

Article

Selected Physical and Mechanical Properties of Wood of *Robinia pseudoacacia* L. Across Hungarian Counties

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Abstract

Robinia pseudoacacia L. wood is globally recognized for its high density, superior mechanical performance and low dimensional changes. Although widely cultivated across Hungary under diverse environmental conditions, potential regional variations in its wood properties remain insufficiently characterized. This study aimed to investigate the density, linear and volumetric shrinkage and swelling, modulus of rupture (MOR), bending modulus of elasticity (MOE) and compressive strength parallel to the grain (CS) of Hungarian *R. pseudoacacia* samples across five counties and under three growth conditions. Results indicated significant regional variations ($p < 0.05$) across some physical and mechanical parameters studied. The mixed stand in poor growth conditions showed significantly higher linear and volumetric shrinkage than pure stands under good and poor growth conditions. Also, the results revealed that samples from Bács-Kiskun county showed the highest density (0.84 g/cm^3) and MOE (13.33 GPa). However, samples from poor growth conditions revealed the greatest density (0.81 g/cm^3), MOR (131 MPa), and CS (71.90 MPa). These findings suggest that regional site conditions and environmental stressors play a critical role in defining the quality of *R. pseudoacacia* wood, offering valuable insights for localized forest management and enabling targeted site selection for high-quality timber production.

Keywords: black locust; density; shrinkage and swelling; strength; variability



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1. Introduction

Black locust (*Robinia pseudoacacia* L.) is an invasive and fast-growing species, introduced from North America to Europe in 1601, and it has become an adopted species across European countries [1–3]. It is characterized by broad ecological plasticity, high drought tolerance, and ease of vegetative propagation [4,5]. In Hungary, *R. pseudoacacia* is widely distributed and located in the Danube–Tisza interfluvium (middle of Hungary), the Nyírség region (northeast) and the hill ridges of Vas and Zala Counties and of Somogy County (west and southwest) [6], occupying 24.6% of the total forest area [7,8] and contributing 25% of the annual timber yield [9].

R. pseudoacacia wood is acknowledged for its high density [10] and biological durability, in addition to its low permeability and low dimensional change. It demonstrates

high resistance to decay and insect attack, often superior to that of native European hardwoods [11,12]. Compared to the juvenile heartwood of Robinia, mature heartwood has greater natural durability [13].

R. pseudoacacia trees have been used for agricultural implements and honey production; however, with high demand for wood for construction and developing wood technologies, it is chiefly used for furniture, outdoor gates and adhesive-based constructions [14].

In Hungary, targeted *R. pseudoacacia* breeding programs have been in place since the 1960s to improve wood quality and biomass yield for industrial applications [15]. Both pure and mixed stands of *R. pseudoacacia* have been established alongside species such as poplar, thriving in both good- and poor-quality soils. Across Hungarian counties, our previous studies revealed significant differences in fiber parameters and the growth rate of *R. pseudoacacia*, with the longest fiber length (1.11 mm) observed in Szabolcs-Szatmár-Bereg County and under good growth conditions [16]. In terms of extractive composition, the Vas and Bács-Kiskun Counties yield the highest content of total extractives, with average values of 13.4% and 11.1%, respectively. However, Baranya County showed the lowest value (7.37%). Compared with pure stands in good and poor growth conditions, the mixed stand in poor-quality soil revealed the maximum value (13.4%) [17].

Despite a few studies investigating the characteristics of *R. pseudoacacia* wood in Hungary [18], no study has yet assessed these properties across different Hungarian sites or under different growth conditions, such as soil quality. Therefore, we assume that the density and strength properties are significantly affected by site conditions and soil quality.

Given the anticipated impacts of climate change in Hungary [19], *R. pseudoacacia* serves as a promising alternative species projected to supply a substantial share of raw material for the timber industry [20]. Consequently, the application of this wood for indoor or outdoor use depends on its characteristics, including its physical and mechanical properties. However, these properties can vary between the site growth conditions, such as its anatomical properties and chemical composition [17,18].

This study is aimed to evaluate the (i) density at 12% moisture content (D_{12}) and basic density (BD), (ii) linear and volumetric shrinkage and swelling, (iii) modulus of elasticity, modulus of rupture, and compressive strength parallel to the grain of *R. pseudoacacia* samples across five Hungarian counties under three growth conditions. The results of this study are critical for determining which sites yield wood with superior density, dimensional stability (shrinkage and swelling), and mechanical strength.

2. Materials and Methods

2.1. Materials

Free from large defects, a total of 22 logs from *R. pseudoacacia* from both pure and mixed plantations were collected from five Hungarian counties: Bács-Kiskun, Szabolcs-Szatmár-Bereg, Vas, Baranya, and Győr-Moson-Sopron (Figure 1). The tree age ranged between 30 and 47 years old. Log sections were taken at approximately 130 cm above stump height for larger trees, whereas smaller-diameter trees required longer log segments to yield sufficient test specimens. Detailed site characteristics, including sample quantities, tree ages, diameter at breast height (DBH), and geographic coordinates, are summarized in Table 1 [17].

