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Policy Brief

Hot Water Treatment as a Measure to Minimize Growth Stress-Related Defects in the Processing of Falcata (Falcataria Falcata (L.) Greuter & R. Rankin) Wood

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ABSTRACT

Falcataria falcata timbers are prone to defects such as heart checks, cracks, and end-splitting when felled, which negatively affect log quality and market price. These defects are caused by growth stresses—mechanical stresses that naturally occur due to cell maturation and the increasing load of the tree crown. While growth stresses cannot be directly measured, they can be assessed through strain measurements. In this study, Surface Released Strain (SRS) was used to assess stress patterns around the tree's circumference, and Residual Released Strain (RRS) was measured to determine residual stress from pith to bark.

The study examined several factors: growth orientation (straight vs. leaning), age (young vs. mature trees), season (dry vs. wet), and geographic location (Regions 10 and 13). Trees with high strain and steep strain patterns were subjected to hot water treatment at 80°C for 48 hours as a thermal relaxation method.

Results revealed that all SRS values were negative, indicating tensile stress near the bark. For RRS, compressive stress was observed near the pith and tensile stress near the bark, with age and channel position (pith to bark) significantly influencing RRS ($P < 0.05$). boards treated with hot water showed a more balanced strain gradient, with values ranging from 200% to -200% while untreated boards exhibited a steep strain gradient, ranging from approximately 600% to -1,400%. These findings demonstrate that hot water treatment effectively reduces growth stress in *F. falcata* timbers. Therefore, it is recommended that logs be subjected to hot water treatment before further processing to minimize growth stress-related defects

Keywords: Growth Stress, Strain, Wood Defect

1. INTRODUCTION

Growth stress plays a vital role in the structural integrity of trees, enabling them to support their considerable weight overtime against the force of gravity. However, the accumulation of growth stress during wood development increases the risk of defects during processing into lumber or veneer. Tree growth stress refers to the mechanical stress permanently present in wood as a tree grows (Gril et al., 2017). Cassens & Serrano (2004) emphasized that longitudinal growth stresses are present in all standing timber and cut logs. When logs are harvested, processing defects become unpredictably severe, significantly diminishing the final yield (Gril et al., 2017).

A study by the USDA Forest Service found that, on average, 12.6% of potential lumber yield is lost due to multiple defects (Cahill & Cegelka, 1989). In the Philippines, *Falcataria falcata* (L.) Greuter & R. Rankin plantations are a key source of income for tree farmers in Mindanao. This species is widely planted across Mindanao, as well as parts of the Visayas and Luzon, due to its demand for various wood products. The Caraga Region, designated as the country's timber corridor by DENR DAO No. 99-13, provides ideal conditions for tree plantations, with abundant land and favourable environmental conditions. Tree farming has long been an integral part of life for many Caraganons.

Despite the demand for *Falcata*, farmers often face fluctuating market prices due to log defects such as radial cracks at the log ends and crooking of lumber during harvesting. These defects reduce the logs' value and contribute to lower recovery rates during wood processing. One measure to minimize these defects is treating wood with hot water. Hot water treatment is based on the assumption that the thermal relaxation of wood reduces internal strain. Residual stress relaxation can be achieved when both heat and moisture penetrate the log (Nogi et al., 2003). When heated, lignin and hemicellulose become thermoplastic (Hon & Ou, 1989). Moisture that penetrates the microfibrils in the cell wall acts as a lubricant, allowing some relative movement between the microfibrils (Silvester, 2013). This forms the basis for assuming that inherent stress developed during wood growth can be reduced when the wood is heated while saturated with water. This study was conducted to determine the effects of hot water treatment in minimizing growth stress.

2. APPROACHES AND RESULTS

The study was conducted in tree plantations located in Regions 10 (Northern Mindanao) and 13 (CARAGA), where *F. falcata* is extensively planted. A 2x2x2x2 factorial design, replicated three times with one tree per replication, was used. Factors such as growth orientation (straight and leaning), age (3 to 6 years and 7 to 10 years), season (wet and dry), and location (Regions 10 and 13) were considered in selecting the *Falcata* tree samples. Growth data, including diameter and height, were collected before strain measurements.

