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Basic Characteristics of Black Locust (*Robinia pseudoacacia* L.) Wood Grown Under Different Site Conditions: A Review

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Abstract – This study provides an overview of the basic characteristics of *Robinia pseudoacacia* cultivated throughout Europe. After studying the literature, we concluded that air temperature and precipitation amounts significantly influenced the annual ring width of *R. pseudoacacia*. In addition, the light, water, and nutrient supply affected tree growth by increasing growth intensity, thus reducing vessel diameters and pieces per unit area. Black locust wood grown in Belgium has a higher volumetric shrinkage (16 %) and tangential shrinkage (8.8 %) and a considerably higher modulus of elasticity (15,700 MPa) compared to wood from Poland and Hungary. The vessel diameters measured in the latewood of Robinia wood grown in Hungary (70-140 µm) exceeded those in Greece (24 µm). Knowledge of the mechanical and physical characteristics of new black locust clones wood already in cultivation via breeding is incomplete. The same applies to climate change effects. The review article recommends that future research investigate the basic characteristics of new cultivars planted in different locations.

climate change / *Robinia pseudoacacia* / environmental factors / hardwood

Kivonat – Különböző termőhelyeken nőtt akác (*Robinia pseudoacacia* L.) faanyagának alapvető jellemzői: áttekintés. A cikk célja, hogy áttekintést nyújtson az Európa-szerte termesztett fehér akác (*Robinia pseudoacacia* L.) alapvető jellemzőiről. A szakirodalmakat áttanulmányozva arra a következtetésre jutottunk, hogy az akác évgyűrűszélességét nagymértékben befolyásolta a levegő hőmérséklete és csapadék mennyisége. Ezenkívül a fény-, víz- és tápanyagellátottság befolyásolta a fa növekedését azáltal, hogy előbbiek intenzitásának növekedése csökkentette az edények átmérőjét és a területegységre jutó darabszámot. A Belgiumban termesztett akác faanyag térfogati (16 %) és tangenciális zsugorodása magasabb (8,8 %), és a rugalmassági modulus (15,700 MPa) jelentősen nagyobb a Lengyelországból és Magyarországról származó faanyagokhoz képest. A Magyarországon nőtt akác faanyagok kései pásztájában mért edényátmérők (70-140 µm) meghaladták a görögországi értékeket (24 µm). A fajtanemesítés eredményeként már termesztésben lévő új akácklónok fafaanyagának mechanikai és fizikai jellemzőire vonatkozó ismeretek hiányosak, akárcsak a klímaváltozás hatásai. Az áttekintő cikk azt javasolja, hogy a jövőbeni kutatások során vizsgálják meg a különböző termőhelyekre telepített új fajták alapvető tulajdonságait.

klímaváltozás / *Robinia pseudoacacia* / környezeti tényezők / lombosfa

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1 INTRODUCTION

The atmospheric concentration of greenhouse gases (GHG) continues to increase (Lamb et al. 2022). Consequently, these phenomena have resulted in a rise in global temperatures. For instance, in the specific case of Napkor – a region of significant black locust cultivation in Hungary – the average temperature in 2021 was 10.7 °C, representing a 0.3 °C increase compared to the mean temperature observed throughout the period spanning from 1985 to 2020. The period saw decreased precipitation (Ábri et al. 2022), drought occurrences, unpredictable rainfall patterns, flooding, biodiversity declines, and photoperiod changes, revealing some effects of GHG increase. In some areas, minerals are transferred from the soil and deposited elsewhere. These occurrences are recorded as an effect of climate change (Larchar 1995).

The growth condition consists of climatic, edaphic, and biological components. Typically, temperature, photoperiod, light intensity, moisture, soil fertility, and gravity are key factors influencing the structure of wood (Wodzicki 2001). One environmental component may be responsible for wood property variability. Conversely, interactions between two or more environmental factors and the genetic makeup of species may also occur (Kim et al. 2011).

Depending on the tree species, changes in growth conditions may affect wood quality physiologically by altering the anatomical structure of the wood, such as the number of vessels in 1mm^2, ray, parenchyma, fiber, and widths, and vessel characteristics (Usta et al. 2014, Zhang et al. 2020, Nazari et al. 2020). Additionally, the influence of tree age cannot be overlooked (Panshin – de Zeeuw 1980, Lowe – Greene 1990, Barajas 1997, Nugroho et al. 2012, Kalbarczyk et al. 2016, Kalbarczyk – Ziemiańska 2016, Keyimu et al. 2021). Understanding the impact of environmental components on wood formation is complex because it is necessary to assess the consequences of radial diameters, cell wall thickness, and other impact variables responsible for these outcomes (Arnold – Mauseth 1999).

