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Assessment of the Boron Treatability Level of Lesser-Known Timber Species by the Impregnation Method

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Abstract. Faced with the escalating crisis of global deforestation, including particularly alarming rates in Sri Lanka, researchers have turned their attention to the potential of boron-based preservatives for treating timber. The comprehensive study of the samples has revealed a significant negative correlation between the treatability of timber under pressure and the total area of vessels and wood density. Woods with fewer and smaller vessels are more receptive to boron treatment, making them more suitable for preservation. The study also identified a positive, though somewhat weak, correlation between treatability and the total ray area within the wood, indicating that the internal structure of timber plays a crucial role in its preservation potential. The timber during the research has been categorized based on the depth of boron penetration, with categories ranging from fully penetrated to less than 5 mm. The findings obtained suggest that boron preservatives offer a promising and sustainable alternative to traditional timber treatment methods. By categorizing wood based on the treatability and anatomical properties, we can optimize the treatment processes, thereby maximizing resource utilization and minimizing waste. Thus boron-treated timber could become a cornerstone in the fight against deforestation in future, providing a responsible and environmentally friendly alternative to the untreated wood. In doing so, the research contributes significantly to the preservation of our forests and the overall well-being of our planet, offering a promising trajectory in sustainable forestry practices.
Keywords: anatomical features, boron, chemical retention, density, penetration, preservative, pressure impregnation, treatability
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Научная статья

Оценка степени обработки бором древесины методом пропитки

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Аннотация. На сегодняшний день остро стоит проблема глобального обезлесения, его темпы особенно тревожны на Шри-Ланке. Этим обусловлены исследования потенциала консервантов на основе бора для обработки древесины. Всестороннее изучение образцов выявило значительную отрицательную корреляцию между пропитываемостью древесины под давлением и общей площадью сосудов, плотностью древесины. Древесина с меньшими количеством и объемом сосудов оказалась более восприимчивой к обработке бором – и в связи с этим более пригодной для консервации. Также выявлена хотя и достаточно слабая, но положительная корреляция между пропитываемостью и общей площадью лучей древесины, указывающая на решающую роль внутренней структуры древесины в сохранности древесины в целом. В ходе исследования древесина категоризирована в зависимости от глубины проникновения бора: от полной до менее 5 мм. Полученные результаты свидетельствуют о том, что борсодержащие консерванты представляют собой перспективную и устойчивую альтернативу традиционным методам обработки древесины. Категоризация древесины по степени пропитываемости и анатомическим свойствам открывает возможность для оптимизации процессов обработки с максимальным использованием ресурсов и минимальным количеством отходов. Таким образом, в будущем древесина, обработанная бором, способна стать основой в борьбе с обезлесением, представляя собой надежную и экологически чистую альтернативу необработанной древесине. Тем самым исследование вносит значительный вклад в сохранение лесов и общее благополучие планеты, предлагая многообещающую траекторию развития устойчивого лесоводства.

Ключевые слова: анатомические особенности, бор, удержание химикатов, плотность, проникновение, консервант, пропитка под давлением, пропитываемость
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Introduction

Timber, meaning "building material" in old English, is a specific type of wood used in construction and engineering [5, 8]. It is highly valued for its low heat transfer, strength, and lightness, but its high demand has led to shortages. Traditionally, construction and wood products rely on natural timber, but this is becoming increasingly scarce [1, 20]. The timber industry needs to find new types of wood that do not come from natural forests, as natural forests are running out. This can compromise safety and cause financial losses. The natural durability, design, and protection measures applied to wood determine its lifespan [2, 10]. With proper care, wooden objects like historical structures, instruments, and artifacts can last for centuries.

Wooden elements like beams, cabinets, and flooring are widely used in construction but are susceptible to decay from various factors like water, heat, and microbes [6, 19]. Several factors can damage wood, including fungi, insects, bacteria, marine animals, weather, wear and tear, and chemicals [3, 17]. Some of the insects that harm wood include termites, carpenter bees, longhorn beetles, and ambrosia beetles. Timber preservation involves treating wood with chemicals or other agents to prevent or slow down its degradation by organisms or other factors [4, 14]. These preservatives should be toxic only to specific target organisms (fungi, insects, etc.), easily penetrate wood, remain stable over time, and not damage the wood itself. Additionally, they should be affordable, readily available, and not increase wood flammability. Depending on the intended use of the treated wood, additional properties like odorlessness, colorlessness, and non-corrosiveness may be desirable. Three main types of preservatives exist: oily, organic solvent-based, and water-soluble [11, 15]. Preservatives can be applied using non-pressure methods like brushing or dipping, or through pressure processes.

