Leaflet No.6/2021

The Republic of the Union of Myanmar
Ministry of Natural Resources and Environmental Conservation
Forest Department

Study on Wood Properties of Two Indigenous Species from Kachin State, Myanmar

Win Oo Naing, Assistant Research Officer
Dr. Cho Cho Myint, Assistant Research Officer
Chaw Yupar Soe, Research Assistant-2
Forest Research Institute, Yezin

December, 2021

Contents

List of tables

List of Figures

Study on Wood Properties of Two Indigenous Species from Kachin State, Myanmar

Win Oo Naing, Assistant Research Officer
Dr. Cho Cho Myint, Assistant Research Officer
Chaw Yupar Soe, Research Assistant-2

Abstract

In this research, a single tree per species as Kyilan (*Shorea assamica* Dyer.) and Kalaung-ni (*Dysoxylum gotadhora* Mabb.) were collected from protected public forest of Myitkyina township in Kachin State. Physical and mechanical properties of these two species were conducted in accordance with American Society for Testing Material- ASTM D143-52(2007) and BS 373 (1957). Kyilan (*Shorea assamica* Dyer.) is a large and tall tree, producing relatively large volume of wood. It is a moderately heavy wood species with a basic specific gravity of 0.448. Its shrinkage value is somewhat high. Thus, it should be proper dried before use and also should be used in median construction due to its low strength of bending test results. Kalaung-ni (*Dysoxylum gotadhora* Mabb.) is a good timber in term of strength and the basic specific gravity is 0.664. It is a heavy wood species and it's comparable with the basic specific gravity of Thabye, Kyana and Kanyin-ni. But its shrinkage value is high. Thus, it should be properly dried before use. It should be used especially for building as beam and post due to its somewhat high strength of bending test results. But it would not be suitable for high quality wood products.

Key words: Two indigenous species, Kyilan (*Shorea assamica* Dyer.), Kalaung-ni (*Dysoxylum gotadhora* Mabb.), physical and mechanical properties.

ကချင်ပြည်နယ်မှစျေးကွက်ဝင်ဒေသမျိုးရင်းသစ်(၂)မျိုး၏သစ်ဂုဏ်သတ္တိများကို စူးစမ်းလေ့လာခြင်း

ဝင်းဦးနိုင်၊ လက်ထောက်သုတေသနအရာရှိ
ဒေါက်တာချိုချိုမြင့်၊ လက်ထောက်သုတေသနအရာရှိ
ဒေါ်ချောရူပါစိုး၊ သုတေသနလက်ထောက်–၂

စာတမ်းအကျဉ်း

ဤသုတေသနစာတမ်းတွင် စျေးကွက်ဝင်ဒေသမျိုးရင်း သစ်(၂)မျိုးဖြစ်သည့် ကြေးလံ (*Shorea assamica* Dyer.) နှင့် ခလောင်နီ(*Dysoxylum gotadhora* Mabb.) သစ်တစ်ပင်စီကို ကချင်ပြည်နယ်၊ မြစ်ကြီးနားမြို့နယ်အတွင်းရှိ ကြိုးပြင်ကာကွယ်တောအတွင်းမှ ရယူ စုဆောင်းခဲ့ပါသည်။ ၎င်းသစ်(၂)မျိုး၏ ရူပနှင့်အင်အားဆိုင်ရာဂုဏ်သတ္တိများကို ASTM D-143-52 (2007) နှင့် BS 373(1957) စံချိန်စံညွှန်းများနှင့်အညီ ဆောင်ရွက်ခဲ့ပါသည်။ ကြေးလံသစ်သည် အရွယ်အစားကြီးမားပြီး သစ်ထွက်အားကောင်းသော သစ်မျိုးဖြစ်ကာ အတော် အသင့်လေးသော သစ်မျိုးထဲတွင် ပါဝင်ပါသည်။ ကျုံ့မှုတန်ဖိုး အတော်အသင့် မြင့်မားသည့် အတွက် အသုံးမပြုမီ စနစ်တကျ အခြောက်ခံသင့်ပါသည်။ အင်အားပိုင်းဆိုင်ရာ ဂုဏ်သတ္တိဖြစ်သည့် ကွေးညွှတ်ခံနိုင်မှုအင်အား နည်းသည့်အတွက် အလယ်အလတ် တည်ဆောက်ရေး လုပ်ငန်းများတွင်သာ အသုံးပြုသင့်ပါသည်။ ခလောင်နီသစ်သည် လေးသောသစ်မျိုးစာရင်း တွင်ပါဝင်ပြီး ဒေသတွင်း သစ်မျိုးများဖြစ်သည့် သပြေ၊ ကျန်၊ ကညင်နီသစ်မျိုးများနှင့် နှိုင်းယှဉ်နိုင်သော သစ်မျိုးဖြစ်ပါသည်။ သို့သော် ကျုံ့မှုတန်ဖိုး မြင့်မားသည့်အတွက် စနစ်တကျ အခြောက်ခံပြီးမှသာ အသုံးပြုသင့်ပါသည်။ ၎င်းကို အိမ်ရာ တည်ဆောက်ရေးလုပ်ငန်းများတွင် အသုံးပြုသင့်ပြီး အထူးသဖြင့် ယက်မနှင့် တိုင်ကဲ့သို့သော နေရာများနှင့်သင့်တော်ကာ သာမန်အားဖြင့် အဆင့်မြင့်ပရိဘောဂများပြုလုပ်ရန် မသင့်တော်ကြောင်း တွေ့ရှိရပါသည်။

