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Correlations between Brinell hardness and basic density in black locust - differences along the stem

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Abstract: *Correlations between Brinell hardness and basic density in Black locust - differences along the stem*. A study of the relationship between wood density and hardness was carried out on straight-trunked black locust trees present in three stands in western Poland. Each stand was represented by 10 trees cut in such a way as to generate logs from the lower, central and top parts of the trunk. Brinell hardness was determined for the samples of wood obtained, as measured in the longitudinal, radial and tangential directions, with Pearson correlation coefficients applied to determine the relationship between the two features. Where the comparison based on sites was concerned, hardness for trunks considered as a whole was only found to correlate with density in the case of the longitudinal measurement of wood from trees representing the Wołów stand (coefficient of 0.44). In contrast, the hardness determined along the trunk for the three different sites correlated with the density of wood from central stem parts as measured radially and tangentially (0.66 and 0.61 respectively), as well as with wood of the lower part, also measured tangentially (0.74). Such results are at odds with the findings of earlier researchers, and the interpretation of the relationships noted needs to be related to the findings from anatomical analyses of wood carried out previously for the same black locust trees.

Keywords: *Robinia pseudoacacia*; Brinell method; wood density; radial, tangential and longitudinal directions

INTRODUCTION

A fuller understanding of the relationship between the hardness and density of a given wood allows for a better assessment or valuation of its structure [1]. In the case of the black locust *Robinia pseudoacacia*, no such detailed insight has thus far been gained into variability along a radial gradient or up the trunk, where these fundamental and linked properties of wood are concerned [2]. In contrast, the relationship has been elucidated much more fully in the case of coniferous species [3], and values of coefficients for the correlation between density and hardness have been found to be high in the maritime pine *Pinus maritima* and Scots pine *P. sylvestris* (ranges $R^2 = 0.73 – 0.94$ and $0.65 – 0.71$ respectively) [4, 5]. It was thus the aim of the work described in this paper to assess the relationship between wood density and wood hardness determined by the Brinell method in the black locust, first and foremost in the context of variability along the trunk axis.

MATERIALS

Analysis of the hardness and density of black locust wood was carried out in 2014, using an approach resembling that with previous research by the team into heartwood circumferential variation and radial growth in the species, by reference to material sampled from stands in the Krosno (KRO), Wołów (WOL) and Mieszkowice (MIE) Forest Districts of Poland's State Forests; in which trees are characterised by straight trunks and a good state of health [6] (Fig. 1).

Table 1. Locations of analyzed stands and selected assessment and valuation features

Forest District	Area [ha]	Forest site type	Age	DBH [cm]	Total height [m]	Crown length [m]	Quality class	Stand stocking	Geographical position
Krosno (KRO)	1.14	LMśw	31	24.7	24.8	9.21	I	0.9	N 52°05'40.2'' E 14°58'13.7''
Wołów (WOL)	2.86	BMśw	38	21.1	22.7	9.85	I	0.8	N 51°25'12.5' E 16°34'41.8''
Mieszkowice (MIE)	1.31	LMśw	46	26.0	24.5	11.14	I	1.0	N 52°51'31.5'' E 14°11'40.7''

