East African Journal of Forestry & Agroforestry
eajfa.eanso.org
Volume 8, Issue 1, 2025
Print ISSN: 2707-4315 | Online ISSN: 2707-4323
Title DOI: https://doi.org/10.37284/2707-4323

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Physical and Mechanical Strength Properties of Resin Tapped *Pinus caribaea* Timber

Christine Betty Nagawa[1], Isaac Ssebuyira Kitiibwa[1], Derrick Mubiru[1], Agatha Syofuna[1], Christine Mugumya Kyarimpa[2], Timothy Omara[1], Edward Nector Mwavu[1] & Simon Savio Kizito[1]*

[1] Makerere University, P. O. Box 7062, Kampala, Uganda.
[2] Kyambogo University, P. O. Box 1, Kampala, Uganda.
[*] Author for Correspondence ORCID ID; https://orcid.org/0000-0002-4252-2718; Email: christinengw@gmail.com

Article DOI: https://doi.org/10.37284/eajfa.8.1.3511

Date Published:

19 August 2025

Keywords:

Basic Density, Mechanical Properties, Modulus of Elasticity, Resin Tapping, Shear Stress.

ABSTRACT

Resin tapping on *Pinus caribaea* Morelet (*P. caribaea*) is an activity that is proven to yield multiple economic benefits to pine growers. However, there is uncertainty as to whether extracting gum resin from *P. caribaea* trees compromises its timber strength properties for structural applications. In this study, the effects of resin tapping on the basic density and strength properties of timber from *P. caribaea* of different ages (one, three, and five years) were investigated. Tests were done on small, clear specimens from *P. caribaea* trees whose resins were tapped, with control samples obtained from an untapped tree. The samples were prepared using the British standard (BS 373:1957) and tested for their basic density, modulus of elasticity, modulus of rupture, shear strength parallel to grain and compressive strength parallel to grain test following the American Standards Testing Methods. The results showed that basic densities and strength properties of *P. caribaea* timber tended to increase with an increase in the age of the resin tapped trees, which were significantly different from the samples of the untapped tree ($P<0.05$). These results suggest that resin tapping of *P. caribaea* using the Chinese method does not have negative effects on the strength properties of its timber. However, further studies are required to understand the effects of resin tapping on timber properties, especially for *P. caribaea* trees that are tapped for more than five years.

APA CITATION

Nagawa, C. B., Kitiibwa, I. S., Mubiru, D., Syofuna, A., Kyarimpa, C. M., Omara, T., Mwavu, E. N. & Kizito, S. S. (2025). Physical and Mechanical Strength Properties of Resin Tapped *Pinus caribaea* Timber. *East African Journal of Forestry and Agroforestry*, *8*(1), 406-414. https://doi.org/10.37284/eajfa.8.1.3511

CHICAGO CITATION

Nagawa, Christine Betty, Isaac Ssebuyira Kitiibwa, Derrick Mubiru, Agatha Syofuna, Christine Mugumya Kyarimpa, Timothy Omara, Edward Nector Mwavu and Simon Savio Kizito. 2025. "Physical and Mechanical Strength Properties of Resin Tapped *Pinus caribaea* Timber" *East African Journal of Forestry and Agroforestry* 8 (1), 406-414. https://doi.org/10.37284/eajfa.8.1.3511.

HARVARD CITATION

Nagawa, C. B., Kitiibwa, I. S., Mubiru, D., Syofuna, A., Kyarimpa, C. M., Omara, T., Mwavu, E. N. & Kizito, S. S. (2025), "Physical and Mechanical Strength Properties of Resin Tapped *Pinus caribaea* Timber", *East African Journal of Forestry and Agroforestry*, 8(1), pp. 406-414. doi: 10.37284/eajfa.8.1.3511.

 |

Article DOI: https://doi.org/10.37284/eajfa.8.1.3511

IEEE CITATION

C. B., Nagawa, I. S., Kitiibwa, D., Mubiru, A., Syofuna, C. M., Kyarimpa, T., Omara, E. N., Mwavu & S. S., Kizito "Physical and Mechanical Strength Properties of Resin Tapped *Pinus caribaea* Timber", *EAJFA*, vol. 8, no. 1, pp. 406-414, Aug. 2025.

