

Article

Site Variability in Fibers, Vessels, and Ring Width of *Robinia pseudoacacia* L. Wood: A Case Study in Hungary

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Abstract: The black locust tree is a plantation-grown species that occupies a large area in Hungary. Due to variations in the growth environment of trees across different locations, the anatomical features of wood may differ. This study investigated the variability in fiber properties (fiber length, width, wall thickness, vessel length, and width) and growth rate of *Robinia pseudoacacia* L. from five counties and in three specific growing conditions. The parameters were investigated based on a sample of discs taken from the trees at breast height. The statistical analysis revealed significant differences in wood fiber and vessel dimensions, as well as ring width, between counties and growth conditions. Nearly all examined parameters showed the lowest values in Bács-Kiskun County, whereas the highest values were observed in Szabolcs-Szatmár-Bereg and Vas. Regarding the growth conditions, wood in poor growth conditions (mixed trees) and good growth conditions produced superior wood fiber properties and ring widths.

Keywords: *Robinia pseudoacacia* L.; fiber; vessel; ring width; good growth conditions

1. Introduction

Rising temperatures, changing precipitation patterns, and increasing frequency of extreme events caused by climate change modify ecosystems all around the world [1]. These developments have a major effect on tree growth, therefore influencing survival, production, and distribution [2]. Depending on tree species, variations in growth conditions obviously influence the anatomical structure of the wood; consequently, its characteristics vary [3].

Black locust (*Robinia pseudoacacia* L.) is a hardwood species native to eastern North America and has been imported to Europe since 1601. All sub-Mediterranean and temperate climates have adopted it. It is drought-resilient and flourishes in regions with annual precipitation as low as 500–550 mm [4]. In Hungary, it is located in the center, northeast, south, and southwest of Trans Danubia. The first major black locust forests were planted at the beginning of the 18th century to stabilize the wind-blown, sandy soil [5,6]. After that, it was planted in several locations with varying soil characteristics [7]. It is a valuable tree, contributing to sectors of the economy and ecology [8–10].

The wood of *Robinia pseudoacacia* L. is characterized by ring porosity, featuring large vessels arranged circularly and exhibiting a heterogeneous structure [11]. The wood properties vary between trees and within each tree, both radially and tangentially [12–16]. Environmental influences, genetic differences, tree age, and site-specific growth circumstances often govern these variations [17–22]. Researchers have noted that changes in water



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availability, heat stress, and carbon dioxide levels in the air could affect cambial activity and xylem development, leading to changes in wood structure and quality [23,24].

The quality of wood is essential in assessing the usability and worth of timber species across diverse uses, including construction and fine woodworking. Fiber dimensions are among the parameters used in wood evaluation [25–27].

Therefore, we assume that the wood anatomical structure and growth rate of *Robinia pseudoacacia* may vary. While characteristics have been looked at before in countries like Greece, Belgium, and Hungary [11,28,29], our study is distinctive since it looks at the variations in wood anatomical features between several sites and growth conditions in a wide area within Hungary.

The specific aim of this research was to investigate the variability in wood fibers, vessels, and ring width in *Robinia pseudoacacia* L. growing in five counties and under three distinctive growth conditions.

2. Materials and Methods

The wood material was collected from eleven spots, which represent five Hungarian counties (Figure 1). Table 1 highlights the information regarding locations, number of discs used, diameter at breast height, tree growth conditions, and coordinates.

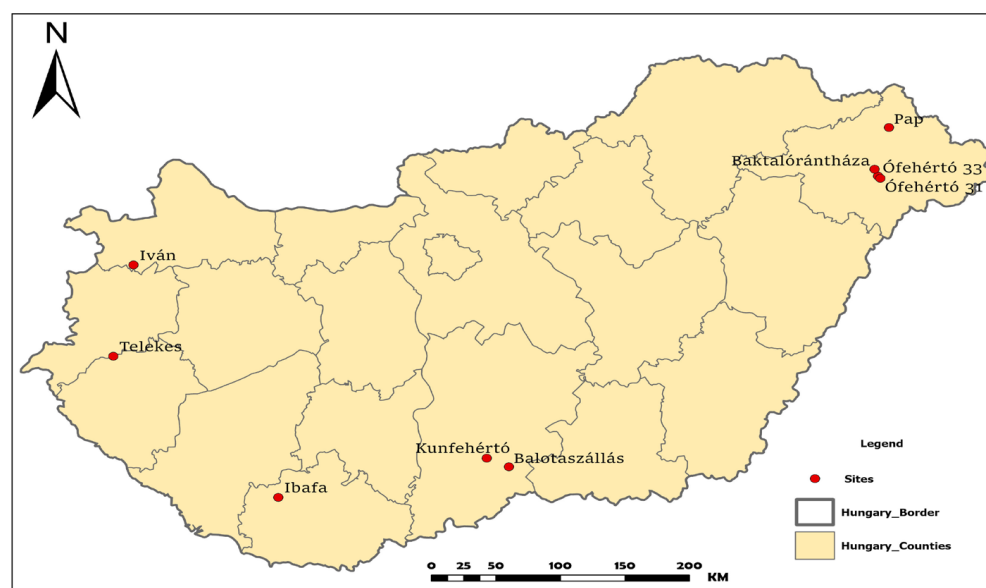


Figure 1. Study area map with specific locations for wood sample collection within the County by name.

