<u>PhD Theses</u>

Comparative study of wood properties for *Quercus Cerris* L. (*Turkey oak*) from different sites In Hungary

by

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in

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Introduction

Environmental research experts have predicted that there will be a warmer and dryer climate across the globe in the years ahead. The predicted climate will affect necessary growth factors such as soil moisture and organic matter breakdown. While some trees may react by slowing down their growth and biomass productions, other trees will have their survivorship threatened. This will also have a rippling effect on trees species diversity among stands. The tree species that have the natural tendency to survive are those termed as drought-tolerant. They provide for the future supply of biomass to related industries. Inarguably, Foresters or tree growers would prefer among other traits, plantlets that are drought-tolerant and fast-growing. Efforts to reach this overall achievement would be easier when naturally occurring drought-tolerant species are prioritised as important.

In Europe, notable drought-tolerant timber species include Turkey oak (Illés & Móricz, 2022; Móricz et al., 2021). Turkey oak species have been cultivated in forest stands across Hungary. It is the fourth most important wood species in terms of area and standing volume. According to a national report, in 2015, a total volume of 815 thousand m^3 of Turkey oak was felled (Nemzeti Élelmiszerlánc-biztonsági Hivatal, Erdészeti Igazgatóság, Budapest, 2016). However, the wood for Turkey oak is industrially under-utilized in this territory, though it's a hard and robust hardwood. A notable valued added application for Turkey oak wood is flooring. Other value-added applications and efficient promotion of the wood from Turkey oak will rely on the availability of extensive knowledge of its wood properties. There should be scientific information that investigated the variability of Turkey oak wood with regards to growth conditions within Hungary. The study was therefore conducted with the following hypothesis:

1. Mixed-species stand of Turkey oak will not produce wood of same properties as counterparts from pure stand.
2. If Turkey oak is planted on soils with distinct quality, then their wood properties will differ to compromise wood quality.

Conferences Attended

1. 2021 and 2024 Hardwood conferences in Sopron, Hungary.
   Topics presented:
   I. A short background to hardwood resources and properties in Ghana
   Govina, J & Németh. R
   II. An introduction of Ghana's hardwood products and market specialties
   Govina, J. K & Németh, R

2. 2023 International Conference on Wood Science and Engineering, Brasov, Romania.
   Topic presented:
   III. Effect of variable growth conditions on selected anatomical properties of Hungarian Turkey oak wood.
   Govina, J. K., Nemeth, R., Bak, M., & Bader, B.

3. 2024 Annual Convection of the Society for Wood Science and Technology, Portoroz, Slovenia.
   Topic presented:
   IV. Tree-Ring Characteristics and Climate-growth Relationship for *Quercus cerris* (L.) in West Hungary.
   Govina, J. K. & Nemeth, R

Research aim and objectives

Aim:

Macroscopic and microscopic characterization variability, as well as mechanical properties in Turkey oak wood as induced by different site conditions and silviculture to promote their efficient and valuable utilization.

Objectives:

1. To determine the proportion of heartwood and sapwood.
2. To determine annual tree-ring characteristics.
3. To determine the relationship between the annual tree-ring and climate variable (precipitation and temperature).
4. To determine the dimensions of fibre and vessels.
5. To determine the proportion of fibre, vessels and parenchyma per 1 mm^2 area for the wood Turkey oak.
6. To determine basic wood density.
7. To determine the bending and compression strength, bending modulus of elasticity, and Janka hardness.

Literature review

The review of literature centered on scientific articles, government reports and books that covered the main issues in the dissertation. There are notes and diagrams regarding the fundamentals needed to understand wood formation and tissues involved. Additionally, there are information on the stock and relevance of Turkey oak in Hungary.

