	50
Myaukchaw	*Homalium tomentosum*	130	16693	51
Nabe	*Lannea coromandelica*	114	13121	58
Petthan	*Haplophragma adenophyllum*	129	15790	57
Pyinma	*Lagerstroemia speciosa*	86	10046	43
Taungokshit	*Elaeocarpus spp.*	115	17660	52
Thande	*Stereospermum personatum*	131	14939	59
Thitswele	*Schrebera swietenioides*	105	14497	47
Yinma	*Chukrasia tabularis*	126	15748	56
Yinzat	*Dalbergia fusca*	122	16934	50

MOR=modulus of rupture; MOE=modulus of elasticity;
MCS=maximum crushing strength

5.3.1 Variation in Mechanical Properties of Cherry-bo

The results of the analysis of variance on mechanical properties of Cherry-bo at green and at 12% moisture content are summarized in table (4) and (5). At green condition, the mean values of MOE, MOR and MCS vary significantly between trees but not in woodzone (table 5). At 12% moisture content, all the mechanical properties vary significantly between trees and woodzone. The interaction has significant effects on them except MCS (table 6). MOE, MOR, MCS and hardness at 12% moisture content increased significantly from juvenile to sapwood (fig-7, 8, 9, 10). Tree -1 has higher properties than tree (2). It might be due to the higher amount of juvenile wood content in tree (2).

Table (5) Analysis of variance of mechanical properties of Cherry-bo at green

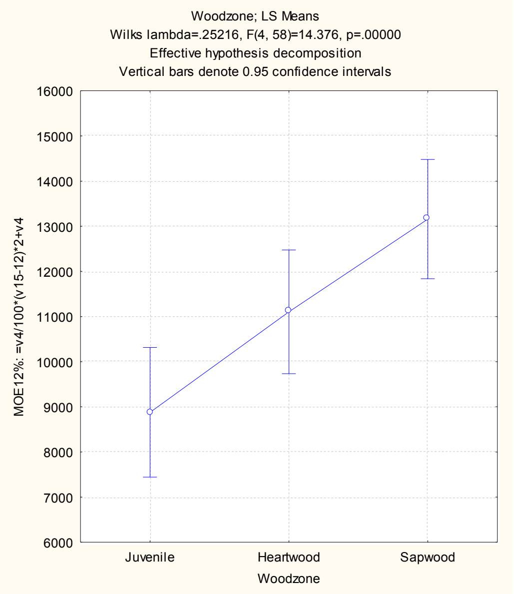
Source of variation	Static Bending		Compression Parallel	Compression Perpendicular	Hardness		
	MOR	MOE	MCS	FS@PL	R	T	E
Tree	*	*	*	*	*	*	*
Woodzone	ns	ns	ns	*	*	*	*
Tree x Woodzone	*	*	ns	*	*	*	*

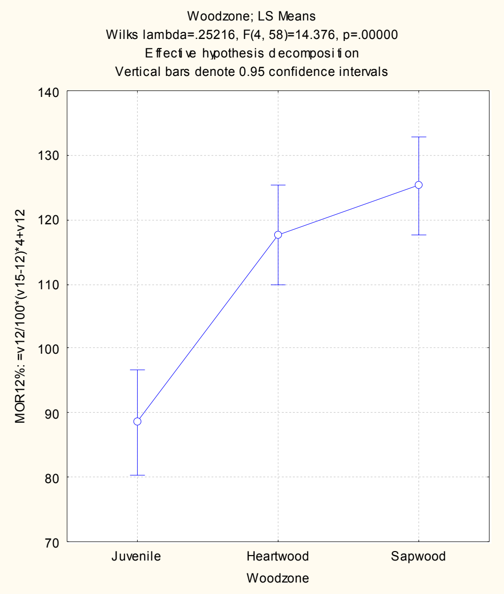
MOE=modulus of elasticity; MOR=modulus of rupture;
MCS= maximum crushing strength; FS@PL=fiber stress at proportional limit
R=Radial; T= tangential; E=end, *= significant($p<0.05$), ns= not significant ($p>0.05$)

Table (6) Analysis of variance of mechanical properties of Cherry-bo at 12% moisture content