The growth conditions were classified into three categories: pure stand in good-quality soil (good growth conditions), pure stand in poor-quality soil (poor growth conditions), and mixed stand in poor-quality soil (poor growth conditions-mixed species). The good growth conditions sites (GGC) were characterized by rusty brown forest sandy soils (60–100 cm in depth) featuring high fertility, balanced nutrient profiles, and optimal drainage with a pH range of 6.0–7.0. However, poor growth condition sites (PGC) were defined by rusty

brown forest loamy soils (40–100 cm in depth) exhibiting stagnating water, high salinity, and poor structural aeration [21,22]. In poor growth conditions-mixed species (MPGC), *R. pseudoacacia* grows mixed with Pinus, Populus, and Quercus species. Historical climatic data (1982–2023) of the study area sourced from the NASA POWER database (accessed 7 December 2025) indicated regional variations in temperature and precipitation across the study sites. During this period, Bács-Kiskun had the most arid environment, with the highest average temperature (11.5 °C) and the lowest annual precipitation (585.1 mm). In contrast, Baranya and Vas counties provided more humid conditions, with Baranya recording the highest annual precipitation (739.2 mm). The regions of Szabolcs-Szatmár-Bereg and Győr-Moson-Sopron were characterized by lower mean temperatures (10.6–10.7 °C) [23].

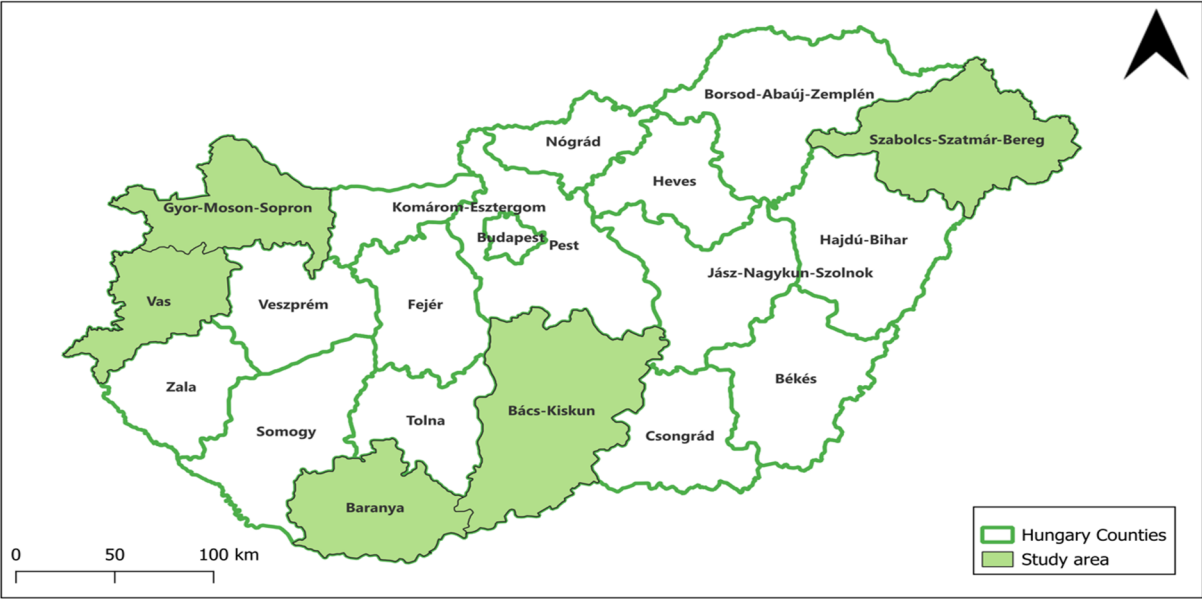


Figure 1. Map of Hungary indicating counties (shaded green) where wood samples were collected.

Table 1. County, sites, number of discs, tree age, average diameter at breast height (DBH), growth condition and coordinates. GGC—good growth condition; PGC—poor growth condition; MPGC—poor growth condition mixed stand [17]. The EOY coordinates are given in meters, with the Y (eastern coordinate) first, followed by the X (northern coordinate).

County	Sites Within the County	Number of Trunk/Used	Tree Ages	Average DBH (cm)	Growth Condition	EOV Coordinates
Bács-Kiskun	Balotaszállás	2	35	24.5	GGC	686,546, 109,105
	Kunfehértó	3	38	17	PGC	674,622, 114,344
Szabolcs-Szatmár-Bereg	Ófehértó 33	2	38	26	GGC	877,527, 291,922
	Ófehértó 31	2	40	22	PGC	878,676, 290,636
	Pap	2	33	26	GGC	881,955, 321,529
	Baktalórántháza	2	40	27	PGC	875,568, 296,031
Vas	Telekes	3	47	27	MPGC	475,547, 179,632
Baranya	Ibafa	1	37	22	GGC	460,918, 175,459
	Ibafa	1	30	20	PGC	
Győr-Moson-Sopron	Iván	2	40	18	PGC	4,744,633, 1,691,224
	Iván	2	38	27	GGC	

2.2. Sampling

The logs were sawn into boards at the workshop of the University of Sopron, Hungary (Figure 2A,B). They were subsequently kiln-dried to reduce their moisture content. After that, the specimens for targeted tests were prepared from the heartwood zone. In general, without specifying or distinguishing, both juvenile and mature heartwood were used in proportions representative of the cross-section. Thus, with the appropriate number of samples, it was possible to obtain a realistic picture of the overall quality of the wood used in the study.



Figure 2. A *R. pseudoacacia* logs (A), boards (B), and specimens used for density, shrinkage, and swelling tests (C).

2.2.1. Densities and Linear and Volumetric Shrinkage and Swelling

A total of 347 specimens, each 20 mm in width, 20 mm in thick and 30 mm in length, were conditioned (20 °C temperature and 65% humidity) until constant mass in the climate chamber to reach a moisture content of 10%–12% (Figure 2C). These specimens were used to evaluate D_{12} and BD according to ISO 13061-1 standard [24]. Also, they were used to assess radial (RSH), tangential (TSH), longitudinal (LSH) and volumetric shrinkage (VSH), as well as radial (RSW), tangential (TSW), longitudinal (LSW) and volumetric swelling (VSW) according to ISO 13061-13, 14, 15 and 16 [25–28]. All physical and mechanical test procedures in this study were performed in compliance with International Organization for Standardization (ISO) norms to guarantee measurement accuracy and reproducibility. ISO 13061 standards establish universally accepted technical frameworks for small clear wood specimens governing specimen geometry, environmental conditions, and analytical formulas, ensuring that the empirical results of this study align with global research benchmarks.