Several studies have investigated how environmental factors influence wood structure (Farrar – Evert 1997, Rigatto et al. 2004, Ross et al. 2015, You et al. 2021). Arnold – Mauseth (1999) examined how light, water, and nutrient levels affected wood growth in *Cereus peruvianus* and demonstrated that low nitrogen and low phosphorus treatments reduced vessel width and shoot elongation, while low light reduced vessel density. Also, high moisture levels caused broader vessels and greater shoot elongation.

There is a considerable correlation between the physical and chemical soil characteristics and variation in wood quality during tree growth. While sites with suitable soil conditions are likely to produce large amounts of wood, the quality of this wood may be insufficient for structural use. Moya – Perez (2008) indicated that the physical and chemical soil properties did not affect the physical properties (specific gravity and volumetric shrinkage) of the wood in *Tectona grandis* plantations in Costa Rica. Nevertheless, Moya – Calvo (2012) mentioned that *Tectona grandis* produces a dark color with deep and fertile soil under dry conditions than in wet conditions. On the other hand, air temperature and rainfall had a notable impact on the annual ring width of *R. pseudoacacia*. Moreover, temperature and precipitation also influenced the radial cell growth, secondary wall thickening, and xylem cell generation of larch stem (*Larix sibirica*) (Antonova – Stasova 1997).

This study provides a general overview of the basic properties (physical, mechanical, anatomical, and chemical characteristics) of *Robinia pseudoacacia* wood and identifies gaps for future research.

2 THE ORIGIN AND DESCRIPTION OF BLACK LOCUST

Regional population increases have cleared large forested areas for farming and to supply raw materials for the wood industry. Since the amount of wood produced is insufficient to satisfy the rising demand, governments and industry are looking for fast-growing species to substitute premium quality, durable wood. Only a few tree species in Europe can produce wood with the high natural durability of black locust (Grosser 2003). Black locust (also known as yellow locust or false Acacia) is a promising species of the Leguminosae family. Native to the Southeast United States (Ross 2010), *R. pseudoacacia* ranks among the most important globally planted tree species and is third only to eucalyptus and hybrid poplar trees in terms of economic significance. Black locust trees reach heights of 12 to 18 m and have breast-height diameters (DBH) of 30 to 76 cm (Huntley 1990).

However, *R. pseudoacacia* is also an invasive tree in Central Europe and is included on national blacklists and inventories of alien species across Europe (Vtková et al. 2017). The species is highly adaptable and expands rapidly (Mantovani et al. 2014). *R. pseudoacacia* was introduced to Europe from North America in the 17th century and Korea in the 19th century. The species arrived in Hungary between 1710 and 1720 (Lee et al. 2004, Redei et al. 2008). The first substantial black locust forests were planted on the Great Hungarian Plain at the beginning of the 18th century to stabilize the wind-blown, sandy soil. It is spreading throughout Central Europe, including Poland, Slovakia, Slovenia, Germany, Austria, and the Czech Republic (*Figure 1*), and in Mediterranean countries, including Italy, France, and Greece. Notable black locust tree stands exist in Bulgaria, Croatia, Ukraine, FYR Macedonia, Belgium, Bosnia, Herzegovina, Romania, and Serbia. China and Korea are the most vital *R. pseudoacacia* cultivators in Asia (Vítková et al. 2017, Nicolescu et al. 2020, Vítková et al. 2020).

Figure 1. Distribution R. pseudoacacia in Central Europe. Source: (Vítková et al. 2017)

R. pseudoacacia plantations occupy large areas in Bulgaria (151,000 ha), France (191,000 ha), Romania (250,000 ha), Ukraine (423,000 ha), Italy (377,000 ha), and Serbia (191,000 ha) (Nicolescu et al. 2018). It is present in 3.35% of Poland’s State Forests National

Forest Holding stands (Wojda et al. 2015) and has been steadily expanding in Hungary, where it covered around 37,000 ha in 1885 and spread to about 465,000 ha in 2015, amounting to 23.8% of the total forest area (Rédei et al. 2011, Rédei et al. 2015). The species occupies around 41,919,601 ha worldwide (Ciuvăţ et al. 2013). *R. pseudoacacia* is the second hardwood species introduced for wood production in Europe after *Quercus rubra*. In Hungary, it provides 25% of the country's annual wood production (Tobisch – Kottek 2013).