Source of variation	Static Bending		Compression Parallel	Compression Perpendicular	Hardness		
	MOR	MOE	MCS	FS@PL	R	T	E
Tree	*	*	*	*	*	*	*
Woodzone	*	*	*	*	*	*	*
Tree x Woodzone	*	*	ns	*	*	*	*

MOE=modulus of elasticity; MOR=modulus of rupture;
MCS= maximum crushing strength; FS@PL=fiber stress at proportional limit





R=Radial; T= tangential; E=end, *= significant ($p<0.05$), ns= not significant ($p>0.05$)

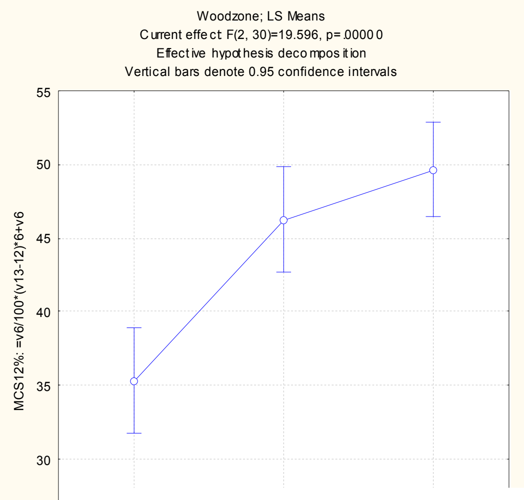


Fig- 7 modulus of elasticity variation in woodzone at 12% moisture content

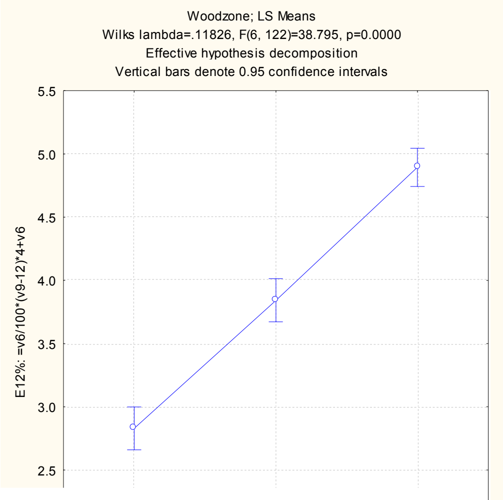


Fig- 8 modulus of rupture variation in woodzone at 12% moisture content ng strength

5.4. Physical properties of Tayok- khaung-bin (Chinese coffin wood)

Table (7): Physical Properties of Tayok-khaung-bin (Chinese coffin wood)

Property	Min	Max	Mean	Standard deviation
Green MC%	121.18	150.22	143.08	11.03
Basic specific gravity	0.334	0.395	0.358	0.024
Specific gravity12%	0.353	0.421	0.379	0.027
Basic density (kg/m^3)	334	395	358	24
Density (12%) (kg/m^3)	395	472	425	30
Oven-dry density (kg/m3)	380	436	402	23
Shrinkage (green to air dry):				
Radial (%)	0.83	1.01	0.90	0.08
Tangential (%)	2.49	3.57	2.94	0.39
Longitudinal (%)	0.26	0.69	0.46	0.17
Volume	.63	7.24	6.66	0.60
Shrinka				
Radial (%)	1.38	1.69	1.50	0.13
Tangential (%)	4.12	5.95	4.91	0.65
Longitudinal (%)	0.43	1.15	0.76	0.29
Volumetric (%)	9.38	12.07	11.09	0.99

Fig-10 End hardness variation in wood zone

Table (7) shows physical properties of Tayok- khaung-bin. Moisture content ranges from 121.18% to 150.22%. The mean moisture content is 143.08%. The mean basic specific gravity is 0.358. This value is similar to that of Shaw (0.352), is higher than those of Hmyaseik (0.335), Myaukthwegyi (0.339) and Thapan (0.344), and is lower than those of Didu (0.363), Baing(0.376) and Taungmeok (0.388). Thus, Tayok-khaung-bin is a light wood species. The mean radial and tangential shrinkage from green to oven dry are 1.5% and 4.91%, respectively. The mean tangential shrinkage value is higher than twice of the radial shrinkage value. The mean longitudinal shrinkage value is 0.76% from green to oven-dry condition.