Dimensional measurements were conducted across three distinct moisture states. First was at 12% MC. Second was in the green (or fully saturated) state, achieved by soaking the specimens in water for three days at a temperature of (20 ± 2) °C. In the green state the dimension change checked was by repeating the measurements at the same point until the difference did not exceed 0.01 mm. Finally, measurements were taken in the oven-dry state, achieved by drying the specimens at (103 ± 2) °C until a constant weight was reached.

2.2.2. Mechanical Tests

A total of 345 specimens sized 20 × 20 × 300 mm (width, thickness and length) were prepared (Figure 3A) in accordance with ISO 13061-3 and 13061-4 [29,30] to evaluate the MOR and MOE by using Equations 1 and 2. A constant rate of 8.0 mm/min was used, and a support span of 240 mm was used for the 3-point bending tests. Deflection measurement was done using the crosshead displacement of the material testing machine, since *R. pseudoacacia* is one of the hardest types of wood among all European wood species.

Where possible, the test was carried out in the radial anatomical direction. A similar number of replicates (345) sized $20 \times 20 \times 30$ mm (width, thickness and length) was prepared to conduct the CS (Equation 3) test according to ISO 13061-17 [31]. A constant rate of 0.4 mm/min was used. Tests were stopped when the load reached a stable state during continuous compression. The specimens were tested using an Instron 5985 material testing machine (Illinois Tool Works Inc., Norwood, MA, USA; Figure 3B).

$$\text{Modulus of elasticity (Ew)} = \frac{PL^2}{4bh^3 f} \quad (1)$$

where the components are as follows:

P = load equal to the difference between the upper and lower limits of loading, in N;

L = span in 28 cm;

b = breadth of the test piece in mm;

h = height of the test piece in mm;

f = the deflection equal to the difference between the result obtained in measuring the deflection at the upper and lower limits of loading, in mm.

$$\text{Modulus of Rupture (MPa)} = \frac{3FL}{(2RT)^2} \quad (2)$$

where the components are as follows:

L = 28 cm.

R = width.

T = thickness.

F = maximum force.

$$\sigma \text{ (MPa)} = \frac{F_{\max}}{R \times T} \quad (3)$$

where the components are as follows:

σ = compressive strength.

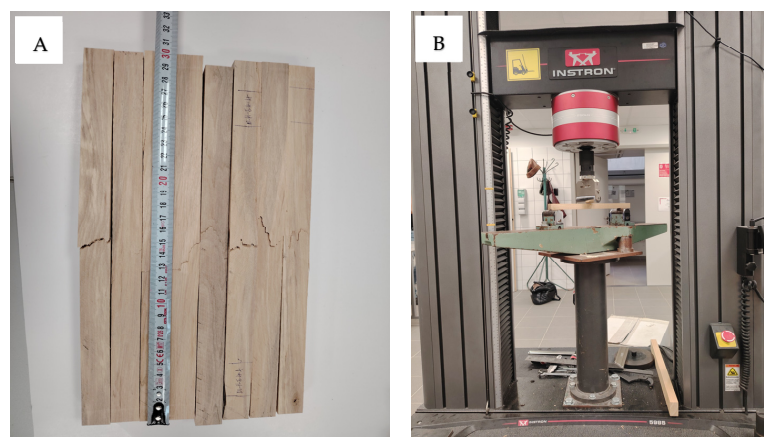


Figure 3. *R. pseudoacacia* specimens used for the MOE and MOR test (A); testing machine (B).

2.2.3. Data Analysis

Statistical data processing was performed using R software version 4.3.2 [32]. The analysis was conducted within the RStudio (version 2026.07.0+139) integrated development environment [33]. The normality of the data was assessed using the Shapiro–Wilk test. Since the data exhibited significant non-normality ($p < 0.05$), differences between groups were performed using the Kruskal–Wallis rank-sum test instead of ANOVA. When the Kruskal–Wallis test revealed a significant difference, post hoc comparisons were conducted to identify the difference between the groups.

3. Results

3.1. Density at 12% Moisture Content and Basic Densities of *R. pseudoacacia* Samples

Table 2 presents the summary statistics for the D_{12} and BD of *R. pseudoacacia* samples across Hungarian counties. For all counties, the average D_{12} was 0.80 ± 0.07 g/cm³, while the BD was 0.71 ± 0.06 g/cm³. Among counties, Bács-Kiskun showed the highest mean values of 0.84 g/cm³ for D_{12} and 0.75 g/cm³ for BD. The lowest density values were recorded in Baranya ($D_{12} = 0.73$ g/cm³; BD = 0.64 g/cm³).

Table 2. Density at 12% moisture content (D_{12}) and basic density (BD) of *R. pseudoacacia* wood samples across different counties (mean $\pm$ Std).

County	No. of Replicates	D_{12} (g/cm ³)	BD (g/cm ³)
Szabolcs-Szatmár-Bereg	82	0.78 ± 0.05 ^b	0.69 ± 0.04 ^c
Bács-Kiskun	77	0.84 ± 0.05 ^a	0.75 ± 0.04 ^a
Győr-Moson-Sopron	75	0.82 ± 0.07 ^a	0.72 ± 0.06 ^b
Baranya	55	0.73 ± 0.04 ^c	0.65 ± 0.04 ^d
Vas	58	0.76 ± 0.05 ^c	0.66 ± 0.04 ^d
All	347	0.80 ± 0.07	0.71 ± 0.06

The difference superscript lowercase letters within a column mean statistically significant difference and similar letters indicate no significant differences.