R. pseudoacacia grows in the following Hungarian regions (*Figure 2*): between the Danube-Tisza interfluve (in the center of Hungary) and the northeast of Hungary (Nyírség region). It has also expanded over the south and southwest Transdanubia (the hill ridges of Vas and Zala counties and the hill ridges of Somogy County).

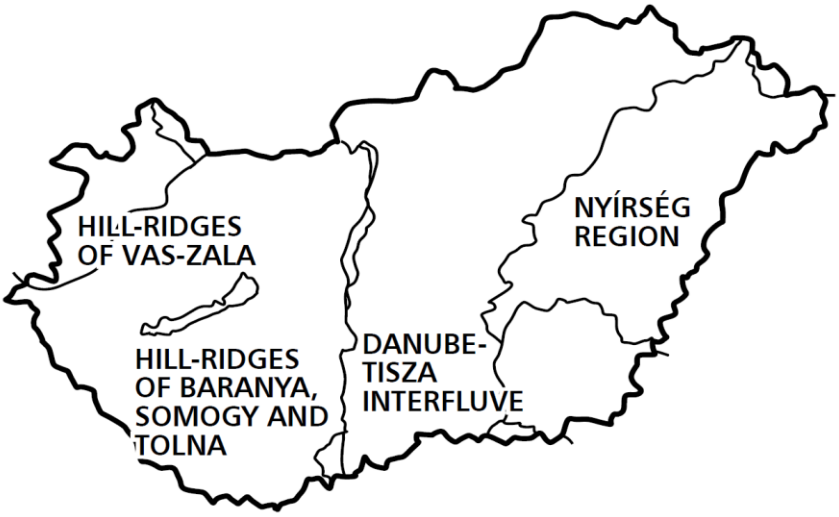

Figure 2. The main R. pseudoacacia-growing regions in Hungary. Source: (Rédei et al. 2011)

Black locust grows in deep, nutrient-rich, moist, and uncompacted sandy soils, silt, and sandy loams (Rédei et al. 2011). Growth limitations include soil characteristics (compressed soil, oxygen deficiency, wetland (frequent and long-term saturated), climate (late frost damages the leaves and young shoots), competition with other species, and ongoing significant disturbance. Qiu et al. 2010 noted that black locust can enhance the cation exchange capacity of soils and improve organic carbon, total nitrogen, nitrate, carbon, nitrogen, and phosphorus ratios, and the ratios of several enzymes. Nevertheless, *R. pseudoacacia* plantations negatively influence soil moisture recharge at depth (Liang et al. 2022, Li et al. 2022).

R. pseudoacacia trees have been tested on high, medium, and low-quality sites in Hungary; however, high-quality wood (and reasonable log dimensions) can be achieved only in areas with sufficient moisture, well-aerated soil, and nutrient-rich, light, humus-rich soils. Black locust forests in locations with medium and poor nutrient content are managed to produce wood fuel, feed, poles, honeybees, soil conservation, and environmental enhancement. *R. pseudoacacia* wood has been applied for many purposes, including sawn lumber, adhesive constructions, windows, gates, and agricultural equipment (Molnar 1995, Enescu – Danescu 2013, Vasiliki – Ioannis 2017).

R. pseudoacacia is ring-porous (large vessels with circular arrangement) and displays heterogeneous structures (Adamopoulos – Voulgaridis 2002). The sapwood is formed of two to six annual rings and is bright yellow. Heartwood ranges in hue from yellow-brown to bluish-gray. The bark is net-like and grayish-brown (Sandor – Mahaly 2002). *R. pseudoacacia* flaws include forked or curved stems – negative for wood production – and frost sensitivity (Podrázský – Prknová 2019). Wood modification technologies (thermal and chemical modifications) have been used to improve wood properties (Kesik et al. 2014, Nemeth et al. 2016, Dzurenda 2018, Stanciu et al. 2020, Hackenberg et al. 2021, Shapchenkova et al. 2022).