The sites studied were classified into three growth conditions based on soil qualities according to [30,31]. Precisely, they were classified as GGC (good growth conditions) sites, which had good-quality soil (rusty brown forest sandy soil of about 60–100 cm depth, high fertility, good structure, balanced nutrient levels, adequate drainage, and balanced pH between 6 and 6–7); PGCs (poor growth conditions), characterized by poor-quality soil (rusty brown forest loamy soil with stagnant water and about 40–100 cm depth, low fertility, poor structure, compaction, waterlogging, and high salinity); and MPGCs (mixed species in poor growth conditions). We did not use hybrid varieties to eliminate the resulting variation.

Table 1. Counties, sites, numbers of discs, average diameters at breast height (DBH), growth conditions, and coordinates. Abbreviations: GGC—good growth condition; PGC—poor growth condition; MPGC—poor growth condition (mixed species). The numbers 31 and 33 in Ófehértó refer to the compartment number inside the forest.

County	Sites Within County	Number of Discs/Sites	Average DBH (cm)	Growth Conditions	Coordinates
Bács-Kiskun	Balotaszállás	2	24.5	GGC	68.6546° N, 10.9105° E
	Kunfehértó	3	17	PGC	67.4622° N, 11.4344° E
Szabolcs-Szatmár-Bereg	Ófehértó 33	2	26	GGC	87.7527° N, 29.1922° E
	Ófehértó 31	2	22	PGC	87.8676° N, 29.0636° E
	Pap	2	26	GGC	88.1955° N, 32.1529° E
	Baktalórántháza	2	27	PGC	87.5568° N, 29.6031° E
Vas	Telekes	3	27	MPGC	47.5547° N, 17.9632° E
Baranya	Ibafa	1	22	GGC	46.0918° N, 17.5459° E
	Ibafa	1	20	PGC	
Győr-Moson-Sopron	Iván	2	18	PGC	47.44633° N, 16.91224° E
	Iván	2	27	GGC	

2.1. Sampling

We extracted discs with a thickness of 4 cm from each log at breast height (130–140 cm). Then, a 2 cm wide strip was taken from bark to bark and divided subsequently into two strips (each 2 cm in width and 2 cm in thickness). One strip was used to determine the wood fiber length (FL), width (FW), wall thickness (FWT), lumen diameter (LD), and vessel length (VL) and width (VW). The second strip was used to measure the annual ring width (Figure 2).

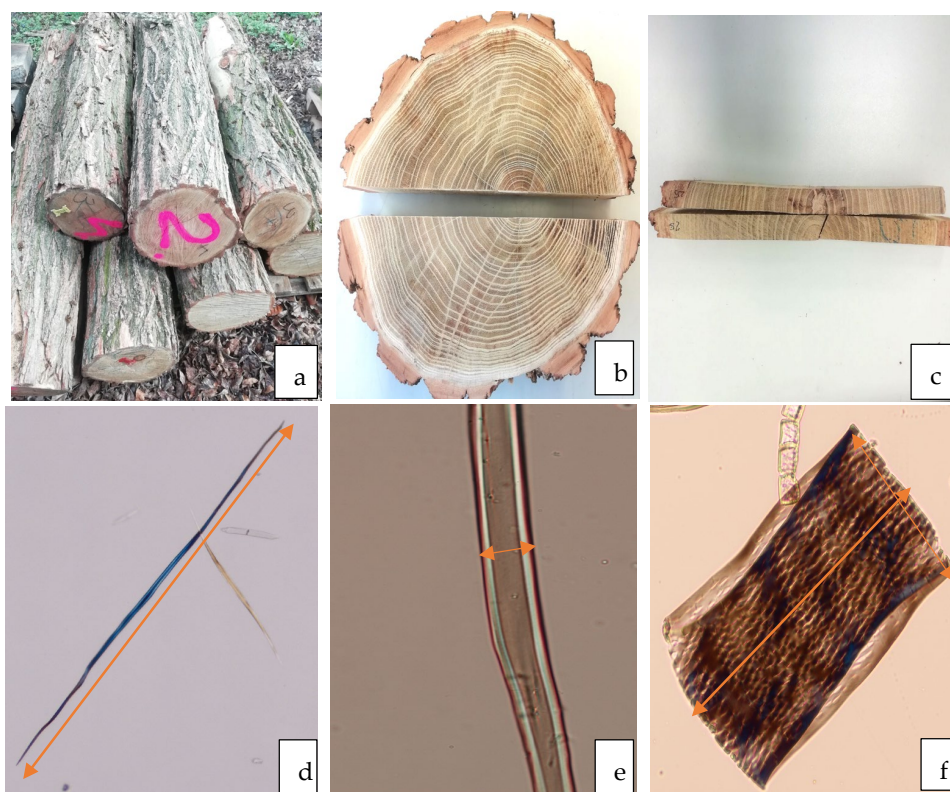


Figure 2. Images for (a) wood material; (b) disc; (c) strips from bark to bark; (d) fiber length (4× lens); (e) fiber width (10× lens); and (f) vessel dimensions (40× lens).

2.2. Measurements of Fiber Parameters

Small pieces were extracted from various positions on the strip. The pieces were placed in test tubes and macerated using a mixed solution of equal volumes of glacial acetic acid (98%) (Avantor; VWR International Kft) and hydrogen peroxide (30%) (ES Lab Hungary Ltd.), then heated to 65 °C for 24–28 h in a water bath. We then washed the macerated pieces with distilled water [32]. Afterwards, a small amount of the macerated fibers was placed on glass microscope slides. The fiber and vessel properties were observed using a light microscope equipped 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). Separately, from each disc, a total of fifty wood FL (mm) and twenty-five FW (μm), FWT (μm), LD (μm), VL (μm), and VD (μm) measurements were taken.

