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Wood 4 Sustainability

Processing, Construction, Products and Design

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Főszerkesztő: Dr. Csiha Csilla

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SOPRON, 2024

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Relationships of Fibers length and Ring Width with Precipitation and Temperature on Wood of *Robinia pseudoacacia*

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ABSTRACT

This study examined the wood fiber parameters and yearly ring width of Robinia pseudoacacia grown in Bács-Kiskun County, Hungary, Plus, the relationships between fiber length and ring width with environmental factors, particularly precipitation and temperature, were investigated. The results revealed that the radial trends of fiber length, width, and wall thickness gradually increased from the pith to the bark, although the lumen diameter remained constant. The annual ring width displayed a decreasing pattern towards the bark. Statistical analysis showed significant relationships between temperature and both fiber length and ring width however, no relationship was detected with precipitation.

Keywords: Black locust, growth ring, wood anatomy, correlations, Industry, innovation and infrastructure

1. Introduction

In Hungary, *Robinia pseudoacacia* demonstrates regional variations in growth patterns. It grows in the Danube-Tisza interfluve (central Hungary) and the northeastern Nyírség region. Additionally, its distribution has expanded across southern and southwestern Transdanubia, covering the hill ranges of Vas, Zala, and Somogy counties (Rédei et al. 2011). The site characteristics (e.g., soil types), tree age, and climatic variables (e.g., temperature, precipitation) can affect the wood properties such as density, fiber and growth ring (Bijak and Lachowicz, 2021, Kalbarczyk and Ziemiańska, 2017). Previous studies have primarily focused on inherent variations within the wood of *Robinia pseudoacacia*. For instance, Hejnowicz and Hejnowicz (1959) examined the variations in fiber properties and vessel members, while Adamopoulos and Voulgaridis (2002) investigated the differences in fiber properties and growth rate between trees and within earlywood and latewood zones. The levels of greenhouse gases are still on the rise, leading to higher global

temperatures, increased droughts, unpredictable changes in rainfall, and shifts in photoperiods (NOAA, 2023). We assume these changes may affect the wood fiber properties and growth rate of *Robinia pseudoacacia*. Bakhshi et al. (2011) investigated the influence of climate on the fiber properties of maple wood (*Acer velutinum* Boiss). They found no significant effect on fiber length and cell wall thickness, but a notable correlation between fiber diameter and specific monthly precipitation and temperature values. Recently, Kalbarczyk and Ziemiańska (2016) specifically focused on the impact of air temperature, air humidity, and precipitation on the ring width of *R. pseudoacacia* trees growing in Poland between 1954 – 2014 years.

This study investigated (1) radial variations in fiber properties such as fibers length (FL), fiber width (FW), fiber wall thickness (FWT) and lumen diameter (LD) and ring width (RW) (2) the relationships of fiber length and ring width with temperature and precipitation of *Robinia pseudoacacia* from Bács-Kiskun county, Hungary.

2. Material and methods

2.1. Study area

Wood of R. pseudoacacia trees aged between 35 and 38 years, were collected from Bács-Kiskun county, Hungary in 2023. The historical climate data of the study area between 1988–2022 years was collected from the POWER | Data Access Viewer (nasa.gov) website (1/2/2024) for the county. Mean annual temperature and total precipitation were 11.56 ºC and 522.2 mm, respectively, given in Table 1. The yearly temperature and precipitation patterns shown in Figure 1.