Kruskal–Wallis tests revealed significant inter-county variations for D_{12} ($H(4) = 118.84$, $p < 0.001$) and BD ($H(4) = 123.01$, $p < 0.001$). Subsequent post hoc comparisons (represented by the letter groupings in Table 2) further delineate the specific differences between individual counties, with distinct letters indicating significant differences at the $p = 0.05$ level. However, the uniform letter indicates no significant differences.

Across the growth conditions, the densities under the PGC were the highest, compared with others (Figure 4). The D_{12} reached 0.81 g/cm³, and the BD reached 0.72 g/cm³. In contrast, the MPGC group exhibited the lowest density values (0.76 g/cm³ for D_{12} and 0.67 g/cm³ for BD). The kw-squared $H(2) = 27.469$ for D_{12} and 31.27 for BD.

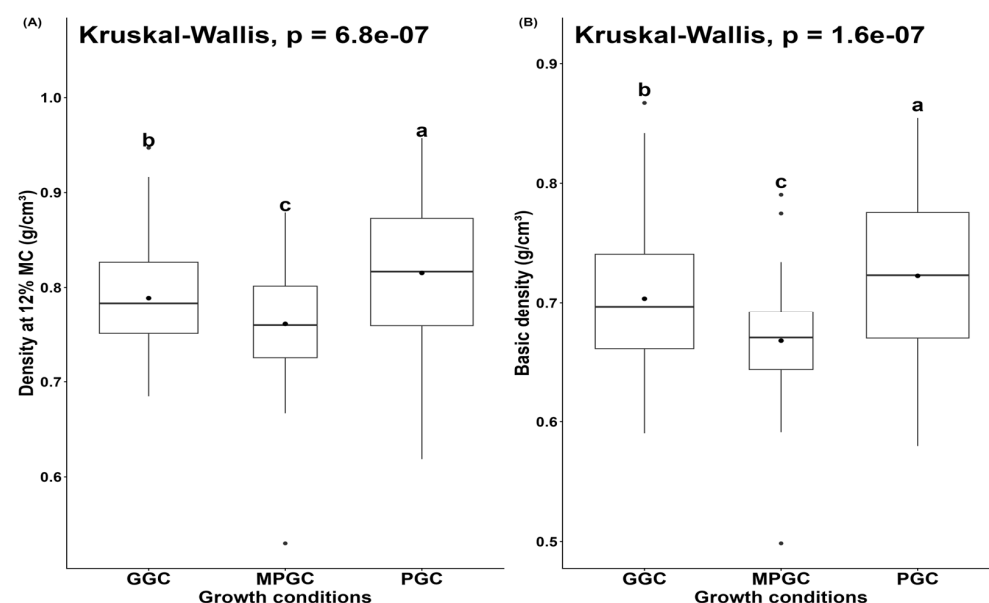


Figure 4. Density at 12% MC (A) and basic density (B) of *R. pseudoacacia* wood samples under different growth conditions. Different letters and letter combinations for a given measurement indicate significantly different mean values at $p < 0.05$ level. Error bars indicate standard deviation. GGC—good growth condition; PGC—poor growth condition; MPGC—poor growth conditions-mixed stand.

3.2. Linear and Volumetric Shrinkage and Swelling of *R. pseudoacacia* Samples

Among the sampled regions, Bács-Kiskun County exhibited the lowest mean values for RSH, TSH, and VSH, with averages of 4.13%, 4.78%, and 9.31%, respectively. In contrast, the highest linear and volumetric shrinkage ratios were observed in Vas County. For swelling, the county of Bács-Kiskun demonstrated the lowest mean values of 5.48%, 7.06%, and 13.8% for RSW, TSW, and VSW, respectively, while Győr-Moson-Sopron County recorded the highest values (Table 3). Except for LSW, which did not exhibit statistically significant differences between the counties, the linear and volumetric shrinkage and swelling were differed significantly ($p < 0.001$). The Kruskal–Wallis test confirmed these variations, with H (4) values of 32.45 for RSH, 41.59 for TSH, 64.73 for LSH, and 64.31 for VSH. The corresponding H values for RSW, TSW, and VSW were 17.53, 52.29, and 37.14, respectively.

Table 3. Mean and standard deviation (Std) of shrinkage and swelling of *R. pseudoacacia* samples. RSH = radial shrinkage; TSH = tangential shrinkage; LSH = longitudinal shrinkage; VSH = volumetric shrinkage; RSW = radial swelling; TSW = tangential swelling; LSW = longitudinal swelling; VSW = volumetric swelling.