2.3. Ring Width Measurements

The wood strips were polished using sandpaper to smooth the rough surfaces. The smooth strips were scanned using a scanner (CanonScan LiDE 110, Canon, Japan) [33]. Then, the annual ring widths were measured with ImageJ software (V1.54d, National Institutes of Health, MD, USA).

2.4. Data Analysis

All data were analyzed using R statistical software (V4.3.2 (2023-10-31 ucrt)). At first, the Shapiro–Wilk test was used to check if the data distribution was normal. The test result revealed that no variable follows a normal distribution. Based on that, we used the Kruskal–Wallis nonparametric test to determine the statistical significance instead of ANOVA. Only when the Kruskal–Wallis test revealed significant differences did we use the post hoc test, Dunn pairwise comparison (the Bonferroni method), to identify the differences between groups.

3. Results

Across all counties, wood FL varied between 1.04 and 1.11 mm, while FW, FWT, and LD varied between 15.5 and 18.4 μm , 2.55 and 3.76 μm , and 8.19 and 9.98 μm , respectively. The VL, VW, and RW varied from 118.9 to 126 μm , 191 to 223 μm , and 2.15 to 3.90 mm, respectively (Table 2). The VL and VW dimensions were measured from both early and late wood, resulting in higher standard deviations.

A Kruskal–Wallis test revealed significant differences in FL (kw-squared = 12.4, $p = 0.01$), FW (kw-squared = 30.21, $p < 0.0001$), FWT (kw-squared = 85.66, $p < 0.0001$), VW (kw-squared = 14.31, $p = 0.01$), and RW (kw-squared = 195.77, $p < 0.0001$). In contrast, no significant differences were observed for LD (kw-squared = 8.59; $p = 0.08$) or VL (kw-squared = 3.87, $p = 0.42$).

The Dunn test (Table 3) showed that only Szabolcs-Szatmár-Bereg had a significantly higher median FL (1.09 mm) than Vas County (1.02 mm). Likewise, there was a significant difference in VW between Bács-Kiskun and Szabolcs-Szatmár-Bereg. The median values of FW (15.93 μm), FWT (2.78 μm), and RW (1.19 mm) were significantly lower in Bács-Kiskun County than in the other counties.

As shown in Table 4, the simple statistics for wood fibers, vessels, and annual ring width under the three growth conditions are summarized. The result shows that GGCs (good growth conditions) produced the longest FL (1.12 mm) and VL (125 μm) and the widest VW (227 μm). Similarly, the FW, FWT, and LD parameters were highest in MPGCs, poor growth conditions for mixed species. However, in the case of PGCs, most of the parameters were the lowest compared to those observed in other growth conditions.

Table 2. The descriptive statistics of fibers, vessels, and ring width of *Robinia pseudoacacia* L. wood across counties.

County	Statistic	FL (mm)	FW (μm)	FWT (μm)	LD (μm)	VL (μm)	VW (μm)	RW (mm)
Szabolcs-Szatmár-Bereg	Mean	1.11	17.6	3.47	8.97	139	177	3.63
	Median	1.09	17.50	3.80	8.18	140.85	172.31	3.12
	Min	0.81	11.87	2.13	5.24	91.07	103.61	1.54
	Max	1.42	21.82	4.83	13.30	202.76	288.95	6.34
	Std	0.130	2.288	0.674	2.13	28.6	42.9	1.34
Bács Kiskun	Mean	1.08	15.5	2.55	8.19	136	242	1.25
	Median	1.07	15.93	2.78	9.05	128.81	271.79	1.19
	Min	0.82	12.95	1.70	5.52	100	107.97	0.30
	Max	1.39	17.63	3.33	9.84	195.76	366.73	2.68
	Std	0.117	1.31	0.332	1.91	28.1	79.9	0.72
Győr-Moson-Sopron	Mean	1.08	17.1	3.24	8.90	118	193	3.21
	Median	1.06	16.86	3.60	8.29	142.71	200.03	3.02
	Min	0.83	12.47	2.24	5.69	82.14	96.69	0.98
	Max	1.37	22.96	4.44	13.13	228.55	299.64	5.95
	Std	0.139	2.71	0.596	2.15	48.5	58.7	1.28
Baranya	Mean	1.06	17	3.30	9.98	144	188	3.11
	Median	1.07	16.13	3.19	8.87	150.43	184.24	3.06
	Min	0.72	11.19	2.08	5.04	91.92	124.18	1.36
	Max	1.47	23.98	4.82	16.59	194.51	283.57	5.09
	Std	0.139	3.71	0.602	2.64	39.1	48.1	1.04
Vas	Mean	1.04	18.4	3.76	9.14	144	179	3.68
	Median	1.02	18.63	3.72	8.89	142.08	171.71	3.91
	Min	0.75	13.46	2.24	5.06	92.43	141.53	1.36
	Max	1.34	22.47	5.06	13.89	196.24	209.66	6.02
	Std	0.155	2.71	0.757	2.40	31.4	26.3	1.25

Min = minimum; Max = maximum; Std = standard deviation.

Table 3. Post hoc pairwise comparisons (Bonferroni method) between county groups.