MLA CITATION

Nagawa, Christine Betty, Isaac Ssebuyira Kitiibwa, Derrick Mubiru, Agatha Syofuna, Christine Mugumya Kyarimpa, Timothy Omara, Edward Nector Mwavu & Simon Savio Kizito. "Physical and Mechanical Strength Properties of Resin Tapped *Pinus caribaea* Timber". *East African Journal of Forestry and Agroforestry*, Vol. 8, no. 1, Aug. 2025, pp. 406-414, doi:10.37284/eajfa.8.1.3511

INTRODUCTION

Pines (*Pinus* species) is one of the most widely distributed coniferous trees worldwide. They are valued for their fast growth, adaptability to a range of environments, and versatile wood properties (Singh et al., 2018). *Pinus* (Pinaceae) is considered the largest genus of conifers, with at least 100 taxonomically identified species, many of which are cultivated in both temperate and tropical regions for timber, pulp, resin and other forest products (Dziedziński et al., 2021). In plantation forestry, pines are preferred for reforestation and afforestation due to their high biomass yield, ease of management and relatively short rotation cycles (Sullivan et al., 2025).

Pinus caribaea, commonly known as the Caribbean pine, is a hard, fast-growing and the most widely cultivated conifer in tropical regions (Lima et al., 2023; Rojas-Sandoval & Acevedo-Rodríguez, 2013; Zziwa et al., 2020). In Uganda and other parts of Eastern Africa, the species has gained economic importance due to its adaptability to the local climates, rapid growth and the dual-purpose value it offers, that is, yielding timber for construction and pulp as well as oleoresin (Ssebuliba, 2022).

Resin tapping of oleoresin from *Pinus* species have been recognised as a potential carbon sequestration initiative (Demko & Machava, 2022; Rodrigues-Corrêa et al., 2011; Rodrigues-Honda et al., 2023). It involves inducing controlled incisions into the bark of living pine trees to expose resin ducts and promote resin exudation. This can result in anatomical changes, resin canal proliferation, fungal infections and localised degradation of the xylem tissue (López-Álvarez et al., 2023), which can in turn influence important physical and mechanical properties of the pine timber. Previous authors have argued that resin tapping may compromise the strength characteristics of timber produced from resin-tapped trees (Liu et al., 2022; Moura et al., 2023). This is partly because timber from resin-tapped trees tends to have reduced growth (Chen et al., 2015; Kopaczyk et al., 2023), but the effect of resin tapping on *Pinus* species remains controversial (García-Méijome et al., 2023; López-Álvarez et al., 2025; Moura et al., 2023). For example, resin tapped *Pinus pinaster* resinous wood were found to possess high resin content but had reduced value due to machining difficulties (García-Iruela et al., 2016). Another study indicated that the base density of the tree trunk of *Pinus elliottii* after 3 years of resin tapping increased with years of resin tapping (Wu et al., 2022). To date, little information exists on whether resin tapping of Uganda's *P. caribaea* may negatively impact timber strength properties of its trees. The focus of this study was therefore to establish the physical and strength properties of timber from resin tapped and non-tapped *P. caribeae* trees.

MATERIALS AND METHODS

Sample Collection

Specimens of *P. caribaea* timber were collected from Busoga Forestry Company, Eastern Uganda (0.431382, 33.395910). Tapped trees of ages 1, 3 and 5 years and an untapped tree (control) were systematically selected from the plantation stand (plot-based sampling from plots containing trees of the same age). Since differences in properties between individual trees are significantly higher than the differences within the same tree, systematic sampling was employed. Four trees of each age were used since the smaller the sample size, the smaller the variability in the results.

Article DOI: https://doi.org/10.37284/eajfa.8.1.3511

Thus, there was a need for a reasonable number of samples to give realistic property values (Zziwa et al., 2010).