There are two main ways to protect wood: treating it with chemicals (preservation) or modifying its structure (modification). Preservatives have a long history of success, extending the life of wood products and reducing costs by minimizing repairs and replacements [7, 9]. They help protect wood from insects, fungi, marine creatures, bacteria, fire, weathering, and harmful chemicals. Boron protects wood from fungi, insects (like termites) and fire, making it a safe and effective preservative for interior wooden products. Applied through pressure impregnation using a 6 % boric acid equivalent solution, boron treatment offers reliable protection [16, 18].

Despite its sustainability credentials, timber faces challenges due to limited resources of high-grade species and rising costs. Lesser-known timber presents a potential alternative, however, difficulties in identification, lack of data on properties, and poor grading hinder its wider adoption. Furthermore, these species are susceptible to insect damage, necessitating the use of preservatives for their protection. In essence, the utilization of lesser-known timber requires addressing identification issues, enhancing property data, improving grading practices, and implementing effective preservation strategies. This research successfully demonstrates the viability of using boron treatment through the impregnation as a means to replace lesser-known timber species, presenting a solution to the challenges associated with their treatment.

Research Objects and Methods

The study was conducted at the State Timber Corporation of Battaramulla and the Timber Complex at Bossa since February 2023 until July 2023. In this investigation, 20 lesser-known timber species (Table 1) have been selected that can be used for construction and other purposes.

Table 1

Lesser-known timber species selected for the experiment

Common name	Botanical name	Family
Acacia	*Acacia mangium*	Fabaceae
Aladu	*Allaeanthus zeylanicus*	Moraceae
Arawkeriya	*Araucaria columnaris*	Araucariacea
Attikka	*Ficus racemosa*	Moraceae
Bora-Daminiya	*Grewia helicterifolia*	Malvaceae
Dunu-Madala	*Stereospermum personatum*	Bignoniaceae
Helamba	*Mitragyna parvifolia*	Rubiaceae
Katu-Boda	*Cullenia ceylanica*	Malvaceae
Kaha-Milla	*Vitex altissima*	Lamiaceae
Karaw	*Margaritaria indica*	Phyllanthaceae
Katu-Andara	*Dichrostachys cinerea*	Fabaceae
Kora-Kaha	*Memecylon umbellatum*	Melastomataceae
Kurumbettiya	*Syzygium rubicundum*	Myrtaceae
Maha-Kadol	*Rhizophora mucronata*	Rhizophoraceae
Maha-Nuga	*Ficus benghalensis*	Moraceae
Na-Imbul	*Harpullia arborea*	Sapindaceae
Path-Kela	*Bridelia moonii*	Phyllanthaceae
Pelan	*Bhesa ceylanica*	Centroplacaceae
Ruk-Aththana	*Alstonia scholaris*	Apocynaceae
Wana-Sapu	*Cananga odorata*	Annonaceae

Identification of the Wood Anatomy Using a Hand-Held Digital Microscope with a Computer. Two sample blocks of the selected lesser-known timber species of 2×2×3 cm have been prepared and labelled. Authentication has been ensured in the first stage by comparing the authentic timber samples. Cross-sectional timber samples have been identified using a hand-held digital microscope. Anatomical observations have been made at 20 magnifications within 25 mm^2 areas using the photographs taken with Micrometrics SE Premium 4 software. Paper cut into 25 mm^2 squares has been used to determine 25 mm^2 areas. The identity of the wood has been confirmed with the authentic timber sample data available from the State Timber Corporation, Battaramulla.

Identification of the Wood Anatomy Using the Accu-Scope 3000 Series Trinocular Microscope with a Camera. Two sample blocks of the selected species of 2×2×3 cm have been taken to prepare the slides. The selected samples have been soaked in water for two weeks before being prepared for slides. Using a microtome (Model LEICA SM 2000R-SCHITTEN MIKROTOM), the specimens have been taken from transverse, radial, and tangential sections of the samples in the range of 10–15 µm thickness.

Staining and Mounting. The wood sections have been dehydrated in 50 % alcohol, then stained with safranin in 50 % alcohol to remove moisture and color. Further dehydration involved washing in 70 and 90 % alcohol, followed by absolute alcohol. After mixing with absolute alcohol and xylene, they have been kept in absolute alcohol again. Finally, they have been kept in xylene and mounted on slides using Canada balsam. After drying for 24 h, the prepared slides have been observed under the microscope.