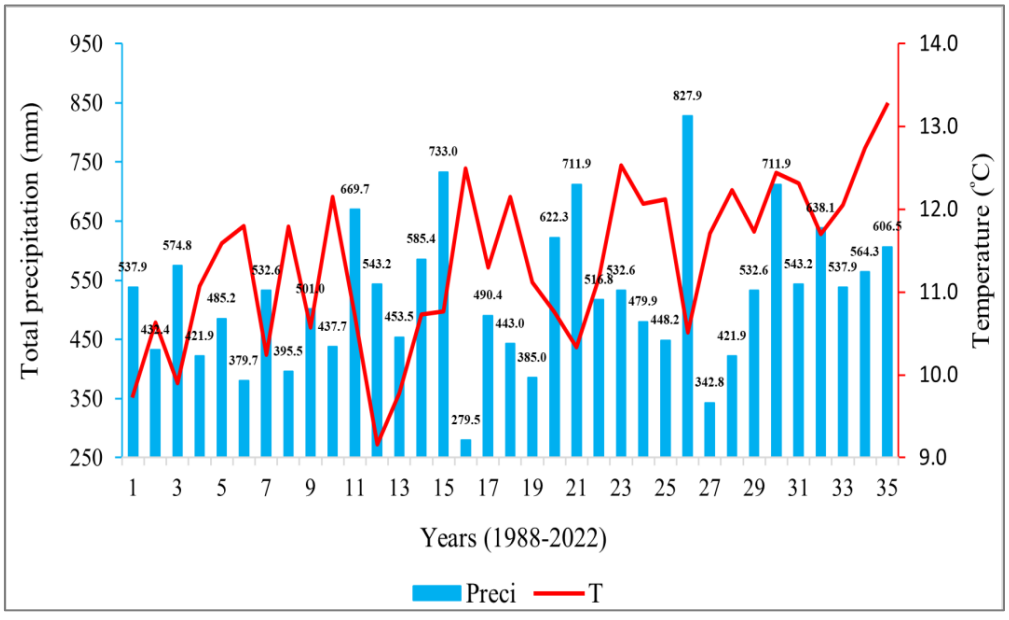

Figure 1. Mean temperature and total precipitation mm pattern from 1988–2022 of Bács-Kiskun county, Hungary. Abbreviation: Perci – preciptitation, T - temperature

2.2. Sampling

Discs around 4 cm thick were selected at the breast height of the trees. After that, a strip from bark -to-bark, was extracted, and divided into two strips. The upper strip was used to determine the FL, FW, FWT and LD from each annual ring (from pith to bark). The second strip was used to assess the RW. From each annual ring, small pieces were taken and macerated with Franklin solution. Then the specimens were heated at 65 ^{o}C for 24 or 48 hours (Nugroho et al, 2012). The fiber dimensions were measured under a light microscope supplied with a digital camera. From each annual ring, 50 fiber length measurements were obtained, while 25 measurements were taken for fiber width, fiber wall thickness, and lumen diameter. The ring width was assessed by ImageJ-analysis software after smoothing the wood strips with sandpaper on their transverse surfaces and scanning them with scanner.

2.3. Data analysis

The analysis was done using R statistical software program. The ggplot packages, geom_line and geom_point commands were applied to show the trend of FL, FW, FWT and LD, in addition to the RW. Pearson's correlation test and regression coefficient were applied to determine the relationships of FL and RW with temperature and precipitation.

3. Results and discussion

Figure 2 shows the radial variation in fiber properties across annual rings of *Robinia pseudoacacia* wood. Mean FL ranged from 0.68 mm near the pith to 1.08 mm adjacent to the bark. While that was 13.05 to 16.07 µm, 1.87 to 2.65 µm and 6.52–10.63 µm for FW, FWT and LD, respectively (Figure 2a–d). In addition, the RW varied from 0.54 mm to 6.37 mm (Figure 3).

Radial trends in FL revealed an initial increase in the first seven growth rings, followed by a minor decline in the subsequent three rings. Beyond this transitional phase, FL resumed a gradual, sustained increase toward the outer wood. Comparable patterns were observed for FW and FWT (Figure 2b, c), while LD showed stable radial variability (Figure 2d). In contrast, the RW had a rapid initial increase in the pith (first 5-12 rings), followed by a gradual decrease towards the outer growth ring of the tree. Analysis of variance (ANOVA) showed significant radial variation in fiber parameters and RW ($p < 0.001$) (Table 1).

Both FL and RW patterns aligns with previous reports for *Robinia pseudoacacia* (Adamopoulos and Voulgaridis, 2002; Dünisch et al., 2010). The phenomenon of radial variation discussed in previous research by Adamopoulos and Voulgaridis (2002), they indicate that the growth rate and fiber dimensions are influenced by climatic conditions, with a notable increase in fiber length during the juvenile growth phase. Also, Stringer and Olson (1987) and Panshin and De Zeeuw (1980) mentioned that the fiber length increases radially from the pith to the cambium, with significant variation based on growth conditions and tree age.

3.1 Relationships of climate factors with fiber length and ring width

The total precipitation for each year and the average annual temperature were correlated with the average FL of each annual ring and RW (Figure 4 and 5). The FL and RW were not significantly correlated with precipitation (figure 4). Despite that, significant correlations were observed with temperature (Figure 5). FL exhibited a strong positive correlation (R = 0.62), but RW demonstrated a moderate negative relationship (R = −0.44).

These results partially diverge from earlier studies, which identified both precipitation and temperature as key drivers of functional traits in *Robinia pseudoacacia* (Song et al., 2013).