Sample Preparation

The control tree and selected trees of 1, 3 and 5 years with a history of resin tapping were felled, and processed into sizeable timber of dimensions of 80 × 70 × 250 mm to accommodate the rigorous stepwise sample preparation in the wood machining workshop. To ensure consistency in sample collection, specimens were extracted from three sections that were the top (one meter above the tapping wound), middle (at the tapping wound one meter) and bottom (one meter below the tapping wound). The specimens were transported to the Department of Forestry laboratory (Makerere University, Kampala), stacked and left to air dry for a month to reduce the moisture content to about 20%.

Following the British Standard BS 373:1957, twenty small clear test specimens measuring 280 × 20 × 20, 60 × 20 × 20 mm, and 20 × 20 × 20 mm (for bending strength, compressive stress and shear parallel to grain tests, respectively) were prepared from each section of both the tapped and untapped trees. Physical and strength property tests were performed at 63±3% relative humidity and a temperature of 21±3°C. The properties tested included basic density, static bending strength (modulus of elasticity, modulus of rupture), shear strength and compression strength parallel to grain.

Measurement of Physical Properties

Tests and sample preparation were done in accordance with the British Standard BS 373:1957. Basic density (in kg/cm^3) was calculated using green volume (V_1) and oven-dry weight (W_3) using equation 1 (Vieilledent et al., 2018).

$$\text{Density } (\rho) = \frac{W_3}{V_1} \quad (1)$$

Strength Property Tests

Strength property tests were carried out on Testometric Universal Testing Machine (UTM) AX M500–25KN connected to a computer system controlling the test operations. The length, breadth, width, and expected deflection were fed into the computer with testing speed set for each test at a given rate for bending strength (6.6 mm per min), compressive stress (1.2 mm per min) and shear stress (3.2 mm per min).

Briefly, the samples used were 280 × 20 × 20 mm for bending strength, 60 × 20 × 20 mm for compressive stress test and 20 × 20 × 20 mm for shear parallel to grain test. The loading equipment was inserted into the UTM depending on the strength property test and then the machine height was adjusted according to the specimen size for the cross-head loading equipment to just touch the specimen to be loaded. The machine was started and stopped on rapture after sample failure, and the corresponding load deflections were recorded while the curves were plotted on the computer. The steps were repeated for all the samples.

Modulus of Elasticity

Modulus of elasticity (MOE) reflects the elastic limit of the wood beyond which the specimen runs into permanent deformation. Specimens used in the measurement of strength properties were loaded to failure in three-point loading over a span of 280 mm. The loads at the elastic limit and the corresponding deflections were recorded and used for the computation of MOE using equation 2.

$$\text{MOE} = \frac{PL^3}{48ID} \quad (2)$$

From which MOE is in MPa, P = applied centre load (N), D = deflection at mid span (mm), L = the span (mm) and I = moment of inertia in (mm^4) obtained using equation 3.

$$I = \frac{bh^3}{12} \quad (3)$$

Where: b is the breadth of the test piece in mm and h is the depth of the specimen in mm.

Article DOI: https://doi.org/10.37284/eajfa.8.1.3511

Modulus of Rapture

Modulus of rupture (MOR) reflects the maximum load-carrying capacity of wood samples in bending and is proportional to the maximum moment borne by the specimen. It was determined using equation 4.

$$MOR = \frac{1{\cdot}5PL}{bh^2} \quad (4)$$

Where P = the maximum applied load (N), L = the test span, *b* = breadth, and h = thickness.

Shear Strength Parallel to Grain

Shear stress (Fs) determined using equation 5.

$$Fs = \frac{P}{bh} \quad (5)$$

The variables P, b and h follow from equation 4 (Naylor, Hackney, & Noel, 2012).

Compressive Strength Parallel to Grain Test

Compressive strength (Fc) was determined using samples of 60× 20 × 20 mm. The maximum load was recorded and the maximum compressive stress parallel to the grain was calculated using equation 6.

$$Fc = \frac{P}{ab} \quad (6)$$

Where ab = cross-sectional area of the specimen.

Statistical Analysis

Data normality test was initially checked using the Shapiro-Wilk test to eliminate outliers, mainly from samples with failure mode caused by internal defects. The data were then subjected to One-Way Analysis of Variance (one-way ANOVA) at 5% significance level using GraphPad Prism for Windows (version 9.3.1, GraphPad Software, San Diego, CA, USA). Sections of timber from tapped pine trees for a given period were compared to establish if there are any differences in their strength properties using Tukey's multiple comparisons test.