Materials and methods

Study sites (County level)

This comparative study collected Turkey oak materials from 5 counties in Hungary. The counties are Vas (sites include Vasvár, Hosszúpereszteg, Bögöte, Egyházasrádóc), Gyor-Moson-Sopron (areas include Sopron, Nagycenk, Ivan), Komárom-Esztergom (around Pilis Mountain range), Bács-Kiskun (areas include Kisszallas, Melykut, Janoshalma, Nyarlorinc), Baranya (areas include Ibafa, Hetvehely). These sites are expected to have varied growing conditions that influence growth for the trees in the near-natural forest environment. Essentially, the varied growth conditions are related to key climate variables (precipitation and temperature). Notably, the western part of Hungary is comparatively moist than the central and eastern part (Fekete et al., 2023; Gadermaier et al., 2024; Várallyay, 2015a).

Study sites (within Vas County)

The study was conducted with wood materials from Vas County in western Hungary, sharing its west boundary with Slovenia. Turkey oak trees were randomly harvested from four different sites. There are two types of soil quality that supported the stands' growth. The plots categorized as 'Good Soil' had a rusty brown forest sandy soil of about 60-100 cm deep. It was reported to have high fertility, good structure, balanced nutrients levels, adequate drainage and balanced pH. The 'Poor Soil' category had rusty brown forest loamy soil of about 40-100 cm dept. Additionally, the Poor Soils sometimes had low fertility, poor structure, easily compacted and waterlogged (Tóth et al., 2007; Várallyay, 2015a). On each soil type are plots of pure and mixed species planting of Turkey oak. In the mixed species plot were other broad-leaf species ash and hornbeam species. Unfortunately, the genotype of the individual trees selected for this study is not readily known. Logs of the 12 harvested trees were conveyed to the University of Sopron for processing and subsequent transfer into the wood anatomy laboratory.

Sapwood-heartwood proportion, ring characteristics

The test samples for the annual ring study were extracted from the point on the stems known as the diameter at breast height (dbh). Two discs of about 4 cm thickness were taken from each stem for anatomical studies. For the measurement of annual ring characteristics and sapwood-heartwood proportion, the discs were left to naturally dry to about 20% moisture content. The drying of discs facilitated their sanding operation. Sanding papers of increasing grit sizes (from 180 to 600) were engaged on an electric-powered sanding machine to produce clean and smooth cross-sectional surfaces.

The sampled discs had the typical distinct heartwood and sapwood portions, and their boundaries were not ambiguous. The cross-sectional surfaces were sanded. Four cross-diameter measurements were taken on each disc with

Teeuwen, S., Mark van Benthem, M., Jan Oldenburger, J., van Best, S., & Guus Beerkens G. & Butler, R. (2021). Europe's sourcing of verified tropical timber and its impact on forests: What Next? IDH, the Sustainable Trade Initiative, The Netherlands.

Tóth, T., Németh, T., Fábián, T., Hermann, T., Horváth, E., Patocskai, Z., Speiser, F., Vinogradov, Sz., & Tóth, G. (2007). Internet-based Land Valuation System Powered by a GIS of 1:10,000 Soil Maps. *Agrokémia És Talajtan*, *55*(1). https://doi.org/10.1556/agrokem.55.2006.1.12

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Zobel, B. J., & van Buijtenen, J. P. (1989). *Wood variation: its causes and control*. Springer Science & Business Media.

List of Publications related to Theses

1. Govina, J. K., Ebanyenle, E., Appiah-Kubi, E., Owusu, F. W., Korang, J., & Németh, R. (2021). Tissue proportion, fibre, and vessel characteristics of young Eucalyptus hybrid grown as exotic hardwood for wood utilization. *Acta silvatica et lignaria hungarica: an international journal in forest, wood and environmental sciences*, *17*(2), 121-133. https://doi.org/10.37045/aslh-2021-0008
2. Komán, S., Németh, R., Govina, J. K., Vörös, Á., Horváth, D. Á., & Fehér, S. (2024). Wood Research at the University of Sopron–Physical-mechanical Properties. In *E3S Web of Conferences* (Vol. 514, p. 04002). EDP Sciences. https://doi.org/10.1051/e3sconf/202451404002
3. Govina, J. K., Nemeth, R., Bak, M., & Bader, M. (2023). Effect of Variable Growth Conditions on Selected Anatomical Properties of Hungarian Turkey Oak Wood. *Bulletin of the Transilvania University of Brasov. Series II: Forestry• Wood Industry• Agricultural Food Engineering*, 83-98. https://doi.org/10.31926/but.fwiafe.2023.16.65.3.6
4. Govina, J. K., & Nemeth, R. (2024). Annual growth ring characteristics of *Quercus cerris* (l.) trees grown under different conditions. *Wood Research 69(2)*. https://doi.org/10.37763/wr.1336-4561/69.2.196208