To determine the effect of hot water treatment on growth stress patterns in *Falcata* boards, two boards were prepared per tree. The first board served as a control, while the second was treated with hot water at 80°C for 48 hours. Six trees were used for this study. Residual Released Strain (RRS) measurements were conducted on both boards, which were prepared by sawing logs into boards with a thickness of 5 cm (centered on the pith) and a length equal to 2.6 times the DBH, following Kojima, M. et al. (2009); Okuyama, T. et al. (1981); Yamamoto, H. et al. (1989); and Yoshida, M. et al. (2002).

Sampling points (8 gauges per board) were set from pith to bark. The board surface was prepared evenly and cleaned by sanding. A strain gauge (electric-wire strain gauge, 10 mm length, KFG-10-120-C1-11L3M3R, Kyowa Co., Tokyo, Japan) was glued to the sampling points across the board and connected to a strain meter. After measuring the initial strain in the tree sample, the residual stress was released using a handsaw, and the strain was recorded. The difference in RRS was calculated by subtracting the minimum RRS value from the maximum RRS value in each log sample. Differences in strain patterns between the treated and untreated boards were statistically analyzed using multifactor analysis of Statgraphics Centurion 16.1 software (2010), the strain pattern difference between hot water treated boards and untreated was analyzed descriptively.

Results revealed a negative strain near the pith and a positive strain near the bark. This suggests that wood elements near the pith are under compressive stress while those near the bark are under tensile stress. A multifactor analysis showed that location, season and growth orientation did not significantly affect RRS ($P<.05$). Age of trees significantly contributed to strain patterns, trees with a diameter of 30 cm and more showed a more favourable strain pattern.

Figure 1 illustrates the difference between the mean RRS of hot water-treated and untreated boards. A steep strain gradient is observed in untreated boards, with values ranging from approximately 600% to -1,400%. In contrast, a more relaxed strain gradient is seen in hot water-treated boards, with values ranging from 200% to -200%. This indicates that hot water treatment is an effective method for balancing residual stress in wood. A lower strain gradient from pith to bark reduces the occurrence of growth stress-related defects. Multifactor ANOVA revealed that the interaction between treatment and channel position (distance from the pith) significantly affects RRS. The strain readings near the bark are significantly different from those near the pith. However, in hot water-treated wood, this difference is less pronounced than in untreated wood.

Hot water treatment is based on the assumption that the thermal relaxation of wood will reduce the internal straining. Residual stress relaxation can be achieved when both heat and moisture penetrate the log (Nogi et al., 2003). The study demonstrated that hot water treatment at 80°C for 48 hours effectively reduces release strain in logs, which is crucial for minimizing defects during wood processing. This method allows for better stabilization of the wood structure, leading to higher quality falcata wood products. As cited in Gilbero (2019) There were several methods to reduce the growth stress in the logs: Stress relaxation also occurs at high temperatures induced by boiling (Skolmen, 1967), steaming (Sujan et al, 2015) and smoking (Barber & Meylan, 1964; Noack 1969; Tanaka et al. 2014). Hot water treatment is one of the efficient methods to reduce the residual release strain inside the logs.

According to Nogi et al (2003) residual stress relaxation occurs only when both heat and moisture exist inside the logs further, they concluded that at 80°C for 33 hrs resulted in residual relaxation of the bolt. In this study, the board is heated at 80°C for 48 hours. Locked-in strains are partially released by cutting specimens from the tree and more completely by boiling them in a green state to exceed the softening point of lignin (Gril & Thibaut, 1994). However, Nogi et al (2003) further explained that stress relaxation is associated not only with lignin softening but also with the degradation of the matrix substance comprising the cell walls. This relaxation is referred to as hygrothermal recovery (HTR) where wood elements relieve internal stress when green wood is heated. HTR is an irreversible dimensional change (Matsuo-Ueda et al, 2023). HTR occurs when the wood is subjected to a high temperature between 60 to 90°C where wood reaches a glass transition temperature (Pelozzi et al, 2014). As explained by Moya and Tenorio (2021), Enhancement of residual stress occurs because there is a rearrangement of the molecular and microstructure of material that consequently results in the relaxation of internal stresses.

