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Róbert Németh, Christian Hansmann, Holger Militz, Miklós Bak, Mátyás Báder

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Compensatory Anatomical Studies on *Robinia*, *Sclerocarya* and *Ulmus*

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Keywords: *Robinia*; earlywood; wavy vessel; fibre characteristic

ABSTRACT

This study shows the differences in fibre characteristics of *Robinia pseudoacacia* growing in Hungary and *Sclerocarya birrea* growing in Sudan. Also, the analysis and comparison of the growing zone widths (the vessel lumina diameters in the earlywood and the wave amplitudes of the wavy vessel bands) for *Ulmus minor* were studied. The mean values of fibre length (mm), lumen diameter (µm), fibre diameter (µm), and cell wall thickness (µm) of *R. pseudoacacia* were 0.83, 13.18, 18.35, and 513, respectively. While they were 0.82, 26.37, 18.01, and 8.36 for *S. birrea*. The results also show that the fibre characteristics do not change gradually from pith to bark. The anatomical studies of *Ulmus minor* revealed significantly different results in the latewood widths, between 0.775 mm and 2.776 mm. Most vessels in the earlywood are below 0.721 mm diameter. The latewood vessel band amplitudes are mostly between 0.138 and 0.230 mm.

INTRODUCTION

The University of Sopron, Hungary deals extensively with the proper management of trees and wood from both scientific and practical perspectives. The Faculty of Forestry is the only place in Hungary to train, among others, forest engineers and nature conservation engineers, while the Faculty of Wood Engineering and Creative Industries trains, among others, engineers for the wood industry, specialists in the creative industry, and product designers. The former Institute of Wood Science, now part of the Institute of Basic Sciences, deals with the properties and modification possibilities of wood. Good examples are the following scientific publications: (Komán 2022; Fehér et al. 2014; Lublóy et al. 2023; Komán and Varga 2020; Kern et al. 2022; Bak 2012; Horváth and Fehér 2023; Fodor and Bak 2023). Our aim with this study is to present the activities and some of our important results we have carried out in the recent years, in order to present research in connection with the wood industry. We believe that the work we do is globally important. In this article, we mainly present some of our research and results on the anatomical properties of wood.

The comprehensive knowledge of the anatomical features of wood is crucial in the process of selecting the most suitable wood for a certain purpose. Anatomical traits can be classified into two broad categories: macro and micro. The measurement of fibre length in wood is a crucial factor that significantly impacts the overall quality and characteristics of pulp and paper products. Various methods can be employed to measure the fibre lengths of different wood species (Figure 1). Wood species exhibit great variations in their fibre lengths. In general, softwood fibres possess higher length and strength compared to hardwood fibres, hence contributing to the tensile strength of paper, as an example. Hardwood fibres are shorter and opaque, and they add smoothness and better printability to paper (Salminen et al. 2014). Environmental elements, including climate, soil conditions, and silviculture practices, can also exert an influence on the length of fibres in pulpwood (Desch and Dinwoodie 1996). Hence, the assessment of wood fibre length important in pulp and paper production. Several previous studies investigated the variation in wood anatomical properties (Adamopoulos and Voulgaridis 2002; Chowdhury et al. 2012; Nugroho et al. 2012; Salvo et al. 2017; Rungwattana and Hietz 2018; Liu et al. 2020). This article comprises a couple of parts, with the first part focusing on the investigation of radial variation in fibre characteristics of *Robinia pseudoacacia* and *Sclerocarya birrea* wood species.