Hungary has extensive experience with black locust (*R. pseudoacacia*) cultivation, having grown the species for 300 years. Several programs have been instituted in Hungary to resolve the limitations of *R. pseudoacacia* and enhance wood quality. Some of the programs generated the development of clonal materials (Rédei et al. 2012, 2013, 2019, 2020; Ábri et al. 2021, Keserű et al. 2021).

3 RESULTS AND DISCUSSION

3.1 Physical and mechanical properties

Density, moisture content, and shrinkage are the most essential physical characteristics of wood (Shmulsky – Jones 2011). Cell size and cell wall thickness are structural parameters that affect wood density. Consequently, changes in wood structure substantially affect the quality and production of pulp and paper products and the durability and usability of solid wood products. In connection with expected timber use, several mechanical properties characterize wood attributes. Strength and elasticity can be used to characterize wood properties concerning its anticipated usage (Younis et al. 2022). The mechanical properties and their correlations with other features of earlywood and latewood vary, even within the same growth ring (Desch – Dinwoodie 1996).

Stringer – Olson (1987), Sell – Kropf (1990), and other earlier researchers were interested in the basic properties of black locust wood. *R. pseudoacacia* wood is dense, brittle, extremely impermeable, and is classified as medium or semi-heavy. It has relatively low shrinkage values but shows poor dimension stability because of fiber slope (a consequence of curved logs). It is more resistant to decay, weather, and insects than most tree species indigenous to Europe (Passialis et al. 2008, Cobas 2018, Podrázský – Prknová 2019). In addition, it has a higher calorific value and ash concentration (Komán 2018). The freshly sawn wood of *R. pseudoacacia* contains only about 30% water and burns without initial drying (Wojda et al. 2015, Bijak – Lachowicz 2021). The literature on black locust reveals that age significantly impacts density, oven-dry density, basic density, porosity, shrinkage, compression strength parallel to the grain, and static bending. Similarly, significant differences in annual ring width, fiber length, and density (basic and oven-dry) of wood were revealed for 10 *R. pseudoacacia* clones aged six, eight, and 13 (Klašnja et al. 2000).

Several studies have also investigated the difference in the basic characteristics of *R. pseudoacacia* wood within a tree and between different sites (Niklas 1997, Klisz et al. 2015). According to Klisz et al. (2017), the lower part of the bole has the highest hardness in the longitudinal directions. However, Adamopoulos (2002) revealed no significant difference in radial and tangential modulus of elasticity and rigidity. Analyses of wood samples taken at breast height indicated that specific gravity showed significant radial variation (Stringer – Olson 1987). From the pith, the specific gravity increased radially, rising to 0.68 (average value) near the cambium. A comparison between juvenile and mature wood samples of similar densities revealed that juvenile wood showed significantly lower static bending strength and dynamic strength. The conclusion shows that black locust forests can be efficiently managed to reduce the proportion of juvenile wood by increasing the rotation age (Adamopoulos 2007).

The mechanical strength and behavior of *R. pseudoacacia* wood collected from plantations in Greece and Hungary appear comparable to beech wood, a species of similar density and widely utilized in the furniture industry. Meanwhile, except for impact bending strength and tangential hardness, the Hungarian *R. pseudoacacia* wood was consistently stronger than materials from Greece. However, both have mechanical strength like beech wood (Kamperidou et al. 2016). *R. pseudoacacia* wood had satisfactory shear bond strength, particularly when using Polyvinyl acetate adhesive and when employing less intensive pressure during the construction of the specimens. However, it is weaker than the same product made from beech (Vasiliki – Ioannis 2017).

Table 1 summarizes the physical properties of *R. pseudoacacia* wood in three European countries: Belgium, Hungary, and Poland. *Table* 2 presents various mechanical properties in the same countries. Black locust trees were collected from five sites in Belgium (mixed forests) with silty soil and good drainage to assess physical and mechanical properties. Site factors significantly influenced ring width, axial, tangential, volumetric, and radial shrinkage (Pollet et al. 2012). In Poland, trees of various sizes and ages collected from mixed forests (dominated by black locust) inhabit a transition zone between maritime and continental types in a temperate climate. The most predominant growth conditions are dystrophic and oligotrophic sites developed on rusty, podzolic, and riverine soils. This research investigated the effect of the age and size of trees on their physical and mechanical properties. Age had a substantial impact on most physical and mechanical properties. However, tree diameter had less effect, and no significant effect was observed for latewood proportion, anisotropy, and nearly all shrinkage parameters (Bijak – Lachowicz 2021). In Greece, naturally grown trees were taken to study the strength properties of juvenile and mature black locust wood. The trees grew under cold winters and relatively warm summers. The findings demonstrate that juvenile wood has significantly lower strength than mature wood, except for axial compressive strength (Adamopoulos 2007).