Study on Wood Properties of Two Indigenous Species from Kachin State, Myanmar

1. Introduction

According to the Global Forest Resource Assessment (2015), natural forests resources occupy 42.92% or about 29,041,000 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.

Timbers are useful for various engineering purposes such as roof trusses, door, windows, staircases, bridge and many others. Therefore, it is necessary to know basic wood properties for exploration of end-uses of wood species. Physical properties such as moisture content and basic specific gravity are the indicative of mechanical properties of some wood species.

Myanmar forests are diverse and rich in species as already known, especially in Kachin state. It is the second largest state in Myanmar. And also it is rich with valuable timber species. Among the species, many species are still left for testing the utilization-oriented properties. Of those species, tow indigenous species as Kyilan *(Shorea assamica* Dyer.) and Kalaung-ni (*Dysoxylum gotadhora* Mabb.) of Kachin State are untested until now to assess their suitability for proper uses.

Kyilan (*Shorea assamica* Dyer.) and Kalaung-ni (*Dysoxylum gotadhora* Mabb.) can grow abundantly in hilly region and especially can be found in Myitkyina district of the Kachin State. In those species, Kyilan is a large and tall tree, producing relatively large volume of wood. The timber is good for making a range of high quality products after proper drying. But the species has been threatened in recent year due to illegal logging in those areas.

And also Kalaung-ni (*Dysoxylum gotadhora* Mabb.) 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 situations are favorable its drying behavior, natural durability, anatomy characteristics and other properties would be tested by the respective researchers of the Forest Research Institute.

Therefore, keeping the assumption in mind that the information on the properties will promote the utilization of Kyilan and Kalaung-ni, their physical and mechanical properties were tested. In this study, the variation in physical and mechanical properties of two indigenous as Kyilan and Kalaung-ni of Kachin State in Myanmar was investigated in order to provide the information on the wood quality variation for specifying and classifying the utilization of species.

The objectives of this study are:

(1) To investigate the physical and mechanical properties of Kyilan and Kalaung-ni.
(2) To compare the investigated properties of Kyilan and Kalaung-ni with those of some Myanmar timber species.
(3) To afford reliable data for wood entrepreneurs, interest group, scholars and researchers.

2. Literature Review

Shorea assamica Dyer (Kyilan) is a tall deciduous tree growing up to 55 meters tall. The bole can be up to 150cm in diameter and has prominent buttresses. The tree is harvested from the wild for its wood, which is known as white meranti and is commonly traded. A major source of timber within its native range, the tree also used to be widely exploited for the resin it yields. It is very variable with 4 subspecies which occur in evergreen or semi-evergreen forest on fertile clay soils on well-drained flat or hilly country up to 1000 m altitude. The density of the wood is 420-680 kg/m^3 at 15% moisture content.

The genus *shorea* belongs to the family of Dipterocarpacea. It occurs in India, Myanmar, Thailand, Laos, Malaysia, Indonesia and the Philippines. The species occurring in individual areas are plenty. As many as 59 species or more in Malaysia, 32 species in the Philippines, 4 species in India, 16 species in Thailand, and 11 species in Myanmar are found (Desch, 1941). Genus *shorea* as a whole provides the highest exporting of the timber exploited in Malaysia and it is one of the genus commercially important in the countries of occurrence. Malaysia, Indonesia, Philippines and Thailand are exporting this timber.

