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Investigation of Drying Behaviours and Proposed Kiln Schedules for Two Indigenous Wood Species from Kachin State

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Abstract

Wood drying is an initial and most crucial step in producing high-quality wood products, and finding solutions to drying problems is essential in determining the value of a particular wood species. Therefore, it is important to study the susceptibility to drying behaviours or drying defects such as checks, honeycombing, and deformation. By understanding these defects related to wood drying, appropriate drying schedules can be developed. In this research, the drying behaviours and proposed kiln schedules for two indigenous wood species, Kyilan (*Shorea assamica* Dyer.) and Kalaung-ni (*Dysoxylum gotadhora*Mabb.), were investigated. One tree from each species was collected from a protected public forest in Myitkyina Township, Kachin State, Myanmar. The experiment used the Quick Drying Test method of Terazawa (1965) modified by Jonkosky (1992). The lumbers used in this study were prepared from the heartwood portion and carefully selected to be free from defects such as knots and decay. The results indicated that both Kyilan and Kalaung-ni species did not exhibit any initial checks (surface and end checks) (Class 1) during the initial drying stage. Additionally, there was no honeycombing (Class 1) observed, but mild to moderate deformation (Class 2) was observed. The initial moisture content of Kyilan and Kalaung-ni was 87.34% and 51.89%, respectively. Based on these results, the proposed drying schedule ($D_{44}W_{44}$) for Kyilan, which is 25 mm thick, is to start at an initial temperature of 60˚C and gradually increase to a final temperature of 85˚C. The wet bulb depression should range from 5-30˚C and the relative humidity should range from 77-23%. Similarly, for Kalaung-ni, which is also 25 mm thick, the proposed kiln schedule ($D_{52}W_{43}$) is to start at an initial temperature of 70˚C and gradually increase to a final temperature of 90˚C. The wet bulb depression should range from 5-30˚C and the relative humidity should range from 79-26% to prevent deformation of the lumber.

Key Words: drying defects, Kyilan (*Shorea assamica* Dyer.), Kalaung-ni (*Dysoxylum gotadhora* Mabb.), moisture content, proposed kiln schedules, quick drying test

ကချင်ပြည်နယ်မှ ဈေးကွက်ဝင်ဒေသမျိုးရင်းသစ်(၂)မျိုး၏ အခြောက်ခံမှုစရိုက်လက္ခဏာများနှင့် အဆိုပြုသစ်ပေါင်းဖိုဇယားများအားလေ့လာဖော်ထုတ်ခြင်း