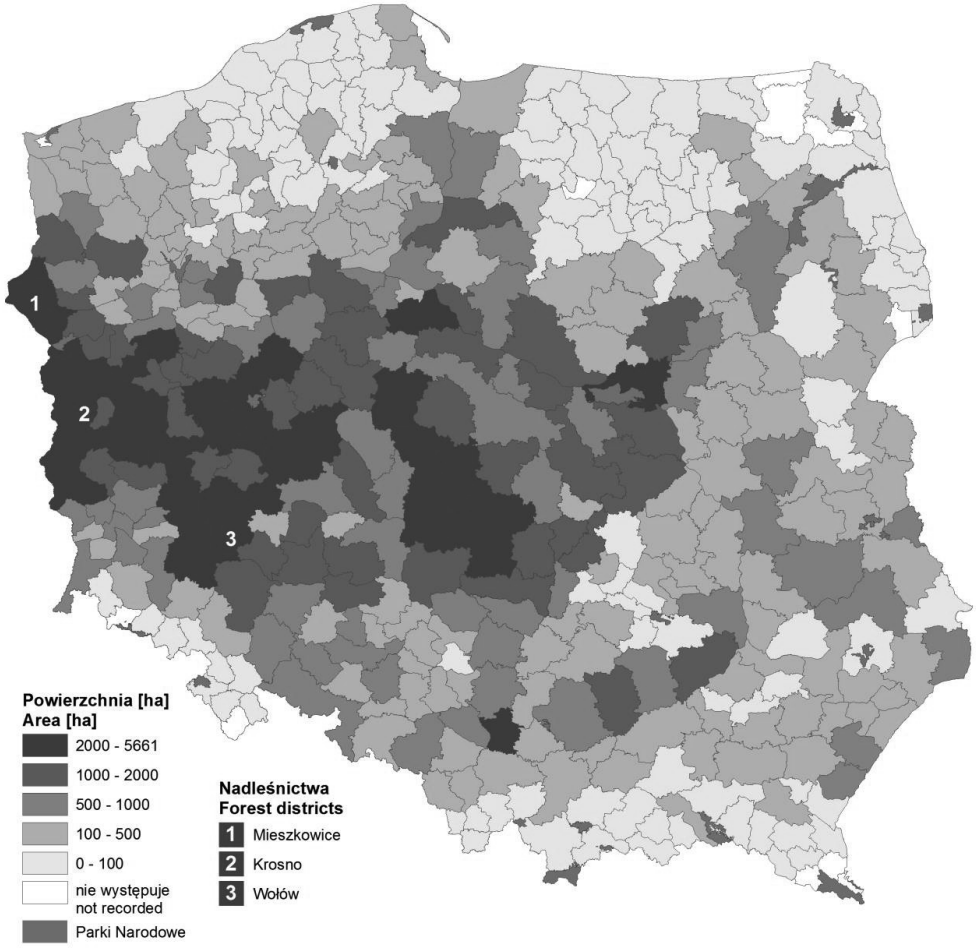

Figure 1. Location of the Mieszkowice, Krosno and Wołów experimental sites.

The methodology underpinning the selection of research sites and specimens is as presented in work on the assumptions underpinning Research Project BLP - 386 [7]. In brief, the stands selected are of more or less the same age, and are characterised by similar biometric features (Table 1). As the Table below makes clear, the WOL site stands out somewhat from KRO and MIE in its poorer habitat conditions (this being a fresh mixed/coniferous forest site, as opposed to fresh mixed/broadleaved forest).
In each of the stands, it was from among trees of Kraft Classes I and II that 10 specimens representative of the research site were singled out. The trees selected for study were straight-trunked and visibly symmetrical, with well-shaped crowns. The health of their assimilatory apparatus was checked for, as were signs of any previous damage done by pathogens. Sample trees so selected were cut and then divided into three 3m logs from along the trunk, between a height of 1.3m above the ground and the base of the crown (Fig. 2).