Dysoxylum, which belongs to family Meliaceae, is widely distributed from South East Asia to Australia. About a dozen species of Dysoxylum such as D. binectariferum, D. malabaricum, D. hamiltonii, etc. are found in India and many of the Dysoxylum species are known to possess good medicinal and antimicrobial properties (Anon. 1952; Kritikar and Basu, 1981; Hisham, et al., 2001; Parcha and Gahlot, 2003). D. binectariferum is a rare tree, endemic to Western Ghats of India and takes years to grow. The crude extracts of the tree have been found to be highly effective against ovarian and breast cancer lines (Mohanakumara, et al., 2010).

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 properties 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 classifying strength as

beams, strength as post, columns, strength as tool handles, and strength as slippers. 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 are very considerably between and within species.

Even pieces of 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.

3. Materials and Methods

3.1. Materials

For each species, a single tree was collected from protected public forest of Myitkyina township in Kachin State. The trees were authenticated from herbarium material and anatomy identification. The measurements of the sample tree are shown in Table 1

Table 1: Girth at breast height, clear bole length and whole length of each species

Local Name	Scientific Name	GBH	Clear bole length	Whole length
		(cm)	(m)	(m)
Kyilan	*Shorea assamica* Dyer.	168	10.5	35
Kalaung-ni	*Dysoxylum gotadhora* Mabb.	137	7.1	30

3.2 Methods

Sample trees were tested for moisture content percent, specific gravity, density, shrinkage, static bending, compression parallel to grain and compression perpendicular to grain. Physical properties were investigated following American Society for Testing and Material-ASTM D143-52(2007) while strength properties were conducted in accordance with British Standard- BS 373-1957.

Figure 1: Photo showing tree sample collected in the forest

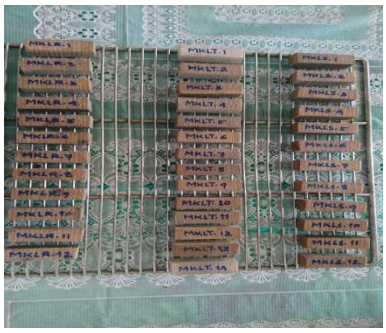

Figure 2: Photo showing wood samples

Figure 3: Photo showing measurement of dimension of wood sample

3.2.1 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 physical properties such as radial, tangential, longitudinal and volumetric shrinkage, density and specific gravity. The rest parts of the log were used for mechanical tests.
The sizes of specimens for this research were shown in Table 2.

Table 2: Number and size of specimens for physical tests

Sr. No.	Tests	Size of specimen (mm)	No. of specimens
1	Radial shrinkage	25 x 25 x 50	15
2	Tangential shrinkage	25 x 25 x 50	15
3	Longitudinal shrinkage	20 x 20 x 100	15
4	Volumetric shrinkage, Density, Specific gravity	20 x 20 x 100	15

Table 3: Number and size of specimens for mechanical tests

Sr. No.	Tests	Size of specimen (mm)	No. of specimens
1	Static bending	20 x 20 x 300	15
2	Compression parallel to grain	25 x 25 x 80	15
3	Compression perpendicular to grain	20 x 20 x 60	15

3.2.2 Testing procedures

After preparation of specimens for testing physical properties, they were sanded and cleaned to remove the loose material so that they could not affect the moisture content. They were weighed and measured for determination of shrinkage and moisture while green and the data were recorded. Then they were air-dried. When the specimens had attained constant weights and measurements under air-drying, the data was 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 and measurements were read nearest to the thousandth of a millimeter (mm) and weighted to the thousandth of a gram (g). The moisture contents were determined by the oven-dry method.

For mechanical properties, green and air-dry tests were conducted according to the designations in British Standard-BS. 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.1) Modulus of elasticity (MOE)
  a.2) Modulus of rupture (MOR)
  a.3) Fiber stress at proportional limit (FS@PL)
b) Compression parallel to grain
  b.1) Maximum crushing strength (MCS)
  b.2) Fiber stress at proportional limit (FS@PL)
c) Compression Perpendicular to grain
  c.1) Fiber stress at proportional limit (FS@PL)

4. Data analysis

In this research, the minimum, maximum, and standard deviation of physical and mechanical properties were calculated by using Microsoft Excel 2010.