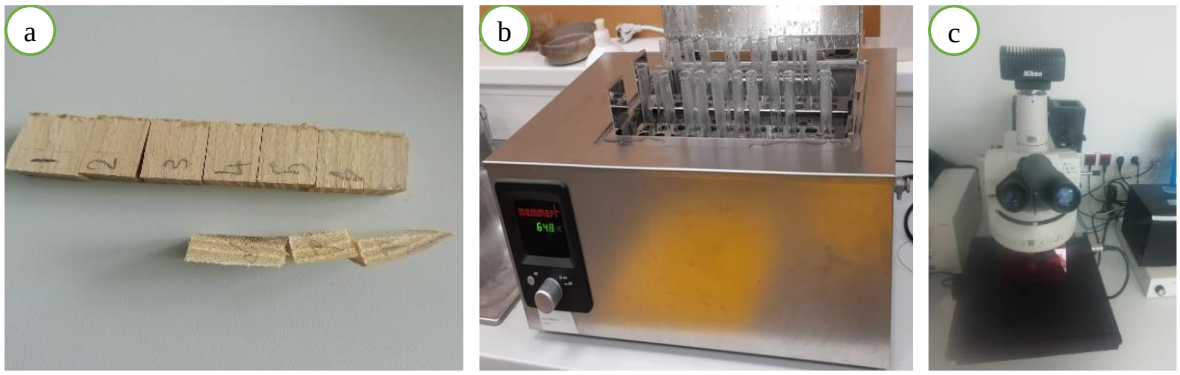

Figure 1: Three stages of measuring fibre characteristics: (a) R. pseudoacacia specimens marked from pith to bark, (b) specimens in water bath, (c) microscope with digital camera

Another topic was the examination of some anatomical properties of field elm (*Ulmus minor* Mill.). This wood species has a special vessel arrangement in the latewood region, called wavy vessel bands as it can be seen in Figure 2. The field elm can be classified as a ring-porous wood species, similarly to the *Robinia pseudoacacia*. Its vessels have an average diameter of 35 µm in the latewood and 150 µm in the earlywood. In the latewood, wavy vessel bands can be seen, which are interrupted in some places (Figure 2) (Molnár and Börcsök 2016). The aim of the second part of this article was the analysis and comparison of the growing zone widths; the vessel lumina diameters in the earlywood and the wave amplitudes of the wavy vessel bands.

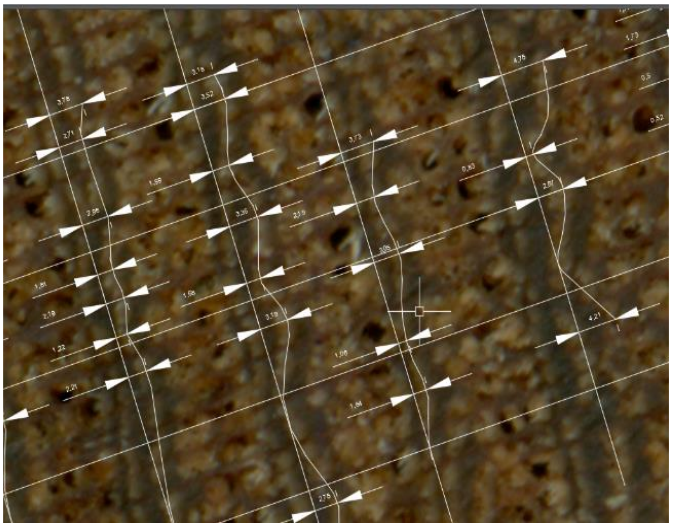

Figure 2: Wavy vessel band measurement in the latewood of field elm

MATERIALS AND METHODS

Fibre characteristics of Robinia pseudoacacia and Sclerocarya birrea

The wood samples of *S. birrea* were obtained from the Laboratory of Wood Science, Faculty of Forestry at the University of Khartoum, Khartoum, Sudan. The *R. pseudoacacia* wood samples were obtained from trees grown in Hungary and processed at the former Institute of Wood Science, University of Sopron, Sopron, Hungary. The radial strips were used to measure the fibre length (mm), fibre diameter (µm), lumen diameter (µm), and wall thickness (µm).

Continuous removal of small pieces, at intervals of 1 cm, was conducted from the pith to the bark for *R. pseudoacacia*. Similarly, for *S. birrea*, small pieces were continually removed, but at intervals of 2 cm. The wood samples underwent maceration using a Franklin solution, which is composed of glacial acetic acid and hydrogen peroxide in equal quantities. Subsequently, the samples were subjected to a temperature of 60°C for 24 hours (Kitin 1999). The fibre traits were assessed using a Nikon light microscope equipped with a digital camera (BR Nikon E80i) and an image-analysis software (NIS-Elements). A total of fifty wood fibres and twenty-five-lumen diameter and wall thicknesses were measured in each specimen.

Anatomical properties of Ulmus minor

The fresh-cut end grains of green *Ulmus minor* mature wood specimens were scanned on a HP Scanjet G4050 (Hewlett-Packard Development Company, USA). In AutoCAD software Autodesk, USA), with the help of a ruler scanned together with the specimens, we were able to scale the images to be able to measure accurate data.

We measured the width of the latewood and earlywood along a predetermined, radial straight line. Since the earlywood widths were almost the same, we later dealt only with the latewood.

In the earlywood vessel diameter examinations, we measured the diameters of the vessels in each annual ring within a 4 mm wide radial band of the test plots, and then calculated the averages and standard deviations.