Anatomical Measurements. Under a 40× magnification light microscope, anatomical measurements have been determined. The research division of the State Timber Corporation has been used to obtain the anatomical photographs and their measurements. Vessel diameter and vessels per 3.14 mm^2 have been measured in the transverse sections, and ray height, ray width, and rays per 3.14 mm^2 have been measured in the tangential sections of timber species using the prepared anatomy photos. One set of slides from each species have been prepared and the measurements have been taken for each sample. All the data of quantitative anatomical features have been tabulated. Mean tangential vessel diameter: an average of 10 measurements has been taken from the anatomical photos using Micrometrics SE Premium 4 software. Mean ray height and ray width: an average of 10 measurements has been taken from the anatomical photos using Micrometrics SE Premium 4 software.

The parameters have been calculated by:

$$\text{Ray area} = \text{Width of ray} \times \text{Height of ray}; \tag{1}$$

$$\text{Total ray area} = \text{Ray area} \times \text{Number of rays}; \tag{2}$$

$$\text{Vessel area} = \pi(\text{Tangential vessel diameter} / 2)^2; \tag{3}$$

$$\text{Total vessel area} = \text{Vessel area} \times \text{Number of vessels}. \tag{4}$$

Determination of the Wood Density. Two samples blocks of lesser-known timber species of 2×2×2 cm have been prepared, labeled, and cleaned to remove saw dust, mud, or any other dirty particles. Wood density has been measured by a densitometer and using the water displacement method (Archimedes' law). The weight of a water-filled beaker has been measured. A timber sample has been submerged in water to a constant depth and the final weight of the beaker has been measured. The timber samples have been oven-dried at 103 °C for 2 days until a constant weight has been reached. After cooling in a desiccator, the dry weight of each sample has been measured using an electronic balance (g).

Calculating the Wood Density. Consistent procedure has been maintained for each timber sample and density has been calculated by using the following equations:

$$\text{Timber weight} = \text{Final beaker weight} – \text{Initial beaker weight}; \quad (5)$$

$$\text{Density at 0 \% moisture level} = \text{Oven dry weight of a timber sample} / / \text{Timber sample weight} \times \text{Density of water (1,000 kg/m}^3\text{)}; \quad (6)$$

$$\text{Density at 12 \% moisture level} = = \text{Density at 0 \% moisture level} \times 112 / 100\ \text{kg/m}^3. \quad (7)$$

Boron Treatment through the Impregnation Method. The timber samples of each species of 5×10×13 cm have been prepared and labeled for boron treatment. Prior to treatment, the surfaces have been meticulously cleaned to remove sawdust and any other contaminants. A moisture meter has been used to record the moisture content of each sample at room temperature and 80 % relative humidity. Finally, the samples have been weighed using a precision balance (A&D Weighing GF-3000) to obtain their initial weights before boron treatment.

Boron Treatment through the Impregnation Process. Treatability has been tested for the samples of lesser-known timber species having the thickness of 5 cm and 10 cm and the length of 13 cm. Six replicates of each lesser-known timber species have been tested with an 8 % borax and boric acid equivalent solution of boric acid and borax in the ratio of 1 : 1.5 in a commercial treatment plant at Boossa Timber Corporation. The treatment cylinder has had the length of 3 m and the diameter of 1.2 m. All the timber samples have been placed into the treatment cylinder with a full load of sawn *Pinus* wood. The impregnation process steps have been as follows. The timber sample has been placed into the treatment vessel and subjected to a vacuum pressure of 635 mmHg for 20 min, removing air for deeper preservative penetration. A heated (60 °C) boron preservative has then been added to the vessel, its warmth facilitating smoother flow and better wood absorption. Next, the vessel has been pressurized to 12 bar for 45 min, effectively forcing the preservative into the wood. Removing excess preservative, a final 45-minute vacuum of 635 mmHg has ensured complete extraction. Now, treated with the boron preservative, the timber sample has been ready for its protected life.

Determination of the Chemical Retention. Retention is the amount of chemical preservatives that are kept in a unit volume of wood, which is measured in kilograms per cubic meter. Then the weight gain has been obtained and the chemical retention calculated by following the equation:

$$\text{Chemical Retention (kg/m}^3\text{)} = G{\cdot}C \cdot 10^3 / V, \quad (8)$$

where G – the amount of the solution absorbed by timber that is calculated by T_2-T_1; T_2 – the weight of wood after the impregnation (g); T_1 – the weight of wood before the impregnation (g); C – the solution concentration as percentage; V – the volume of the sample (cm^3).

Determination of Boron Penetrability. To uncover the penetration depth of a preservative, a turmeric solution has been applied, revealing bright yellow areas. Subsequently, treating these yellow zones with a salicylic acid solution triggers a color shift: yellow turning to red signifies the presence of boron, indicating the preservative's penetration depth. This simple method provides a visual indicator of the preservative's effectiveness.