ခရစ္စတီနေဝင်း၊ လက်ထောက်သုတေသနအရာရှိ
သစ်တောသုတေသနဌာန

စာတမ်းအကျဉ်း

သစ်အခြောက်ခံခြင်းသည် အရည်အသွေးမြှင့် သစ်သားထွက်ကုန်များ ဖန်တီးရာတွင် ကနဦးနှင့် အရေးအကြီးဆုံး အဆင့်ဖြစ်ပြီး အခြောက်ခံခြင်းဆိုင်ရာ အပြစ်အနာအဆာများအတွက် ဖြေရှင်းနည်းများ ရှာဖွေခြင်းသည် သစ်မျိုးစိတ်တစ်ခု၏ တန်ဖိုးကို ဆုံးဖြတ်ရာ၌ မရှိမဖြစ်လိုအပ်ပါသည်။ ထို့ကြောင့် မျက်နှာပြင်အက်ကွဲခြင်း၊ ထိပ်အက်ကွဲခြင်း၊ ထိပ်မှ မျက်နှာပြင်အက်ကွဲခြင်း၊ အတွင်းပိုင်းအက်ကွဲမှုများ၊ ပုံပျက်မှုများကဲ့သို့ အခြောက်ခံခြင်း ဆိုင်ရာ အပြစ်အနာအဆာများကို လေ့လာသိရှိရန် အရေးကြီးပါသည်။ ထို့အပြင် သစ်အခြောက်ခံခြင်းနှင့် ပတ်သက်သည့် အဆိုပါ အပြစ်အနာအဆာများကို သိရှိခြင်းဖြင့် သင့်လျော်သော အခြောက်ခံချိန်ဇယားများ ဖော်ထုတ်နိုင်မည်ဖြစ်သည်။ ဤသုတေသန စာတမ်းသည် ကချင်ပြည်နယ်မှ ဈေးကွက်ဝင် ဒေသမျိုးရင်းသစ်(၂)မျိုးဖြစ်သည့် ကြေးလံနှင့် ခလောင်နီသစ်၏ အခြောက်ခံမှုဆိုင်ရာ စရိုက်လက္ခဏာများနှင့် အဆိုပြုသစ်ပေါင်းဖိုဇယား များကိုလေ့လာတင်ပြထားပါသည်။ သစ်မျိုးတစ်မျိုးစီမှသစ်နမူနာတပင်စီကို ကချင်ပြည်နယ်၊ မြစ်ကြီးနားမြို့နယ်အတွင်းရှိ ကြိုးပြင်ကာကွယ်တောအတွင်းမှ ရယူ စုဆောင်းခဲ့ပါသည်။ သစ်နမူနာများအား အမျက်၊ အပြစ်အနာအဆာများ လွတ်ကင်းသည့် အနှစ်သားမှ ရယူပြီး ခွဲစိတ်ပြင်ဆင်ခဲ့ပါသည်။ စမ်းသပ်ဆောင်ရွက်ရာတွင် Jonkosky (1992) မှ ပြုပြင်ထားသော Terazawa (1965) ၏ Quick Drying Test method ကို အသုံးပြုခဲ့ပါသည်။ စမ်းသပ်မှု ရလဒ်များအရ ကြေးလံနှင့် ခလောင်နီ သစ်မျိုးနှစ်မျိုးစလုံးသည် ကနဦးကွဲအက်မှုများ ဖြစ်ပေါ်ခြင်းမရှိ (အဆင့် ၁) သည် ကိုတွေ့ရှိပါသည်။ ထို့အပြင် အတွင်းပိုင်း အက်ကွဲမှုများ မရှိ (အဆင့် ၁) သော်လည်း ပုံပျက်မှုများသည် အနည်းငယ်မှ အသင့်အတင့် (အဆင့် ၂) ဖြစ်ပေါ်သည်ကို တွေ့ရှိရပါသည်။ ကြေးလံနှင့် ခလောင်နီသစ်၏ ကနဦး အစိုဓာတ်ပါဝင်မှုမှာ ၈၇.၃၄% နှင့် ၅၁.၈၉% ရှိပါသည်။ အဆိုပါရလဒ်များအပေါ် အခြေခံ၍ ၂၅ မီလီမီတာထု ရှိသော ကြေးလံသစ်ခွဲသားများအား ပေါင်းဖိုဖြင့် အခြောက်ခံရာတွင် အဆိုပြု ပေါင်းဖိုဇယား ($D_{44}W_{44}$)၊ အပူချိန် ၆၀–၈၅ဒီဂရီ စင်တီဂရိတ်၊ အခြောက်သာမိုမီတာ နှင့် အစိုသာမိုမီတာတို့၏ အပူချိန်ခြားနားမှု ၅–၃၀ ဒီဂရီ စင်တီဂရိတ်၊ စိုထိုင်းဆ ၇၇–၂၃ ရာခိုင်နှုန်းဖြင့်လည်းကောင်း၊ ခလောင်နီသစ်ခွဲသားများအား ပုံပျက်မှုများမှကာကွယ်ရန် အဆိုပြုပေါင်းဖိုဇယား($D_{52}W_{43}$)၊ အပူချိန် ၇၀–၉၀ဒီဂရီစင်တီ ဂရိတ်၊ အပူချိန်ခြားနားမှု ၅–၃၀ ဒီဂရီစင်တီဂရိတ်နှင့် စိုထိုင်းဆ ၇၉–၂၆ရာခိုင်နှုန်းဖြင့်အခြောက်ခံသင့်ပါသည်။

Investigation of Drying Behaviours and Proposed Kiln Schedules for Two Indigenous Wood Species from Kachin State

1. Introduction

Our society relies on wood and wood products for a variety of purposes. Wood drying is an initial and crucial step in creating high-quality wood products, and finding solutions to drying problems is essential in determining the value of a particular species of wood. Therefore, it is important to study the susceptibility of wood to drying behaviours or drying defects such as splits, checks, deformation, and honeycombing. These defects are closely related to the wood's interaction with moisture and can provide valuable information on its suitability for specific purposes at different moisture levels. Additionally, measuring these defects relevant to wood drying is necessary for developing appropriate drying schedules for specific end uses.

