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Study on Utilization- oriented Technological Properties of Bebya (*Cratoxylum neriifolium* Kurz.)

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ပဲ့ပြားသစ်၏ အသုံးချမှုဆိုင်ရာနည်းပညာဂုဏ်သတ္တိများကိုလေ့လာခြင်း

ဒေါက်တာချိုချိုမြင့်၊ လက်ထောက်သုတေသနအရာရှိ
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ချိုချိုဝင်း၊ လက်ထောက်သုတေသနအရာရှိ
စုစုလှိုင်၊ လက်ထောက်သုတေသနအရာရှိ
ခရစ္စတီနေဝင်း၊ လက်ထောက်သုတေသနအရာရှိ

စာတမ်းအကျဉ်း

ဤသုတေသနစာတမ်းတွင် ပဲ့ပြားသစ်၏ ရူပဆိုင်ရာဂုဏ်သတ္တိများ၊ ကြာရှည်ခံမှု၊ အခြောက်ခံမှု ဆိုင်ရာလက္ခဏာများနှင့် အဆိုပြုပေါင်းခံဇယားတို့ကို စမ်းသပ်ဖော်ထုတ်ထားပါသည်။ ပဲ့ပြားသစ်သည် ရေချိန်သိပ်သည်းဆ ၀.၆၃၃ ရှိသဖြင့် လေးသောသစ် ဖြစ်ပါသည်။ ယင်းသစ်၏ အစိုဓာတ်ပါဝင်မှုမှာ ၇၄.၀၅ % ဖြစ်ပါသည်။ အစိုအခြေအနေမှ ပေါင်းခံအခြောက်အခြေအနေ အထိ အခြောက် ခံရာတွင် ပျမ်းမျှအားဖြင့် နှစ်ကွင်းနှင့်ထောင့်မတ်ကျ ကျုံ့မှုသည် ၄.၆၄%၊ နှစ်ကွင်းနှင့် အပြိုင်ကျုံ့မှု သည် ၉.၉၃ % နှင့် သစ်ကြောအလိုက်ကျုံ့မှုသည် ၀.၁၇%ဖြစ်သဖြင့် ကျုံ့မှုတန်ဖိုးမြင့်မားပါ သည်။ ပဲ့ပြားသစ်သည်ကျုံ့ကွဲမှုများပြီး ပုံသဏ္ဌာန်တည်မြဲမှုတန်ဖိုးမှာ ၂ ထက်ကြီးသဖြင့် အရည် အသွေးမြင့် ပရိဘောဂများ ပြုလုပ်ရာတွင် အသုံးပြုရန် မသင့်ပေ။ ပဲ့ပြားသစ်၏ အမြင့်ဆုံး ရေစုပ်ယူမှုမှာ ၅၈၂ . ၃၇ kgm^{-3} ဖြစ်ပြီး ကုက္ကို၊ ပျဉ်းမ၊ တောသရက် နှင့် တောင်သရက်တို့ ထက်နည်းကြောင်း တွေ့ရှိရပါ သည်။ ကြာရှည်ခံနိုင်မှု စမ်းသပ်ချက်များအရ ပဲ့ပြားသစ်သည် အသင့်အတင့် ကြာရှည် ခံသော သစ်မျိုးဖြစ်ပြီး ခြစားမှုကိုခံနိုင် ကြောင်း တွေ့ရှိရပါသည်။ အခြောက်ခံမှုဆိုင်ရာ သွင်ပြင် လက္ခဏာ များတွင် မျက်နှာပြင်နှင့် ထိပ်အက်ကွဲမှုများသည် အတော်အတန်ဖြစ်ပေါ်ပြီး အတွင်း ပိုင်းအက်ကွဲမှု များနှင့် ပုံပျက်မှုများ အနည်းငယ် ဖြစ်ပေါ်သည်ကို တွေ့ရှိရပါသည်။ ဤ အပြစ်အနာအဆာများအရ ပဲ့ပြားသစ်သည် ပေါင်းဖိုဖြင့် အခြောက်ခံရာတွင် အတော်အတန် ခက်ခဲသော သစ်မျိုးဖြစ်ပြီး ၂၅ မီလီမီတာ ထုသစ်များအား အပူချိန် ၅၅ ဒီဂရီစင်တီဂရိတ်နှင့် စိုထိုင်းဆ ၈၁ ရာခိုင်နှုန်းဖြင့် စတင် အခြောက်ခံသင့်ပါသည်။

Study on Utilization-oriented Technological Properties of Bebya (*Cratoxylum neriifolium* Kurz.)

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Abstract

This research paper investigated physical properties, durability, drying characteristics and proposed dry kiln schedule of Bebya **(***Cratoxylum neriifolium* Kurz.). Bebya is a heavy wood species with a basic specific gravity of 0.633. Its green moisture content is 74.05%. It has high shrinkage values with radial shrinkage of 4.64%, tangential shrinkage of 9.93% and longitudinal shrinkage of 0.17% from green to oven-dry condition. Its dimensional stability is greater than 2 and thus not suitable for high quality furniture. Its maximum water absorption is 582.37 kgm^{-3} and lower than those of Kokko, Pyinma, Tawthayet and Taungthayet. According to the durability test, Bebya is Moderately Durable and resistant to termite attack. In drying characteristics, moderate little checks in initial checks (surface and end checks), little mild checks of honeycombing (internal checks) and deformation were observed. According to these defects, Bebya is a moderately refractory timber and boards with a thickness of 25 mm should be dried with an initial temperature (DBT) 55˚C and 81% relative humidity (RH) in the early stage of kiln drying.

Key words: Bebya (*Cratoxylum neriifolium* Kurz.), Physical properties, Durability, Drying characteristics and proposed temperatures and relative humidities

Study on Utilization- oriented Technological Properties of

Bebya (*Cratoxylum neriifolium* Kurz.)

1. Introduction

Forestry plays a major role in Myanmar because of financial and environmental reasons. However, the number of tree species involved in the trade was barely a dozen- compared to hundreds of timber species in the forest. The commercially important timbers are including Teak, Pyinkado, Padauk, Thitya, Ingyin, Tamalan, In, Kanyin, Thinwin, Taung-Thayet and Hnaw. Yon, Taukkyan, Sagawa, Binga, Kokko, Tinyu and Yindaik sometimes appeared on the list of timber export. But the amount was very small.

The rest of the species, perhaps, be utilized locally or left intact in the Forest. Preliminary studies indicated that a number of timber species which are currently commercially unimportant were proved to be comparable to commercial species in many aspects. Selective exploitation of only the high value species, leaving in the forest a majority of the species of currently non-market table, would eventually lead to the lowering of the value of the forest. To compensate for such stock imbalances, it is needed to promote the proper utilization of yet invaluable species.