Results and Discussion

Moisture Content. The moisture content of wood, expressed as a percentage of its dry weight, reveals the actual amount of water it contains. Before undergoing any treatment, wood typically requires its moisture content lowered to an acceptable range of 10–25 %. As shown in Fig. 1, the average moisture content varied considerably among the 20 different timber species analyzed. Interestingly, *Harpullia arborea* (Na-Imbul) possessed the lowest average moisture content, while *Rhizophora mucronata* (Maha-Kadol) exhibited the highest. This information highlights the diverse moisture levels inherent in different wood species. Understanding the wood moisture content is crucial for ensuring its long-term performance and durability. While managing moisture content without boron treatment is possible, it requires careful consideration of environmental factors and implementation of the appropriate control measures. Boron treatment offers a valuable solution for regulating moisture content, providing numerous benefits for wood preservation and enhancing its stability and resistance to decay.

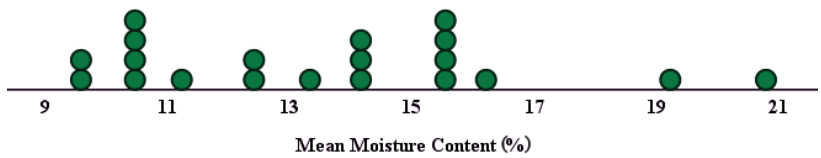


Fig. 1. The moisture content of timber samples

Fig. 1 shows that the moisture content ranges from 9 to 21 %. The mean moisture content is 10 %.

Density. Wood density, the dry mass per unit volume, is a crucial property that significantly influences various wood characteristics, including strength, stability, durability, and fire resistance. While it exhibits inherent variation across different species, it also changes dynamically throughout a tree's developmental stages. Wood density, the dry mass per unit volume, varies depending on the tree's stage of development and can be seen as a range for a specific timber species. Fig. 2, calculated using densitometers and water displacement, shows the diverse mean densities of lesser-known timber species, with *Memecylon umbellatum* (Kora-Kaha) exhibiting the highest and *Cananga odorata* (Wana-Sapu) the lowest. This information underscores wood density's role in selecting suitable wood for specific applications. Understanding the variation in wood density with tree development is crucial for various applications. It allows for the selection of the appropriate wood for specific uses, optimization of forest management practices, and development of effective wood processing techniques [12].

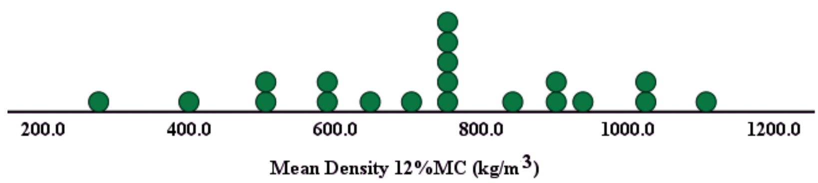


Fig. 2. The density of timber species

Fig. 2 shows the Mean Dencity 12 % MC (kg/m^3). The mean density is 12 % and it is difficult to say whether the data is symmetrical or skewed. The range varies from 9 to 21 % with a range of 12 %.

Development of the Classification Scale for Boron Retention. Highest boron retention has been recorded from *Cananga odorata* (Wana-Sapu) and the lowest boron retention has been recorded from *Bridelia moonii* (Path-Kela). Based on the degree of treatability, 20 species of lesser-known timber have been chosen and categorized into 4 groups: very difficult, moderately difficult, easy and very easy to treat. Similar grading ratings for treatability have also been produced in a prior study. It is preferable to create a categorization scale with 4 categories due to the simplicity of chemical application and application method.

Chemical retention classification has been prepared as follows (classes):

1) boron retention less than 3.5 kg/m^3 – very difficult to treat: *Grewia helicterifolia* (Bora-Daminiya), *Harpullia arborea* (Na-Imbul), *Bridelia moonii* (Path-Kela);

2) boron retention in between 3.5 and 7 kg/m^3 – moderately difficult to treat: *Acacia mangium* (Acacia), *Stereospermum personatum* (Dunu-Madala), *Vitex altissima* (Kaha-Milla), *Margaritaria indica* (Karaw), *Dichrostachys cinerea* (Katu-Andara), *Memecylon umbellatum* (Kora-Kaha);

3) boron retention in between 7 and 15 kg/m^3– easy to treat: *Allaeanthus zeylanicus* (Aladu), *Syzygium rubicundum* (Kurumbettiya), *Rhizophora mucronata* (Maha-Kadol), *Bhesa ceylanica* (Pelan);

4) boron retention higher than 15 kg/m^3– very easy to treat: *Araucaria columnaris* (Arawkeriya), *Ficus racemose* (Attikka), *Mitragyna parvifolia* (Helamba), *Cullenia ceylanica* (Katu-Boda), *Ficus benghalensis* (Maha-Nuga), *Alstonia scholaris* (Ruk-Aththana), *Cananga odorata* (Wana-Sapu).