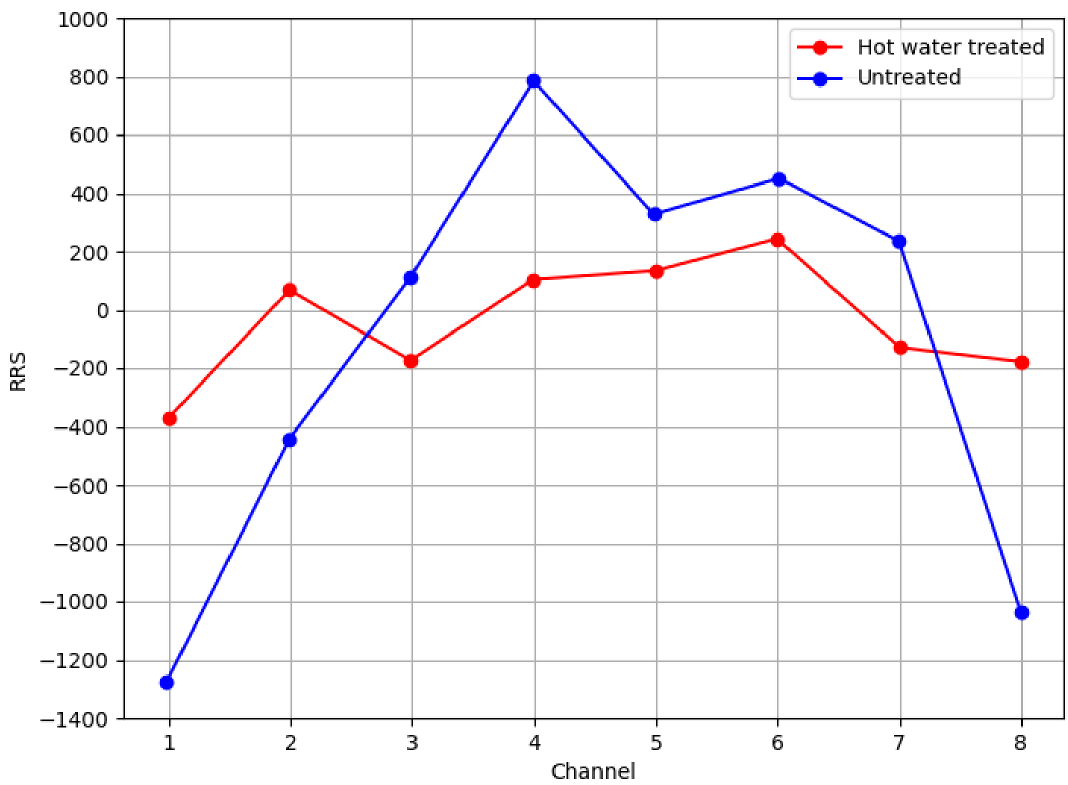

Figure 1. Mean Residual release strain (%) in hot water-treated and untreated falcata flitches from pith to bark (the pith is located between channels 4 and 5, while the bark is near channels 1 and 8).

3. CONCLUSION

In conclusion, the findings of the study highlight the importance of managing growth stress in Falcata trees to improve the quality of lumber and reduce waste and defects during processing. It was emphasized that wood elements near the pith are under compressive stress while those near the bark are under tensile stress. a more relaxed strain gradient is seen in hot water-treated boards, with values ranging from 200% to -200%. The study suggests that treating logs with hot water at 80°C for 48 hours can significantly help in reducing internal stresses, leading to better-quality falcata wood products.

By adopting these pre-log treatments and creating clear guidelines for local Falcata farmers, we can not only improve the quality of the wood but also reduce waste and increase profits for those in the lumber industry. These steps are vital for ensuring that Falcata remains a sustainable and lucrative resource for communities in the Philippines, ultimately supporting the livelihoods of many tree farmers and contributing to the local economy.

4. IMPLICATIONS AND RECOMMENDATIONS

Based on the results of the study, it is recommended that Falcata logs undergo hot water treatment at 80°C for 48 hours before wood processing. This is especially important for Falcata products like veneer and plywood, where growth-related defects can significantly affect quality and, consequently, market value. Additionally, it is recommended to harvest Falcata timber once it reaches a diameter at breast height (DBH) of at least 30 cm, as this ensures a more balanced strain pattern.

Author Contributions: The authors Mark Jun A. Rojo, Dennis M. Gilbero, Jason A. Parlucha, and Jupiter V. Casas contributed to the conceptualization, data collection, processing, and interpretation of results for this study. Mark Jun A. Rojo, as the primary author, took the lead in preparing this policy brief. Joseph C. Paquit, Trisha Marie T. Lopez, Vanessa Jay M. Casas, and Khenneth John D. Tanong provided valuable contributions, specifically in data collection, processing, analysis, and drafting of this policy brief. All authors have read and agreed to the published version of the manuscript."

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