There are about 700 wood species which attain merchantable sizes in Myanmar (Han et.,al, 1999), only a part of which have been widely utilized since their properties and processing technologies are already known. Meanwhile, the rest species remain unknown, lesser used except using by local people and on un-commercial status because of inadequate data on technological properties that relates to the utilization of the species. Therefore, it needs effort to upgrade proper (better) utilization of these lesser-used species.

Kyaukmasin is one of the reserved forests with useful timber species. Many species are still left for testing the utilization-oriented technological properties. Bebya (*Cratoxylum neriifolium* Kurz.) is one of the species among them. According to inventory data collected for Modified Myanmar Selection System Project in 2017 (Data unpublished), Bebya is one of 112 timber species growing in Compartment No 20, Kyaukmasin Reserved Forest, which is situated in Yetashe Township, Bago District and its composition stands at 13th place with 2.29%. Therefore, its species composition is relatively high. This species has not been investigated yet. Therefore, Bebya species was investigated to improve its utilization.

2. Objectives

The objectives of this paper and the forthcoming ones are to find out the various properties of the commercially non-marketable timber, Bebya and to give suggestions for proper utilization of the species.

The specific objectives of this research are:

(1) to present the test result of physical properties, durability, drying characteristics and proposed dry kiln schedule of Bebya species

(2) to recommend the suitable utilization of Bebya Species

(3) to use the data for wood entrepreneurs and scientific researchers

3. Literature Review

Specific gravity is the density of wood relative to the density of water, and for this reason the terms *relative density* is sometimes used. Specific gravity is used as a basis to standardize comparisons among species and products.(Forest Product Laboratory, 1999).

Wood is a hygroscopic material, continually giving off or taking on moisture in accordance with the relative humidity and temperature to which it is exposed (Forest Products Laboratory, 1951). Wood normally shrinks as it dries and swells as it absorbs moisture. The use of insufficiently dried lumber that shrinks under service conditions commonly results in subsequent checking, opening of joints, loosening of nails, and the warping and distortion of wood structures as a whole. If lumber is dried too far below the moisture content it will reach in use, swelling may cause drawers, windows, and doors to stick (Forest Products Laboratory, 1957).

The moisture content at which only the cell walls are completely saturated (all bound water) but no water exists in cell lumens is called the fiber saturation point. The fiber saturation point of wood averages about 30% moisture content, but in individual species and individual pieces of wood it can vary by several percentage points from that value (Forest Product Laboratory, 1999).

Wood is exposed to both periodic water absorption and desorption process. In residential buildings and in industrial applications some of the components are often of wood or wood based. The ability of micro-organisms to attack wood depends on the moisture content of the wood cell wall. Wood changes dimensions as it gains or loses moisture from the cell wall and swells when gaining moisture in the cell wall. This shrinking and swelling can result in warping, checking, splitting and loosening of tool handles, gap in wooden applications or performance problems that detract from the usefulness of wood products. (Jain, S. K. and Kurhekar, S.P, 2015) .

And also wood is anisotropic material. Anisotropic characteristics of wood swell when exposed to a humid condition and shrink non-uniformly into a smaller dimension when subjected to a condition of lower humidity. It shrinks most in the direction of the annual growth ring (tangentially), about half as much across the rings (radially), and only slightly along the grain (longitudinally) (Forest Product Laboratory, 1999). This shrinkage anisotropy results in to drying defects like warping, cupping, bowing, twisting, checking, splitting, honeycombing, collapse, casehardening, distorting, etc.

Honeycombing in samples is the separation of the fibers in the interior of the piece, usually occurs along the rays. The failures can be the extended result from surface and end checks. It could weaken the wood strength, thus affect the quality and the value of wood (Phonetip et al., 2017). It is invisible within the inner side of the wood and can only be viewed when the wood is further re-sawn. Therefore, it is considered to choose the best drying condition that will not allow the development of any honeycomb in the wood (KarnitaYunaiarti et al., 2017).

Not every wood species is easy to be kiln-dried without developing any defect. According to Effah (2014) each wood species has its own sensitivity to drying defects and drying temperature. And also, Yuniarti *et al.* (2015) has even proven that the sensitivity of one particular species will be also different under different drying temperatures. Therefore, it is assumed that each wood will also have different drying schedule which is adjusted based on the wood moisture content and drying characteristics to be applied in a kiln.

Despite many advantages, it has also disadvantages. One of its disadvantages is biological degradation. Due to sugars and starch in untreated wood, it is a source of food for a variety of fungi, insects and other organisms. Given the right circumstances, they can break down and consume the cellulose, lignin and other components of wood and damage the wood members of a structure (Milton, 1995). Thus, it is also necessary to test natural durability of lesser-used timber species.

4. Materials and Methods

4.1 Materials

Bebya (*Cratoxylum neriifolium* Kurz.) was studied in this research. One sample tree of tested specie was collected from Compartment No 20, Kyaukmasin Reserved Forest, which is situated in Yetashe Township, Bago District. This species was identified in wood Anatomy section from Forest Research Institute. The collected material was tested for physical properties, durability, drying characteristics and proposed dry kiln schedule.

4.1.1 Physical properties

Physical properties was investigated in accordance with the procedures given in (American Society for Testing Material) ASTM D-143-52 (2007) and German Standard DIN 52184. The photos of Bebya wood samples and physical properties testing were shown in Figures (1-3). Number and size of specimens for physical properties were shown in Table 1. The digital caliper, oven and electric balance were used for this study.

Figure1. Wood samples for Radial and Tangential Shrinkage

Figure 2. Drying Wood samples in an oven

Figure 3. Soaking wood samples in wax to find oven-dry volume

Table 1. Physical properties, size of specimen and number of specimens for Bebya Species

Sr. No	Physical Properties	Size of specimen (mm)	Number of specimens
1	Moisture content, specific gravity, density, longitudinal shrinkage, volumetric shrinkage	25.4 mm x 25.4 mm x 101.6 mm	7
2	Shrinkage (Radial, Tangential), Dimensional stability	25.4 mm x 25.4 mm x 88.9 mm	7
3	Swelling (Radial, Tangential, Longitudinal), Swelling anisotropy	30 mm x 30 mm x 10 mm	10
4	Fiber saturation point	30 mm x 30 mm x 10 mm	10
5	Water absorption	30 mm x 30 mm x 10 mm	10

4.1.2. Wood durability

Sample preparation was carried out at Saw-mill of FRI. 12.5 mm x 12.5 mm x 25 mm blocks were prepared for decay resistance test and 20mm x 20mm x 20 mm blocks were prepared for termite resistance test. Fifteen replications were selected for each test. These blocks were free from knots, drying defects and without visible evidence of fungus infection. All the test blocks were conditioned by oven-drying for 48 hours at 60ºC and weighed periodically until constant weights were attained. These test blocks were used for the field test.