Drying cannot be omitted in wood industrial processing, and good drying quality comes from perfect drying schedules. Therefore, it is necessary to study drying defects first, and then predict the drying schedules based on the relationships between drying defects, and drying conditions, and finally adjust the schedules through kiln drying experiments.

Drying schedules vary depending on the species, thickness, moisture content, and intended use of the wood (Simpson, 1991). Kiln schedules are based on the average moisture content of the wood, as it indicates the difference between the interior and surface moisture levels. The drying process begins with mild conditions and gradually increases in temperature and decreases in relative humidity, with variations depending on the species.

Myanmar's forests are home to a diverse range of species, including Kyilan and Khalaung-ni, which are commonly found in hilly regions, specifically in Myitkyina Township, Kachin State. These species are commonly used by local people and are known to be suitable for construction and house-building.

Kyilan (*Shorea assamica* Dyer.) is a tall deciduous tree that can grow up to 55 meters tall with a bole diameter of up to 150 cm. The heartwood of this species is creamy white and becomes yellow-brown with age. The wood is of medium weight, moderately hard, and moderately durable, making it commonly used for door and window frames, posts, beams, flooring, ceilings, and furniture.

Kalaung-ni (*Dysoxylum gotadhora* Mabb.) is an evergreen tree that can grow from 8 - 30 meters tall, with a straight bole. The heartwood of this species is red or reddish-grey, and the wood is hard and moderately heavy, commonly used in furniture making.

Not every wood species can be easily dried without developing defects, as each species has its sensitivity to drying temperature. A lack of understanding of the drying process for each species can result in high costs, longer drying times, and lower-quality finished products. By understanding the specific drying defects of each type of wood, appropriate kiln schedules can be developed. Therefore, it is important to study minimizing defects in wood so that the wood can be used in a wider range of advanced applications.

This research investigates the drying behaviors of Kyilan and Khalaung-ni, two commonly used timber species native to the Myitkyina Township, Kachin State, and proposes kiln schedules for their optimal drying.

2. Objectives

The objectives of this study are:

(1) to investigate the drying behaviours of Kyilan and Kalaung-ni,

(2) to formulate the proper kiln schedules based on these drying behaviours, and

(3) to enhance the efficiency of the wood drying process for Kyilan and Kalaung-ni, by utilizing these kiln schedules.

3. Materials and Methods

3.1. Materials

3.1.1. Sample collection

For this study, two species of wood, Kyilan (*Shorea assamica* Dyer.) and Kalaung-ni (*Dysoxylumgotadhora* Mabb.) were selected as the main materials for the experiment. The trees chosen from the field were mature with diameters of 137 cm and 168 cm at breast height. One tree from each species was collected from the public forest in Myitkiyna township, Kachin State, Myanmar.

3.1.2. Preparation of experimental samples

The flat-sawn boards were carefully selected from each species, ensuring that all the boards were heartwood and in a green condition. Additionally, all boards were free from defects such as knots and decay. Next, the board was planned, trimmed, and cut to a specific size of 20 mm x 100 mm x 200 mm in thickness, width, and length, respectively. The tests were conducted at the wood drying laboratory of the Forest Research Institute, using equipment such as a laboratory oven, balance, band saw, digital caliper, ruler, and writing tools.

3.2. Methods

3.2.1. Quick Drying Test

The Quick Drying Test method was used to determine the basic drying defects. This method originally developed by Terazawa (1965) and later modified by Jankowski (1992) and Hisada et.al. (1986), was used in this research. This method is used as a starting point in developing a drying schedule that illustrates the appropriate temperature and relative humidity levels for the specific timber species, while also determining the basic drying defects such as end checks, surface checks, deformation, and honeycombing.

3.2.2. Observation of drying behaviours or drying defects

Initially, the test specimens were weighed and placed in an oven at a temperature of 103±2°C. During the first eight hours, the test specimens were weighed and observed for end checks extending to the surface, end checks extending from the surface, and isolated surface checks every hour. If any checks were observed, the time at which the maximum checks and closing occurred was recorded. The samples were then weighed daily until they reached a constant weight.