Parameters	Comparison	Z-Statistic	Adjusted <i>p</i> -Value
FL	Szabolcs-Szatmár-Bereg vs. Vas	3.12	0.008
FW	Bács Kiskun vs. Győr-Moson-Sopron	−2.97	0.04
	Bács Kiskun vs. Szabolcs-Szatmár-Bereg	−4.55	0.0001
	Bács Kiskun vs. Vas	−4.63	0.0001
	Baranya vs. Vas	−2.92	0.0001
FWT	Bács Kiskun vs. Baranya	−5.99	0.0001
	Bács Kiskun vs. Győr-Moson-Sopron	−5.54	0.0001
	Bács Kiskun vs. Szabolcs-Szatmár-Bereg	−8.44	0.0001
	Bács Kiskun vs. Vas	−7.26	0.0001
VW	Bács Kiskun vs. Szabolcs-Szatmár-Bereg	3.68	0.001
RW	Bács Kiskun vs. Baranya	−7.95	0.0001
	Bács Kiskun vs. Győr-Moson-Sopron	−7.99	0.0001
	Baranya vs. Szabolcs-Szatmár-Bereg	−11.18	0.0001
	Baranya vs. Vas	−11	0.0001

There were differences in FL (kw-squared = 25, $p < 0.0001$), FW (kw-squared = 8.76, $p < 0.0001$), FWT (kw-squared = 18.50, $p = 0.0001$), VW (kw-squared = 15.64, $p = 0.0001$), and RW (kw-squared = 56.58, $p = 0.0001$) based on the growth conditions, as shown by the Kruskal–Wallis test. The statistics for LD and VL did not show significant differences (kw-squared = 5.81, $p = 0.05$ and kw-squared = 5.17, $p = 0.08$, respectively). The analysis of the statistics for LD and VL did not significantly vary (kw-squared = 5.81, $p = 0.05$ and

kw-squared = 5.17, $p = 0.08$, respectively). The significant differences (Dunn test) between group conditions are shown in Table 5.

Table 4. The descriptive statistics of the fiber and vessel properties of *Robinia pseudoacacia* L. wood grown under GGCs (good growth conditions), PGCs (poor growth conditions), and MPGCs (poor growth conditions (mixed species)).

Growth Conditions	Statistic	FL (mm)	FW (μm)	FWT (μm)	LD (μm)	VL (μm)	VW (μm)	RW (mm)
GGC	Mean	1.12	16.9	3.33	8.34	125	227	3.68
	Median	1.11	16.87	3.21	7.98	143.61	202.98	3.34
	Min	0.80	12.32	1.70	5.04	91.92	103.61	1.05
	Max	1.42	22.96	5.20	13.32	228.55	366.73	5.67
	Std	0.139	2.87	0.745	1.97	43.6	87.9	1.25
PGC	Mean	1.06	17.0	3.09	8.93	118	182	2.70
	Median	1.05	16.29	3.05	8.86	137.04	169.94	2.74
	Min	0.81	11.19	1.65	5.09	82.14	96.69	1.43
	Max	1.39	23.98	4.82	13.80	202.76	299.64	3.81
	Std	0.119	2.93	0.582	2.18	45	95.9	0.67
MPGC	Mean	1.04	18.4	3.76	9.14	122	215	3.68
	Median	1.02	18.44	3.72	8.89	142.08	171.71	3.91
	Min	0.95	13.46	2.24	5.06	92.43	141.53	1.36
	Max	1.34	22.47	5.06	13.89	196.24	209.66	6.02
	Std	0.155	2.71	0.757	2.40	42.2	78.9	1.25

Min = minimum; Max = maximum; Std = standard deviation.

Table 5. Post hoc pairwise comparisons between GGCs (good growth conditions), PGCs (poor growth conditions), and MPGCs (poor growth conditions for mixed trees).

Parameter	Comparison	Z-Statistic	Adjusted p -Value
FL	GGC vs. PGC	4.36	0.0001
	GGC vs. MPGC	3.60	0.0005
FW	GGC vs. PMGC	−2.90	0.005
	MPGC vs. PGC	2.72	0.009
FWT	GGC vs. MPGC	−262	0.01
	GGC vs. PGC	2.50	0.01
	MPGC vs. PGC	4.06	0.0001
VW	GGC vs. PGC	3.9	0.0001
RW	GGC vs. MPGC	−3.89	0.0001
	GGC vs. PGC	4.02	0.0001
	MPGC vs. PGC	7.43	0.0001

The variability in the annual ring width from pith to bark for each county is shown in Figure 3. The curve shows that Bács-Kiskun County has the narrowest annual rings, while those of Szabolcs-Szatmár-Bereg and Vas Counties show the widest width.

Regarding growing conditions, MPGCs (mixed trees) and GGCs (good growth conditions) showed the greatest annual ring widths, respectively. PGCs (poor growth conditions), on the other hand, displayed the narrowest widths (Figure 4).