In the third case, we examined the amplitudes of the vessel bands, that are the heights of the waves of the vessel bands. Along the predetermined 4 mm wide radial band, we marked in AutoCAD a vessel band in each latewood, which does not break in the examined area and well represents the properties of the other vessel bands. We measured the wave heights and calculated the averages and standard deviations.

RESULTS AND DISCUSSION

Table 1 presents the mean values, together with their corresponding standard deviations for fibre length, lumen diameter, fibre diameter, and double cell wall thickness in wood samples of *R. pseudoacacia* and *S. birrea*. The mean values of fibre length and fibre diameter of both species are similar. In comparison, the lumen diameter and cell wall thickness of *S. birrea* are larger than those of *R. pseudoacacia*.

Table 1: Some anatomical results of R. pseudoacacia and S. birrea wood species

	Fibre characteristics	MIN	MEAN	MAX	STD
R. pseudoacacia	Fibre length (mm)	0.71	0.83	0.99	0.09
	Lumen diameter (µm)	8.40	13.18	18.02	3.06
	Fibre diameter (µm)	14.05	18.35	22.58	2.75
	Wall thickness (µm)	4.56	5.13	5.74	0.38
S. birrea	Fibre length (mm)	0.73	0.82	0.90	0.05
	Lumen diameter (µm)	23.45	26.37	29.69	2.23
	Fibre diameter (µm)	14.81	18.01	21.26	2.18
	Wall thickness (µm)	7.51	8.36	9.48	0.57

The fibre length and cell wall thickness of *R. pseudoacacia* exhibit greater values close to the bark. Nevertheless, we observed that the lumen diameter and fibre diameter revealed a decrease near the bark, as shown in Figure 3. The fibres of *S. birrea* wood exhibited the smallest length near the bark. The length of the fibres revealed a rapid growth from the pith until specimen four, after which they exhibited instability towards the bark. Also, the lumen diameter, fibre diameter, and wall thickness decreased constantly after specimens 4–5 and then increased near the bark, as given in Figure 4.