5. Results and Discussion

5.1 Physical properties of Kyilan (*Shorea assamica* Dyer.)

The physical properties of **Kyilan** are presented in Table 4.

Table 4: Physical properties of Kyilan

Property	Minimum	Maximum	Mean	Standard deviation	CV%
Green MC%	76.39	94.50	86.40	4.97	6
Basic specific gravity	0.432	0.469	0.448	0.013	3
Specific gravity 12%	0.464	0.509	0.484	0.015	3
Basic density(Kg/m^3)	432	469	448	13	3
Density 12%(Kg/m^3)	519	570	541	16	3
Oven-dry density(Kg/m^3)	473	524	496	16	3
Shrinkage (green to air dry):					
Radial (%)	1.8	2.1	1.9	0.10	5
Tangential (%)	4.2	4.7	4.5	0.11	2
Longitudinal (%)	0.07	0.15	0.11	0.02	18
Volumetric (%)	5.1	6.3	5.7	0.33	6
Shrinkage (green to oven-dry)					
Radial (%)	3.0	3.5	3.2	0.16	5
Tangential (%)	7.1	7.8	7.5	0.19	2
Longitudinal (%)	0.12	0.25	0.19	0.04	21
Volumetric (%)	8.5	10.5	9.6	0.55	6

The mean moisture content of Kyilan is 86.4%. The minimum and maximum moisture content are 76.3 % and 94.5%. The basic specific gravity of Kyilan range from 0.432 to 0.469 and the mean basic specific gravity are 0.448.

It is higher than those of Kuthan and Uban(0.422), Sagawa(0.426), Taung-panne(0.435) and Ma-u-lettan-she(0.436). It is comparable with the basic specific gravity of Thitpagan(0.440). However, it is somewhat lower than Myaukngo(0.464), Yemane (0.469), Pyinma(0.529), Kokko(0.538), Leza(0.553) and Binga(0.554) (Table 5). The mean basic density and oven dry density are 448 kg/m^3 and 496 kg/m^3, respectively, while the mean density of Kyilan at 12% moisture content is 541 kg/m^3. The coefficient of variation can be high up to 10 % (USDA, 1999).These values of Kyilan is found less than 10%. According to the Win Kyi (2006), Kyilan is moderately heavy wood species.

Table 5: Comparison of Basic specific gravity of Kyilan and some Myanmar Timber Species

Local Name	Scientific Name	Basic Specific Gravity
Kyilan	*Shorea assamica* Dyer.	**0.448**
Kuthan	*Hymenodictyon excelsum* Wall.	**0.404**
Uban	*Shorea farinosa* C.E.C. Fischer	**0.422**
Sagawa	*Michelia champaca* Linn.	**0.426**
Taung-peinne	*Artocarpus chaplasha* Roxb.	**0.435**
Ma-u-lettan-she	*Anthocephalus cadamba* Miq.	**0.436**
Thitpagan	*Millettia brandisiana* Kurz	**0.440**
Myaukngo	*Duabanga grandiflora* (Roxb.)Walp.	**0.464**
Yemane	*Gmelina arborea* Roxb.	**0.469**
Pyinma	*Lagerstroemia speciosa* (L.) Pers.	**0.529**
Kokko	*Albizzia Lebbek* Benth.	**0.538**
Leza	*Lagerstroemia tomentosa* Presl.	**0.553**
Binga	*Mitragyna rotundifolia* (Roxb.) Ktze.	**0.554**

The mean of wood shrinkage from green to air-dry condition are 1.97% and 4.50% for the radial and tangential shrinkage, respectively. The corresponding values from green to oven dry are 3.28% and 7.50%. The values of coefficient of variation for radial and tangential shrinkage can be high up to 15% (USDA; 1989, 1999). It is found that these values for both properties are much less than 15%. Its shrinkage is comparable with that of Pyinma(3.1% and 7.4% from green to oven dry).

Like other wood species, the longitudinal shrinkage of Kyilin is very small. The mean longitudinal shrinkage from green to oven dry condition is only 0.19%. The different 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.

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 lass 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 Kyilan is 2.3 and can be said somewhat high comparable with 2. And also tangential shrinkage percent is somewhat higher than 7%. Thus, it would not be the best timber for high quality wood products.