3.2 Anatomical features

Wood macroscopic characteristics are information-dense because they technically reveal data about the environmental conditions in which the wood grew. They also hint at its physical traits and contribute to wood identification. Understanding wood's anatomical properties can be vital to selecting the appropriate wood for end use. Anatomical features can be categorized as macro and micro.

Table 1. Literature-derived values for the average physical properties of wood R. pseudoacacia. Sources: Hungary (Molnár – Bariska 2002); Belgium (Pollet et al. 2012); Poland (Bijak – Lachowicz 2021).

Characteristics	Hungary	Belgium	Poland
Fresh felled moisture content	35–45		
Fiber saturation point	21.8–22.5		
Oven dry density (kg/m^3)	540–740-870	529–857	
Air dry density (kg/m^3)	580–770-870		
Green density (kg/m^3)	800–900-950		
Longitudinal shrinkage (%)	0.1		0.3
Tangential shrinkage (%)	5.4–7.2	8.8	6.8
Radial shrinkage (%)	3.2–4.6	5.5	5.1
Volumetric shrinkage (%)	11.4–12.2	16	11.7
Porosity (%)	52		52.7
Thermal properties			
Bark-free wood (KJ/Kg)	17,777		
Bark (KJ/Kg)	19,145		
Bole (in bark) (KJ/Kg)	18,047		
Thick roots (KJ/Kg)	17,223		

The macro features include the growth ring and sapwood-heartwood proportion, whereas the micro features include cell characteristics and proportions, pit characteristics, micro-fibril angle, crystals, and vessel inclusions. Usually, the cells of the latewood portions are smaller in radius, have thicker walls, and have smaller lumens, making the tissue dense. (Shmulsky – Jones 2011).

Table 2. Literature-derived mean values for mechanical characteristics of wood R. pseudoacacia. CS = compression strength; JW = juvenile wood; MW = mature wood; MOE = bending modulus of elasticity; IBS = Impact bending strength. Sources: Hungary (Molnár – Bariska 2002); Hungary [b] (Nemeth et al. 2000); Hungary [c] (Kamperidou et al. 2016); Poland (Bijak – Lachowicz 2021); Belgium (Pollet et al. 2012); Greece (Adamopoulos 2007).

Characteristics	Hungary (MPa)	Hungary[b] (MPa)	Hungary[c] (MPa)	Poland (MPa)	Belgium (MPa)	Greece (MPa)
Tree age (years)					61–100	21–37
Mean axial CS					63.3	
Longitudinally CS	62-72-81			75		
Across the grain CS	18.5					
Axial CS in JW						61.57–65.56
Axial CS in MW						64.48–71.02
Tensile strength	166.8					
Bending strength (MOR)	103-136-169	152	173.02	155.5	138	
Bending strength in JW						28.30–153.5
Bending strength in MW						142.8–156.7
Share strength	11-13-16					
Radial cleavage	1.12					
Tangential cleavage	0.6–1.1					
Average hardness					5.22	
End hardness	67-78-88					
Side hardness	28					
Radial hardness			8.09			
Tangential hardness			7.48			
Mean MOE	9,000-11,300-13,000	12,631-13,384	18,122	14,228	15,700	
MOE in JW						13,507–15,416
MOE in MW						14,437–15,256
IBS	12-14-18 J/cm^2		3.37 N/mm^2		17.21 J/cm^2	

Juvenile wood (JW) and mature wood (MW) characteristics are used to evaluate wood quality (Bao et al. 2001). Analysis of fiber length and microfibril angle of earlywood and latewood within stems establishes the demarcation between JW and MW (Lu et al. 2021, Wang et al. 2021). Adamopoulos – Voulgaridis (2002) mentioned that the width of the first 5–9 growth rate from the pith of *R. pseudoacacia* is larger and declines gradually. In a vertical variation, the growth rate gradually slowed as the cambium development aged. Stringer – Olson (1987) showed that the radial variability curves are common for cell size (fibers, vessel members), specifically, the fiber length. The wood fiber length increased radially from 0.75 mm in the pith to 1.06 mm in the under-cambium.