The following categories have been used to classify 20 species under study.

Relationship between the Boron Treatability and Density. Using the densitometer and the water displacement method, density has been achieved and the values compared. Those values have been nearly similar. Depending on the stage of a tree growth, the density might change. Fig. 3 has shown that there has been a strong negative relationship between the density and boron retention.

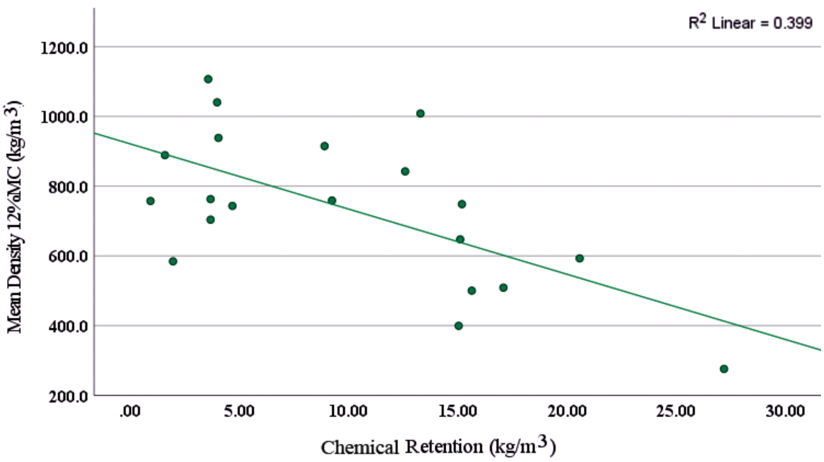


Fig. 3. The relationship between the boron treatability and density

Relationship between the Boron Treatability, Total Vessel Area and Total Ray Area. Various types of wood have different numbers, positions and sizes of rays and vessels. Table 2 has shown the Pearson correlation values and probability values of boron retention with the total vessel area and total ray area.

Table 2

The anatomy measurements of lesser-known timber species

Common name	Vessels			Rays			
	Mean diameter (μm), N = 10	Number per mm²	Total area per mm² (μm²)	Mean height (μm), N = 10	Mean width (μm), N = 10	Number per mm²	Total area per mm² (μm²)
Acacia	130.76	7	98400.97	208.28	14.20	26	76294.89
Aladu	104.86	4	38520.42	454.08	27.79	9	112508.12
Arawkeriya	0.00	0	0.00	341.10	21.44	7	48905.27
Attikka	101.55	4	30964.14	401.30	40.39	11	185835.18
Bora-Daminiya	69.50	36	136570.86	345.55	21.08	23	169344.43
Dunu-Madala	145.60	6	100787.20	298.55	33.40	9	88927.64
Helamba	113.40	13	128701.26	534.81	31.62	7	113097.85
Kaha-Milla	128.25	5	61733.47	314.61	30.00	15	138246.40
Karaw	87.11	18	104424.84	956.40	43.40	6	264404.51
Katu-Andara	71.53	15	60167.33	545.78	26.34	17	238027.44
Katu-Boda	150.33	4	73511.98	828.11	48.73	9	346978.78
Kora-Kaha	30.12	63	44726.90	124.65	9.00	129	144698.42
Kurumbettiya	88.95	10	61377.35	634.46	18.10	15	175558.20
Maha-Kadol	54.47	19	44538.67	1362.57	51.43	4	267809.50
Maha-Nuga	196.18	2	57781.83	644.77	63.93	9	367583.10
Na-Imbul	125.36	1	15730.43	337.80	17.98	32	195329.80
Path-Kela	100.31	14	108270.27	522.84	44.48	9	199966.40
Pelan	77.37	11	52423.47	411.03	27.04	7	74320.16
Ruk-Aththana	136.10	6	88062.72	503.29	35.99	12	213460.30
Wana-Sapu	218.07	2	83293.09	1281.45	55.85	3	205126.40

The relationship between the retention and total vessel area has been negative (Fig. 4), while the relationship between the retention and total ray area has been positive (Fig. 5).