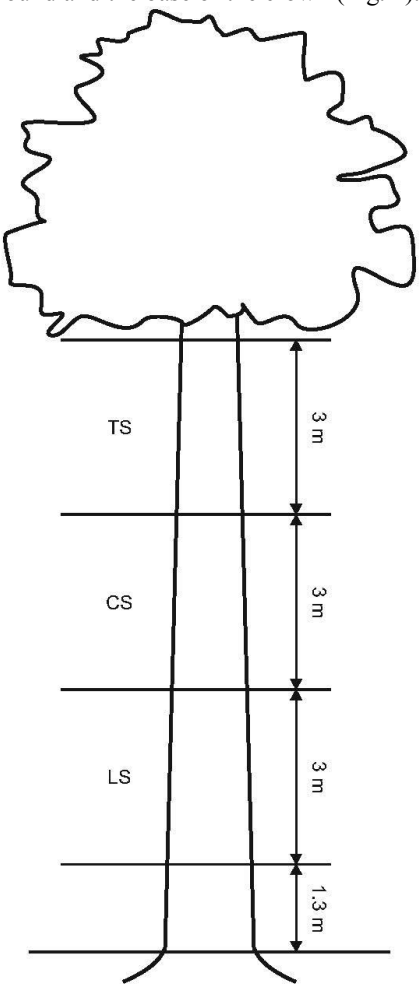

Figure 2. Diagram illustrating approach to wood sampling from selected trees for the purposes of the study: LS – lower stem part, CS – central stem part, TS – top stem part.

The logs were sawn away from any sawmill and the lumber then chamber-dried to a humidity of 12±2%. Samples of dimensions 30 × 50 × 50 mm were then cut from the wood prepared in this way, these being subjected to standard climatic conditions (65%/25C°) before being

assessed using standard tests for Brinell hardness in the longitudinal, radial and tangential directions [8]. Wood-density measurements were also made for the logs obtained [9]. Results for hardness were analysed using the statistical models described by Klisz *et al.* [10]. Pearson correlation coefficients were calculated to determine the relationships between hardness measured in the three different directions and wood density. All statistical analysis were made using *STATISTICA 10PL* package [11].

RESULTS AND DISCUSSION

Correlations between wood hardness and density – differences between sites

In the case of trunks considered as a whole and measurements made in the longitudinal direction, correlations with wood density for mean hardness did not achieve statistical significance for trees deriving from any of the source stands (R^2_{WOL} = -0.03; R^2_{KRO} = 0.04 and R^2_{MIE} = -0.04). The same was true for measurements in the radial direction (R^2_{WOL} = 0.17; R^2_{KRO} = -0.18 and R^2_{MIE} = 0.03). These findings represent a departure from those of similar studies carried out by the authors for Norway spruce and Scots pine taken together (where R^2_{longit} = 0.76 and R^2_{radial} = 0.87) [12]. However, a significant dependent relationship of the kind in question was obtained (solely) for the tangential direction of measurement in the case of wood from the black locust trees at the WOL site (R^2_{WOL} = 0.44; R^2_{KRO} = 0.15; R^2_{MIE} = 0.04). A positive correlation between hardness and density of wood was likewise found in the aforementioned study by Dubovský and Rohanová [12] (with $R^2_{tangent}$ = 0.76), as well as in work wherein the same authors analysed hardness-density correlations for the wood of 8 species of broadleaved and coniferous species taken together (with the black locust also included), and obtained an R^2 value of 0.74 [13]. In comparing the results presented here with those obtained by the Slovak authors, we need to note differences in the method used by the latter to determine hardness and density (i.e. Janka's method and PILODYN 6J). The two methods of determining hardness reveal a close correlation (R^2 = 0.83), albeit with the relationship least well-defined in the case of the radial direction of measurement (R^2 = 0.66) [14].

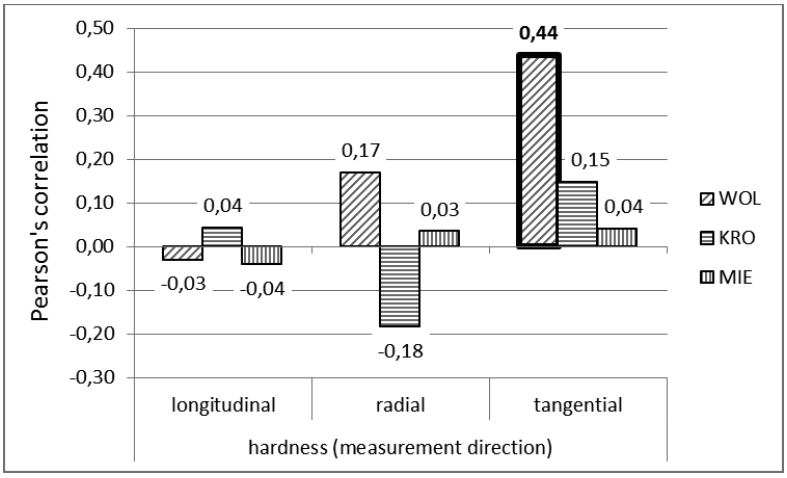

Figure 3. Pearson correlation coefficients between wood density and Brinell hardness (in different measurement directions). Sites: WOL, KRO, MIE. Bold framing – significant correlation (P<0.05).