County	No. of Replicates	Statistic	RSH %	TSH %	LSH %	VSH %	RSW %	TSW %	LSW %	VSW %
Szabolcs-Szatmár-Bereg	82	Mean	4.47 ^{ab}	5.43 ^b	0.61 ^a	10.2 ^b	6.08 ^{ab}	8.07 ^{bc}	0.80 ^a	15.6 ^{bc}
		Std	0.97	1.29	0.36	1.85	1.46	1.82	0.36	3.47
Bács-Kiskun	77	Mean	4.13 ^a	4.78 ^a	0.71 ^a	9.31 ^a	5.48 ^a	7.06 ^a	0.81 ^a	13.8 ^a
		Std	0.75	0.84	0.35	1.26	1.29	1.08	0.45	2.42
Győr-Moson-Sopron	75	Mean	4.58 ^{bc}	5.41 ^b	0.67 ^a	10.3 ^b	6.17 ^b	8.67 ^c	0.77 ^a	16.4 ^c
		Std	0.78	0.76	0.41	1.26	1.24	1.31	0.51	2.97
Baranya	55	Mean	5.52 ^{ab}	5.37 ^b	0.62 ^a	10.1 ^b	5.62 ^{ab}	7.98 ^b	0.73 ^a	14.8 ^{ab}
		Std	0.88	0.99	0.25	1.61	1.12	1.42	0.26	2.62
Vas	58	Mean	5.12 ^c	5.93 ^b	1.62 ^b	11.9 ^c	6.15 ^b	8.35 ^{bc}	0.76 ^a	15.9 ^{bc}
		Std	1.04	1.17	0.09	2.00	1.49	1.39	0.26	2.51
All	347	Mean	4.54	5.35	0.82	10.28	5.91	8.01	0.78	15.29
		Std	0.94	1.09	0.66	1.79	1.37	1.54	0.40	2.99

The difference superscript lowercase letters within a column mean statistically significant difference and similar letters indicate no significant differences.

Regarding the growth conditions, specimens sourced from the MPGC exhibited the highest linear and volumetric shrinkage, as shown in Figure 5. The MPGC was significantly different ($p < 0.001$) from the GGC and PGC in linear and volumetric shrinkage. Kruskal–Wallis values were = 21.55 for RSH; 19.59 for TSH; 62.85 for LSH; and 43.91 for VSH. However, Figure 6 displays the linear and volumetric swelling in the MPGC that was slightly higher than the GGC and PGC but with no significant differences.

3.3. Mechanical Properties

For all counties the mean MOE, MOR, and CS were 126 MPa, 12.67 GPa, and 67.00 MPa, respectively, as presented in Table 4. Also, the table shows their means and standard deviations along with their variability across the five counties in Hungary.

Bács-Kiskun revealed the highest MOE, with a mean of 13.33 GPa. The highest MOR (146 MPa) and CS (73.4 MPa) were recorded in Győr-Moson-Sopron County. The Kruskal–Wallis H (4) for the MOE was 16.309, $p = 0.002$; it was 52.312, $p = 0.001$ for the MOR and 63.536, $p = 0.001$ for CS.

Concerning the growth conditions (Figure 7), the MPGC exhibited the highest mean MOE value, 13.32 GPa. Also, the PGC exhibited the highest MOR of 131 MPa and the highest CS of 71.90 MPa (Figure 6). Apart from the MOR, there were significant differences in the MOE ($H = 12.91$, $p = 0.003$) and CS ($H = 68.817$, $p = 0.001$) between the growth conditions.

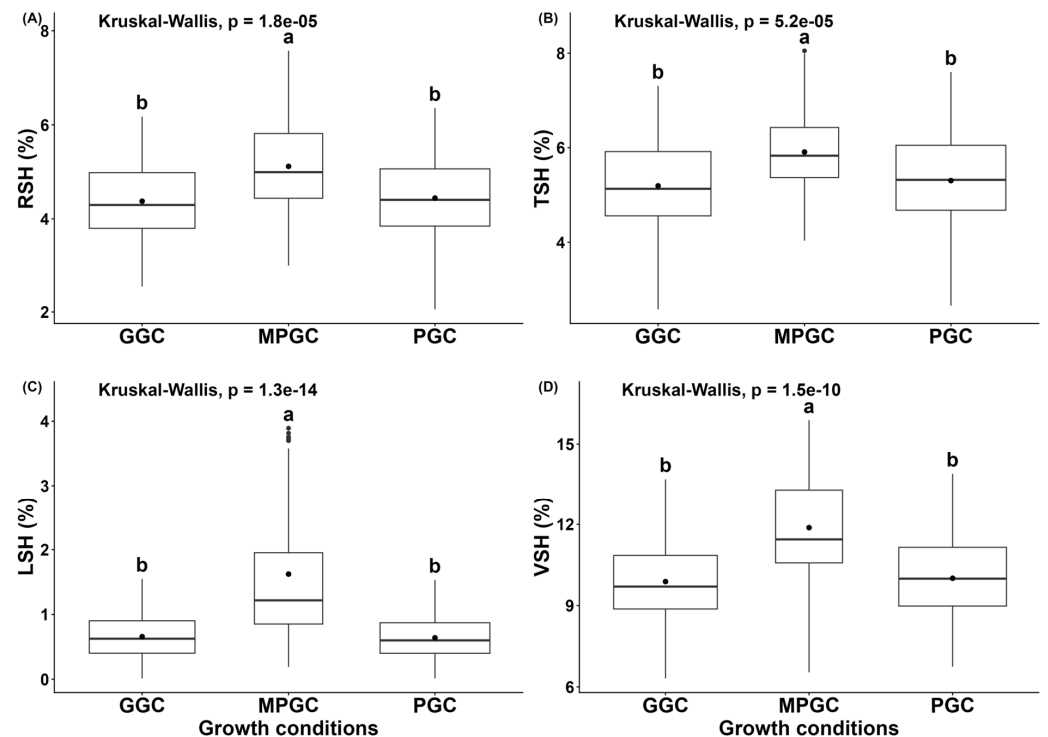


Figure 5. Variations in radial (A), tangential (B), longitudinal (C) and volumetric shrinkage (D) of *R. pseudoacacia* wood samples under the growth conditions. Different letters and letter combinations for a given measurement indicate significantly different mean values at $p < 0.05$ level. Error bars indicate standard deviation. GGC—good growth condition; PGC—poor growth condition; MPGC—poor growth condition (mixed species). RSH = radial shrinkage; TSH = tangential shrinkage; LSH = longitudinal shrinkage; VSH = volumetric shrinkage.