After the drying process was completed, two additional types of defects, honeycombing, and deformation, were observed and evaluated. To assess these defects, the specimens were cut in half lengthwise. The thickness of each sample was measured from the initial point to the maximum deformed point to determine the extent of deformation. At the same time, the presence of honeycombing was checked. This process provided valuable data on the grade of initial checks, honeycombing, and deformation, which can be used to develop a drying schedule for one-inch boards of each species.

3.2.3. Classification of drying behaviours

A set of criteria was used to assess three types of defects (initial checks, deformations, and honeycombing) in the dried lumber. The size and number of defects on the surface were evaluated using a scale ranging from 1 to 6 for initial checks (end and surface check) and honeycombing (internal checks), and from 1 to 8 for deformation defects, as shown in Tables 1 and 2. A higher score indicates a more severe defect, while a lower score indicates a less severe defect.

Table1. Classification of initial checks and honeycombing based on Terazawa (1965) and modified by Jankowski (1992)

Class no.	Initial Checks -D_1		Honeycombing (internal checks) - D_3
	End check(mm)	Surface check(mm)	
1	No check	No check	No check
2	Small checks L<10 W< 0.8	Small checks L<50 W<0.5	Large 1, Small 2
3	Small checks L >10 W< 0.8	Small to medium checks 5<L<100 1<W<1	Large 2, Small 4-5 Large 1 & small 3
4	Medium checks L<10 0.8<W<1.5	Medium to large checks L<150 W<1.5	Large 4, Small 7-9 Large 1 & small 4-6
5	Medium to large checks L>10 0.8<W<1.5	Large checks L >150 W>1.5	Large 6-8, Small 15 Large 4 & small 6-8
6	Large checks L >10 W >1.5		Large15-17 small checks appearing continuously

Note: L = check length, W= check width
Source: Jankowski (1992), Terazawa (1965)

Table 2. Classification of deformation – D_2

Deformation	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
A-B (mm)	0~0.3	0.3~0.5	0.5~0.8	0.8~1.2	1.2~1.8	1.8~2.5	2.5~3.5	> 3.5

Source: Terazawa (1965)

3.2.4. Kiln schedule determination

The kiln schedule code numbers for Kyilan and Kalaung were determined by identifying the intersection points of the straight lines drawn using a combination of initial checks (D_1), deformation (D_2), honeycombing (D_3), and initial moisture content U_a as shown in Figures 1 and 2.

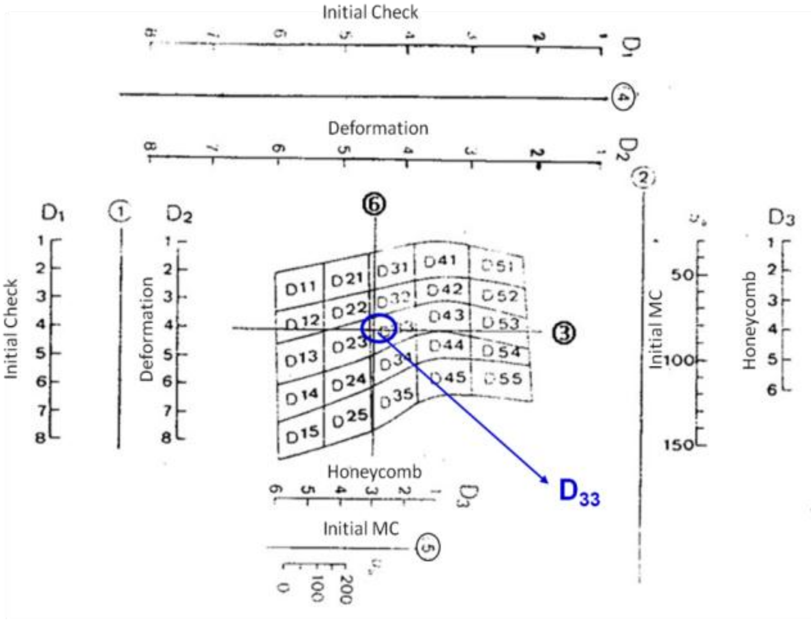

Figure 1. Chart for the code number of patternized dry-bulb temperature schedule (based on Hisadaet.al, 1986)