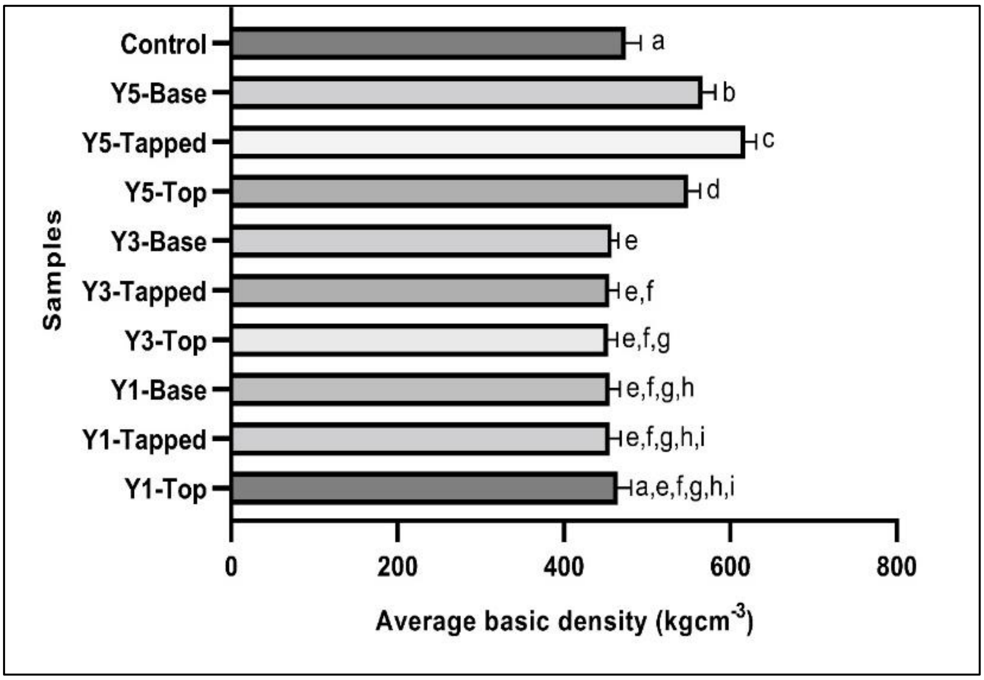
RESULTS AND DISCUSSION

Basic Density of Timber from Resin-Tapped *P. caribaea* Trees

The basic density of timber samples from each tree section of the tapped trees compared to those from the untapped trees are shown in Figure 1. The average basic density of the samples ranged from 336.21±11.24 kg/cm^3 for samples from the top part of incisions on a 3-year-old resin tapped tree (Y3-Top) to 464.50±16.37 kg/cm^3 for the top part of 1-year-old resin tapped tree (Y1-Top) samples. Overall, the average density of the samples from resin tapped trees was significantly higher than that of the control samples ($P<0.05$) except for those prepared from the top part of the tapping incision on the one-year (Y1-Top) tree. In addition, statistically significant and higher average basic densities ($P<0.05$) were only observed among samples that were obtained from the 5-year-old tapped tree (Figure 1). Thus, the effect of sampling position in the resin tapped trees was only significant among the 5-year-old tree samples.

Article DOI: https://doi.org/10.37284/eajfa.8.1.3511

Figure 1: Average Basic Density of Timber from Resin-Tapped *P. caribaea* Trees in Uganda.



Note: Error bars are standard deviations of replicates. Y1, Y3 and Y5 refer to the age of the tapped trees, i.e., 1, 3 and 5 years. Bars carrying different alphabetical letters are statistically different at P<0.05 and P<0.01.