The test site at FRI, highly susceptible to subterranean termites was chosen for study. The design of the field test procedure is as follows: a ditch of consistently 15-20 cm depth is dug to partly layer with residues from coconut fibers and susceptible wood veneers (to bait and aggregate termites). After two weeks later, the bait veneers were covered with termites. The site was ready to test.

4.1.3. Drying characteristics

In this study, the base log (3m, 9 ft) was used and the lumber pieces were cut in a tangential direction. Free defects eighteen flat-sawn samples for tested species was further sawn into specific sizes of 20 mm thickness x 100 mm width x 200 mm length and planed smooth surface by planning machine. After preparation the required size, specimens were labeled on the surface, and also, the specimens were maintained in green condition before running test by fully immersing in water. The equipment used is as follow.

(a) Oven- Laboratory Hot Air Oven (natural air circulation) set at 103±2˚C

(b) Balance -Electric balance (weighing range 0-3,000 g, minimum readability 0.01g)

(c) Measuring Instrument- Digimatic caliper (maximum length 150 mm, minimum readability 0.05 mm) to measure length, width of defects and deformations of samples

4.2 Methods

4.2.1 Physical Properties

4.2.1.1 Moisture content

Moisture content is generally expressed as a percentage of the dry weight of the wood. Moisture content of Bebya wood samples was determined by using oven-dry method. The green weight was obtained by weighing saturated Bebya wood samples after soaking them in the water. The wood samples were dried in an oven at 103±2 °C until constant weight was attained to get oven-dry weight. The weight of specimen was determined using electric balance. The moisture content was determined as follows:

$$MC\ (\%) = \frac{(\text{Green Weight} - \text{Oven- Dry Weight})}{(\text{Oven - Dry Weight})} \times 100$$

where M.C % is moisture content of wood sample.

4.2.1.2 Density

Density is the mass contained in a unit volume of material (Tsoumis, 1991). The determination of density by measurement of mass and volume takes a considerable period of time (Dinwoodie, 2000). Thus, weight was used instead of mass. Green density, oven dry density and air-dry density were calculated as follows:

Green density $= W_g / V_g$

Oven dry density $= W_{od} / V_{od}$

Air-dry density $= W_{ad} / V_{ad}$

Where W_g = Green weight of wood, V_g = Green volume of wood

W_{od} = Oven-dry weight of wood, V_{od} = Oven- dry volume of wood

W_{ad} = Air-dry weight of wood, V_{ad} = Air-dry volume of wood

Moreover, air-dry density at 12% moisture content was estimated as follows:

$$\rho = G\ (1+ 0.01\mu)\ \rho_w$$

Where ρ is the density at moisture content µ. G is the specific gravity at moisture content µ and ρ_w is the density of water.

4.2.1.3 Specific gravity

Specific gravity is the ratio of the weight of the wood to the weight of an equal amount of water at a given temperature (usually at 4°C). It is expressed in terms of dry or oven dry weight which is obtained after the wood is dried in an oven set at a constant temperature of more than 100°C (Negi, 1997). In this research, basic specific gravity was calculated as follows:

$$\boldsymbol{Basic\ specific\ gravity} = \frac{\boldsymbol{Oven - dry\ weight}}{\boldsymbol{Green\ volume}}\ \boldsymbol{x}\ \frac{\mathbf{1}}{\boldsymbol{Density\ of\ water}}$$

4.2.1.4 Shrinkage

4.2.1.4.1 Radial, Tangential and Longitudinal shrinkage

Shrinkage was calculated on the basis of dimensions in the green condition (above fiber saturation point). Radial, tangential and longitudinal shrinkage were calculated by using the following formula:

$$\boldsymbol{a}\ \% = \frac{\boldsymbol{L1 -\ L2}}{\boldsymbol{L1}}\ \boldsymbol{x}\ \mathbf{100}$$

where ***a%*** is radial, tangential and longitudinal shrinkage of specimen, respectively. L_1 represents radial or tangential or longitudinal green dimensions of the specimen and L_2 represents radial or tangential or longitudinal dry dimensions of the specimen. The dimensions of specimens were measured using a digital caliper.

4.2.1.4.2 Volumetric shrinkage

Volumetric shrinkage was determined by using the following formula, in which volume was determined by water displacement method.

$$\mathbf{V.S\%} = \frac{\boldsymbol{Vol\ green - Vol\ dry}}{\boldsymbol{Vol\ green}}\ \boldsymbol{x}\ \mathbf{100}$$

where V.S % is volumetric shrinkage of specimen.

Vol_{green} is volume of specimen at green condition.

Vol_{dry} is volume of specimen at dry condition.

4.2.1.5 Swelling

Radial, tangential, longitudinal and swelling anisotropy were determined according to DIN 52184 as follows:

$$S_R = \frac{L_s - L_0}{L_0}\ x\ 100 \quad (\%)$$

$$S_T = \frac{L_s - L_0}{L_0}\ x\ 100 \quad (\%)$$

$$S_L = \frac{L_s - L_0}{L_0}\ x\ 100 \quad (\%)$$

Swelling Anisotropy = $\frac{S_T}{S_R}$

where S_R, S_T, S_L are radial, tangential and longitudinal swelling of a specimen, respectively. L_s and L_o represent radial or tangential or longitudinal dimensions of the specimen in saturated and oven-dry conditions. The dimensions of specimens before and after soaking in water were measured using a digital caliper.

4.2.1.6 Fiber saturation point

Volume of the specimens in saturated and oven- dry conditions was determined by multiplying radial, tangential, longitudinal dimensions of the specimen in saturated and oven-dry conditions. Fiber saturation point (FSP) was calculated using the following formula:

$$FSP = \frac{V_{sat} - V_{dry}}{W_{dry}} \; x \; density \; of \; water \; x \; 100 \quad (\%)$$

where

FSP = fiber saturation point of a specimen (%),

V_{sat} = Volume of the specimen at fully swollen condition (cm^3),

V_{dry} = Volume of the specimen at oven- dry condition (cm^3) and

W_{dry} = oven- dry weight of the specimen (g).

4.2.1.7 Water absorption

Water absorption was determined as follows:

$$WA = \frac{W_{end} - W_{start}}{V} \; (kg/m^3)$$

where WA is water absorption by a specimen, W_{start} and W_{end} weights of the specimen at the start and after a specific time (after 1, 2, 3, 4 hour, etc.), and V volume of the specimen through which water diffuses.

4.2.1.8 Data analysis

For physical properties, minimum, maximum, mean, standard deviation and coefficient of variation was calculated by using Statistica Software.