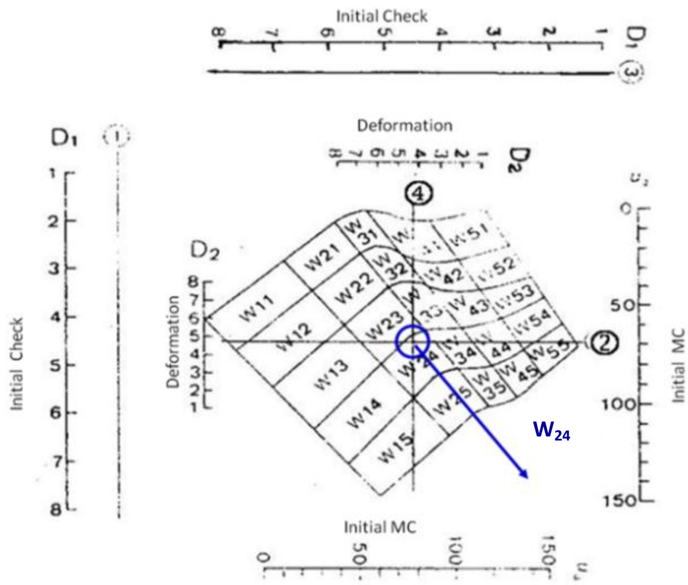

Figure 2. Chart for the code number of patternized wet-bulb depression schedule (based on Hisadaet.al, 1986)

After obtaining the schedule code number, the dry bulb temperature (DBT) and wet bulb depression (WBD) were determined by using moisture content as an indicator from Tables 3 and 4. These values were combined with the relative humidity values to create the proposed kiln schedule for the kiln.

Table 3. Patterned dry bulb temperature schedule

Moisture content (%)	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
60	45	45	45	45	45	50	50		50	50	55	55	55	55	55	60			60	60	70			70	70
55–50					50					55					60					65					75
50–45								50										60					70		
45–40				50					55					60			60		65			70		75	
40–35			50		55			55		60			60		65			65		70			75		80
35–30		50		55			55		60			60		65			65		70		75	75		80	
30–25	50	55	55		60	55	60	60		65	60	65	65	70	70	65	70	70	75	75		80	80		
25–20	55	60	60	60	65	60	65	65	65		65	70	70		75	70	75	75		80	80		85	85	85
20–15	60	65	65	65		65	70	70	70	70	70	75	75	75		75	80	80	80		85	85			
15–10	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

Dry Bulb Depression for each schedule type (°C)

Source: Hisada et.al. (1986)

Table 4. Patterned wet bulb depression schedule

Wet Bulb Depression for each schedule type (°C), MC (%) 80, 70, 60, 50, 45, 40, 35, 30, 25, 20, 15, 10

Schedule type								
W 11	2	3	4	5	7	10	17	20
W 12	2	3	6	9	15	25		
W 13	2	3	5	7	10	16	25	
W 14	2	3	4	6	8	11	16	25
W 15	2	3	5	8	12	18	25	
W 21	3	5	8	13	21	30		
W 22	3	4	6	10	15	22	30	
W 23	3	4	6	8	11	16	22	30
W 24	3	4.5	7	9	12	16	21	30
W 25	3	4	6	9	14	20	30	
W 31	4	6	9	13	20	30		
W 32	4	5	7	10	15	21	30	
W 33	4	5	7	9	12	16	21	30
W 34	4	5	8	12	18	25	30	
W 35	4	5	7	10	13	18	23	30
W 41	5	7	10	14	20	25	30	
W 42	5	7	9	12	15	20	25	30
W 43	5	7	10	13	16	20	25	30
W 44	5	7	9	13	18	24	30	
W 45	5	6	8	11	14	19	25	30
W 51	7	9	12	16	20	25	30	
W 52	7	10	15	20	25	30		
W 53	7	9	13	19	25	30		
W 54	7	9	12	15	20	25	30	
W 55	7	8	10	13	16	20	25	30

Source: Hisada et.al. (1986)

4. Results and Discussion

4.1. Observation and classification of drying behaviours

The results of the quick drying test are presented in Table 5. This table includes the moisture content, types of defects (initial checks, honeycombing, and deformation), and classes of drying defects for the two species.