For instance, Kalbarczyk and Ziemiańska (2016) reported that ring widths in temperate regions are sensitive to winter warmth and July cooling trends, while He et al. (2023) emphasized the combined influence of moisture availability, thermal indices, and temperature on radial growth.

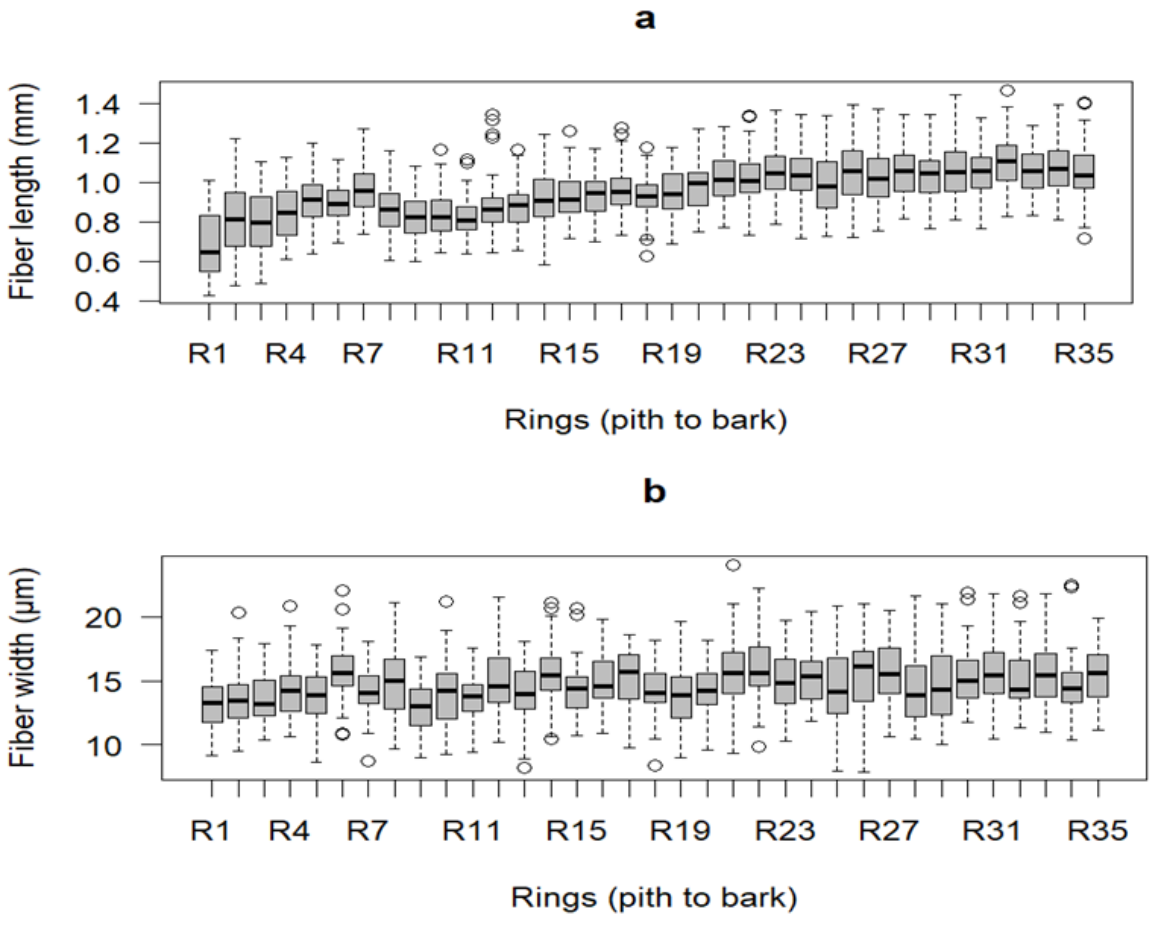

Figure 2/ a, b. Radial variations in (a) fiber length, (b) fiber width, (c) cell wall thickness, and (d) lumen diameter in Robinia pseudoacacia wood