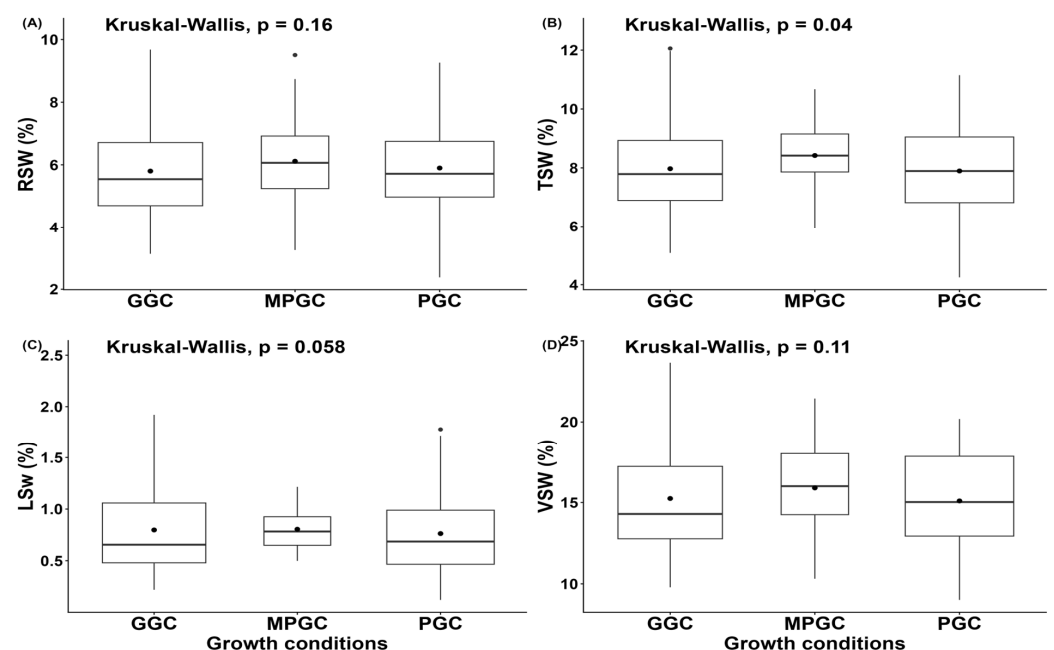


Figure 6. Across growth condition variations, radial (A), tangential (B), longitudinal (C), and volumetric swelling (D) of *R. pseudoacacia* wood samples. Error bars indicate standard deviation. GGC—good growth condition; PGC—poor growth condition; MPGC—poor growth condition (mixed species). RSW = radial swelling; TSW = tangential swelling; LSW = longitudinal swelling; VSW = volumetric swelling.

Table 4. Mean and standard deviation of the mechanical properties of *R. pseudoacacia* wood samples across Hungary. MOE = modulus of elasticity; MOR = modulus of rupture; CS = compressive strength parallel to the grain.

County	No. of Replicates	MOR (MPa)	MOE (GPa)	CS (MPa)
Szabolcs-Szatmár-Bereg	84	122.00 ± 13.1 ^a	12.81 ± 2.66 ^a	62.8 ± 6.20 ^b
Bács Kiskun	77	112.20 ± 20.7 ^a	13.33 ± 3.18 ^a	68.00 ± 8.26 ^a
Győr-Moson-Sopron	72	146.00 ± 28.6 ^b	12.37 ± 2.36 ^{ab}	73.10 ± 11.10 ^a
Baranya	57	122.00 ± 24.3 ^a	11.43 ± 2.46 ^b	67.90 ± 4.31 ^a
Vas	55	124.60 ± 16.3 ^a	13.32 ± 2.64 ^a	60.60 ± 6.87 ^b
All	345	125.36 ± 24.4	12.67 ± 2.74	67.00 ± 9.1

The difference superscript lowercase letters within a column mean statistically significant difference and similar letters indicate no significant differences.

