University of Sopron

Faculty of Wood Engineering and Creative Industries

Cziráki József Doctoral School of Wood Sciences and Technologies

Effect of environmental factors on anatomical, chemical, physical and mechanical properties of Hungarian black locust (*Robinia pseudoacacia* L.) wood as function of geographical locations

By

Fath Alrhman Awad Ahmed Younis

Supervisor:

Prof. Dr. Németh Róbert PhD

Sopron, 2025

Introduction

It is a well-known fact that the atmospheric concentration of greenhouse gases (GHG) continues to increase globally (Lamb et al. 2022). Consequently, this rise has resulted in a significant increase in global temperatures. Localized data demonstrates these trends in Napkor, Hungary, a region known for significant black locust cultivation. The average temperature in 2021 was 10.7 °C. This shows a 0.3 °C increase compared to the mean temperature observed over the 1985–2020 period.

Changes in growth conditions can physiologically impact wood quality, depending on the tree species. This influence is often manifested through alterations to the wood anatomical structure, such as the number of vessels, ray, parenchyma, fiber, and widths, and vessel characteristics (Usta et al. 2014, Zhang et al. 2020, Nazari et al. 2020).

Robinia pseudoacacia L. is a species of considerable value and history in Hungary, having been cultivated for 300 years (Rédei 1999; Rédei and Meilby 2000; Rédei and Meilby 2009). It is extensively planted in both pure and mixed stands across diverse ecological zones (Rédei et al. 2008), currently comprising 24.42% (458,296 ha) of the total forested area (Csaba, 2023). Recognizing its economic importance, Hungary has implemented several programs, such as the INCO-

COPRNICUS project, specifically aimed at resolving cultivation limitations and enhancing wood quality. These strategic efforts have successfully driven the development of superior clonal materials (Rédei et al. 2020).

Considering the wide geographical distribution of Robinia pseudoacacia L., trees within Hungary, we assume that:

- The internal structural of Robinia wood can be influenced by site-specific growth conditions.
- The site-related factors play a crucial role in chemical composition of Robinia wood.
- The Variability in physical and mechanical properties of Robinia wood can be attributed to differences in site and growth conditions.

Research Objectives

The main objective of this study is to investigate the wood characteristics of R. pseudoacacia L. from five Hungarian counties and among three growth conditions.

Specific objectives are:

1- To investigate the anatomical features
- ✔ Wood fiber length, width, wall thickness and lumen diameter
- ✔ Vessel length and width

- ✔ Width of the annual ring.

2- To analyse the organic and inorganic composition

- ✔ Ash content (%)
- ✔ Extractives content (%)
- ✔ Total polyphenol content (mg GAE/g dw)
- ✔ Antioxidant capacity (mg AA/g dw).

3- To determine physical properties

- ✔ Wood density
- ✔ Wood shrinkage and swelling (radial, tangential and volumetric)
- ✔ Wood color parameter

4- To investigate the mechanical properties

- ✔ Modulus of rupture
- ✔ Modulus of elasticity
- ✔ Compressive strength parallel to the grain

Materials and Methods

From the bottom and tope of trees, a total of 22 sample logs were obtained from nine locations across Hungary (Northern, Central, and Western). These locations represent five counties. The examined sites were classified into three growth conditions based on soil characteristics: GGC–good growth conditions, PGC–poor growth conditions and MPGC–mixed species under poor growth conditions as defined by Várallyay (2015) and Tóth et al. (2007).

Sampling

Three discs, each measuring 4 cm in thickness, were taken from every log at breast height (130–140 cm).

Anatomical properties

Fiber properties

The fiber and vessel characteristics were assessed using a light microscope integrated with a digital camera (Nikon Eclipse, Nikon, Japan) and ProScan III software (V31XYZE/D, Prior Scientific Instruments Ltd., Wilbraham Road, Fulbourn, Cambridgeshire, CB21 5ET, UK).

Ring width

The smooth strips were scanned using a scanner (CanonScan LiDE 110, Canon, Japan) (Abràmoff eat al. 2004). Then, the annual ring widths were measured with ImageJ software.

Chemical Compositions

The ash content, chemical extractives, total polyphenol content, and antioxidant capacity were investigated using wood particles (Fodor and Hofmann 2024).

Physical properties

Color parameters (lightness, redness and yellowness)

The CIELAB parameters were determined using the D65 illuminant. Thirty replicates were measured from wood samples for each location within the county, with a test-window of 5 mm in diameter (Tolvaj and Varga, 2012; Baar et al. 2019).

Density, shrinkage and swelling

From both bottom and top logs, a total of 347 samples, each sized 20 × 20 × 30 mm, were used to evaluate moisture content, basic density, density at 12% moisture content, and linear shrinkage and swelling across all counties (ISO 13061, 2017 and ISO 13061, 2014).

Mechanical properties

Samples sizes around 20 × 20 × 300 mm were prepared to evaluate the modulus of elasticity and rupture. The test specimens were done by INSTRON testing machine according to ISO 13061-4: 2014 and ISO 13061-3: 2014. The compression strength parallel to the grain was obtained according to ISO 13061-17:2017. Samples size of specimens was 20 × 20 × 30 mm.