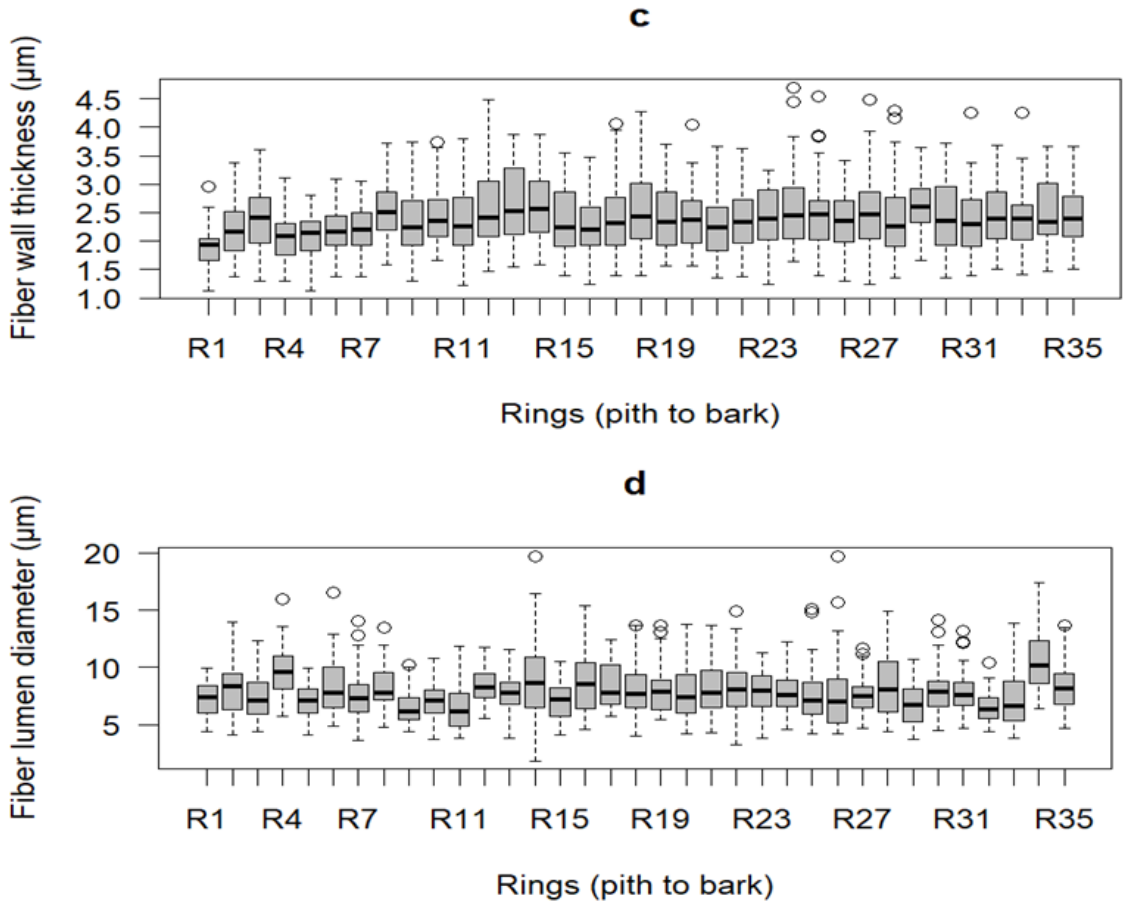

Figure 2/ c, d. Radial variations in (a) fiber length, (b) fiber width, (c) cell wall thickness, and (d) lumen diameter in Robinia pseudoacacia wood

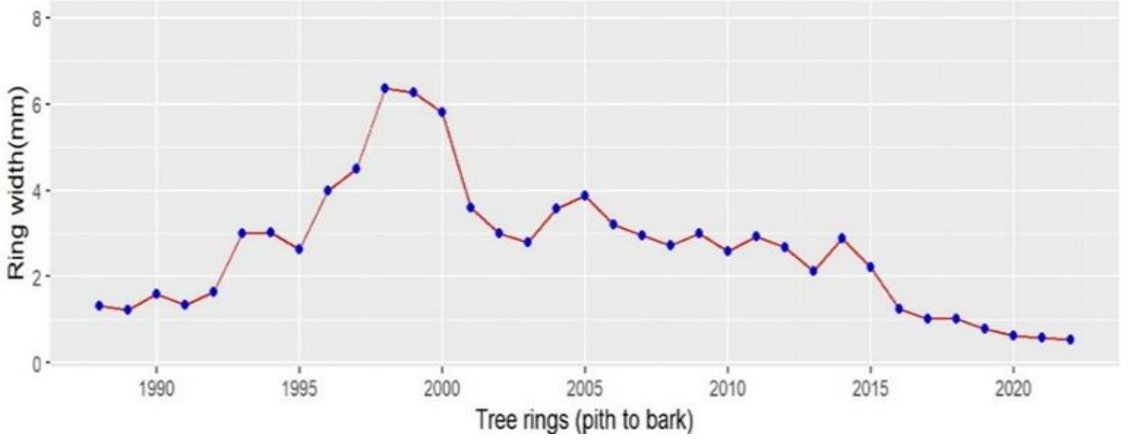

Figure 3. Internal variation in ring width from 1985–2022 of Robinia pseudoacacia wood