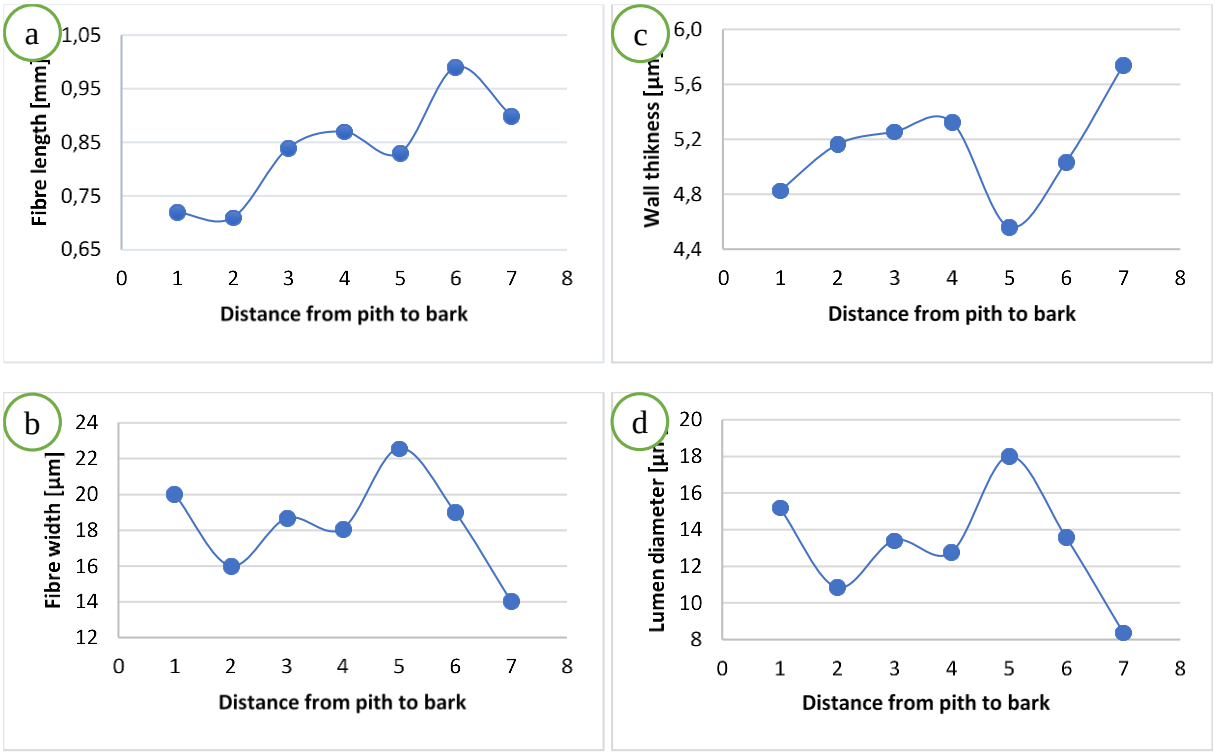

Figure 3: Fibre length (a; mm), fibre width (b; µm), cell wall thickness (c; µm), and lumen diameter (d; µm) of R. pseudoacacia from pith to bark

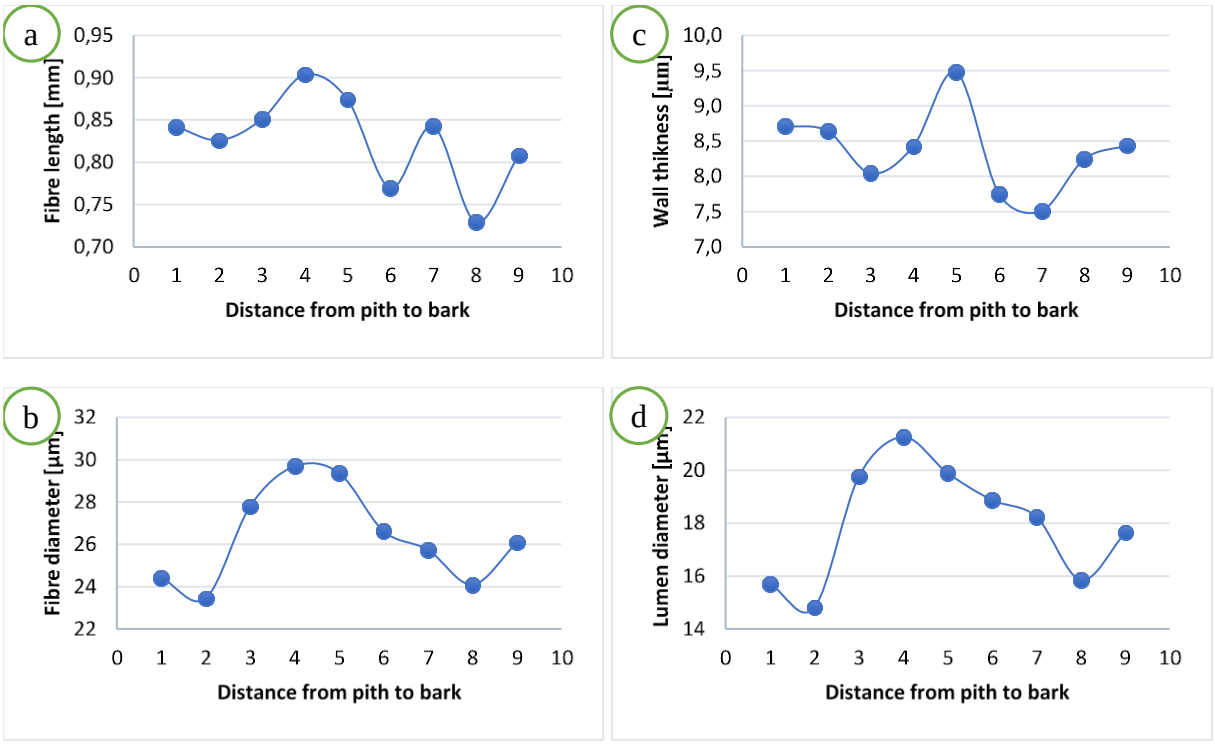

Figure 4: Fibre length (a; mm), fibre width (b; µm), cell wall thickness (c; µm), and lumen diameter (d; µm) of S. birrea from pith to bark

Figure 5 illustrates the significant difference in the mean of pair groups of samples for *R. pseudoacacia* (a) and *S. birrea* (b), as observed from the pith to the bark. Whenever, the interval between groups includes zero, it suggests that there is no statistically significant difference in the means of the groups.