5.2 Mechanical properties of Kyilan

Table (6) Mechanical Properties of Kyilan

Property	Seasoning	Minimum	Maximum	Mean	Standard deviation	CV%
Static Bending						
	Green	22	45	38	5	13
FS@PL(N/mm^2)	Air-dry	56	69	63	4	6
MOR(N/mm^2)	Green	35	69	58	8	
	Air-dry	85	103	96	5	5
MOE(N/mm^2)	Green	9850	16584	12985	1800	14
	Air-dry	12299	16446	14893	2476	16
Compression Parallel to grain						
	Green	3	24	11	7	63
FS@PL(N/mm^2)	Air-dry	12	33	27	6	22
MCS(N/mm^2)	Green	4	26	12	7	
	Air-dry	15	38	32	7	22
Compression Perpendicular to grain						
	Green	2	6	3	0.91	30
FS@PL(N/mm^2)	Air-dry	2	8	6	2	33

MOR= Modulus of Rupture; MOE= Modulus of Elasticity:
MCS= Maximum Crushing Strength; FS@PL= Fiber Stress at Proportional Limit

In static bending test, fiber stress at proportional limit of Kyilan is from 22 to 45 N/mm^2 at green condition and from 56 to 69 N/mm^2 at air-dry condition. The modulus of rupture of Kyilan is from 35 to 69 N/mm^2 at green condition and from 85 to 103 N/mm^2 at air-dry condition. Modulus of elasticity of Kyilan is from 9850 to 16584 N/mm^2 at green condition and from 12299 to 16446 N/mm^2 at air-dry condition.

And also compression parallel to grain and compression perpendicular to grain test results are presented in Table 6.

Table (7) Comparison of mechanical properties of Kyilan and some Myanmar Timber Species

No.	Species	Seasoning	Static Bending (N/mm$^{2)}$		Compression Parallel to grain (N/mm$^{2)}$	Compression Perpendicular to grain (N/mm$^{2)}$
			MOR	MOE	MCS	FS@PL
1.	**Kyilan**	**Green**	**58**	**12985**	**12**	**3**
		Air-dry	**96**	**14893**	**32**	**6**
2.	Kuthan	Green	46	9749	22	4
		Air-dry	**74**	**10570**	39	7
3.	Chinyok	Green	55	9777	28	8
		Air-dry	**84**	**10963**	44	8
4.	Sagawa	Green	56	10218	38	5
		Air-dry	**78**	**12204**	56	7
5.	Taung-peinne	Green	56	7143	26	7
		Air-dry	**50**	**7026**	37	8
6.	Ma-u-lettan-she	Green	57	10853	24	5
		Air-dry	**96**	**14583**	51	10
7.	Thitpagan	Green	14	2503	7	1
		Air-dry	**42**	**6750**	25	3
8.	Myaukngo	Green	43	7185	24	5
		Air-dry	**66**	**9798**	40	8
9.	Yemane	Green	59	10459	26	8
		Air-dry	**70**	**10136**	37	7
10.	Pyinma	Green	59	9777	27	4
		Air-dry	**86**	**10046**	43	11
11.	Kokko	Green	71	10177	33	8
		Air-dry	**99**	**12135**	51	12
12.	Leza	Green	69	11853	30	8
		Air-dry	**108**	**13611**	50	13
13.	Binga	Green	54	9281	29	7
		Air-dry	**82**	**11053**	42	12

MOR= Modulus of Rupture; MOE= Modulus of Elasticity:
MCS= Maximum Crushing Strength; FS@PL= Fiber Stress at Proportional Limit

The strength properties of Kyilan are comparable to those of Myanmar conventional timber species shown in table 7. At air-dry condition, MOR and MOE value of Kyilan is 96 N/mm^2 and 14893 N/mm^2. Its value is somewhat higher than those of Kuthan, Chinyok, Sagawa, Taung-peinne, Thitpagan, Myaukngo, Yemane, Pyinma and Binga. It is almost similar to Ma-u-lettan-she (MOR 96, MOE 14583 N/mm^2) and comparable with Leza(MOR 108, MOE 12135 N/mm^2) and Kokko(MOR 99, MOE 12135 N/mm^2.

5.3 Physical properties of Kalaung-ni (*Dysoxylum gotadhora* Mabb.)

The physical properties of **Kalaung-ni** are presented in table 8.