5.4.1 Variation in physical properties of Tayok-khaung- bin

The results of the analysis of variance of physical properties of Tayok-khaung-bin are presented in table (8). Woodzone has no significantly effect on moisture content, basic specific gravity, shrinkage from green to air-dry and green to oven-dry. Sapwood has the highest specific gravity while heartwood has the lowest value.

Table (8) Physical properties of Tayok-khaung- bin

Source of variation	Moisture content	Basic specific gravity	Shrinkage (Green to air-dry)			Shrinkage (Green to oven- dry)		
			R	T	L	R	T	L
Woodzone	ns	ns	ns	ns	ns	ns	ns	ns

R=radial, T=tangential, L=longitudinal, ns=not significant

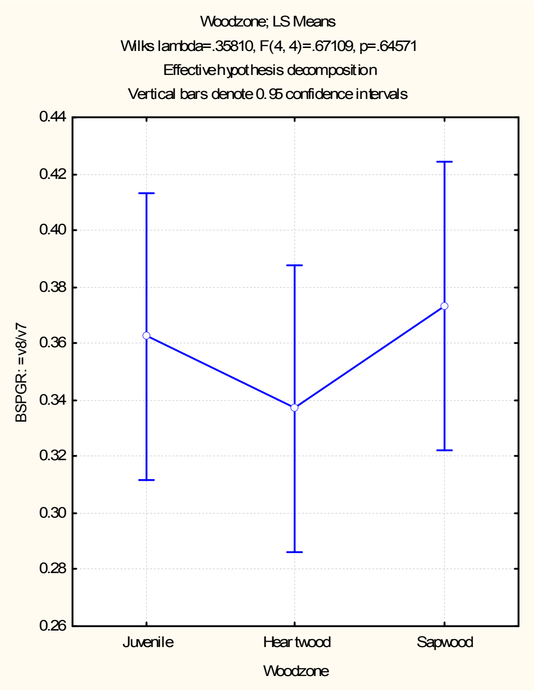


Fig-11 Basic specific gravity variation in woodzone

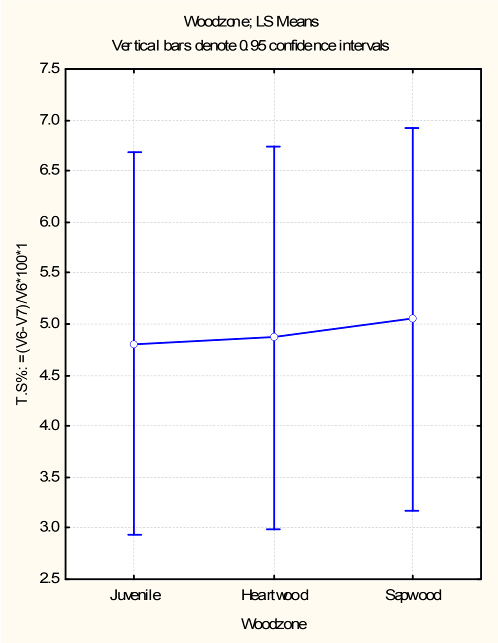


Fig- 12 Tangential shrinkage variation in woodzone

5.5 f Tayok- khaur

Table (9) Mechanical properties of Tayok-khaung-bin at 12% moisture content

Property	Min	Max	Mean	Std.Dev	No.of specimen
Static Bending					
MOR(N/mm^2)	44	69	56	7.43	16
MOE(N/mm^2)	2660	5306	3848	676	16

Compression Parallel					
MCS(N/mm^2)	15.79	21.76	18.21	1.59	17
Compression Perpendicular					
FS@PL(N/mm^2)	5.8	11.32	7.48	1.69	17
Hardness(kN)					
Radial	0.51	1.73	0.95	0.32	17
Tangential	0.49	1.82	0.96	0.31	17
End	1.27	2.80	1.79	0.38	17

MOR=modulus of rupture; MOE=modulus of elasticity;
MCS=maximum crushing strength

Table (10) Comparison of Mechanical properties of Tayok-khaung-bin and some LUS species