4.2.2 Wood durability determination

4.2.2.1 Evaluation of termite resistance

Wood blocks were placed about (15-20cm) depth above the residue layer and additional amounts of residues added to conceal the blocks, and the ground covered with top soil. The blocks (5 replications) were kept together according to species to aid identification of the specimens at the end of test. After 16 weeks, the specimens were removed from the tested sites and cleaned up. The ground was unearthed, the blocks carefully retrieved, weighed immediately to determine the final wet weight and then oven dried. Determinations of final block moisture content (% g/g), absolute mass loss (in mg) and percentage mass loss (% g/g) were carried out. Then these final mass of specimens were weighed after 48 hour at 60°C in oven by the same way of determination of initial mass. The test blocks were also rated according to an arbitrary 0-5 visual scale. The grading by mass loss of specimen was corrected by visual observation.

4.2.2.2 Evaluation of decay resistance

Schyzophyllum commune, the white rot fungi were used in this study. Potatoes-Dextrose agar (PDA) media was used for the stock test tube culture and petridis culture of the test fungus. The samples were exposed to fungal attack by placing them over the fungus mycelium in the test tubes. Tiny chips of glass- rod were placed between wood samples and the fungus in order to prevent the direct contact between them. The test tube were placed at ordinary room temperature and incubated for 16 weeks. After completion of the incubation period, the blocks were taken out and attached mycelium was carefully cleaned. The test blocks were oven dried at 103 ± 2° C until the constant weights were obtained and then, the oven-dry weights were recorded to calculate the weight loss percentages of the test blocks.

4.2.2.3. Data analysis

To estimate the calculated oven dry weight of each test block, the average initial moisture content (MC) of the MC-samples was used. The MC of the samples was determined by using oven-dry method and MC was calculated by the following equation.

$$\text{MC (\%)} = \frac{\text{I.Wt - O.D Wt}}{\text{O.D Wt}} \times 100$$

where,

M.C	=	moisture content of the sample
I.wt	=	initial weight of the sample
O.D.wt	=	Oven Dry weight of the sample

The calculated oven dry weight of each test sample for vacuum-pressure treatment was calculated by using the following formula.

$$\text{C.O.D.Wt} = \frac{\text{I. Wt x 100}}{(100 + \text{M.C \%})}$$

where,

C.O.D.Wt =calculated oven dry weight of the sample

To determine the weight loss percent of each of the test samples the following formula was used.

$$\text{Wt. Loss (\%)} = \frac{(\text{C.O.D .Wt} - \text{F.O.D Wt})}{\text{C.O.D. wt}} \times 100$$

where,

C.O.D wt = calculated oven dry weight

F.O.D wt = final oven dry weight

Table 2. Durability Classification of Timber based on Weight Loss

Durability Class	Life of Test Stake in the field		Average loss in dry weight (%)
	England	Tropics	
Very Durable	Over 25 yr.	Over 10 yr.	Nil- or negligible
Durable	15 - 20 yr.	5 -10 yr.	Up to 5%
Moderately Durable	10 - 15yr	(not given)	5-10%
Non-Durable	5- 10 yr.	2 - 5 yr.	10-30%
Perishable	Less than 5 yr.	Less than 2yr	Over 30%

Source: W. P. K. Findlay (1985)

Table 3. Termite Resistance Classification of Timber based on Weight Loss

Termite resistance Class	Average loss in dry weight (%)	Visual Rating
Very Resistance (Class I)	0-6	Sound=1
Resistance (Class II)	7-10	Surface attack=2

Moderately Resistance (Class III)	11-14	Light attack=3
Non- Resistance (Class IV)	15-17	Heavy/Severe attack=4
Perishable(Class V)	Over 17	Completely destroyed=5

Source: P. K. SEN-SARMA (1975)

4.2.3 Drying characteristics

This study was carried out and evaluated with reference to Quick Drying Test method formulated by Terazawa, 1965 from Forestry and Forest Products Research Institute (FFPRI) of Japan. It is the most simple and effective empirical fast drying method used as starting point to predict wood drying characteristics and determine on appropriate drying schedule for any timber species.

4.2.3.1. Research procedures

Before running the test, each tested specimens was weighed for the initial green weight and the data was recorded to calculate the initial moisture content of the samples. The dimension of each specimen was measured using the digital caliper for thickness, width and length respectively and recorded. Six specimens of each orientation were tested in each drying test and they were placed stand erect at more than 75 mm apart each in the oven at temperature of 103 ± 2°C until oven-dry condition (moisture content of 1 %) was reached. Each experiment was replicated thrice to get the better results.

At the first eight hours on the first day drying, each of the samples was weighed and the appearance and development of initial checks including surface checks, end checks and end to surface checks were observed periodically every hour. One end face of each specimen was marked and selected for end-checking observation. On the second and subsequent days, changes in weight and development of checks of samples were monitored twice daily until an average moisture content of 1 % was reached. At the same time, the checks were measured and the data were recorded carefully.

When the test specimens were reached oven-dry condition, they were taken out from the oven and recorded the final weights, measured the final size of all samples. Afterwards, the test specimens were then half-cut to measure the deformation and honeycombing. To determine the deformation, the maximum (A) and minimum (B) thicknesses of each specimen along its freshly cut face were measured with digital clipper and the difference between the two measurements (A-B) recorded as cross sectional spool-like deformation. Likewise, the number of honeycombs and their sizes on newly exposed faces were examined, counted and measured carefully and mean value was determined.

According to the detailed procedure of Terazawa (1965) which was modified and adjusted by Jankowski (1992), level of checks, collapse, and honeycombing were graded based on Table (4). The most severe defect was used as primary indicator to estimate the drying conditions, i.e. initial and final temperatures as well as initial wet bulb depression for 1 inch (25 mm) thick timber of each species as described in Table (5), which is useful to determine the proposed drying schedule.

Table 4. Classification of defects based on Terazawa and modified by Jankowski.

Level of defects	Checks		Deformation (A-B) mm	Honeycomb
	End checks (mm)	Surface check(mm)		
1	No check	No check	0-0.3	No
2	L < 10 W< 0.8	L<50 W<0.5	0.3-0.5	1 ~2
3	L >10 W< 0.8	5<L<100 1<W<1.5	0.5-0.8	3~4
4	L < 10 0.8<W<1.5	L<150 W<1.5	0.8-1.2	5~7
5	L > 10 0.8<W<1.5	L>150 W>1.5	1.2-1.8	8~10
6	L > 10 W< 0.8	L>150 W>1.5	1.8-2.5	>10
7	L > 10 W< 0.8	L>150 W>1.5	2.5-3.5	
8	L > 10 W< 0.8	L>150 W>1.5	Over 3.5	

Note: L is length ,W is Width.

Table 5. Estimation the drying condition based on level of checks, deformation and honeycombing.