Results and main conclusion of the research

Thesis 1: Anatomical feature of wood *Robinia pseudoacacia* L., across Hungary and among the growth conditions

I establish that the length, width, wall thickness of fiber and vessels length and width of wood *Robinia pseudoacacia* L. were greatest in Szabolcs-Szatmár-Bereg and Vas. Among the growth conditions, I found that in poor growth conditions (mixed species) and good growth conditions produced superior wood fiber properties and ring widths.

Thesis 2: Relationships of Fibers length and Ring Width with Precipitation and Temperature on Wood of *Robinia pseudoacacia* L.

I proved that the fiber length, width, and cell wall of Robinia pseudoacacia L., from Bács Kiskun increased from pith to bark. While the lumen diameter remained without change. I found that the fiber length and ring width were not significantly correlated with precipitation and temperature.

Thesis 3: Chemical compositions and color parameters of *Robinia pseudoacacia* L., wood across Hungary and among the growth conditions

I found that *Robinia pseudoacacia* L., from Vas and Győr-Moson-Sopron exhibited the highest total contents of extractives, polyphenol, antioxidant capacity and intense lightness. Under growth conditions, MPGC yield higher chemical composition. I also found that the extractives from the cyclohexane-ethanol solvent significantly correlated with all color parameters and conversely with total extractives content.

Thesis 4: Densities, shrinkage and swelling of wood *Robinia pseudoacacia* L., across Hungary and among the growth conditions

I found that the air-dry and basic density of *Robinia pseudoacacia* L., were highest in Bács Kiskun County and lowest shrinkage and swelling. I found that The PGC revealed greatest densities, and tangential and longitudinal shrinkage. While the MPGC recorded the greatest values for volumetric shrinkage, radial, tangential and longitudinal and volumetric swelling. I found that there were no significant differences in linear and volumetric swelling between the growth conditions.

Thesis 5: Mechanical properties of wood *Robinia pseudoacacia* L., across Hangry and among the growth conditions

I found that the Bács-Kiskun has the highest mean values for MOE, while the highest MOR and CS were greatest in Győr

Moson Sopron. I found that the MPGC demonstrated the highest MOE, whereas the MOR and CS were greatest in PGC.

I proved that the sites specific factors and growth conditions significantly affected the wood properties of *Robinia pseudoacacia* L., in Hungary. With highest studied properties in Vas County and MPGC.

References

Lamb, W.F., Grubb, M., Diluiso, F. and Minx, J.C., 2022. Countries with sustained greenhouse gas emissions reductions: an analysis of trends and progress by sector. Climate Policy, 22(1), pp.1-17.

Nazari, N., Bahmani, M., Kahyani, S., Humar, M. and Koch, G., 2020. Geographic variations of the wood density and fiber dimensions of the Persian oak wood. Forests, 11(9), p.1003.

Zhang, S., Belien, E., Ren, H., Rossi, S. and Huang, J.G., 2020. Wood anatomy of boreal species in a warming world: a review. iForest-Biogeosciences and Forestry, 13(2), p.130

Usta, A., Yilmaz, M.U.R.A.T., Malkocoglu, S., Serdar, B., Yilmaz, S. and Bozlar, T., 2014. Effects of environmental factors on wood anatomy of black alder (Alnus glutinosa (L.) Gaertner subsp. barbata (CA Meyer) Yalt) from two different

origins of eastern black sea region in Turkey. Fresenius Environmental Bulletin, 23(8), pp.1778-1784.

Redei, K., 1999. Black locust (*Robinia pseudoacacia* L.) energy plantations in Hungary. Silva Gandavensis, 64.

Rédei, K.M. and Meilby, H., 2009. Effect of Thinning on the Diameter Increment in Black Locust (*Robinia pseudoacacia* L.) Stands. ACTA SILVATICA ET LIGNARIA HUNGARICA: AN INTERNATIONAL JOURNAL IN FOREST, WOOD AND ENVIRONMENTAL SCIENCES, 5, pp.63-74.

Rédei, K. and Meilby, H., 2000. Effect of thinning on the diameter increment in black locust (*Robinia pseudoacacia* L.) stands. Silva Gandavensis, 65.

Rédei, K.M., Osvath-Bujtas, Z. and Veperdi, I., 2008. Black locust (*Robinia pseudoacacia* L.) improvement in Hungary: a review. ACTA SILVATICA ET LIGNARIA HUNGARICA: AN INTERNATIONAL JOURNAL IN FOREST, WOOD AND ENVIRONMENTAL SCIENCES, 4(1), pp.127-132.

Csaba Sz., 2023. Summary data of Hungary's forests (in Hungarian language).

List of related publications

Journal articles:

Younis, F.A.A.A., Báder, M., Bak, M. and Németh, R., 2025. Site Variability in Fibers, Vessels, and Ring Width of *Robinia pseudoacacia* L. Wood: A Case Study in Hungary. Forests, 16(5), p.807.