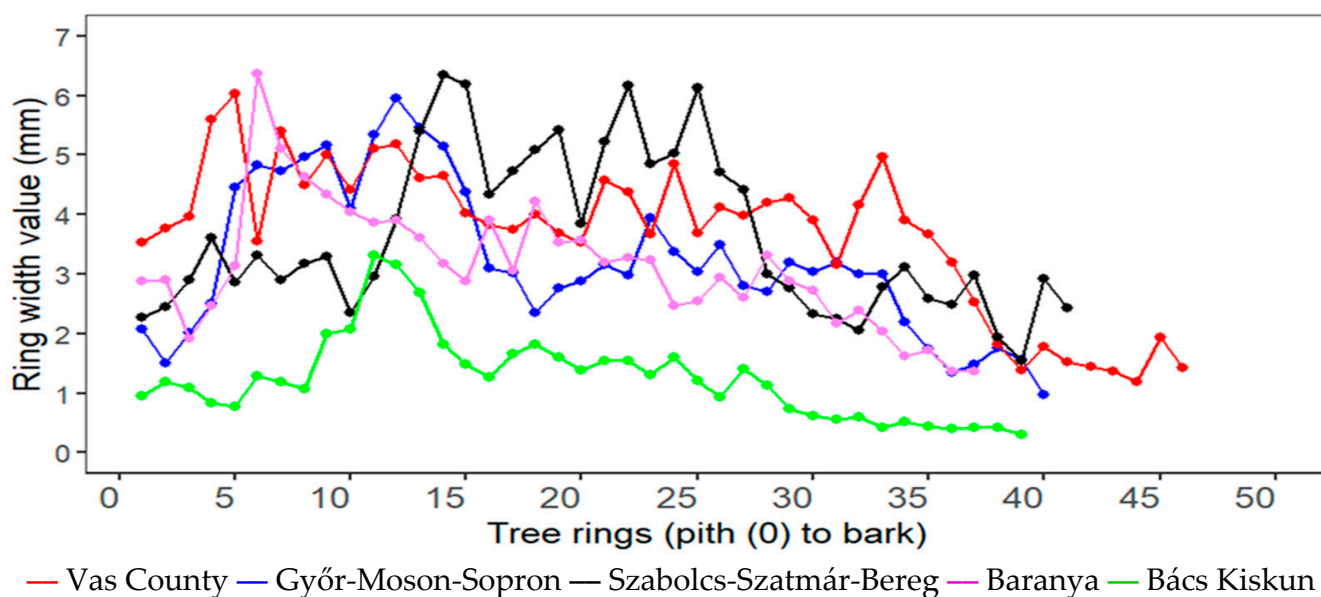


Figure 3. Variability among counties in annual ring width from pith to bark of wood of *Robinia pseudoacacia* L. wood.

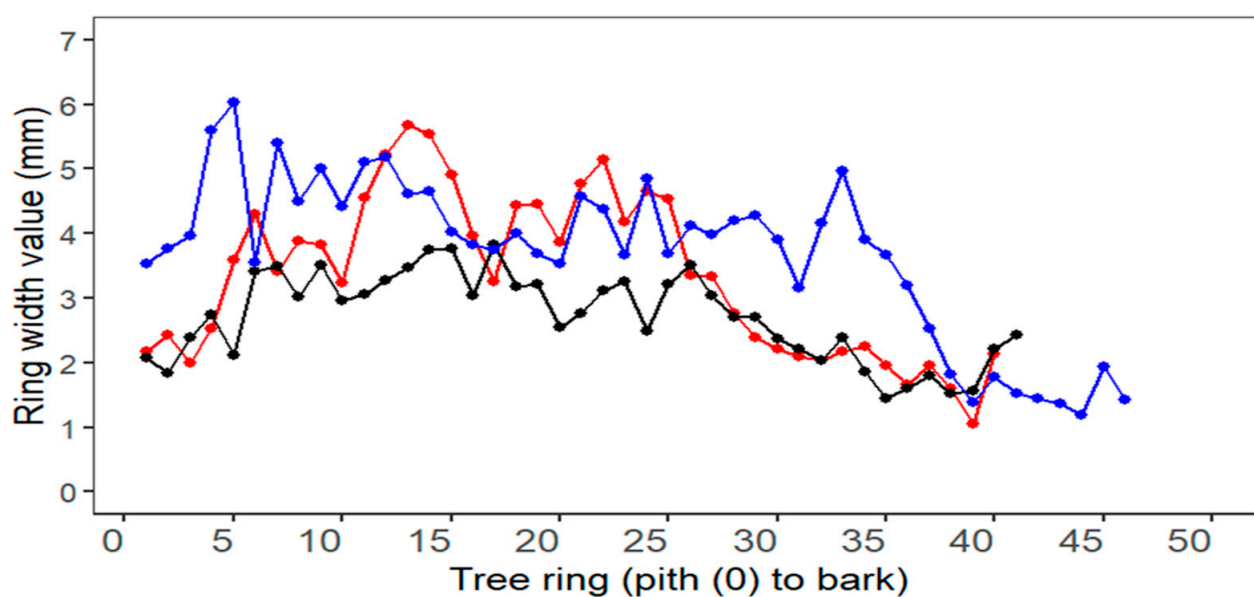


Figure 4. Variability among growth conditions in width of annual rings from pith to bark of *Robinia pseudoacacia* L. wood.

4. Discussion

Robinia pseudoacacia L. trees grow widely around the world, including in Hungary [34]. They have been used for several important purposes [7,35]. In our study, fibers, vessels, and ring width were investigated in several counties and under different growth conditions. These investigated parameters are crucial for the evaluation of wood characteristics [3,25]. Fibers play an important role in determining the mechanical properties of wood, such as strength, flexibility, and durability, which are necessary for applications in construction, furniture production, and tool handles. The characteristics of the vessel influence the porosity and permeability of the wood, which are critical in drying, seasoning, and preservative

treatments. In addition, ring width is an indicator of growth rate, which is related to wood density and overall mechanical performance [36].