Variety of defect	Drying condition	Degrees of defects							
		1	2	3	4	5	6	7	8
I. Initial check	Initial temp. (^oC)	70	65	60	55	53	50	47	45
	W.B.depression(Initial)(^oC)	6.5	5.5	4.3	3.6	3.0	2.3	2.0	1.8
	Final temp. (^oC)	95	90	85	80	80	80	80	80
II. Deformation	Initial temp. (^oC)	70	66	58	54	50	49	48	47
	W.B.depr.(Initial)(^oC)	6.5	6.0	4.7	4.0	3.6	3.3	2.8	2.5

	Final temp. (^oC)	95	88	83	80	77	75	73	70
III.Honeycombing	Initial temp. (^oC)	70	55	50	49	48	45	43	40
	W.B.depr.(Initial)(^oC)	6.5	4.5	3.8	3.3	3.0	2.5	2.2	2.0
	Final temp. (^oC)	95	83	77	73	71	70	68	67

After finishing the drying process, initial MC of each species was determined and the patternized kiln schedule code number for each species was determined by using the levels of defects and initial moisture content U_a from Figure 4 and 5 which provided by Terazawa.

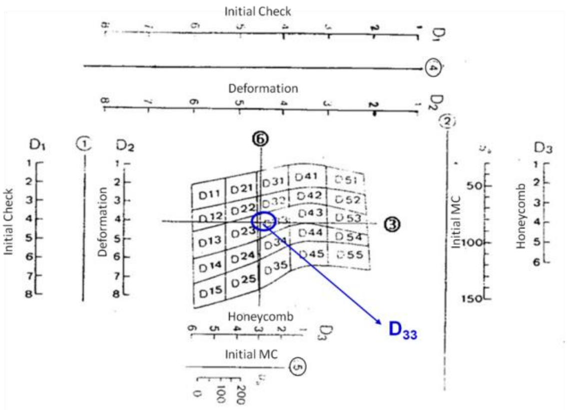


Figure 4. Chart for estimation of the code number of patternized dry bulb temperature schedule (Terazawa, 1965)

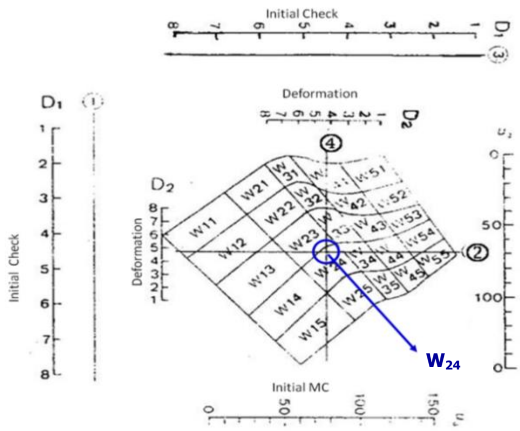


Figure 5. Chart for estimation of the code number of patternized wet-bulb depression schedule (Terazawa , 1965)

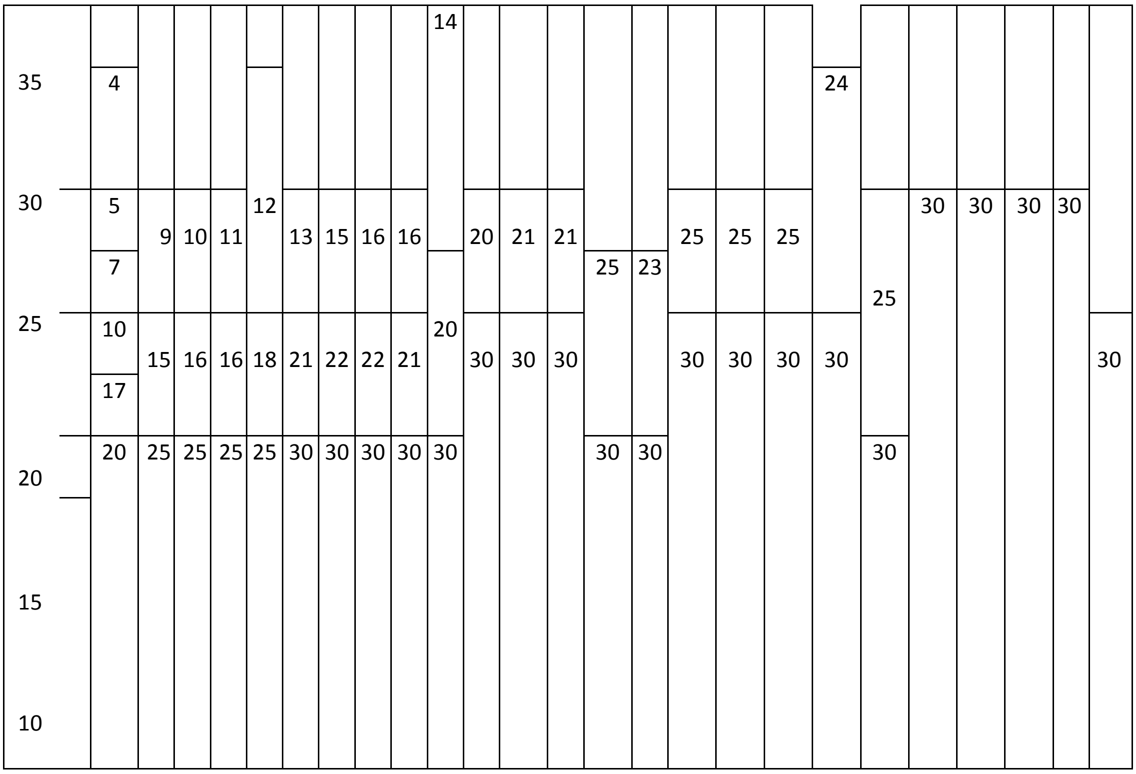
As a final step, the value of dry bulb temperature (DBT) and wet bulb depression (WBD) were found by using moisture content as indicator from Table 6 and 7 and the values of relative humidity (RH) were determined from Appendix I.