Illés, G., & Móricz, N. (2022). Climate envelope analyses suggests significant rearrangements in the distribution ranges of Central European tree species. *Annals of Forest Science*, *79*(1). https://doi.org/10.1186/s13595-022-01154-8

ISO 13061 (2017). Physical and mechanical properties of wood – Testing methods for small clear wood specimen

Mészáros, I., Adorján, B., Nyitrai, B., Kanalas, P., Oláh, V., & Levanič, T. (2022). Long-term radial growth and climate-growth relationships of Quercus petraea (Matt.) Liebl. and Quercus cerris L. in a xeric low elevation site from Hungary. *Dendrochronologia*, *76*. https://doi.org/10.1016/j.dendro.2022.126014

Móricz, N., Illés, G., Mészáros, I., Garamszegi, B., Berki, I., Bakacsi, Z., Kámpel, J., Szabó, O., Rasztovits, E., Cseke, K., Bereczki, K., & Németh, T. M. (2021). Different drought sensitivity traits of young sessile oak (Quercus petraea (Matt.) Liebl.) and Turkey oak (Quercus cerris L.) stands along a precipitation gradient in Hungary. *Forest Ecology and Management*, *492*. https://doi.org/10.1016/j.foreco.2021.119165

Nazari, N., Bahmani, M., Kahyani, S., Humar, M., & Koch, G. (2020). Geographic variations of thewood density and fiber dimensions of the Persian oak wood. *Forests*, *11*(9). https://doi.org/10.3390/f11091003

Perkins, D., Uhl, E., Biber, P., du Toit, B., Carraro, V., Rötzer, T., & Pretzsch, H. (2018). Impact of climate trends and drought events on the growth of oaks (Quercus robur L. and Quercus petraea (Matt.) Liebl.) within and beyond their natural range. *Forests*, *9*(3). https://doi.org/10.3390/f9030108

Samariha, A. (2011). Effect of altitude index on growth rate and physical properties of hornbeam wood (case study in Mashelak forest of Iran). *World Applied Sciences Journal*, *13*(9).

Schweingruber, F. H. (2007). Preparation of wood and herb samples for microscopic analysis. *Wood Structure and Environment*, 3–5.

Sousa, V. B., Louzada, J. L., & Pereira, H. (2018). Variation of Ring width and wood density in two unmanaged stands of the Mediterranean Oak Quercus faginea. *Forests*, *9*(1). https://doi.org/10.3390/f9010044

a simple measuring tape. The heartwood portions were measured as a cross diameter and averaged. The averaged sapwood portion was deduced subsequently.

Climate data (precipitation and maximum temperature) for the Vas County were retrieved from the Hungarian National Metrological Service database for the period between 1961 to 2021. The study concentrated on maximum temperature because of the prediction that mean value for air temperature will increase in future. Based on knowledge of actual growing season for oak (Perkins et al., 2018), the climate data was concentrated between April and October. The precipitation and temperature of the previous year were correlated with the growth ring of the current year (Mészáros et al., 2022).

Determination of wood tissue dimensions

Matchstick-sized wood samples were collected from both sapwood and heartwood portion of each tree to absorb any variability within each tree. Samples were macerated (the process of disintegrating the wood into individual tissues by dissolving the lignin that binds them) using standard protocols and adopted in earlier studies (Govina et al., 2021; Schweingruber, 2007). The samples were kept in labeled vials containing a solution of 1:1 glacial acetic acid and hydrogen peroxide and placed in a water-bath at 65 °C. Complete maceration was achieved after 72 hours. The macerates were thoroughly rinsed with distilled water and allowed to stay for 24 hours. The fibres and vessels were observed and measured using an advance microscope (Nikon Eclipse 80i, Nikon, Japan) with ProScan III software (Prior Scientific Limited, United Kingdom). Only straight and unbroken tissues (fibres and vessels) were measured.