Tree age, timing and method of tapping are some of the factors known to strongly influence resin yield in pines and could equivalently determine their timber properties (Zas et al., 2020). The results of this study indicated that irrespective of the tree section sampled (the top, middle or base), the basic density of *P. caribeae* timber increased with an increase in the age of trees that were resin tapped when compared with the control (P<0.05) except for samples from the 1-year-old tree (Figure 1). A similar pattern was observed for the strength properties, and this could suggest that an increase in the basic density was accompanied by an increase in the stiffness of wood and capacity for elastic deformation. Similar results have been reported by Silva et al. (2018) and van der Maaten et al. (2017) who found that resin tapped pine trees had wider growth rings and the resultant timber had higher wood densities for samples from the incision sites. Resin tapping may insignificantly affect the basic density of pine wood because it does not induce significant anatomical compromises to the width of the growth ring and resin capillary channel area (Jakubowski & Dobroczyński, 2023; Williams et al., 2021; Zaluma et al., 2022).

Strength Properties of Sections of Resin Tapped *P. caribaea* Timber

The average MOE, MOR, maximum load, shear stress, and compressive stress of samples obtained from *P. caribaea* of different ages that were resin tapped and the untapped tree are shown in Table 1. The average MOE ranged from 5880±290 MPa for samples from the base of the 5-year-old (Y5-Base) tree samples to 7560±390 MPa for samples from the top part of the 1-year-old (Y1-Top) tree. The average MOE varied significantly (P<0.05) among the samples. However, the average MOE of the samples from the tapped portion of a 1-year-old tree (Y1-Tapped), the top of a 3-year-old tree (Y3-Top) and the tapped portion of a 3-year-old tree (Y3-Tapped) did not differ significantly from that of the control sample (P>0.05). The average MOE of Y1-Top, Y1-Base, and Y5-Tapped also did not differ significantly (P>0.05).

Article DOI: https://doi.org/10.37284/eajfa.8.1.3511

Table 1: Mean Strength Properties of Wood from Sections of Resin Tapped *P. caribaea* Trees

Sample	Modulus of elasticity (MPa)	Modulus of rupture (MPa)	Shear stress (N/mm^2)	Compressive stress (N/mm^2)
Y1-Top	$7560 \pm 390^{d,i}$	$67.00 \pm 2.76^{b,f,i}$	$10.50 \pm 0.494^{g,i,j}$	$31.92 \pm 1.08^{f,j}$
Y3-Top	$6403 \pm 392^{a,f}$	$66.00 \pm 2.25^{b,f}$	10.47 ± 0.229^{g}	$35.37 \pm 0.990^{c,g}$
Y5-Top	6938 ± 290^{b}	$70.00 \pm 2.36^{b,d}$	12.71 ± 0.267^{d}	$30.60 \pm 1.62^{d,f}$
Untapped-Top	$6132 \pm 300^{a,f}$	$48.00 \pm 2.67^{b,f}$	7.07 ± 0.272^{e}	25.06 ± 0.725^{a}
Y1-Tapped	$6944 \pm 391^{a,h}$	$58.00 \pm 2.76^{c,e,h}$	18.80 ± 0.494^{i}	$33.42 \pm 1.08^{c,i}$
Y3-Tapped	$6444 \pm 392^{a,e,f}$	$60.00 \pm 2.25^{c,e}$	10.83 ± 0.229^{f}	31.78 ± 0.990^{f}
Y5-Base	$5880 \pm 290^{b,c}$	58.00 ± 2.36^{c}	$11.71 \pm 0.267^{b,c}$	$30.30 \pm 1.62^{b,d}$
Control (Untapped)	6577 ± 300^{a}	52.00 ± 2.67^{a}	5.40 ± 0.272^{a}	20.90 ± 0.725^{a}
Y1-Base	$7331 \pm 393^{g,d}$	$65.00 \pm 2.76^{f,g,i}$	$9.74 \pm 0.494^{e,h}$	$28.24 \pm 1.08^{f,h}$
Y3-Base	$6144 \pm 392^{c,e,f,h}$	61.00 ± 2.25^{e}	9.84 ± 0.229^{e}	$29.09 \pm 0.990^{d,e,f}$
Y5-Tapped	$7258 \pm 290^{b,d,i}$	68.00 ± 2.36^{b}	11.89 ± 0.267^{c}	34.57 ± 1.62^{c}
Untapped-Base	$6008 \pm 300^{c,e,f,h}$	$46.00 \pm 2.67^{b,f}$	4.68 ± 0.272^{a}	17.79 ± 0.725^{a}