Regarding the variability between sites, our results indicate that significant differences in FL occurred only between Szabolcs-Szatmár-Bereg and Vas Counties, and similarly between Bács-Kiskun and Szabolcs-Szatmár-Bereg for VW. Significant differences were also observed between several counties for FW, FWT, VW, and RW (Table 3). In contrast, there were no differences for LD or VL in any counties. We found that all counties had almost similar characteristics, except Bács-Kiskun County, which had the lowest values for FW, FWT, and RW and the highest VW, while Szabolcs-Szatmár-Bereg and Vas Counties had the best characteristics.

Previous studies mentioned that there are many factors that cause variations in wood anatomical features between sites. These factors include the type of soil and its corresponding nutrient and moisture availability [37]. For instance, water availability significantly determines wood vessel and fiber sizes specifically in *Robinia pseudoacacia* L. [38]. In dry climates or areas with variable water availability, plants typically develop narrower vessels with thicker walls, which reduces the probability of embolism during drought conditions [39]. Conversely, areas with increased and stable water availability can produce larger vessels and fiber diameters [40,41]. Also, under favorable growing conditions, the ring widths increase [42–45]. In addition, genetic adaptations likely interact with environmental pressures to alter traits such as fiber wall thickness, vessel diameter, and ring width in response to specific site conditions [46]. Significant variations in fiber properties and growth rings of *Robinia pseudoacacia* L. wood were observed within a single growth ring [15] and within the radial direction (between early and late wood) [11,47]. Furthermore, regarding tree ages, old trees had longer fiber lengths than the youngest trees [48,49]. In comparison to our findings, the fiber length ranged between 1.04 and 1.11 mm, which is higher than values given by [48] and lower than values reported by [49] for trees aged 60 and 71 years.

In terms of growth conditions, GGCs—good growth conditions—showed the greatest fiber, vessel, and ring widths compared to PGCs and MPGCs—poor and mixed growth conditions. Interestingly, the MPGCs had better parameters than PGCs (poor growth conditions), which indicated that the mixed trees have better properties because of different root structures and canopies, allowing for more efficient use of sunlight, water, and nutrients. These reduce the competition and promote better growth conditions, which can enhance fiber properties and growth rate. Previous research has indicated that high-quality sites yield high-quality timber from *Robinia pseudoacacia* L. [7]. Our findings confirmed this due to the long fibers and wide ring widths.

The ring width patterns in our study resemble the curves identified by [11,13,28]. The widths of the annual rings decreased from pith to bark, which is attributed to the age of the cambium (ring width diminished as age increased). Other species, such as *Alnus glutinosa*, also display a comparable pattern [50].

5. Conclusions

Across all counties, we observed significant differences in FL only between Szabolcs-Szatmár-Bereg and Vas Counties, as well as between Bács-Kiskun and Szabolcs-Szatmár-Bereg, in terms of VW. In contrast, there were notable variations in FW, FWT, and RW between many counties. But there were no significant differences in LD and VL. Furthermore, we found that GGCs and MPGCs produce the best fiber properties and the widest ring widths. Future studies will focus on chemical, physical, and mechanical properties to provide additional information regarding these areas of study and growth conditions.