Table 6. Patternized dry bulb temperature schedule

Moisture content (%)	Dry bulb temperature for each schedule type (°C)																								
	D 11	D 12	D 13	D 14	D 15	D 21	D 22	D 23	D 24	D 25	D 31	D 32	D 33	D 34	D 35	D 41	D 42	D 43	D 44	D 45	D 51	D 52	D 53	D 54	D 55
					45					50					55					60					70
				45					50					55					60					70	
					50					55					60					65					75
60			45					50					55					60					70		
		45		50			50		55			55		60			60		65			70		75	
																					70				
50																									
	45		50		55	50		55		60	55		60		65	60		65		70			75		
		50					55					60		65			65		70			75			80
40																									
				55					60												75			80	
	50	55	55		60	55	60	60			60	65	65		70	65	70	70		75			80		
30																									
										65				70					75			80			
	55	60	60	60		60	65	65	65		65	70	70			70	75	75			80				
20					65										75					80			85	85	85
	60	65	65	65		65	70	70	70	70	70	75	75	75		75	80	80	80		85	85			
10																									
	70	70	70	70	70	75	75	75	75	75	80	80	80	80	80	85	85	85	85	85	90	90	90	90	90

Table 7. Patternized wet bulb depression schedule

MC (%)	Wet bulb depression for each schedule type (°C)																								
	W 11	W 12	W 13	W 14	W 15	W 21	W 22	W 23	**W 24**	W 25	W 31	W 32	W 33	W 34	W 35	W 41	W 42	W 43	W 44	W 45	W 51	W 52	W 53	W 54	W 55
																				5					7
															4				5	6				7	8
80																									
										3				4	5								7	9	10
70																									
																		5	7	8		7			
					2																				
60																									
									3	4			4	5	7		5				7		9	12	13
																		7	9	11					
																						10			
				2	3			3				4	5			5	7				9				
50									4.5	6				8	10								13	15	16
			2	3			3	4			4	5	7			7	9	10			12				
					5														13	14		15			
		2	3	4		3	4	6	7		6	7	9			10	12	13			16				
45										9				12	13								19	20	20
	2	3	5	6		5	6	8	9		9	10	12			14	15	16	18		20	20			
																				19					
40	3	6	7	8	8	8	10	11	12		13	15	16	18	18	20	20	20			25	25	25	25	25



5. Results and Discussion

5.1 Physical Properties

5.1.1 Moisture content

Table 8. Moisture content (M.C%) of Bebya (*Cratoxylum neriifolium* Kurz.)

Species	Number of specimen	Moisture content (%)			Standard Deviation	C.V (%)
		Min	Max	Mean		
Bebya	7	69.24	80.42	74.05	4.51	6.09

The moisture content of Bebya is shown in Table 8. Its minimum moisture content is 69.24% whereas its maximum moisture content is 80.42%. Its mean moisture content is 74.05% with a standard deviation of 4.51. The maximum possible moisture content of green wood can be 267% with a basic specific gravity of 0.3 and the minimum possible moisture content can be 44% with a basic specific gravity of 0.9 (Rowel, 2005). Bebya is found between this range. It is similar to Lettok (74.1%) and Nyan (74.7%) in term of moisture content (Kyi, 1993).

5.1.2 Density

Table 9. Density of Bebya (*Cratoxylum neriifolium* Kurz.)

Properties	Number of specimen	Min	Max	Mean	Standard Deviation	CV%
Green Density (kgm^{-3})	7	1081	1122	1101	12.99	1.18

Air-dry Density (kgm^{-3})	7	757	816	789	23.31	2.95
Oven-dry Density (kgm^{-3})	7	711	761	742	18.81	2.54
Basic Density (kgm^{-3})	7	610	653	633	16.83	2.66

The density of Bebya is shown in Table 9. Its green density ranges from 1081 kgm^{-3} to 1122 kgm^{-3} whereas its air-dry density is from 757 kgm^{-3} to 816 kgm^{-3} with the average of 789 kgm^{-3}. Based on air dry density, timbers can be classified as very light, light, moderately heavy, heavy, very heavy or extremely heavy. Woods with air-dry density of less than 300 kgm^{-3} are considered to be very light, those with 301 kgm^{-3} to 450 kgm^{-3} light, those with 451 kgm^{-3} to 600 kgm^{-3} moderately heavy, those with 601 kgm^{-3} to 800 kgm^{-3} heavy, those with 801 kgm^{-3} to 950 kgm^{-3} very heavy and more than 951 kgm^{-3} extremely heavy. In accordance with this classification, Bebya is a heavy wood species. There are many other ways of classification of woods based on their densities. According to Malaysian Grading Rules (Anonymous, 1984), timbers can also be classified as heavy hardwoods, medium hardwoods, light hardwoods and softwoods. Based on this grading rule, Bebya is a medium hardwood type as its air-dried density ranges from about 720 to 880 kgm^{-3}. The mean oven dry density of Bebya is 742 kgm^{-3} while its basic density ranges from 610 to 653 kgm^{-3} and the mean basic density of Bebya is 633 kgm^{-3} with a standard deviation of 16.83.

5.1.3 Specific gravity

Table 10. Specific gravity of Bebya (*Cratoxylum neriifolium* Kurz.)

Properties	Number of specimen	Min	Max	Mean	Standard Deviation	CV%
Basic Specific Gravity	7	0.610	0.653	0.633	0.017	2.69

Specific gravity of Bebya is shown in Table 10. The mean basic specific gravity of Bebya is 0.633 with standard deviation of 0.017. The basic specific gravity of Bebya (0.633), when compared with other species, is higher than those of Chinyoke (0.601) and Hnaw (0.601) but it is lower than those of Lein (0.644) and Nyan (0.650). It is comparable to the basic specific gravity of Thingan (0.637). Based on basic specific gravity, wood is classified as very light, light, moderately heavy, heavy, very heavy and extremely heavy. Wood with basic specific gravity of less than 0.28 is considered to be very light, 0.28 to 0.42 to be light, 0.42 to 0.56 to be moderately heavy, 0.56 to 0.70 to be heavy, 0.70 to 0.85 to be very heavy and above 0.85 to be extremely heavy (Negi, 1997). According to this classification, Bebya is a heavy wood species.

5.1.4 Shrinkage

Table 11. Shrinkage value for Bebya (*Cratoxylum neriifolium* Kurz.)

Sr. No.	Properties	N	Min	Max	Mean	Standard Deviation	CV%
1.	Radial Shrinkage (Green to oven dry) %	7	4.21	4.98	4.64	0.29	6.25

2.	Tangential Shrinkage (Green to oven dry) %	7	9.40	10.17	9.93	0.28	2.82
3.	Longitudinal Shrinkage (Green to oven dry) %	7	0.03	0.43	0.17	0.13	76.47
4.	Volumetric Shrinkage (Green to oven dry) %	7	14.21	15.13	14.63	0.36	2.46
5.	Dimensional stability	7	1.98	2.30	2.15	0.12	5.58