Table 2. Between tree rings variations in fiber properties and ring width (ANOVA test)

Anatomical properties	Sum Sq	Mean Sq	F value	P value
FL	15.35	0.4515	66.5	OOO
FW	1053	30.961	5.72	OOO
FWT	45.8	1.3478	4.39	OOO
LD	1248	36.71	8.13	OOO
RW	29.57	14.79	13.95	OOO

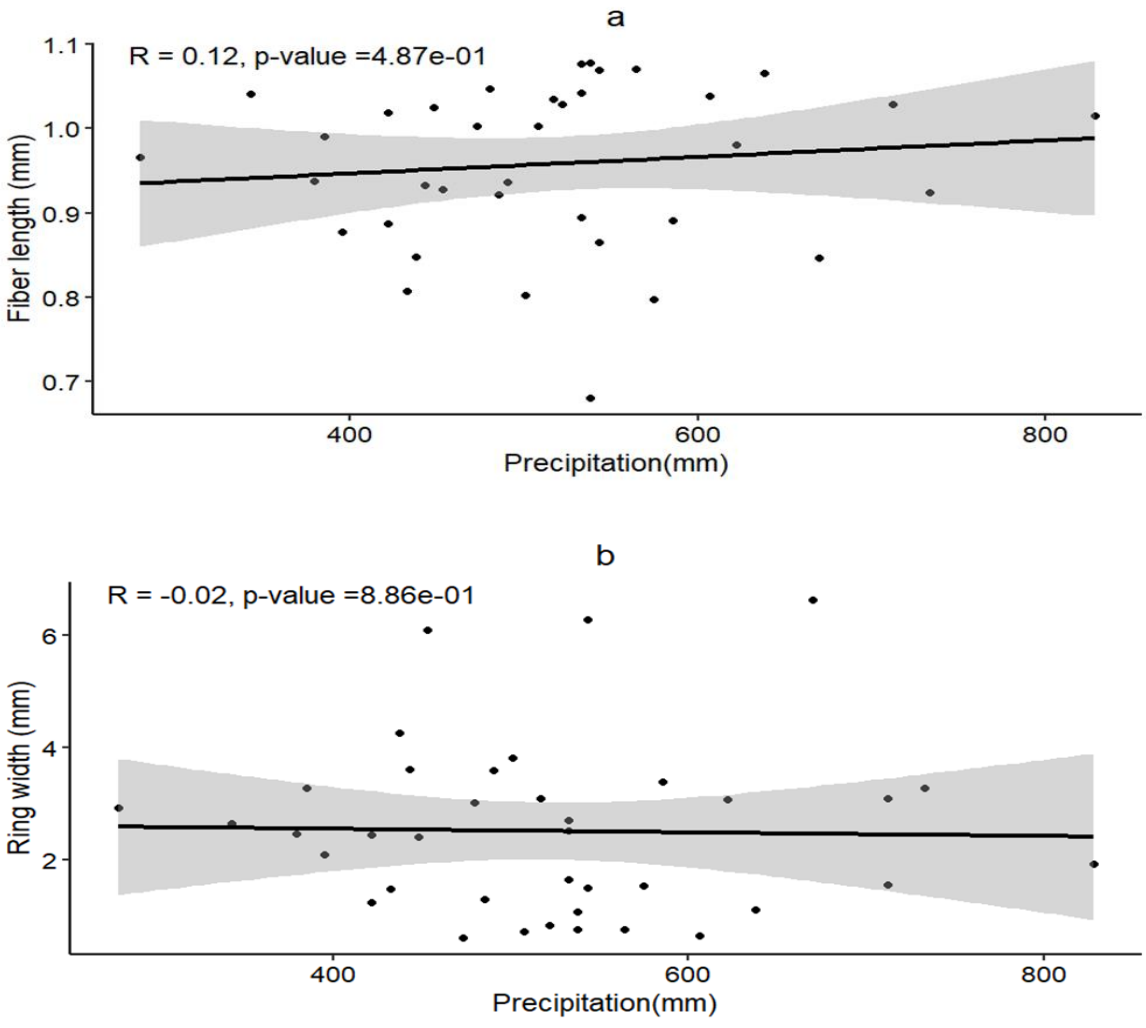

Figure 4. Correlation of total annual precipitation with FL (a) and RW (b) of wood *R. pseudoacacia*