Table 5. Type and classification of drying defects in Kyilan and Kalaung-ni

Species	moisture content(%)	Class of drying defects		
		Initial Checks	Deformation	Honeycombing
Kyilan	87.34	1	2	1
Kalaung-ni	51.89	1	2	1

The average moisture content of Kyilan was 87.34%, with a maximum of 93.32% and a minimum of 82.66%. Similarly, for Kalaung-ni, the average moisture content was 51.89%, with a maximum of 56.92% and a minimum of 47.31%. These values are crucial in determining the appropriate kiln schedule for drying the wood. The moisture content of wood plays a significant role in its drying rate and susceptibility to defects, making it a key factor in determining kiln schedules. However, the inner wood remains moist, preventing the outer wood from shrinking completely. This creates tension on the outer wood and compression on the inner wood, resulting in defects such as surface checks, end checks, honeycombing (or) internal checks, and deformations.

Based on the results of the quick drying test, it was determined that neither the Kyilan nor Kalaung-ni species showed any initial checks (surface and end checks) (D_1) during the initial drying stage. Additionally, no honeycombing (D_2) was observed. However, mild to moderate deformations (D_3) were observed in both species, with average values of 0.4 mm and 0.31 mm, respectively. Deformation occurs due to the high initial moisture content of the wood. According to Ofori, J. et al. (2005) and Basri, et al. (2015), a higher moisture content can cause warping in wood samples. Simpson (1991) explains that the differences in radial and tangential shrinkage during the drying process can also lead to deformation. It is important to avoid severe deformation or collapse on the cross-section of the board, as it is a serious defect. Deformations are generally related to the initial and final temperatures, as well as the initial relative humidity, but not to the final relative humidity. If the level of deformation is high, it indicates that the wood is prone to collapse, so the drying temperature should not be too high.

Based on the classification of drying defects shown in Tables 1 and 2, it can be seen that both the Kyilan and Kalaung-ni species did not show any initial checks (surface and end checks) (Class 1) during the initial drying stage. Additionally, there was no honeycombing (Class 1) observed, but mild to moderate deformation (Class 2) was observed.

4.2. Determination of kiln schedule codes

The Quick Drying Test has provided 25 patterns of kiln-drying schedule codes for dry-bulb temperature (DBT) and wet-bulb depression (WBD). These codes range from the mildest schedule D_{11}-$D_{15,}$ to the highest schedule D_{51}-D_{55}, and from the mildest schedule W_{11}-$W_{15,}$ to the highest schedule W_{51}- W_{55}.

Based on the drying behaviours and initial moisture content, a kiln schedule ($D_{44}W_{44}$) was proposed for Kyilan, and a kiln schedule ($D_{52}W_{43}$) was proposed for Klaung-ni.

4.3. Formulation of proposed kiln schedules

The proposed kiln schedules determine both temperature and relative humidity levels for drying, based on the type and severity of defects, as shown in Table 3 and Table 4. The schedule code is a method used to identify the specific dry bulb temperatures (DBT), wet bulb depressions (WBD), and moisture contents (MC) for each step of the drying process.

According to schedule code $D_{44}W_{44}$, the dry bulb temperature changes were 60, 65, 70, 75, 80, and 85˚C, while the wet bulb depression values were; 5,7,9,13,18, 24, and 30˚C for Kyilan. Similarly, in $D_{52}W_{43}$, the temperature changes were expressed as 70, 75,78, 80, 85, and 90˚C, with corresponding wet bulb depression values of 5, 7, 10, 13, 16, 20, 25, and 30˚C for Kalaung-ni. The combination of dry bulb temperature and the wet bulb depression determines the relative humidity.

The moisture content levels were classified and adjusted as follows: above 65%, 65-55%, 55-45%, 45 - 35%, 35-25%, 25- 20%, 20- 15%, and less than 15%. These values were used as the final step in the drying process for Kyilan. For Kalaung-ni, the levels were above 55%, 55-50%, 50-45%, 45-40%, 40-35%, 35-30%, 30-25%, 25-20%, 20- 15%, and less than 15%. Once the values were determined, detailed kiln drying schedules were proposed and are shown in Tables 6 and 7.

Table 6. Proposed kiln schedule ($D_{44}W_{44}$) for Kyilan

Step No.	Moisture content Range (%)	DBT(˚C)	WBD(˚C)	RH(%)
1	Above 65	60	5	77
2	65~55	60	7	69
3	55~45	60	9	62
4	45 ~ 35	65	13	51
5	35 ~25	70	18	40
6	25 ~ 20	75	24	30
7	20 ~15	80	30	22
8	15 to Final	85	30	23

DBT= Dry Bulb Temperature, WBD = Wet Bulb Depression
RH = Relative Humidity

This schedule, $D_{44}W_{44}$, is designed to achieve faster moisture diffusion and surface evaporation by starting with moderately higher temperatures and relative humidity. The initial temperature of 60°C is maintained until the moisture content reaches 45%, while the relative humidity is gradually decreased to maintain efficient drying. As the process continues, the moisture content of the wood will decrease and the dry bulb temperature is gradually increased from 60°C to 85°C until the target final moisture content is reached.