Anatomical Measurements of Lesser-Known Timber Species Taken by Micrometrics Premium 4 Software. The highest mean diameter of vessels has been registered in *Ficus benghalensis* (Maha-Nuga), but there are only 2 vessels per mm². The lowest mean diameter of vessels has been registered in *Memecylon umbellatum*

(Kora-Kaha) but it has the highest number of vessels per mm². *Grewia helicterifolia* (Bora-Daminiya) has the highest mean total vessel area, whereas *Harpullia arborea* (Na-Imbul) has the lowest mean total vessel area. *Araucaria columnaris* (Arawkeriya) vessel area is zero. Because Arawkeriya is a softwood tree, it does not have vessels.

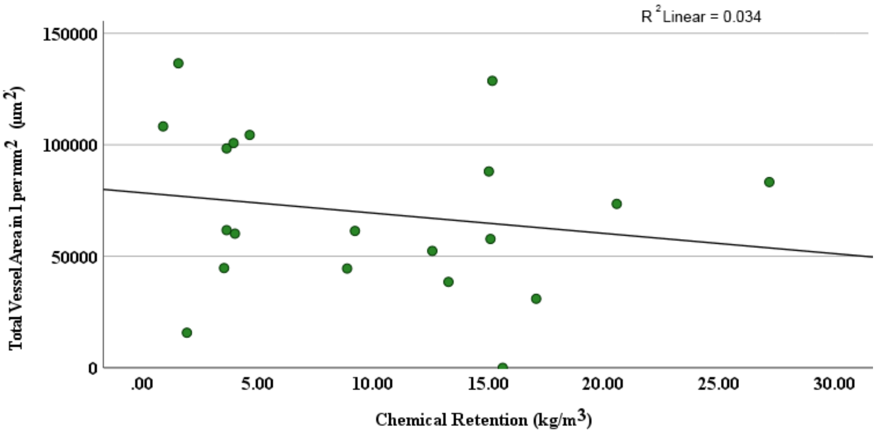


Fig. 4. The relationship between the total vessel area and boron retention

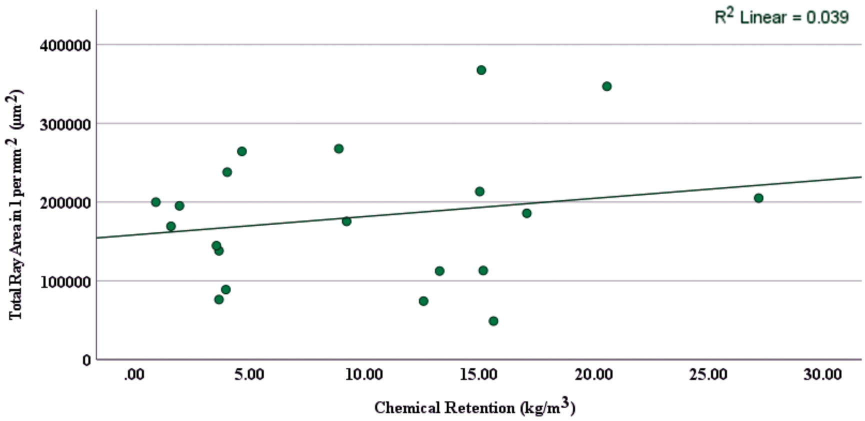


Fig. 5. The relationship between the total ray area and boron retention

Rhizophora mucronata (Maha-Kadol) has the highest mean height of rays, but there are only 4 rays per mm². The lowest mean height and width of rays has been registered in *Memecylon umbellatum* (Kora-Kaha), but it has the hightest number of rays per mm². The highest mean width of rays has been registered in *Ficus benghalensis* (Maha-Nuga), but there are only 9 rays per mm². *Ficus benghalensis* (Maha-Nuga) has the highest mean total ray area, whereas *Araucaria columnaris* (Arawkeriya) has the lowest mean total ray area (Fig. 6).

The effectiveness of boron-based wood preservatives depends heavily on the penetration depth of the boron compound into the wood structure. This penetration determines the extent of protection against decay and other biological attacks. Currently, no standardized classification system specifically exists for boron penetration in wood. Developing a reliable and consistent classification scale for boron penetration offers several advantages. Enhanced evaluation is a key factor and a standardized scale allows for objective and consistent assessment across different laboratories, reducing subjectivity and ensuring data accuracy. Improved communication as a common language for describing boron penetration facilitates communication and collaboration between researchers, wood treatment professionals, and end users. Treatment processes can be optimized by accurately measuring penetration depth to achieve the desired level of protection while minimizing boron usage [13]. Table 3 explains the development of classification for penetration of boron. It is a novel concept to the classification scale for penetration of boron.