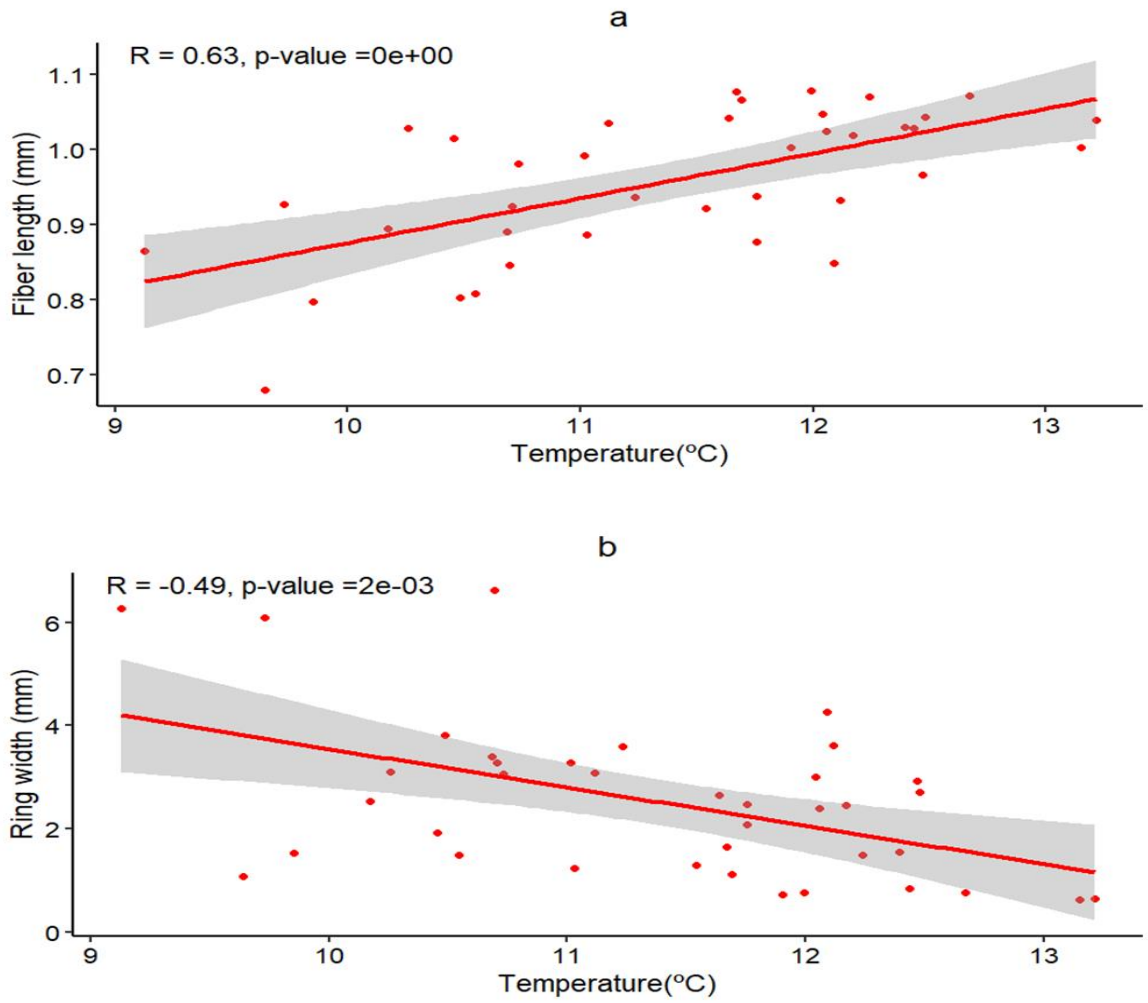

Figure 5. Correlation of yearly average temperature with FL (c) and RW (d) of wood *R. pseudoacacia*

4. Conclusion

The study concluded that:

- The length, width and wall thickness of fibers increase from the pith to the bark. However, the lumen diameter exhibited no significant variation.
- The ring width decreased from pith to bark.
- The fiber length and ring width were significantly correlated only with the temperature.

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Author statements

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Mátyás Báder – author.
Bak Miklós – author.
Róbert Németh – head of the research and Supervisor.

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