The anatomical features (ratios of libriform fiber, vessels, rays, fiber length, vessel member diameter, vessel member length, wide earlywood vessel, and ring width) of *R. pseudoacacia* wood from Hungary, Greece, and Belgium were evaluated from the same material used for physical and mechanical properties (*Table* 3). The vessel diameter of latewood in Hungarian black locust is larger (more than double) compared to wood from Greece.

Table 3. Values of anatomical features of R. pseudoacacia wood derived from the literature. VT= vessel tissue; FL= Fiber length; VD= vessel diameter; VL= vessel length; EW= early wood; LW=late wood; GM= general mean; WEV= Wide earlywood vessel; RW= ring width. Sources: Hungary (Molnár – Bariska 2002); Greece ^{b} *(Adamopoulos – Voulgaridis 2002); Belgium (Pollet et al. 2012)*

	Libriform fiber (%)	VT (%)	Rays (%)	FL (mm)			VD (µm)		VL (mm)		WEV (µm)	RW (mm)
Literature				GM	EW	LW	EW	LW	EW	LW		
Hungary	58	15	21	1				70–140			150–220	
Greece ^{b}					0.77	1.04	47	24	0.16	0.18		3.4
Belgium												2.9

3.3 Chemical composition

Wood cell walls contain cellulose, hemicellulose, lignin, and minor quantities of extractives. Cellulose adds to tensile strength, while lignin offers tree stiffness and enables vertical development. Lignin may be removed with chemical or inorganic solvents (Sjöström – Alén 1998). Extractives are important in hardwood utilization because they prevent deterioration, protect the natural wood color and scent, and enhance grain patterns (Chow et al. 1996, Conners 2015, Sablík et al. 2016). The extractive content could be removed from a piece of wood using benzene-alcohol, acetone, and organic and inorganic solvents. This varies due to many factors such as extraction process solvent type, wood origin, and type of chemical compounds present in the wood ((Desch – Dinwoodie 1996).

Both benzene-EtOH and total extractive content displayed radial variation in the *R. pseudoacacia* wood. The outer heartwood tissue held the highest benzene-EtOH content (4.60%) and extractive amounts (8.54%), while the sapwood tissue had the lowest at 2.70 % and 6.8 %, respectively (Stringer – Olson 1987). Hot water extractives content and lignin in heartwood were higher than in sapwood within *R. pseudoacacia* (between heartwood and sapwood and from bottom to top). Heartwood extractives increased vertically, and lignin decreased from the bottom to the top (Adamopoulos et al. 2005). Phenolic compounds and flavonoids are abundant in the cell walls and cell lumens of axial parenchyma and vessels in the mature heartwood of *R. pseudoacacia* (Dünisch et al. 2010). According to chemical analyses (Latorraca et al. 2011), the lack of phenolic compounds and flavonoids in the juvenile heartwood is the primary cause of its reduced durability.

Table 4 contains the chemical compositions of *R. pseudoacacia* wood grown in Hungary, Bulgaria, Greece, and the Czech Republic. *Table 5* shows the inorganic constituents of *R. pseudoacacia* in Hungary and Greece. The wood and bark of black locust cultivated in Greece and Bulgaria and three clones (NY, U, and J) grown in Hungary were examined (Passialis et al. 2008). *Table 4* also lists the range values from the three Hungarian clones.

Researchers examined *Robinia pseudoacacia* wood as a potential chemical pulp and glucose source. They concluded that *R. pseudoacacia* clones harvested from plantations in Bulgaria (growing in calcic Chernozem soil) may offer opportunities for chemical pulp or glucose for bioethanol production (Panayotov et al. 2015). Moreover, the impact of *R. pseudoacacia* heartwood extractive and bark on the durability of Czech beech wood indicated that black locust heartwood extractive chemicals could raise the native durability of European beech from class five to class three (Sablik et al. 2016).

Table 4. Mean values of R. pseudoacacia chemical properties (%) derived from the literature. SW= sapwood; HW= heartwood; JW= juvenile wood; MW= mature wood. Sources: Hungary (Molnár – Bariska 2002); Hungary c (Passialis et al. 2008); Bulgaria (Passialis et al. 2008); Bulgaria ^{b} (Panayotov et al. 2015); Greece ^{c} (Passialis et al. 2008); Greece ^{d} (Adamopoulos et al. 2005); Czech Republic (Sablík et al. 2016).