***Note**: Values are mean ± standard deviation of replicates (n = 20). Values carrying different superscript letters in a column are statistically different at P<0.05 and P<0.01.*

On the other hand, average MOR varied from 52.00±2.67 MPa for the control samples to 70.00 ±2.36 MPa for the samples taken from the top of the incision on the 5-year-old (Y5-Top) tree. Although the MOR of all the samples from resin-tapped trees differed significantly from the control, the MOR of samples taken from the top parts of the incisions of resin-tapped trees (Y1-Top, Y3-Top and Y5-Top) were not significantly different from that of the samples obtained from the tapped part of the 5-year-old tree (P<0.05).

The average shear stress ranged from 9.74±0.494 N/mm^2 in samples from the base of the 1-year-old tree (Y1-Base) to 12.71 ± 0.267 N/mm^2 for samples obtained from the top of the incision on the 5-year-old tree (Y5-Top). All samples had average shear stress that differed significantly from that of the control samples. In addition, some insignificant differences in the average shear stress (P>0.05) were observed between the following samples: Y1-Top and Y3-Top, Y1-Top and Y3-Tapped, Y1-Base and Y3-Base, and Y5-Tapped and Y5-Base.

Similarly, the compressive stress varied from 28.24±1.08 N/mm^2 in samples from the base of the 1-year-old tree (Y1-Base) to 35.37±0.990 N/mm^2 for samples from the top of the 3-year-old tree (Y3-Top). These average values were statistically different from those of the control samples (P<0.05). Nevertheless, the average compressive strengths of Y1-Base and Y3-Base, Y1-Top and Y3-Tapped, Y3-Top and Y5-Tapped, Y1-Tapped and Y5-Tapped, Y5-Top and Y5-Base, Y3-Base and Y5-Base, Y3-Tapped and Y5-Top, and Y5-Top and Y5-Base were not statistically different (P>0.05).

Tapped pine timbers in this study had average MOE above 10,000 MPa and MOR above 39 MPa, doubling that of Zziwa et al. (2010), who indicated these thresholds for timber to be recommendable for structural use involving heavy-duty applications. The values of the strength properties in the present study also fell within the specifications of C14-C4O for coniferous (soft) wood as per British Standard Timber Strength Grading System, BS 5268 (BSI, 2002). Based on this finding, timber from resin tapped *P. caribaea* trees can equally be used for all structural purposes in Uganda, as pine timber is the major source of timber, replacing timber from natural forests.

The slightly higher strength properties in resin-tapped pine timber could be attributed to increased resin content in the lower trunk and decline as was observed in samples (Zeng et al., 2021). The results align well with those of

Article DOI: https://doi.org/10.37284/eajfa.8.1.3511

Kopaczyk et al. (2023), who found that there were no significant variations in the mechanical properties of Polish *Pinus sylvestris* wood, which the authors attributed to possible adaptive tree growth and optimisation of the tree's structure to its functions. However, the present results differ from those of Wu et al. (2022), where the base density of the tree trunk of *Pinus elliottii* after 3 years of resin tapping was found to be significantly higher than that after 0, 6 and 8 years of resin tapping. This may be due to differences in the number of years of resin tapping considered, the pine species studied, different environments in which these species were grown and the method of resin tapping used in their study as compared to the current study.

LIMITATIONS

The present study used trees of different tapping years. Future studies should use trees that have been for a longer number of years, preferably by establishing more plots from which the tapped trees are to be harvested.

CONCLUSIONS

Timber from resin tapped *P. caribeae* had higher values of strength properties compared to untapped samples (P>0.05). This implies that resin tapping of *P. caribaea* using the Chinese method does not have negative effects on the strength properties of its timber, which may be utilised for structural purposes in the same way as timber obtained from untapped trees. Further studies should investigate whether resin tapping effects beyond 5 years further improve or reduce the properties of *P. caribaea* timber. Additionally, a comparative analysis of different tapping methods on timber properties, the effects of resin tapping and potential fungal infections on the quality of timber from resin-tapped trees could be explored in future research.