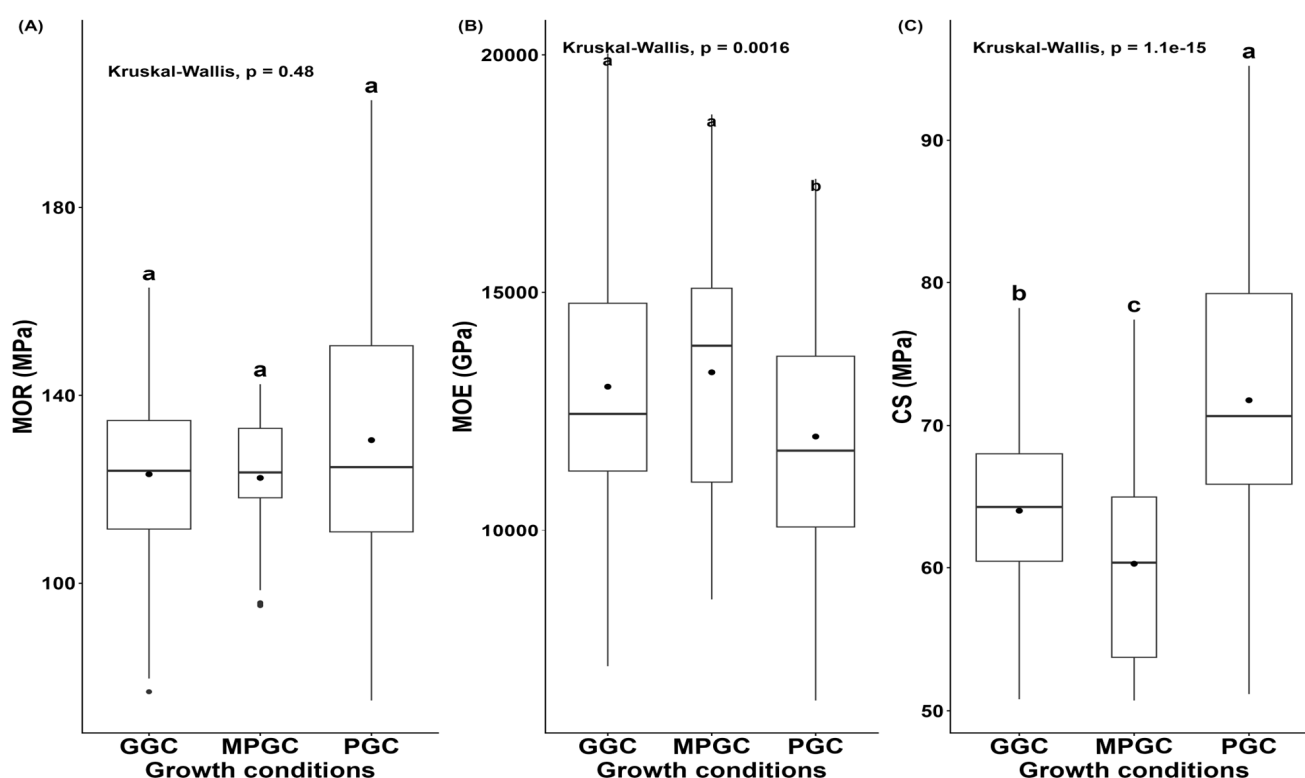


Figure 7. Variability in the mechanical properties of *R. pseudoacacia* samples under the growth conditions. (A) Modulus of rupture; (B) Modulus of elasticity; (C) Compressive strength parallel to the grain. Different letters and letter combinations for a given measurement indicate significantly different mean values at $p < 0.05$ level. Error bars indicate standard deviation. GGC—good growth condition; PGC—poor growth condition; MPGC—poor growth condition mixed species. MOE = modulus of elasticity; MOR = modulus of rupture; CS = compressive strength parallel to the grain.

Figure 8 illustrates the typical load–deflection behavior of *R. pseudoacacia* wood under static bending for two specimens from each county. The response is characterized by an initial linear-elastic region (marked by black dots) used to determine the MOE, followed by progressive plastic yielding up to the peak load defining the MOR prior to ultimate tensile failure.

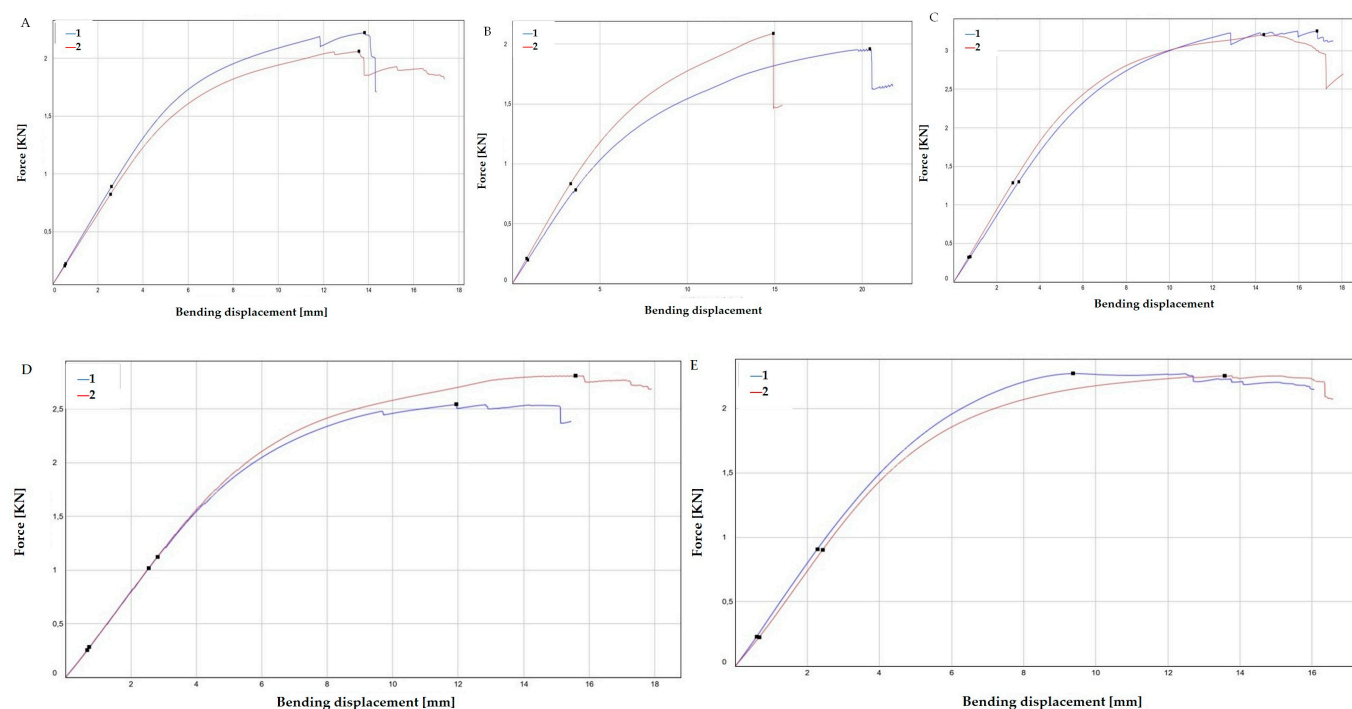


Figure 8. Elasticity profile of *R. pseudoacacia* sample from five counties: Szabolcs-Szatmár-Bereg (A); Bács-Kiskun (B); Győr-Moson-Sopron (C); Baranya (D); Vas (E).