Table 8: Physical properties of Kalaung-ni

Property	Minimum	Maximum	Mean	Standard deviation	CV%
Green MC%	45.8	55.3	50.1	3.01	6
Basic specific gravity	0.648	0.673	0.664	0.01	1
Specific gravity 12%	0.723	0.756	0.743	0.01	1
Basic density(Kg/m^3)	723	756	664	7.79	1
Density 12%(Kg/m^3)	809	846	832	11.26	1
Oven-dry density(Kg/m^3)	758	816	786	15.39	2
Shrinkage (green to air dry):					
Radial (%)	4.4	4.9	4.7	0.14	3
Tangential (%)	5.1	5.8	5.5	0.20	4
Longitudinal (%)	0.07	0.28	0.17	0.06	35
Volumetric (%)	8.5	10.5	9.2	0.590	6
Shrinkage (green to oven-dry)					
Radial (%)	7.3	8.2	7.8	0.24	3
Tangential (%)	8.6	9.8	9.2	0.33	4
Longitudinal (%)	0.12	0.46	0.28	0.10	35
Volumetric (%)	14.1	17.5	15.4	0.983	6

The mean moisture content of Kalaung-ni is 50.1%. The minimum and maximum moisture content are 45.8 % and 55.3%. The basic specific gravity of Kalaung-ni ranges from 0.648 to 0.673 and the mean basic specific gravity is 0.664.

It is higher than those of Chinyok(0.601), Zaungbale(0.597), Taw-thayet(0.582), Kanyin-byu(0.574) and Binga(0.554). It is comparable with the basic specific gravity of Thabye(0.674), Kyana(0.670) and Kanyin-ni(0.0.655). However, it is somewhat lower than Pyinkado(0.779), Yon(0.762), Padauk(0.752), In(0.726) and Sit(0.720)(Table 9). The mean basic density and oven dry density are 664 kg/m^3 and 786 kg/m^3, respectively, while the mean density of Kalaung-ni at 12% moisture content is 832 kg/m^3. The coefficient of variation can be high up to 10%, (USDA, 1999). These values of Kalaung-ni is found less than 10%. According to the Kyi (2006), Kalaung-ni is a heavy wood species.

Table 9: Comparison of Basic specific gravity of Kalaung-ni and some Myanmar Timber Species

Local Name	Scientific Name	Basic Specific Gravity
Kalaung-ni	*Dysoxylum gotadhora* Mabb.	**0.664**
Chinyoke	*Garuga pinnata* Roxb.	**0.601**
Zaungbale	*Lagerstroemia villosa* Wall.	**0.597**
Taw-thayet	*Mangifera caloneura* Kurz.	**0.582**
Kanyin-byu	*Dipterocarpus alatus* Roxb.	**0.574**
Binga	*Mitragyna rotundifolia* (Roxb.) Ktze.	**0.554**

Thabye	*Eugenia jambolana* Lamk	**0.674**
Kyana	*Xylocarpus moluccensis* (Lam,)Roem.	**0.670**
Kanyin-ni	*Dipterocarpus turbinatus* Gaertn.f.	**0.655**
Pyinkado	*Xylia xylocapus* Benth.	**0.779**
Yon	*Anogeissus acuminate* Wall.	**0.762**
Padauk	*Pterocarpus macrocarpus* Kurz.	**0.752**
In	*Dipterocarpus tuberculatus* Roxb.	**0.726**
Sit	*Albizia procera* Benth.	**0.720**

The mean of wood shrinkage from green to air-dry condition are 4.71% and 5.53% for the radial and tangential shrinkage, respectively. The corresponding values from green to oven dry are 7.85% and 9.21%. The values of coefficient of variation for radial and tangential shrinkage can be high up to 15% (USDA; 1989, 1999). It is found that these values for both properties are much less than 15%. Its shrinkage is comparable with that of Gangaw(6.0% and 9.5% from green to oven dry).

Like other wood species, the longitudinal shrinkage of Kalaung-ni is small. The mean longitudinal shrinkage from green to oven dry condition is only 0.28%. The different 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.

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 lass 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 Kalaung-ni is 1.2 and can be said suitable for making high quality wood products. But it radial and tangential shrinkage percent are somewhat higher than 7%. Thus, it should be properly dried before use.