Correlations between wood hardness and density – differences between logs

All values of the correlation coefficients for hardness of wood from the lower, central and top stem parts as set against wood density were found to achieve statistical significance, with positive values noted for both the radial direction of measurement (R^2_{LS} = 0.32; R^2_{CS} = 0.66 and R^2_{TS} = 0.14) and the tangential (R^2_{LS} = 0.74; R^2_{CS} = 0.61 and R^2_{TS} = 0.18). As with the data for differences between sites, these results resemble those of earlier studies [12]. However, the fact that coefficients achieved their highest values in the case of the lowest part of the trunk is the opposite of the finding from Dumail et al. in regard to maritime pines [4]. The latter authors point to relationships between the two features being weakest in the case of the lowest part of the trunk, in its outer part. It emerged that correlations between the analysed features failed to achieve statistical significance in the case of the longitudinal direction (with coefficients R^2_{LS} = 0.05; R^2_{CS} = 0.10 and R^2_{TS} = -0.15).

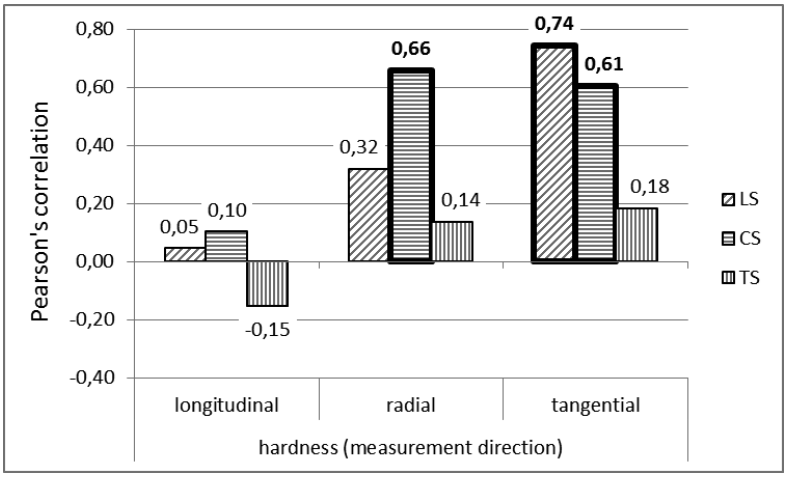

Figure 4. Pearson correlation coefficients between wood density and Brinell hardness (in different measurement directions). Stem parts: LS – lower stem part, CS – central stem part, TS – top stem part. Bold framing – significant correlation (P<0.05).

This lack of a statistical relationship between the hardness of wood measured in the longitudinal direction and wood density would seem very surprising, given converse claims in literature in regard to ring-porous species [1].

REFERENCES

1) DUBOVSKÝ, J., ROHANOVÁ A. 2007B: The hardness of ring-porous wood of chosen tree species." Acta Facultatis Xylologiae 49(1): 5–17
2) POLLET C., VERHEYEN C., HÉBERT J., JOUREZ B. 2012: Physical and mechanical properties of Black locust (Robinia pseudoacacia) wood grown in Belgium. Canadian Journal of Forest Research 42(5): 831–40
3) MAREŠ V., BLAHOVEC, J. 2004: Variation of the tree ring micro-hardness demonstrated on spruce wood. Journal of Forest Science, 50(3): 135–141
4) DUMAIL J. F., CASTÉRA, P., MORLIER, P. 1998: Hardness and basic density variation in the juvenile wood of maritime pine. Annals of Forest Science, 55(8): 911–923