4. Discussion

While black locust is classified as an invasive species in Hungary and across Europe, climate change is shifting its perspective, making it a potential substitute for declining native trees. Thanks to its excellent wood characteristics, *R. pseudoacacia* offers significant promise for industrial wood applications [18]. In this study, the densities, swelling, and shrinkage (both linear and volumetric) plus the bending modulus of elasticity, modulus of rupture, and compressive strength parallel to the grain of *R. pseudoacacia* samples across five counties and under different growth conditions were investigated. Statistical analysis revealed significant variations among some of these parameters. Previous studies mentioned that the variability results from many factors such as tree age, site growth conditions (soil quality, temperature, precipitation), and wood position (heartwood or sapwood, juvenile or mature and bottom or top) [10,34–38].

It is important to mention that we previously examined the fiber parameters, ring width, chemical extractives, and color characteristics of *R. pseudoacacia* samples collected from the same sites and under similar growth conditions [16,17].

Thicker fiber walls and a higher proportion of latewood contribute to increased density and superior mechanical properties [3]. In this study, *R. pseudoacacia* samples from Bács-Kiskun exhibited the highest wood density, matching that observed in the PGC. This finding is unexpected, as our previous work showed that Bács-Kiskun and the PGC had the narrowest ring widths and thinnest cell walls [16]. This can be attributed to the hard growing conditions, where, although the trees grew more slowly and their annual rings became narrower, their density nevertheless increased. This contradicts the typical characteristic of hardwoods, whereby wider annual rings indicate a wider latewood and thus a higher density [39–41].

In comparison with a previous study, the mean density at a 12% moisture content (0.80 g/cm^3) and the basic density (0.71 g/cm^3) for all counties were higher than values reported by Pollet et al. [42] in Belgium and Molnár and Bariska in Hungary [18], in addition to the values mentioned by Porojan and Salca [3]. While tree age typically correlates with

density variations, as evidenced by Bijak and Lachowicz [2], the 30- to 47-year-old samples used in this study exhibited densities comparable to much older trees (60–70 years).

R. pseudoacacia is generally characterized by favorable dimensional change. However, in the present study, samples from Bács-Kiskun County showed the highest dimensional stability, exhibiting lower shrinkage and swelling than those from other counties. Intriguingly, despite differences in wood density between the GGC and PGC, their shrinkage and swelling behaviors did not differ significantly. This lack of variation could be attributable to anatomical similarities in fiber morphology, as previously reported by Younis et al. [16]. In comparison with the published literature [2,18,42], our samples exhibited lower mean RSH, TSH and VSH but elevated LSH. This contrast is evident when compared with Adamopoulos and Voulgaridis [43], who noted higher radial (5.30%) and tangential (6.67%) shrinkage alongside a lower longitudinal value (0.16%). Furthermore, swelling parameters (RSW, TSW, and VSW) were lower across the board than those reported in the INCO Copernicus benchmark study [44]. The minor differences between dimensional changes in the tangential and radial directions can be explained, on the one hand, by anatomical characteristics. For example, narrow rays and smaller vessel diameters result in a more homogeneous structure compared with oaks [45]. On the other hand, the low fiber saturation point means that water molecules, which cause swelling, have fewer opportunities to become incorporated into the fiber walls [3]. Since the ratio of the tangential and the radial shrinkage and swelling is far below 2.0, it can be stated that the examined specimens are less prone to cracking [46].

With respect to mechanical performance, *R. pseudoacacia* wood grown in Belgium was previously reported to exhibit superior properties [42]. At the county level, however, Győr-Moson-Sopron stood out as the sole region to surpass these reported MOR benchmarks. Conversely, the CS across most Hungarian counties assessed here exceeded previous findings, except Szabolcs-Szatmár-Bereg and Vas and the growth condition categorized under PGC. Overall, our results for MOE, MOR, and CS values align closely with the historical Hungarian literature [18]. Recent findings from Poland by Bijak and Lachowicz (2021) [2] similarly demonstrated a higher mean MOE (14.228 GPa) and MOR (156 MPa) yet yielded comparable CS values (75.0 MPa). Despite these geographic variations, *R. pseudoacacia* consistently maintain physical and mechanical properties that match or exceed those of major commercial hardwoods in Europe such as beech, oak, and teak [47]. The high values of the MOE, MOR, and CS are consistent with the high density measured in this study (0.80 g/cm³), since density generally correlates well with the mechanical properties [39,48].

Although mixed-species stands enhance the basic density and mechanical performance (MOE, MOR, and CS) of *Quercus cerris* compared to pure stands [45], *R. pseudoacacia* showed an inverse trend, yielding the highest BD, D₁₂, MOR, and CS under poor growth conditions. This disparity indicates that the impact of stand conditions on wood properties is species-specific.

5. Conclusions

This study analyzed variations in the physical and mechanical properties of *Robinia pseudoacacia* L. across several counties and growth conditions in Hungary. Although notable regional variations were evident across most metrics, particular features, namely swelling and the modulus of rupture, exhibited considerable stability across the three growth conditions examined. Wood obtained from the Bács-Kiskun region and under poor growth conditions demonstrated the highest density and better dimensional stability. Therefore, forest management techniques must emphasize site-specific selection to enhance the production of black locust timber with exceptional technical attributes.

While sampling was confined to a single mixed-species stand with poor growth conditions in Vas County, this study provides a benchmark for future research by delivering a comprehensive, quantitative evaluation of the fundamental material properties of *R. pseudoacacia* wood.

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