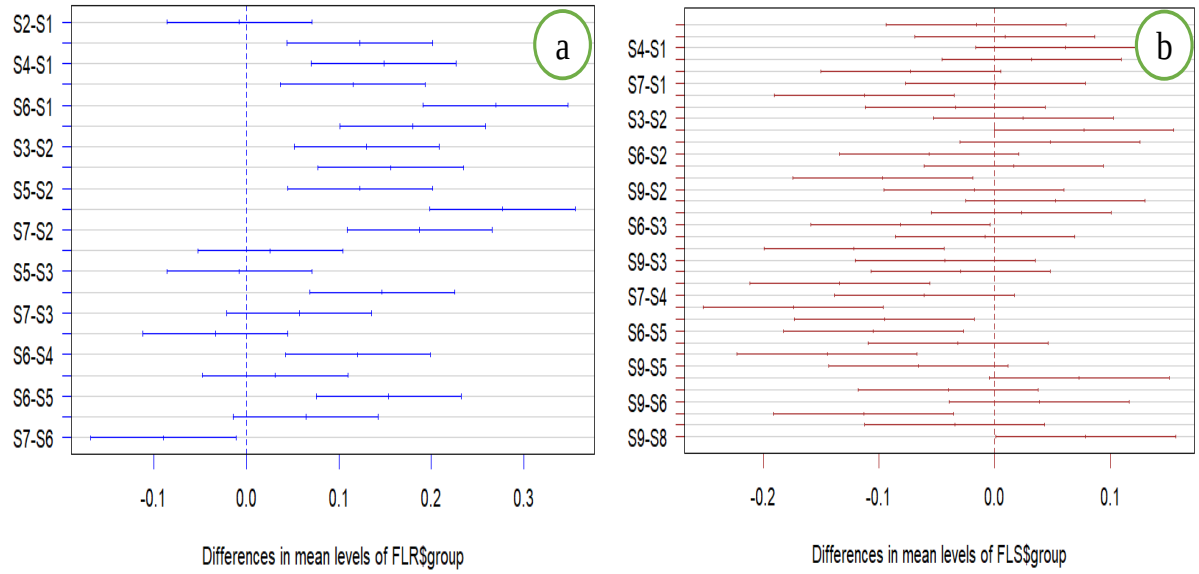

Figure 5: Graphic display of pair-wise comparisons from Tukey's HSD for R. pseudoacacia (a) and S. birrea (b). If the interval contains zero, that indicates the difference in group means is statistically not significant. Abbreviations: S1-S9: numbered specimens

The next results were obtained from the anatomical properties of the field elm. Comparing the earlywood and latewood widths, the standard deviation in the latewood was greater than in the earlywood, as we measured almost similar values in the earlywood. The average width of the earlywood was 1.018 mm, while that of the latewood was 1.537 mm with a relative standard deviation of 41.7%. That is, the significantly different ring widths of these specimens can be largely attributed to the variability of the latewoods, where very different results were obtained, between 0.765 mm and 2.776 mm. For almost half of the measurements there was an annual ring width of more than 2 mm.

The analysis of the vessel diameters of the earlywood was done taking into account the width of the earlywood. Almost identical vessel diameters are found regardless of the different widths of the earlywood. The mean diameter was 0.202 mm with a standard deviation of 0.045 mm. The relative standard deviation is 22.3%.

The amplitudes of the vessel bands in the latewood region range from very small to very large. Almost half of the results are between 0.138 and 0.230 mm. In some cases, very high results have also occurred, over 0.5 mm. The amplitude of vessel bands arranged in a nearly straight line was 0.104 mm on average, which is a value very close to zero if we take into account the circular shape of the annual ring section of these specimens. The smallest measured amplitude was 0.066 mm. In contrast, the amplitude of vessels clearly arranged in a wavy band was 0.336 mm on average. These waves can already be seen with the naked eye on the end-grain surface. It is worth noting that the length of some vessel bands is quite short, regardless of their amplitude.

CONCLUSIONS

Fibre lengths and fibre diameters of *R. pseudoacacia* and *S. birrea* have similar values. The lumen diameter and cell wall thickness of *S. birrea* are larger than those of *R. pseudoacacia*. The fibre length and cell wall thickness of *R. pseudoacacia* exhibit greater values close to the bark. Nevertheless, it was observed that the lumen diameter and fibre diameter revealed a decrease near the bark.

The earlywood widths were almost the same for the field elm (*Ulmus minor* Mill.). On the contrary, significantly different results were obtained for the latewood widths, from 0.775 mm to 2.776 mm. For vessel diameters in the earlywood, most results are below 0.721 mm. Amplitudes between 0.138 and 0.230 mm were mostly measured for vessels arranged in wavy lines in the latewood. In comparison to the average value, outstanding amplitudes occurred in few cases.

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