The shrinkage of Bebya is shown in Table 11. According to the results, the mean radial shrinkage of Bebya from green to oven-dry condition is 4.64%. Radial shrinkage from green to oven dry condition ranges from 4.21% to 4.98%. According to Skaar (1988), the order of magnitude of the total shrinkage in "normal" wood is 3 to 6% in radial direction. Moreover, Rowell (2005) also states that most radial shrinkage value is less than 6%. Thus, the radial shrinkage of Bebya is found within the range. Tangential shrinkage ranges from 9.40 % to 10.17% with mean tangential shrinkage of 9.93% with standard deviation of 0.28. The total tangential shrinkage in "normal" wood is 6 to 12% (Skaar, 1988). Rowell (2005) also states that most tangential shrinkage value is less than 10%. Tangential shrinkage of Bebya is in line with those findings. Win Chit (2005) pointed out that those timber species used for high quality furniture and other furniture should have tangential shrinkage of 7% or less than 7%. According to his suggestion, Bebya should not be used for high quality furniture as its tangential shrinkage is greater than 7%. Again, it is also found that its tangential shrinkage value is twice of its radial shrinkage. This is normal in most timber species (Forest Products Laboratory, 2010). The longitudinal shrinkage of Bebya ranges from 0.03% to 0.43% with the mean value of 0.17%. It is quite small and thus can be negligible (Forest Products Laboratory, 2010). Skaar (1988) mentions that the order of magnitude of the total longitudinal shrinkage in "normal" wood is 0.05 to 0.3%. Volumetric shrinkage of Bebya ranges from about 14.21% to 15.13%. The mean volumetric shrinkage from green to oven dry condition is 14.63%. So, volumetric shrinkage is nearly the same to the sum of radial, tangential and longitudinal shrinkage.

The ratio of tangential to radial shrinkage (T/R) is used as an index of dimensional stability. Ratios higher than 1.5 are considered pronounced and this pronounced differential shrinkage is likely to cause wide splits, checks and distortions if the necessary precautions are not taken during the kiln drying (Ofori et al., 2009). It was reported that the ratios higher than 2.2% are considered to be high (Rijsdijk & Laming, 1994; Jouse, 2004). The mean T/R ratio of Bebya species is 2.15.

5.1.5 Swelling

Table 12. Swelling value for Bebya (*Cratoxylum neriifolium* Kurz.)

Sr. No.	Properties	N	Min	Max	Mean	Standard Deviation	CV%

1.	Radial Swelling (%)	9	3.35	5.85	4.87	0.86	17.66
2.	Tangential Swelling (%)	9	9.57	12.15	11.22	0.97	8.65
3.	Longitudinal Swelling (%)	9	0.11	0.96	0.55	0.29	52.72
4.	Swelling Anisotropy	9	2.03	3.40	2.37	0.47	19.83

The swelling of Bebya is shown in Table 12. Radial swelling ranges from about 3.35% to 5.85%, tangential swelling ranges from about 9.57% to 12.15% and longitudinal swelling from 0.11 %to 0.96%. It can be found that tangential swelling is the largest and radial swelling is the second largest whereas longitudinal swelling is the lowest. In general, radial shrinkage/ swelling is about half of tangential shrinkage / swelling of the same species. This also holds true for Bebya. Longitudinal shrinkage and swelling of normal wood from green to oven dry condition ranges between 0.1% to 0.9% (Kollmann and Cote 1968).

Swelling anisotropy ranges from 2.03 to 3.40. The mean swelling anisotropy of Bebya is 2.37 with standard deviation of 0.47. The value of swelling anisotropy of Bebya is greater than 2. The wood having a low anisotropy is best suited for use (Panshin & de Zeeuw, 1980). This means that shrinkage or swelling problems can occur when putting specie with higher anisotropies into use, but if Bebya properly dried before it is used, these problems can be controlled.

5.1.6 Fiber saturation point

Table 13. Fiber saturation point of Bebya (*Cratoxylum neriifolium* Kurz.)

Sr. No.	Properties	N	Min	Max	Mean	Standard Deviation
1.	Fiber Saturation point (%)	9	19.16	23.92	22.47	1.44

The point at which all the water has been removed from the cell cavities while the cell walls remain saturated is known as the fiber-saturation point. For most species, the moisture content at fiber saturation is from 22 to 30 percent of the weight of the dry wood (Forest Products Laboratory, 1951). According to the results, the fiber saturation point of Bebya is 22.47%.

5.1.7 Water absorption

Table 14. Comparison of Maximum water absorption of Bebya and other tested heavy wood species

Sr.No	Species	Scientific name	Specific gravity	Maximum water absorption (kgm-3)
1.	Bebya	*Cratoxylum neriifolium*	0.633	582.37
2.	Kokko	*Albizia lebbek*	0.538	600.66
3.	Pyinma	*Lagerstroemia speciosa*	0.529	619.84
4.	Tawthayet	*Mangifera spp*	0.582	665.11

5.	Taungthayet	*Swintonia floribunda*	0.558	617.08

Table 14 compares maximum water absorption of Bebya with those of other tested heavy wood species. Water absorption is generally influenced by wood types (sapwood or heartwood), extractives, density or specific gravity and wood directions (Maclean 1935). The main influencing factor is extractive. According to results, the maximum water absorption value of Bebya is 582.37 kg/m^3. Its value is lower than that of Kokko (600.66 kg/m^3), Pyinma (619.84 kg/m^3), Tawthayet (665.11 kg/m^3) and Taungthayet (617.08 kg/m^3). Specific gravity of Bebya (0.633) is higher than that of Kokko (0.538), Pyinma (0.529), Tawthayet (0.582) and Taungthayet (0.558). Bebya with the highest specific gravity absorbed the least amount of water. This is due to its thick cell wall, small lumens, and extractives, thus small space available for water.

5.2 Durability of Tested Species

The decay resistance and subterranean termites resistance of tested wood samples was shown in Table (15). The visual rating of test samples and weight losses are also presented in this table.

Table 15. Moisture content and weight losses of Tested Species

Decay Resistance Test		**Termite Resistance Test**	
M. C (%)	28.76	M. C (%)	11.73
Maximum weight Loss (%)	9.775	Maximum weight Loss (%)	18.46
Minimum weight Loss (%)	2.702	Minimum weight Loss (%)	0.44
Mean Weight Loss (%)	6.241	Mean Weight Loss (%)	7.32
Standard Deviation	1.923	Standard Deviation	5.84
		Visual rating	1

According to the results, the wood samples of Bebya were very resistant to termite attack. They have no any surface damages and can be marked as sound (No Attack) according to visual rating. According to weight loss determination, the mean weight loss of tested wood samples was found to be 7.32. Therefore, it can be said that the wood samples of Bebya is resistant to termite attack.

According to the weight loss determination of decay resistance test, the mean weight loss of tested wood samples was found to be 6.241 and the range was between 9.78 and 2.7. Therefore, it can be said that the wood samples of Bebya is moderately durable.

5.3 Drying Characteristics

According to Quick Drying Test the visual observations were made on the susceptibility to drying characteristics included checking and splitting, collapse and twisting and the results shows as follow in table 16.