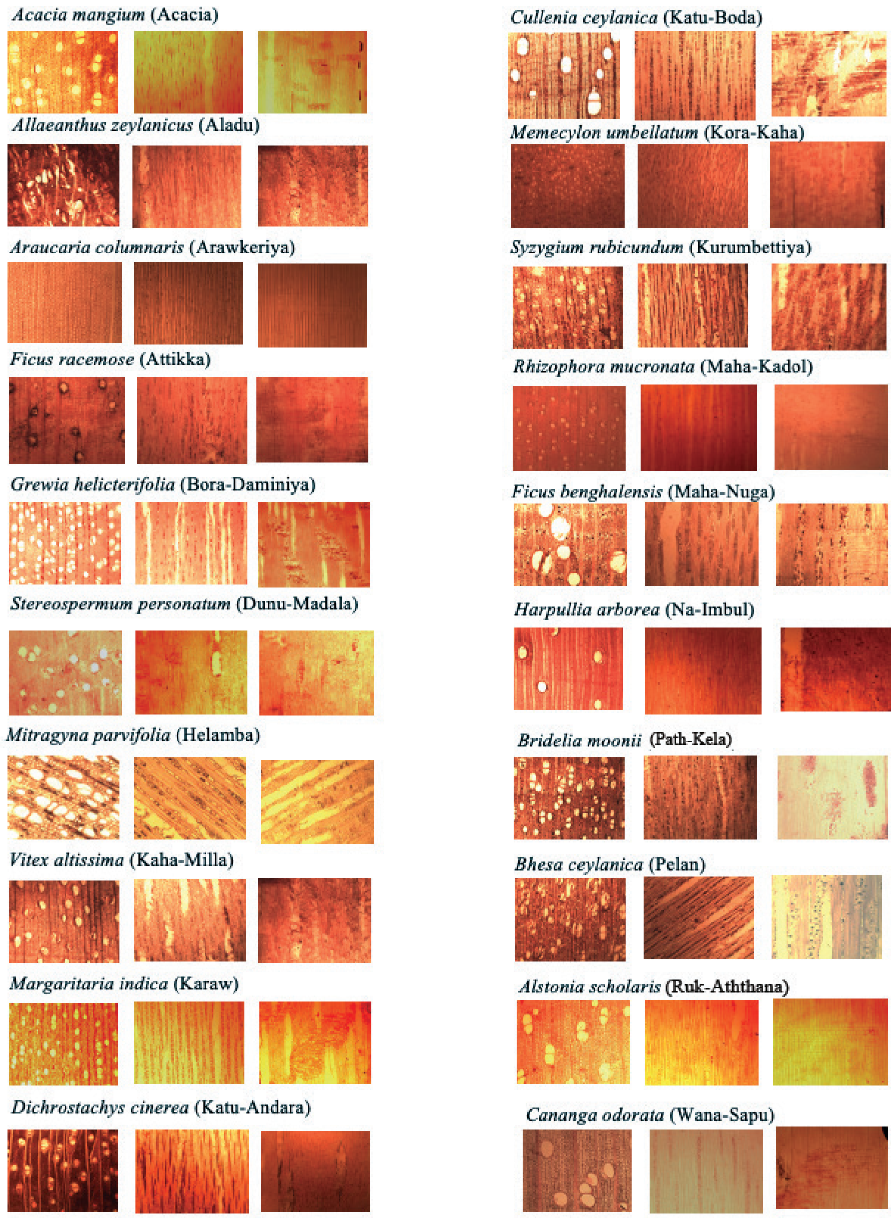
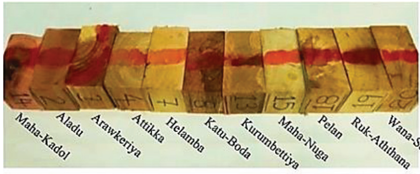


Fig. 6. The microscopic photos of lesser-known timber species (photographic representation of anatomical features of the transverse section (T.S) in the left hand panel, the tangential longitudinal section (T.L.S) in the middle panel and the radial longitudinal section (R.L.S) in the right hand panel)

Table 3

The development of the classification scale for penetration of boron

Penetration category	Timber species
Fully penetrated  	*Rhizophora mucronata* (Maha-Kadol) *Allaeanthus zeylanicus* (Aladu) *Araucaria columnaris* (Arawkeriya) *Ficus racemose* (Attikka) *Mitragyna parvifolia* (Helamba) *Cullenia ceylanica* (Katu-Boda) *Syzygium rubicundum* (Kurumbettiya) *Ficus benghalensis* (Maha-Nuga) *Bhesa ceylanica* (Pelan) *Alstonia scholaris* (Ruk-Aththana) *Cananga odorata* (Wana-Sapu)
Partially penetrated (penetrated more than 5 mm but not fully)  	*Acacia mangium* (Acacia) *Stereospermum personatum* (Dunu-Madala) *Margaritaria indica* (Karaw) *Vitex altissima* (Kaha-Milla) *Dichrostachys cinerea* (Katu-Andara) *Memecylon umbellatum* (Kora-Kaha)
Penetrated less than 5 mm  	*Harpullia arborea* (Na-Imbul) *Bridelia moonii* (Path-Kela) *Grewia helicterifolia* (Bora-Daminiya)