Local Name	Scientific name	MOR (N/mm^2)	MOE (N/mm^2)	MCS (N/mm^2)
Tayauk-khaung-bin	*Taiwania cryptomerioides*	56	3848	18
Bonmeza	*Albizzia chinensis*	40	6578	25
Gwe	*Spondias pinnata*	43	7598	23
Hmyaseik	*Antiaris toxicaria*	41	6461	28
Letpan	*Salmalia malabarica*	39	5970	21
Myauk-thwe-gyi	*Myristica spp*	41	8557	26
Shaw	*Sterculia versicolor*	53	7211	29
Thaphan	*Ficus spp.*	53	7053	31

MOR=modulus of rupture; MOE=modulus of elasticity;
MCS=maximum crushing strength

The minimum, maximum, mean and standard deviation of tested results are presented in table (9). The strength properties of Tayok-khaung-bin are almost similar to those of some light LUS species as shown in table (10). Its MOE and MCS and MOR at 12% moisture content are 3484 N/mm^2, 18 N/mm^{2}and 56 N/mm^2 respectively. MOE and MCS are lower than those of Bonmeza, Gwe, Hmyaseik, Letpan, Myauk-thwe-gyi, Shaw and Thapan but MOR is higher than those of the mentioned species.

5.5.1 Variation in mechanical properties of Tayok-khaung-bin

Table (11) Analysis of variance of mechanical properties of Tayok-khaung-bin (Dry)

Source of variation	Static Bending		Compression Parallel	Compression Perpendicular	Hardness		
	MOR	MOE	MCS	FS@PL	R	T	E
Woodzone	ns	ns	ns	*	*	*	*

MOR=modulus of rupture, MOE=modulus of elasticity, MCS=maximum crushing strength, FS@PL= fiber stress at proportional limit, R=radial, T=Tangential, E=end
*=significant, ns= not significant

The analysis of variance of mechanical properties of Tayok-khaung-bin is summarized in table (11). The modulus of rupture, modulus of elasticity and maximum crushing strength are not significantly different among woodzones. But, in compression perpendicular to grain test, FS@PL decreased significantly. Similarly, radial and end hardness decreased significantly.

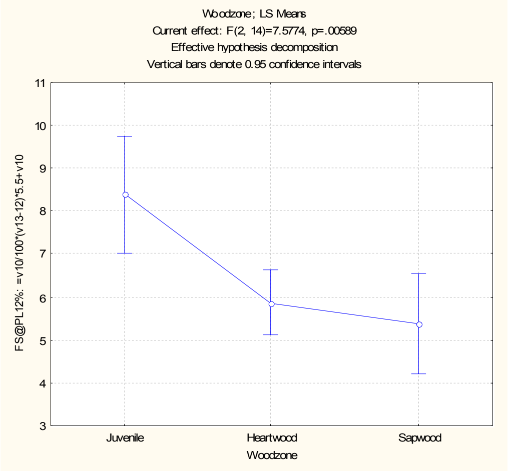


Fig- compression perpendicular variation in woodzone

6.

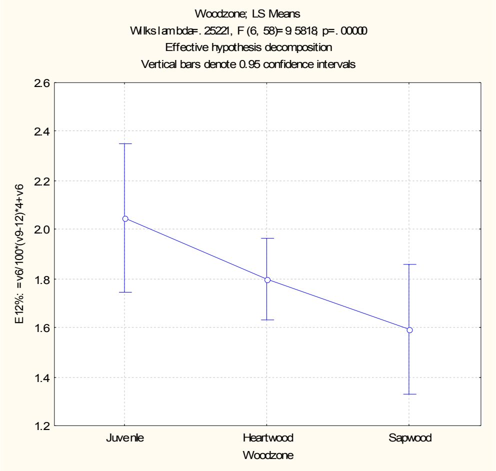


Fig- End hardness variation in woodzone

6. Conclusion

Cherry-Bo is a heavy wood species with a specific gravity of 0.568, which is quite similar to that of teak. The shrinkage values are higher than those of teak. It is comparable to many other lesser used timber species in strength. It should be dried before use as it has high shrinkage. Thus, it can be used in light construction. It can be best used as beams and posts in building.

The basic specific gravity of Tayok-khaung-bin is 0.358. So, it is a light wood species. It is very similar to Didu and Letpan. Thus, it is not suitable for construction or buildings. It might be suitable for uses as board and other engineered wood product. Due to its scented smell, it can be used as fragmented sticks or for sculpturing.

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.

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