5.4 Mechanical properties of Kalaung-ni

Table (10) Mechanical Properties of Kalaung-ni

Property	Seasoning	Minimum	Maximum	Mean	Standard deviation	CV%
Static Bending						
FS@PL(N/mm^2)	Green	41.2	66.3	54.1	7.8	14
	Air-dry	46.0	91.0	74.0	13.0	17
MOR(N/mm^2)	Green	60.7	96.1	81.5	11.1	14
	Air-dry	51.0	145.0	112.0	26.0	23
MOE(N/mm^2)	Green	11940	18279	15803	1723	11
	Air-dry	15117	24594	18333	3060	17
Compression Parallel to grain						
FS@PL(N/mm^2)	Green	20.2	30.4	25.9	3.0	11
	Air-dry	27.5	48.7	34.6	7.2	21

MCS(N/mm^2)	Green	20.4	32.6	28.1	3.0	11
	Air-dry	30.8	53.1	39.1	7.2	18
Compression Perpendicular to grain FS@PL(N/mm^2)	Green	6.1	10.6	7.8	1.2	15
	Air-dry	9.4	16.8	12.0	2.2	18

MOR= Modulus of Rupture; MOE= Modulus of Elasticity:
MCS= Maximum Crushing Strength; FS@PL= Fiber Stress at Proportional Limit

According to the research results, fiber stress at proportional limit of static bending test of Kalaung-ni is from 41 to 66 N/mm^2 at green condition and from 46 to 91 N/mm^2 at air-dry condition. The modulus of rupture of Kalaung-ni is from 61 to 96 N/mm^2 at green condition and from 51 to 145 N/mm^2 at air-dry condition. Modulus of elasticity of Kalaung-ni is from 11940 to 18279 N/mm^2 at green condition and from 15117 to 24594 N/mm^2 at air-dry condition.

And also compression parallel to grain and compression perpendicular to grain test results are presented in table 10.

Table (11) Comparison of Mechanical Properties of Kalaung-ni and some Myanmar Timber Species

No.	**Species**	**Seasoning**	**Static Bending (N/mm^2)**		**Compression Parallel to grain (N/mm^2)**	**Compression Perpendicular to grain (N/mm^2)**
			MOR	**MOE**	**MCS**	**FS@PL**
1.	**Kalaung-ni**	**Green**	**81**	**15803**	**28**	**8**
		Air-dry	**112**	**18333**	**39**	**12**
2.	Chinyok	Green	55	9777	28	8
		Air-dry	**84**	**10963**	44	8
3.	Zaungbale	Green	**79**	**12239**	34	6
		Air-dry	**99**	**13776**	54	7
4.	Kanyin-byu	Green	**65**	**10191**	31	5
		Air-dry	**86**	**13073**	45	6
5.	Binga	Green	**73**	**9170**	36	7
		Air-dry	**97**	**11052**	52	9
6.	Kyana	Green	**77**	**10156**	39	8
		Air-dry	**97**	**11880**	60	11
7.	Kanyin-ni	Green	**76**	**13928**	40	6
		Air-dry	**108**	**15445**	53	8
8.	Pyinkado	Green	**107**	**15617**	55	12
		Air-dry	**142**	**17444**	79	15

9.	Yon	Green	**91**	**13197**	45	9
		Air-dry	**133**	**14990**	65	15
10.	Padauk	Green	**110**	**13080**	57	14
		Air-dry	**142**	**14321**	75	19
11.	In	Green	**80**	**12093**	39	8
		Air-dry	**96**	**13542**	47	6
12.	Sit	Green	**96**	**14859**	33	7
		Air-dry	**140**	**17533**	76	18

MOR= Modulus of Rupture; MOE= Modulus of Elasticity:
MCS= Maximum Crushing Strength; FS@PL= Fiber Stress at Proportional Limit

The strength properties of Kalaung-ni are comparable to those of Myanmar conventional timber species shown in table 11. At air-dry condition, MOR, MOE value of Kalaung-ni is 112 N/mm^2 and 18333 N/mm^2. Its value is somewhat higher than those of Chinyok, Zaungbale, Kanyin-byu, Binga, In and Kyana. It is nearly similar to Kanyin-ni (MOR 108 N/mm^2, MOE 15445 N/mm^2). However, It is somewhat lower than those of Pyinkado (MOR 142 N/mm^2, MOE 17444 N/mm^2), Yon (MOR 133, MOE 14990 N/mm^2), Sit(MOR 140 N/mm^2, MOE 17533 N/mm^2) and Padauk (MOR 142 N/mm^2, MOE 14321 N/mm^2).