Younis, F.A.A.A., Govina, J.K., Seidu, H. and Németh, R., 2023. Basic Characteristics of Black Locust (*Robinia pseudoacacia* L.) Wood Grown Under Different Site Conditions: A Review. ACTA SILVATICA ET LIGNARIA HUNGARICA: AN INTERNATIONAL JOURNAL IN FOREST, WOOD AND ENVIRONMENTAL SCIENCES, 19(1), pp.21-35.

Younis, F.A.A.A. and Németh, R., 2023. Variation in Moisture Content and Density Whitin and Among Freshly Felled Sclerocarya birrea and Anogeissus leiocarpus. BULLETIN OF THE TRANSILVANIA UNIVERSITY OF BRASOV SERIES II-FORESTRY, WOOD INDUSTRY, AGRICULTURAL FOOD ENGINEERING, 16(3), pp.227-234.

Younis, F.A.A.A., Abdelgadir, A.Y., Ahmed, Z.A., Govina, J.K. and Németh, R., 2022. Inter-and intraspecific differences in physical and mechanical properties of wood from *Sclerocarya birrea* and *Anogeissus leiocarpus*. Acta Silvatica Et Lignaria Hungarica: An International Journal in Forest, Wood and Environmental Sciences, 18(1), pp.57-69.

Seidu, H., Németh, R., Owusu, F.W., Korang, J., Appiah-Kubi, E., Govina, J.K. and **Younis, F.A.A.A**., 2023. Mechanical properties of PF and MUF bonded juvenile hybrid eucalyptus plywoods produced in Ghana. Wood Research, 68(3), pp.521-531.

Younis, F.A.A. and Yasin, E.H., 2025. The Characteristics of Popular Hardwood Species in Sudan-Review. Forest Science – Advances Towards Sustainable Development and Climate Resilience. (Book chapter, IntechOpen).

Younis, F.A.A.A., Báder, M., Bak, M. and Németh, R., 2024. Relationships of Fibers length and Ring Width with Precipitation and Temperature on Wood of *Robinia pseudoacacia*. (Book chapter, Sopron University).

Younis Fath Alrhman Awad Ahmed, Tamás Hofmann and Róbert Németh. Site Variability in Chemical Compositions and Color Parameters of black locust (*Robinia pseudoacacia* L.) Wood EUROPEAN JOURNAL OF WOOD AND WOOD

PRODUCTS (0018-3768 1436-736X): Publication: 36459988 | **Work in Progress Not Published Core** |.

Conference publications

Younis Fath Alrhman, Báder Mátyás, Németh Róbert, 2025. Плотность древесины и механические свойства древесины *Robinia pseudoacacia* L. из трех регионов Венгрии. In: Gordin MV (eds.). Русский инженер (Russkii inzhener). Conference: Москва, Russia 2025.10.29. - 2025.10.31. Москва: Bauman Moscow State Technical University, pp 14-15 (2025). Language: Russian | Book link(s): ISBN: 9785703866566.

Younis, F.A.A.A. and Németh, R., 2025. Comparative Study of Fiber Characteristics in Mature and Juvenile *Robinia pseudoacacia* L. Heartwood. Book of Abstracts of 8th International Conference on Process Technologies for the Forest and Biobased Products Industries 2025. Conference: Kuchl, Austria 2025.09.18. - 2025.09.19. Salzburg University of Applied Sciences Design and Green Engineering Department Campus Kuchl, pp 20-20 (2025).

Younis, F.A.A.A., Németh, R. and Báder, M., 2024. Compensatory Anatomical Studies on Robinia, Sclerocarya and Ulmus. In: Németh, Róbert; Hansmann, Christian; Militz, Holger; Bak, Miklós; Báder, Mátyás (eds.) 11TH

HARDWOOD CONFERENCE PROCEEDINGS: Sopron, Hungary, 30-31 May 2024. 10. 14.

Younis, F.A.A.A. and Németh, R., 2023. Variation in Moisture Content and Density Whitin and Among Freshly Felled *Sclerocarya birrea* and *Anogeissus leiocarpus*. BULLETIN OF THE TRANSILVANIA UNIVERSITY OF BRASOV SERIES II-FORESTRY, WOOD INDUSTRY, AGRICULTURAL FOOD ENGINEERING, 16(3), pp.227-234.

Younis, F.A.A. and Németh, R., 2022. Extractives content of wood *Sclerocarya birrea* and *Anogeissus leiocarpus* trees. In: Róbert Németh (Németh Róbert Faanyagtudományok) SOE/FWECI/Institute of Wood Engineering; Christian Hansmann; Peter Rademacher (Rademacher Peter Erdészet, faipar) University of Sopron; Miklós Bak (Bak Miklós Faanyagtudomány) SOE/FWECI/Institute of Wood Engineering; Mátyás Báder (Báder Mátyás Faanyagtudomány) SOE/FWECI/Institute of Wood Engineering (eds.) 10TH HARDWOOD CONFERENCE PROCEEDINGS