Wood tissue proportion

Wood samples with cross-sectional dimensions of 1 x 1 cm and 2 cm long were prepared. Four of the wood samples were taken from each disc to address any variability within. They were left in labelled vials containing water for 14 days to begin wood softening for sectioning procedure. Each piece of wood is boiled in water for about 15 minutes to enhance the softening, before sectioning. The warm sample is mounted on sliding microtome [Epredia™ HM 430, Thermo Scientific, Göteborg, Sweden] set up to cut sections between 10 and 20 µm thickness using disposable blades (Model A35, Feather Safety Razor Co. Ltd, Japan). Only sections for the cross-sections were generated for this study. The best sections were transferred into distilled water to clean off any particle. The cleaned sections were immediately mounted in glycerol on specimen slides and cover slips were carefully dropped on them.

Basic density and selected mechanical properties

Short wood logs of about 50 cm long were cut from the breast height point of each tree. The logs were processed into boards and staked in a dryer to reduce its moisture amount. The desired moisture content (about 12-16%), that could facilitate sample processing, was reached after 6 weeks. Clear and straight-grain samples were prepared from the boards according to standards for respective mechanical property test. The determination of wood basic density, bending strength, modulus of elasticity, compression strength, and Janka Hardness strength were based on DIN 68364 and ISO-13061 (2017, various parts). The test wood samples were conditioned for one week at controlled temperature and humidity (20 ± 1°C; 65 ± 5%).

Results and main conclusions

Thesis 1. Heartwood-sapwood proportion

I concluded that Turkey oak trees grown in Hungary has at least 71% of heartwood. The higher heartwood proportions are recorded for trees grown at the moist sites in Western Hungary like Sopron. I proved that the higher sapwood proportion is recorded for trees in the dryer sites like Pilis and Kecskemet. It is also concluded that soil quality and stand composition, combined, had influence on annual growth rings.

Thesis 2. Annual tree-ring characteristics

I concluded that the annual tree-ring width for Turkey oak across Hungary ranged from 1.32 – 3.68 mm. I found that Turkey oak trees planted in a mixture with other hardwood species produced wider annual tree-ring. Also, Turkey oak grown at western Hungary also produced wider annual rings.

Thesis 3. Annual tree-ring related to climate variable

I concluded that there is a weak to moderate positive correlation (co-efficient = 0.09 – 0.32) between annual growth width and precipitation. This implies that an increase in precipitation could result in a wider annual tree-ring. It is also proved that there is moderate negative correlation (co-efficient = -0.32 to -0.42) between tree-ring width and maximum temperature.

Thesis 4. Wood tissue characteristics

I concluded that poor soils produced Turkey oak wood with longer and thicker wall fibres, especially when planted as mixed-species stand. I also proved that wood materials from Turkey oak planted in mixed stands produced longer and thicker-walled fibres, irrespective of soil quality.

Thesis 5. Tissue proportion

I concluded that Turkey oak planted in pure stand composition produced wood with higher proportion of vessels. I also found that Turkey oak in mixed stand composition produced wood with more fibres proportion per 1 mm^2. It is also concluded that soil quality has an influence on tissue proportion among Turkey oak wood in Hungary.

Thesis 6. Mechanical properties

I concluded that wood from Turkey oak trees grown in mixed-species stands have higher basic wood density, bending modulus of elasticity (MOE), and bending strength (MOR). This resonated with finding mentioned above that mixed-species planted Turkey oak wood materials have longer fibres and thicker cell walls. Overall, I proved that planting Turkey oak in mixed-species stands will warrant the formation of wood with superior strength properties. Turkey oak is therefore recommended for valuable utilization such as floorings, furniture and cabinets, lasting structural construction.

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Guilley, E., Hervé, J. C., & Nepveu, G. (2004). The influence of site quality, silviculture and region on wood density mixed model in Quercus petraea Liebl. *Forest Ecology and Management*, *189*(1–3). https://doi.org/10.1016/j.foreco.2003.07.033