Effectively managing boron treatment in wood preservation requires reliable methods for evaluating the retention and penetration of the boron compound within the wood structure. This is crucial for ensuring the desired level of protection against decay and other biological attacks. Currently, there is no standardized classification scale specifically for boron retention and penetration in wood. The existing methods rely on qualitative descriptions or semi-quantitative scales, which can be subjective and lack precision. This can lead to inconsistencies in treatment evaluation and hinder effective decision-making. In this study a 4 tier classification system has been developed (Table 4). By addressing these considerations and engaging in collaborative efforts, the development of a robust classification scale for boron retention and penetration can significantly contribute to the advancement of wood preservation technologies and ensure the long-term durability and performance of wood products.

Table 4

The development of the classification scale for retention and penetration of boron

Class	Boron retention (kg/m^3)	Ability to treat	Lesser-known timber species	Boron penetration
01	Less than 3.5	Very difficult to treat	*Grewia helicterifolia* (Bora-Daminiya) *Harpullia arborea* (Na-Imbul) *Bridelia moonii* (Path-Kela)	Penetrated less than 5 mm
02	In between 3.5–7	Moderately difficult to treat	*Acacia mangium* (Acacia) *Stereospermum personatum* (Dunu-Madala) *Vitex altissima* (Kaha-Milla) *Margaritaria indica (*Karaw) *Dichrostachys cinerea* (Katu-Andara) *Memecylon umbellatum* (Kora-Kaha)	Partially penetrated (penetrated more than 5 mm but not fully)
03	In between 7–15	Easy to treat	*Allaeanthus zeylanicus* (Aladu) *Syzygium rubicundum* (Kurumbettiya) *Rhizophora mucronata* (Maha-Kadol) *Bhesa ceylanica* (Pelan)	Fully penetrated
04	Higher than 15	Very easy to treat	*Araucaria columnaris* (Arawkeriya) *Ficus racemose* (Attikka) *Mitragyna parvifolia* (Helamba) *Cullenia ceylanica* (Katu-Boda) *Ficus benghalensis* (Maha-Nuga) *Alstonia scholaris* (Ruk-Aththana) *Cananga odorata* (Wana-Sapu)	

Forest stands, defined as a group of trees with similar characteristics, exhibit a complex interplay between tree age, growing conditions, density, and ultimately, their homogeneity. The stands with a single age class and consistent growing conditions, like fertile soil and ample water, tend to be more homogeneous. However, the competition for resources in dense stands creates variations in their size and health, reducing uniformity. Foresters can manipulate density through thinning to promote a more even stand, but perfect homogeneity is not always desirable. A balance between some variation, which fosters a resilient ecosystem, and a degree of uniformity, which can be beneficial for timber production, is often the target for sustainable forest management.

Conclusion

Lesser-known timber species have been categorized into four groups for boron treatability known as class 01 – very difficult to treat (retention less than 3.5 kg/m^3); class 02 – moderately difficult to treat (retention in between 3.5 and 7 kg/m^3); class 03 – easy to treat (retention in between 7 and 15 kg/m^3); class 04 – very easy to treat (retention higher than 15 kg/m^3). According to the above classification seven lesser-known timber species such as *Araucaria columnaris* (Arawkeriya), *Ficus racemose*

(Attikka), *Mitragyna parvifolia* (Helamba), *Cullenia ceylanica* (Katu-Boda), *Ficus benghalensis* (Maha-Nuga), *Alstonia scholaris* (Ruk-Aththana) and *Cananga odorata* (Wana-Sapu) belong to class 03 – very easy to treat. Lesser-known timber species have been categorized into three groups according to boron penetration level. Those are fully penetrated, partially penetrated (penetrated more than 5 mm but not fully) and penetrated less than 5 mm. Comparing the two classifications together, species in class 01 belong to the group of those penetrated less than 5 mm, species in class 02 belong to the group of partially penetrated ones, and species in classes 03 and 04 belong to the group of fully penetrated ones. The relationship between the treatability and wood density has been a strong negative linear one. The relationship between the treatability and total ray area has been positive, while the relationship between the treatability and total vessel area has been negative. Both relationships have been weak.

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