5) GREKIN M., VERKASALO E. 2013: Variations in and models for Brinell hardness of Scots pine from Finland and Sweden. Baltic Forestry, 19(1): 128–136
6) KLISZ M., UKALSKA J., WOJDA T., JASTRZĘBOWSKI S., MIONSKOWSKI M., SZYP-BOROWSKA I. 2014: Radial growth of selected stands of black locust in Poland. Annals of Warsaw University of Life Sciences – SGGW, Forestry and Wood Technology 85: 123–130
7) WOJDA T., KLISZ M., MIONSKOWSKI M., SZYP-BOROWSKA I., SZCZYGIEŁ K. 2013: Występowanie robinii akacjowej w Polsce oraz badania IBL nad tym gatunkiem. Proceedings of: Robinia akacjowa w krajobrazie Ziemi Lubuskiej, 29.10.2013. Łagów: 22–29
8) PN-EN 1534:2011 Podłoga z drewna. Oznaczanie odporności na wgniecenie (metoda Brinella). Metoda badania
9) PN-77/D-04101 ”Drewno. Oznaczanie gęstości”
10) KLISZ M., UKALSKA J., NOSKOWIAK A., WOJDA T., JASTRZĘBOWSKI S. 2015: Black locust hardness in relation with the use in solid wood products. Wood (in press)
11) StatSoft, Inc. STATISTICA (data analysis software system), version 10. (2011), www.statsoft.com
12) DUBOVSKÝ, J., ROHANOVÁ A. 2006: Static hardness of chosen coniferous species wood. Annals of Warsaw Agricultural University, Forestry and Wood Technology 243(58): 239–43.
13) DUBOVSKÝ, J., ROHANOVÁ A. 2007A: Static and dynamic hardness of chosen wood species. (in) Proceedings of the 2nd International Scientific Conference Woodworking Technique, Zalesina, Croatia: 27–32
14) BEKTAS I., ALMA M. H., AS N., 2001. Determination of the relationships between Brinell and Janka hardness of eastern beech (*Fagus orientalis* Lipsky). Forest Products Journal, 51(11-12): 84–88

Streszczenie: *Korelacje twardości drewna Brinella i gęstości drewna robinii akacjowej - zmienność wzdłuż pnia.* Studia wzajemnych relacji twardości i gęstości drewna robinii akacjowej, będące częścią badań nad właściwościami drewna tego gatunku, przeprowadzono w 2014 roku na zlecenie Lasów Państwowych. Do doświadczeń wytypowano trzy drzewostany z nadleśnictw Wołów, Krosno i Mieszkowice charakteryzujące się dobrym pokrojem strzały. Drzewostany próbne zajmowały podobne pod względem żyznościowym siedliska. W każdym z drzewostanów wybrano po 10 drzew próbnych, które następnie ścięto w celu wymanipulowania ze strzał trzech kłód: odziomkowej, środkowej i górnej. Określenie wartości twardości drewna metodą Brinella przeprowadzono zgodnie z normą PN-EN 1534:2011 natomiast gęstości drewna zgodnie z normą PN-77/D-04101. Pomiary twardości wykonano w trzech kierunkach: wzdłużnym, promieniowym i stycznym. Związek obu właściwości drewna zdeterminowano za pomocą korelacji Pearsona. Otrzymane wyniki wskazują na istnienie silnych, pozytywnych korelacji obu cech drewna, dla twardości określana dla całej strzały łącznie, dla kierunku stycznego pomiaru (0.44). Jednocześnie pozostałe korelacje dla tej wersji doświadczenia były nieistotne statystycznie. W wersji doświadczenia, w której twardość drewna określano dla trzech różnych lokalizacji wzdłuż pnia zaobserwowano istnienie istotnych statystycznie korelacji dla kłody środkowej, kierunków pomiaru promieniowego i stycznego (0.66 i 0.61) oraz kłody dolnej, kierunku stycznego (0.74). Otrzymane wyniki pozwoliły uzupełnić dotychczasową wiedzę z zakresu zmienności oraz wzajemnych relacji twardości i gęstości drewna.

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