6. Conclusion

Kyilan (*Shorea assamica* Dyer.) is a large and tall tree, producing relatively large volume of wood. It is a moderately heavy wood species with a basic specific gravity of 0.448, which is comparable with Thitpagan (0.440). But its shrinkage value is lower than that of Thitpagan. The mean shrinkage value of Kyilan is somewhat high at green to oven-dry condition (Radial 3.28 %, Tangential 7.50 %). Thus, it should be properly dried before use. And also should be used in light construction due to its low strength of bending test results.

Kalaung-ni (*Dysoxylum gotadhora* Mabb.) is a good timber in term of strength and the basic specific gravity is 0.664. It is a heavy wood species and it's comparable with the basic specific gravity of Thabye, Kyana and Kanyin-ni. The mean shrinkage value of Kalaung-ni is somewhat high. Thus, it should be properly dried before use. It should be used especially for house building as beam and post due to its somewhat high strength of bending test results. But it would not be suitable for high quality wood products.

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

There is avariability in wood properties between and within tree, 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 zone to overcome the variation within threes.

Acknowledgements

Firstt of all, we would like to thank to Director General, Forest Department for giving us guidance and permission to do this research and also thanks to Director, Forest Research Institute, Yezin who helped to us permission from Director General, Forest Department. Moreover, we would like to express thanks to the Director of Forest Department of in Kachin State and U Naing Naing Tun, Assistant Director of Kachin State who helped us tree sample collection and logistic supports. Finally, we would like to thank all of people, who support us with information for this paper.

References

1. Anonymous. 2007. ASTM Standards of testing for small clear specimens of timber ASTM Designation: D 143-52 (2007)
2. Anonymous. 1961. Some common commercial hardwoods of Burma. Forest Research and Training Circle, Government Timber Depot, Ahlone, Rangoon, Burma.
3. Desch. H. E. 1941. Dipterocarp Timber of the Malay Peninsula.
4. Food and Agriculture Organization. (2015): Global Forest Resource Assessment
5. Forest Research Institute, 2000. Handbook of lesser-used timber species in Myanmar, Forest Department, Ministry of Forestry and International Tropical Timber Organization (ITTO), Yangon, Myanmar
6. Hundley. H. G. 1962. Standard Nomenclature of Forest Plants, Burma, Forest research & Training Circle, Forest Department, Burma.
7. IUCN (International Union for the Conservation of Nature).2012. IUCN Red List of threatened species. WWW.iucnredlist.org.
8. Sepilok J. J. 2004. Some wood properties of *Xylia xylocarpa* planted in Sabah Bulletin 1: 1-15 (2004)
9. Kyi W. Myint C. C. and W. O. Naing. 2003. Density and specific gravity of fifty-four lesser-used timber species of Myanmar.
10. Kyi W. 2000. Market Study on Myanma Lesser-Used Timber Species. Forest Research Institute, Yezin, Myanmar.
11. LAMB. D. 2011. Greening the Bare Hills: Tropical Forest Restoration in the Asia-Pacific Region. Springer, New Yok.
12. Negi, S. S., I.F.S.,1997: Wood science and technology. Applied Forestry Series No.2. Dehra Dun, India.
13. Salang, A. T., W. AIbrahim, W.A.W & Kuroda. N. 1996. Intra-stem variation of basic density and green moisture content of nine species found in Sarawak. Kuching, Sarawak, Malaysia, Research Product semina,11-13 March.
14. Sint K.M & C.C Myint, 2003. A study on Variations in Physical and Mechanical Properties of Two Myanmar Lesser-Used Timber Species.
15. Sint K.M & C.C Myint, 2004. Preliminary Study on Physical and Mechanical Properties of Yinma.
16. Tint S. 1982 Physical and Mechanical Properties of Leza. Forest Research Institute, Yezin, Myanmar.
17. Tint S. & T. Swe. 1991. Physical and Mechanical Properties of Kanyaung (*Shorea argentea* C.E.C Fisher), Forest Research Institute, Yezin, Myanmar.

18. USDA, 1999. Wood handbook –wood as an engineering material Gen.Tech. Rep. FPL-GTR-13.Madison.WI:U.S.Department of Agriculture, Forest Service, Forest Product Laboratory.463p.

19. Win C. C. & W. Kyi-1. 2008. Density, Specific Gravity and Dimensional Stability of Seventy- Five Timber Species in Myanmar

20. ဝင်းချစ်– သစ်သားဆိုင်ရာနည်းပညာ(၂၀၀၆)