According to Schedule $D_{44}W_{44}$, 25 mm thick lumber made from kyilan requires a moderately higher initial-final temperature range of 60˚- 85˚C, an initial-final wet bulb depression range of 5˚-30˚C, and an initial-final humidity range of 77-23 % to achieve the desired changes in moisture content.

Table 7. Proposed kiln schedule ($D_{52}W_{43}$) for Kalaung-ni

Step No.	Moisture content Range (%)	DBT(˚C)	WBD(˚C)	R.H(%)
1	Above 55	70	5	79
2	55~50	70	7	72
3	50~45	70	7	72
4	45~40	70	10	62
5	40~35	70	13	53
6	35~30	75	16	45
7	30~25	78	20	39
8	25~20	80	25	30
9	20~15	85	30	23
10	15 to Final	90	30	26

DBT= Dry Bulb Temperature, WBD = Wet Bulb Depression
RH = Relative Humidity

In this kiln schedule, $D_{52}W_{43}$, the initial dry bulb temperature of 70 °C is held constant until the moisture content reaches 35%. The relative humidity is then gradually decreased to maintain a fast drying rate. As the moisture content continues to decrease, the dry bulb temperature is gradually increased from 70°C to 90°C to achieve faster moisture diffusion from the interior to the surface of the wood.

According to schedule $D_{52}W_{43}$, 25 mm thick lumber made from kyilan requires a relatively higher initial-final temperature range of 70-90°C, an initial-final wet bulb depression range of 5˚-30˚C, and an initial-final humidity range of 79- 26% to achieve the desired changes in moisture content.

The results of the Quick Drying Test for Kyilan and Kalaung-ni species are summarized and shown in Table 8.

Table (8). Summary of quick dry test of Kyila and Kalaung-ni

Species	Initial moisture content (%)	Classification of drying defects			Proposed Drying Condition(ºC)			Schedule codes
		Initial Checks	Deformation	Honey comb	Initial DBT	Initial WBD	Final DBT	
Kyilan	87.34	1	2	1	60	5	85	$D_{44}W_{44}$
Kalaung-ni	51.89	1	2	1	70	5	90	$D_{52}W_{43}$

5. Conclusion

Based on the findings of this study, the following conclusions can be drawn:

After investigating the drying behaviours and proposed kiln schedules for Kyilan and Kalaung-ni, it was determined that neither species exhibited any initial checks (surface and end checks) (Class 1) during the initial drying stage. However, mild to moderate deformation (Class 2) was observed, and there was no honeycombing (Class 1).

Based on the drying characteristics, two kiln schedules were developed. For Kyilan, which is 25 mm thick, the proposed drying schedule ($D_{44}W_{44}$) is to start at an initial temperature of 60˚C and gradually increase to a final temperature of 85˚C. The wet bulb depression should range from 5-30˚C and the relative humidity should range from 77-23%. Similarly, for Kalaung-ni, which is also 25 mm thick, the proposed kiln schedule ($D_{52}W_{43}$) is to start at an initial temperature of 70˚C and gradually increase to a final temperature of 90˚C. The wet bulb depression should range from 5-30˚C and the relative humidity should range from 79-26% to prevent deformation of the lumber.

Deformations are generally related to the initial and final temperatures, as well as the initial relative humidity, but not to the final relative humidity. If the level of deformation is high, it indicates that the wood tends to collapse, so the drying temperature should not be too high.

In Kiln drying, the process starts with a mild condition of low temperature and high humidity levels. As the process continues, the temperature gradually increases and the relative humidity decreases, with variations depending on the species of wood.

The thickness of the lumber must also be considered when choosing to dry it in the same kiln. Different wood species have varying rates of drying, moisture levels, and densities, making it important to avoid drying them together in the same kiln.

At the end of the kiln drying process, it is important to perform equalization and conditioning treatments. These steps help to achieve a more consistent moisture content and alleviate any drying stress present within and among the lumbers.

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