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References

1. IPCC. Climate Change 2023: Synthesis Report. In *Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Core Writing Team, Lee, H., Romero, J., Eds.; IPCC: Geneva, Switzerland, 2023; p. 184.
2. Al Bayati, A.A.S.Y. The Impact of Climate Change on Biodiversity and Ecosystem Functioning. *Acad. Int. J. Pure Sci.* **2024**, *2*, 15–25. [\[CrossRef\]](#)
3. Zhang, S.; Belien, E.; Ren, H.; Rossi, S.; Huang, J.G. Wood anatomy of boreal species in a warming world: A review. *Iforest-Biogeoosci. For.* **2020**, *13*, 130–138. [\[CrossRef\]](#)
4. Nicolescu, V.; Rédei, K.; Mason, W.; Vor, T.; Pöetzelberger, E.; Bastien, J.; Brus, R.; Benčat', T.; Đodan, M.; Cvjetkovic, B.; et al. Ecology, growth and management of black locust (*Robinia pseudoacacia* L.), a non-native species integrated into European forests. *J. For. Res.* **2020**, *31*, 1081–1101. [\[CrossRef\]](#)
5. Rédei, K.; Keserű, Z.; Csiha, I.; Rásó, J.; Takács, M. Promising black locust (*Robinia pseudoacacia* L.) cultivars in Hungary. *Int. J. Hortic. Sci.* **2018**, *24*, 18–20. [\[CrossRef\]](#)
6. Vítková, M.; Müllerová, J.; Sádlo, J.; Pergl, J.; Pyšek, P. Black locust (*Robinia pseudoacacia*) Beloved and despised: A story of an invasive tree in Central Europe. *For. Ecol. Manag.* **2017**, *384*, 287–302. [\[CrossRef\]](#)
7. Rédei, K.M.; Osváth, B.Z.; Veperdi, I. Black locust (*Robinia pseudoacacia* L.) improvement in Hungary: A review. *Acta Silv. Lignaria Hung. Int. J. For. Wood Environ. Sci.* **2008**, *4*, 127–132. [\[CrossRef\]](#)
8. Papadopoulou, F.; Tentsoglidou, M.; Pavloudakis, F.; Papadimopoulos, N.; Papadopoulos, I. Evaluation of honey producing potential of *Robinia pseudoacacia* in reforested old Lignite mines in West Macedonia. *J. Environ. Sci. Eng. B* **2018**, *7*, 354–359.
9. Kortoci, K.M.; Kortoci, Y. Comparison of Growth Rate of Black Locust (*Robinia pseudoacacia* L.) on Productive and Marginal Cultivated Lands for Sustainable Agroforestry Systems. *Ecol. Eng. Environ. Technol.* **2022**, *23*, 206–212. [\[CrossRef\]](#)
10. Rédei, K.; Csiha, I.; Keserű, Z.; Kamandiné, V.Á.; Győri, J. The silviculture of black locust (*Robinia pseudoacacia* L.) in Hungary: A review. *South-East Eur. For.* **2011**, *2*, 101–107. [\[CrossRef\]](#)
11. Adamopoulos, S.; Voulgaridis, E. Within-tree variation in growth rate and cell dimensions in the wood of black locust (*Robinia pseudoacacia*). *IAWA J.* **2002**, *23*, 191–199. [\[CrossRef\]](#)
12. Klisz, M.; Wojda, T.; Jastrzebowski, S.; Ukalska, J. Circumferential variation in heartwood in stands of black locust (*Robinia pseudoacacia* L.). *Drewno Pr. Nauk. Doniesienia Komun.* **2015**, *58*, 195. [\[CrossRef\]](#)
13. Adamopoulos, S.; Passialis, C.; Voulgaridis, E. Ring width, latewood proportion and density relationships in black locust wood of different origins and clones. *IAWA J.* **2010**, *31*, 169–178. [\[CrossRef\]](#)
14. Page, V.M. Anatomical variation in the wood of *Robinia pseudoacacia* L. and the identity of Miocene fossil woods from southwestern United States. *IAWA J.* **1993**, *14*, 299–314. [\[CrossRef\]](#)
15. Hejnowicz, A.; Hejnowicz, H. Variations of length of vessel members and fibres in the trunk of *Robinia pseudoacacia*. *Acta Soc. Bot. Pol.* **1959**, *28*, 453–460. [\[CrossRef\]](#)
16. Rao, B.S. *Variation in Structure of the Secondary Xylem in Individual Dicotyledonous Trees*; University of London, Royal Holloway College: London, UK, 1959.
17. Gadermaier, J.; Vospernik, S.; Grabner, M.; Wächter, E.; Keßler, D.; Kessler, M.; Lehner, F.; Klebinder, K.; Katzensteiner, K. Soil water storage capacity and soil nutrients drive tree ring growth of six European tree species across a steep environmental gradient. *For. Ecol. Manag.* **2024**, *554*, 121599. [\[CrossRef\]](#)