Conflict of Interests

The authors declare no conflict of interest.

Funding

This study was funded by the TWAS-IsDB post-doctoral fellowship awarded to the first author.

REFERENCES

British Standard BS 373:1957. Methods of Testing Small Clear Specimens of Timber. British Standards Institution, London.

BSI. (2002). British Standard BS 5268-2-2002. Structural Use of Timber Part 2: Code of Practice for Permissible Stress Design, Materials and Workmanship. British Standards Institution, London.

Chen, F., Yuan, Y., Yu, S., & Zhang, T. (2015). Influence of climate warming and resin collection on the growth of Masson pine (Pinus massoniana) in a subtropical forest, southern China. *Trees, 29*, 1423–1430.

Demko, J., & Machava, J. (2022). Tree Resin, a Macroergic Source of Energy, a Possible Tool to Lower the Rise in Atmospheric CO2 Levels. *Sustainability, 14*, 3506.

Dziedziński, M., Kobus-Cisowska, J., & Stachowiak, B. (2021). Pinus Species as Prospective Reserves of Bioactive Compounds with Potential Use in Functional Food—Current State of Knowledge. *Plants, 10*, 1306.

García-Iruela, A., Esteban, J. G., de Palacios, P., García-Fernández, F., de Miguel Torres, A., Vázquez Iriarte, E., & Simón, C. (2016). Resinous wood of Pinus pinaster Ait.: Physico-mechanical properties. *BioResources, 11*, 5230-5241.

García-Méijome, A., Rozados Lorenzo, M. J., Fernández Blanco, E., Martínez Chamorro, E., & Gómez-García, E. (2023). Resin-Tapping Production in Pinus pinaster Ait. Stands in Galicia (NW Spain): Effects of Location, Number of Faces, Wound Width and Production Year. *Forests, 14*, 128.

Jakubowski, M., & Dobroczyński, M. (2023). Long-Term Climate Sensitivity of Resin-Tapped and Non-Resin-Tapped Scots Pine Trees Based on Tree Ring Width and Blue Intensity. *Forests, 14*, 593.

Kopaczyk, J., Jelonek, T., & Szwed, T. (2023). The impact of resin harvest history on properties of Scots pine wood tissue. *BioResources, 18*, 6221-6235.

Lima, I. L. d., Ranzini, M., Fioruci, W. J., Bucci, L. A., Longui, E. L., Zanata, M., & Garcia, J. N. (2023). Physical and mechanical wood properties of two varieties of *Pinus caribaea*. *Research, Society and Development, 12*, e7712943146.

Liu, Y., Wang, Z., Zhao, F., Zeng, M., Li, F., Chen, L., . . . Guo, W. (2022). Efficient resin production using stimulant pastes in Pinus elliottii × P. caribaea families. *Scientific Reports, 12*, 13129.

López-Álvarez, Ó., Franco-Vázquez, L., b, A. R.-G., Borges, J. G., & Marey-Perez, M. (2025). Evaluation of the impact of resin tapping on the spectral index response of Pinus pinaster stands in the NW of the Iberian Peninsulá. *Forest Ecology and Management, 594*, 122983.

López-Álvarez, Ó., Zas, R., & Marey-Perez, M. (2023). Resin tapping: A review of the main factors modulating pine resin yield. *Industrial Crops and Products, 202*, 117105.

Moura, M., Campelo, F., Nabais, C., & Garcia-Forner, N. (2023). Resin tapping influence on maritime pine growth depends on tree age and stand characteristics. *European Journal of Forest Research, 142*, 965–980.

Naylor, A., Hackney, P., & Noel, P. (2012). Determination Of wood Strength Properties Through Standard Test Procedures. Proceedings Of the 10th International Conference on Manufacturing Research ICMR 2012: International Conference on Manufacturing Research 2012 - Aston University, Birmingham, UK.

Rodrigues-Corrêa, K. C. D. S., Sausen, T. L., Rocha, F. S., & Fett-Neto, A. G. (2011). Oleoresin yield and carbon stocks in tapped subtropical Pinus elliottii forests. *BMC Proceedings, 5*, P100.