Property	Hungary	Hungary ^{c}	Bulgaria	Bulgaria ^{b}	Greece ^{c}	Greece ^{d}	Czech Republic
Elementary composition in the xylem							
C	49.2						
H	5.91						
O + N	43.1						
Ash (general mean)	0.79			0.32–0.61			
ash in the bark	4.76	7.24–8.56	8.54		8.37		
ash in the SW	0.98	0.72–1.24	1.24		1.13	0.65–0.76	
ash in the HW	0.26	0.34–0.89	0.71–0.89		0.47–0.46	0.36–0.76	
Cellulose	40–50			45.4–49.0			
Hemicellulose	15–22						
Lignin (mean)	25–30			23.0–27.7			
lignin in HW						18.33–25.73	
lignin in SW						18.13–21.42	
Tannin in the bark	3–6						
Tannin in the xylem	2–4						
Hot water extractive contents							
JW		5.15–9.53	6.94–10.10		5.04–8.71	8.7–9.8	
MW						4.7–5.5	
SW		3.33–4.16	4.36		6.76		
bark		9.25–12.31	13.14		13.49		
Dichloromethane extractive contents							
JW		0.53–0.90	0.57–0.71		0.76	0.9–1	
MW							
SW		0.48–1.05	1.47		1.32	1.1–1.9	
bark		3.95–4.03	3.09		3.62		
Methanol:water (1:1, v/v) extractive contents							
HW							7.41
bark							9.56

Table 5. Literature-derived inorganic components of R. pseudoacacia wood and bark in ppm[1]. JW= juvenile wood; MW= mature wood; SW= sapwood; B= bark; HW= heartwood; Mn=Manganese; Fe= Iron; Cu= Copper; Zn= Zinc; Pb= Lead. Sources: Hungary and Bulgaria (Passialis et al. 2008); Greece (Adamopoulos et al. 2005)

previous studies	position	Ca	K	Mg	Na	P	Mn	Fe	Cu	Zn	Pb
Hungary (Clone NY)	JW	1,710	281	112	43	21	0.7	13	4.1	13	15
	MW	821	243	62	39	13	0.6	20	2.6	8.4	15
	SW	1,210	1,486	192	64	122	1.4	8.6	3.8	14	14
	B	20,967	2,592	303	466	119	7.0	59	7.9	29	35

previous studies	position	Ca	K	Mg	Na	P	Mn	Fe	Cu	Zn	Pb
Bulgaria	JW	1,658	965	168	69	15	1.8	14.4	3.1	16	24
	MW	2,462	1,046	173	68	19	1.5	10	2.7	17	12
	SW	2,371	2,634	349	70	151	3.3	15	4.4	21	23
	B	27,406	3,505	526	414	239	33	116	9.2	48	38
Greece	*Bottom*										
	HW	1,615	95	180	118	9	1	30	5	6	0.134
	SW	1,478	1,250	305	168	222	2	32	5	7	0.340
	Middle										
	HW	1,830	383	163	187	21	2	23	5	5	0.268
	SW	2,027	1,067	187	190	206	21	1	5	5	0.550
	Top										
	HW	2,013	650	158	113	35	2	21	4	4	0.088
	SW	183	1,845	617	182	198	27	2	5	6	0.257

(Table continued from previous page)

4 CONCLUSIONS

The following are some conclusions drawn from the literature review:

- Sits, soil, and tree age considerably affected the basic properties of *R. pseudoacacia*. However, tree diameter had no significant impact on latewood proportion, anisotropy, and nearly all shrinkage parameters.
- Air temperature and rainfall significantly impacted the annual ring width of *R. pseudoacacia*. Also, light, water, and nutrient levels affected wood growth by reducing vessel width and density.
- Compared to Poland and Hungary, the tangential and volumetric shrinkage of black locust wood grown in Belgium is higher. There is also a substantial increase in the modulus of elasticity.
- Black locust in plantations have a higher mechanical strength than black locust in natural and mixed forests.
- The vessel diameter in the latewood portions of Hungarian *R. pseudoacacia* is higher than its counterpart in Greece.
- The present climatic conditions and the expected changes due to global warming warrant that future research aims to investigate the properties of hybrid cultivars planted on different sites. Additionally, the currently available black locust have different natural durability levels, which need to be investigated (extract content, fungal resistance tests, outdoor tests).

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