18. Euring, D.; Janz, D.; Polle, A. Wood properties and transcriptional responses of poplar hybrids in mixed cropping with the nitrogen-fixing species *Robinia pseudoacacia*. *Tree Physiol.* **2021**, *41*, 865–881. [[CrossRef](#)]
19. Bijak, S.; Lachowicz, H. Impact of tree age and size on selected properties of black locust (*Robinia pseudoacacia* L.) wood. *Forests* **2021**, *12*, 634. [[CrossRef](#)]
20. Huda, A.S.; Koubaa, A.; Cloutier, A.; Hernández, R.E.; Périnet, P. Anatomical properties of selected hybrid poplar clones grown in southern Quebec. *BioResources* **2012**, *7*, 3779–3799. [[CrossRef](#)]
21. Cedro, A.; Nowak, G. Effects of climatic conditions on annual tree ring growth of the *Platanus x hispanica* “Acerifolia” under urban conditions of Szczecin. *Dendrobiology* **2006**, *55*, 11–17.
22. Fritts, H.C. Relationships of ring widths in arid-site conifers to variations in monthly temperature and precipitation. *Ecol. Monogr.* **1974**, *44*, 411–440. [[CrossRef](#)]
23. Qaderi, M.M.; Martel, A.B.; Dixon, S.L. Environmental factors influence plant vascular system and water regulation. *Plants* **2019**, *8*, 65. [[CrossRef](#)] [[PubMed](#)]
24. Waisel, Y.; Fahn, A. The Effects of Environment on Wood Formation and Cambial Activity in *Robinia pseudoacacia* L. *New Phytol.* **1965**, *1*, 436–442. [[CrossRef](#)]
25. Lozjanin, R.; Jokanović, D.; Nikolić, J.V.; Živanović, K.; Desimirović, I.; Marinković, M. Anatomical Characteristics and Assessment of Wood Fibers Quality of Mature Pedunculate Oak (*Quercus robur* L.) Trees Grown in Different Environmental Conditions. *South-East Eur. For.* **2024**, *15*, 51–57. [[CrossRef](#)]
26. Adebara, S.A.; Hassan, H.; Shittu, M.B.; Anifowose, M.A. Quality and utilization of timber species for building construction in Minna, Nigeria. *Int. J. Eng. Sci.* **2014**, *3*, 46–50.
27. Larson, P.R. Wood Formation and the Concept of Wood Quality. *Yale Sch. For. Environ. Stud. Bull. Ser.* **1969**, *69*, 1–54.
28. Pollet, C.; Verheyen, C.; Hebert, J.; Jourez, B. Physical and mechanical properties of black locust (*Robinia pseudoacacia*) wood grown in Belgium. *Can. J. For. Res.* **2012**, *42*, 831–840. [[CrossRef](#)]
29. Molnar, S. Wood properties and utilization of black locust in Hungary. *Drev. Vysk. Wood Res.* **1995**, *1*, 27–33.
30. Várallyay, G. Soils, as the most important natural resources in Hungary (potentialities and constraints)—A review. *Agrokém. Talajtan* **2015**, *64*, 321–338. [[CrossRef](#)]
31. Tóth, G.; Stolbovoy, V.; Montanarella, L. *Soil Quality and Sustainability Evaluation. An Integrated Approach to Support Soil-Related Policies of the European Union*; Office for Official Publications of the European Communities: Luxembourg, 2007.
32. Franklin, G.L. Preparation of thin sections of synthetic resins and wood-resin composites, and a new macerating method for wood. *Nature* **1945**, *155*, 51. [[CrossRef](#)]
33. Abràmoff, M.D.; Magalhães, P.J.; Ram, S.J. Image processing with ImageJ. *Biophotonics Int.* **2004**, *11*, 36–42.
34. Rédei, K.; Keserű, Z.; CSiha, I.; Rásó, J.; Honfy, V. Plantation silviculture of black locust (*Robinia pseudoacacia* L.) cultivars in Hungary—A review. *South-East Eur. For.* **2017**, *8*, 151–156. [[CrossRef](#)]
35. Sillero, L.; Prado, R.; Labidi, J. Optimization of different extraction methods to obtaining bioactive compounds from larch decidua bark. *Chem. Eng. Trans.* **2018**, *70*, 1369–1374.
36. Jang, H.F.; Seth, R.S.; Wu, C.B.; Chan, B.K. Determining the transverse dimensions of fibers in wood using confocal microscopy. *Wood Fiber Sci.* **2005**, 615–628.
37. Olson, M.E.; Soriano, D.; Rosell, J.A.; Anfodillo, T.; Donoghue, M.J.; Edwards, E.J.; Martínez-Cabrera, H.I. Plant height and hydraulic vulnerability to drought and cold. *Proc. Natl. Acad. Sci. USA* **2018**, *115*, 7551–7556. [[CrossRef](#)]
38. Nola, P.; Bracco, F.; Assini, S.; von Arx, G.; Castagneri, D. Xylem anatomy of *Robinia pseudoacacia* L. and *Quercus robur* L. is differently affected by climate in a temperate alluvial forest. *Ann. For. Sci.* **2020**, *77*, 8. [[CrossRef](#)]
39. Hacke, U.G.; Sperry, J.S. Functional and ecological xylem anatomy. *Perspect. Plant Ecol. Evol. Syst.* **2001**, *4*, 97–115. [[CrossRef](#)]
40. Schreiber, S.G.; Hacke, U.G.; Hamann, A. Variation of xylem vessel diameters across a climate gradient: Insight from a reciprocal transplant experiment with a widespread boreal tree. *Funct. Ecol.* **2015**, *29*, 1392–1401. [[CrossRef](#)]
41. February, E.C.; Stock, W.D.; Bond, W.J.; Le, D.J. Relationships between water availability and selected vessel characteristics in *Eucalyptus grandis* and two hybrids. *IAWA J.* **1995**, *16*, 269–276. [[CrossRef](#)]
42. Fonti, P.; von Arx, G.; García-González, I.; Eilmann, B.; Sass-Klaassen, U.; Gärtner, H.; Eckstein, D. Studying global change through investigation of the plastic responses of xylem anatomy in tree rings. *New Phytol.* **2010**, *185*, 42–53. [[CrossRef](#)]
43. Sass-Klaassen, U.; Couralet, C.; Sahle, Y.; Sterck, F. Juniper from Ethiopia contains a missing link in the tropical tree ring network. *Trees* **2011**, *25*, 299–310.
44. Ladányi, Z.; Blanka, V. Tree-ring width and its interrelation with environmental parameters: Case study in central Hungary. *J. Environ. Geogr.* **2015**, *8*, 53–59. [[CrossRef](#)]
45. He, Y.; Yu, Q.; Wang, G.; Hao, M.; Fan, S.; Hu, D.; Li, Z.; Gao, P. Tree Ring Width Responses of *Pinus densiflora* and *Robinia pseudoacacia* to Climate Variation in the Mount Tai Area of Northern China. *Forests* **2023**, *14*, 2087. [[CrossRef](#)]
46. Zobel, B.; van Buijtenen, J.P. *Wood Variation: Its Causes and Control*; Springer: Berlin/Heidelberg, Germany, 1989; pp. 189–217.

47. Stringer, J.W.; Olson, J.R. Radial and vertical variation in stem properties of juvenile black locust (*Robinia pseudoacacia*). *Wood Fiber Sci.* **1987**, 59–67.
48. Klačnja, B.; Kopitović, Š.; Orlović, S.; Galić, Z. Variability of some structural and physical properties of Black Locust (*Robinia pseudoacacia* L.) wood. *Genetika* **2000**, 32, 9–17.
49. Lachowicz, H.; Bijak, S. Tree Age and Size Affect Selected Fiber Parameters in Black Locust (*Robinia pseudoacacia* L.) Wood. *Forests* **2025**, 16, 111. [[CrossRef](#)]
50. Kiaei, M.; Hamid, R.N.; Hazandy, A.H.; Mohammad, F. Radial variation of fiber dimensions, annual ring width, and wood density from natural and plantation trees of alder (*Alnus glutinosa*) wood. *Wood Res.* **2016**, 61, 55–64.

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