Rodrigues-Honda, K. C. D. S., Junkes, C. F. O., Lima, J. C., Waldow, V. A., Rocha, F. S., Sausen, T. L., . . . Fett-Neto, A. G. (2023). Carbon Sequestration in Resin-Tapped Slash Pine (Pinus elliottii Engelm.) Subtropical Plantations. *Biology, 12*, 324.

Rojas-Sandoval, J., & Acevedo-Rodríguez, P. (2013). Pinus caribaea (Caribbean pine). *CABI Compendium. Available at* https://doi.org/10.1079/cabicompendium.41573.

Silva, M., Loureiro, C., Gaspar, M., Pires, J., Ribeiro, M., Loureiro, C., . . . Lousada, J. (2018). RESIMPROVE - Desenvolvimento de processos de produção e extração de resina de pinheiro para a melhoria da eficiência, racionalização e expansão da atividade. ISBN 978-989-704-264-5.

Singh, S. P., Inderjit, Singh, J. S., Majumdar, S., Moyano, J., Nuñez, M. A., & Richardson, D. M. (2018). Insights on the persistence of pines (Pinus species) in the Late Cretaceous and their increasing dominance in the Anthropocene. *Ecology and evolution, 8*, 10345–10359.

Ssebuliba, S. (2022). Assessing tree mortality intensity at two different periods of resin tapping in Uganda. BSc Dissertation, Makerere University, Kampala, Uganda.

Sullivan, T. P., Sullivan, D. S., Lindgren, P. M. F., Ransome, D. B., & Sullivan, J. H.-R. (2025). Thirty-year responses of ecosystem components to stand thinning in lodgepole pine forest: Old-forest attributes, stand structure, and forest-floor small mammals. *Forest Ecology and Management, 587*, 122733.

van der Maaten, E., Mehl, A., Wilmking, M., & van der Maaten-Theunissen, M. (2017). Tapping the tree-ring archive for studying effects of resin extraction on the growth and climate sensitivity of Scots pine. *Forest Ecosystems, 4*, 7.

Article DOI: https://doi.org/10.37284/eajfa.8.1.3511

Vieilledent, G., Fischer, F. J., Chave, J., Guibal, D., Langbour, P., & Gérard, J. N. (2018). New formula and conversion factor to compute basic wood density of tree species using a global wood technology database. *American journal of botany, 105*, 1653–1661.

Williams, R., Nauman, C., & Zhu, J. (2021). The Effects of Resin Tapping on the Radial Growth of Masson Pine Trees in South China-A Case Study. *Agricultural Research & Technology, 8*, 8–11.

Wu, H.-r., Fan, Y.-r., Niu, X.-y., Luan, Q.-f., Li, Y.-j., Jiang, J.-m., & Jin, J.-e. (2022). Effects of Resin-Tapping Year on Wood Properties of Living Pinus elliottii. *Forest Research, 35*, 31-39.

Zaluma, A., Strike, Z., Rieksts-Riekstiņš, R., Gaitnieks, T., & Vasaitis, R. (2022). Long-term pathological consequences of resin tapping wounds on stems of Scots pine (Pinus sylvestris L.). *Trees, 36*, 1507–1514.

Zas, R., Quiroga, R., Touza, R., Vázquez-González, C., Sampedro, L., & Lema, M. (2020). Resin tapping potential of Atlantic maritime pine forests depends on tree age and timing of tapping. *Industrial Crops and Products, 157*, 112940.

Zeng, X., Sun, S., Wang, Y., Chang, Y., Tao, X., Hou, M., . . . Zhang, L. (2021). Does resin tapping affect the tree-ring growth and climate sensitivity of the Chinese pine (Pinus tabuliformis) in the Loess Plateau, China? *Dendrochronologia, 65*, 125800.

Zziwa, A., Mukasa, J., & Kizito, S. (2020). Structural suitability of 10-year old Pinus caribaea timber with a forest fire history in farm buildings. *Agricultural Engineering International, 22*, 49–58.

Zziwa, A., Ziraba, Y., & Mwakali, J. (2010). Strength properties of selected Uganda timbers. *International Wood Products Journal, 1*, 21–27.