5.3.1 Checks in the early stage of drying

In early drying process, it is observed that moderate little checks were appeared on the wide surface and end-grain surface of the samples of Bebya (*Cratoxylum neriifolium* Kurz.). End checks were initiated after 3 hours. The main reason for the end checks is their high growth stress and another reason is the high temperatures which make them lose more water in a short time at the early stage of the test. As the test goes on, the end checks become stronger and some of them stretch to the surface becoming to end-to surface checks and at this time the surface checks arise also. It was found that all these initial checks stop stretching and closed in the samples within 26 hours, and a general appearance is that the end checks closed first. Classification of initial checks determined in class 3.

5.3.2 Honeycombing (internal check) and cross sectional spool-like deformation

Little mild checks of honeycombing and deformation were observed and classified them into class 2. According to Johanson (2005), the presence of honeycomb defect is affected by the initial moisture content of the board, the wood mass loss, the presence of pith and the speed of drying process.

5.3.3. Estimating the drying condition (initial temperature, relative humidity)

Initial checking is strictly related to initial relative humidity, and less so to initial temperature. Since the tested species did not exhibit severe initial splitting, moderately higher initial dry bulb temperature of 60°C, a larger wet bulb depression (WBD) of 4.3°C and relative humidity 82% may be used.

In kiln drying, honeycombing is related to the initial and final temperature and the initial relative humidity but not to the final relative humidity. Since mild little checks of honeycombing was found in tested samples of *Cratoxylum neriifolium* Kurz., it can tolerate mild initial dry bulb temperature of 55°C, a larger wet bulb depression (WBD) of 4.5°C and relative humidity 76%.

Deformation is related to the initial and final temperatures, and less so, to the initial relative humidity, but not to the final relative humidity. Thus, relatively higher initial dry bulb temperatures of 66°C, a high initial WBD 6°C and relative humidity 75% may be employed for drying *Cratoxylum neriifolium* Kurz..

The estimated drying conditions, the mildest conditions (viz. overall lowest initial dry bulb temperature, overall smallest initial wet bulb depression, and final dry bulb temperature) were selected because the drying condition is inferred from the most severe class of defects. It was observed from the critical drying conditions corresponding to the defect type class in Table (16) that checks on early stages of drying is the most critical defect that governs the kiln drying of *Cratoxylum neriifolium* Kurz.. By this reason, the estimated initial temperature, initial wet bulb depression and final temperature were 55˚C, 4.3˚C, and 83˚C for tested species.

Table 16. Results of the types of defects, classes of drying defects and the critical drying condition based on class of each defects obtained from the samples of *Cratoxylum neriifolium* Kurz.

Defect type	**classes of drying defects**	**critical drying conditions corresponding to adopted classes of drying defects**			
		Initial dry bulb temperature (˚C)	**Initial wet bulb depression (˚C)**	**Final dry bulb temperature (˚C)**	**Relative humidity %**
Initial Checks	3	60	4.3	85	82
Honeycombing	2	55	4.5	83	76
Deformation	2	66	6	88	75

5.3.4 Determination of patternized kiln schedule codes

For *Cratoxylum neriifolium* Kurz. the patternized kiln schedule code which was determined based on the combination of three drying defects and initial moisture content was ($D_{43}W_{34}$) according to Figure 4 and 5 provided by Terazawa (1965) and given in Table 17.

Table 17. Summary of initial moisture content and adopted classification of defect types used in estimating drying conditions

Species	**Initial MC (%)**	**Adopted classification of defect type**			**Estimated drying conditions**		**Patternized Schedule Code**	**Estimated drying time**
		Initial Checks	**Honey combing**	**Defor-mation**	**Initial temperature (C)**	**Relative humidity %**		**Kiln drying (days)**
Bebya	78.07	3	2	2	55	82	D_{43} W_{34}	4~7

5.3.5 Proposed experimental kiln drying schedules

According to "Quick Drying Test" based on the type and degree of defects, a kiln drying schedule establish the series of temperatures and relative humidity that are applied at various stages of drying. There are six kinds of kiln schedule types A to F (A is the most serve and F is the mildest). Finally, in formulation a kiln drying schedule, minimum temperature (Dry Bulb Temperature-DBT) 55˚C and maximum relative humidity (RH) 81% in the early stage of drying and maximum temperature 80˚C and minimum relative humidity 22% in final stage should be used for *Cratoxylum neriifolium* Kurz and given in Table (18). Based on the drying defects, it could be classified as moderately-refractory timber (Kiln Schedule Type C) and it is similar to Leza, Myaukchaw, Myaukngo, Lein, etc.

Table 18. Proposed drying schedule for Bebya (*Cratoxylum neriifolium* Kurz.)

MC (%)	DBT(˚C)	WBD(˚C)	R.H(%)
Above 50	55	4	81
50 - 40	55	8	64
40 - 35	60	8	66
35 - 30	60	12	52
30 - 25	65	12	54
25 - 20	70	18	42
20-15	75	25	28
Below 15	80	30	22

6. Conclusion

Physical properties, durability and drying characteristics of Bebya species were determined in this research. According to physical properties, the mean moisture content of Bebya species is 74.05%. Average air-dry density of Bebya is 789 kgm^{-3}. So, Bebya species is heavy wood species. The mean basic specific gravity of Bebya is 0.633. The basic specific gravity of Bebya is higher than those of Chinyoke and Hnaw but it is lower than those of Lein and Nyan. It is comparable with that of Thingan. Shrinkages in the radial, tangential and longitudinal directions from green to oven dry condition are 4.64%, 9.93% and 0.17% respectively. The mean T/R ratio of Bebya species is 2.15. Bebya species is found to have a higher tangential to radial swelling ratio of greater than 2. The fiber saturation point of Bebya species is 22.47%. The maximum water absorption value of Bebya species is 582.37 kg/m^3. Its value is lower than that of Kokko , Pyinma, Tawthayet and Taungthayet.

According to durability test, Bebya species is resistant to termite attack and moderately durable.

Drying characteristics revealed that the wood of *Cratoxylum neriifolium* Kurz. was susceptible to moderate little checks on the wide surface and end-grain surface and little mild checks of honeycombing (internal check) and deformation. According to these defects, Bebya is a moderately-refractory timber and kiln drying schedule D_{43} W_{34} is proposed. Boards with a thickness of 25 mm should be dried with an initial dry bulb temperature of 55˚C and 81% relative humidity (RH) in the early stage of kiln drying. These proposed kiln drying schedule is need to be adjusted through practical experiment to get the “Optimum Kiln Schedules” of the tested species without any difficulties based on the results given in this paper.

According to the findings of physical properties and durability, Bebya species can be used for building, pole, fence post and other outdoor utilities. These research findings are useful not only for knowledge of wood properties but also for wood based industries to make the efficient uses of Lesser Used Species.

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