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RADIAL VARIABILITY OF SELECTED STRUCTURAL PARAMETERS OF WOOD AS INDICATION OF THE JUVENILE GROWTH PERIOD OF ROBINIA TREES (*Robinia pseudoacacia* L.)[1]

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The study reported in this paper was undertaken to determine the variability of the anatomical parameters of robinia trees, which could be used as indicators of the juvenile period of tree growth. From the annual growth rings the early and late wood were separated and subjected to maceration conducted in a mixture of glacial acetic and 30% of hydrogen peroxide. The measurements were performed using a system for image processing controlled by the program Imager 512.

Key words: robinia, fibers, vessel members, growth ring, diameter, length, juvenile and mature wood

INTRODUCTION

The cross-section of both coniferous and deciduous trees reveals the presence of two zones of juvenile and mature wood. The first zone occurs in the central part of the stem and spreads over several annual growth rings around the pith, while the second covers farther rings towards the circumference (e.g. Zobel and van Buijtenen 1989, Haygreen and Bowyer 1996). The formation of juvenile wood is controlled by production of auxin in the tree crown. Some authors call it crown wood (Larson 1962).

The contribution of juvenile wood increases with the tree height and in the tree top part it reaches 100%. The wood of young trees and tree-tops is juvenile irrespective of the age of the tree. The period of juvenile wood formation is different in different spe-

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cies and also in individual trees of a given species, e.g. depending on the conditions of growth. From the point of view of timber use, a significant content of juvenile wood is undesirable due to its worsening of wood quality, especially solid wood (Senft et al. 1985, Zobel and van Buijtenen 1989, Helińska-Raczkowska 1993). The contribution of juvenile wood is responsible for inhomogeneities in the properties of wood as a raw product (Bendtsen 1978, Gorman 1985, Kopitovič et al. 1989, Klašnja and Kopitovič 1992).

From the practical point of view it is important to be able to delineate the border between juvenile and mature wood. The study reported in this paper was undertaken to determine the variability of the anatomical parameters of robinia tree, which could be used as indicators of the juvenile period of tree growth.

METHODS OF THE STUDY

As the experimental trees we have chosen three robinia trees (*Robinia pseudoacacia* L.) devoid of any visible defects, about 50 years of age and belonging to the dominant trees group, growing in the Rakownia Forest Range, Forest Experimental Station - Murowana Goślina of the Agricultural University in Poznań (Table 1).

Table 1

Tabela 1

Characterisation of the experimental trees

Charakterystyka drzew doświadczalnych

Characteristic features Cechy charakterystyczne drzewa	Tree I Drzewo I	Tree II Drzewo II	Tree III Drzewo III
Age*) [years] Wiek drzewa *) [lata]	53	49	50
Breast diameter outside bark [cm] Pierśnica w korze [cm]	40.1	39.8	41.5
Tree height [m] Wysokość drzewa [m]	24	24	23.8
Length of living crown [m] Długość żywej korony [m]	11.65	14.36	11.3
Crown index**) Wskaźnik korony **)	0.485	0.598	0.475

*) number of increments in the butt cross-section

*) liczba przyrostów na przekroju odziomkowym

**) the ratio of the crown length to the total height of the tree

**) stosunek: długość korony/wysokość drzewa

The material studied were about 30 mm thick disks cut out at 1/4 of the total height of the tree, so at about 6 m from the root neck. From these disks a few strips oriented toward the north of about 15 mm width in the tangential direction were cut out. For analysis we have selected fragments covering the following annual growth rings, counting from the pith no. 3, 6, 9, 12, 18, 25 and then every fifth up to the circumference. The number of the growth ring counted from the pith corresponds to the cambial age of the growth rings. From the annual growth rings the early and latewood were separated and subjected to maceration conducted in a mixture of glacial acetic acid and 30% of hydrogen peroxide solution at the (1:1) ratio at 60°C for 24 hours. From the macerates unstable microscopic preparations in a drop of glycerine were made.

In order to determine the border between juvenile and mature wood, the radial gradient of the length and diameter of wood fibers and vessel members were determined for the early and latewood. The length of vessel members was measured together with vessel member ends and their diameter was measured at the middle of the length. The measurements were performed using a system for image processing controlled by the program Imager 512. In each annual ring measurements were performed for 30 fibers and 15 vessel members from early and latewood, the total number of measurements was over 5000.

RESULTS

Analysis of variation in the width of the annual growth rings along the north radius of the cross-section indicates a similar dynamics of the experimental trees growth (Fig. 1).

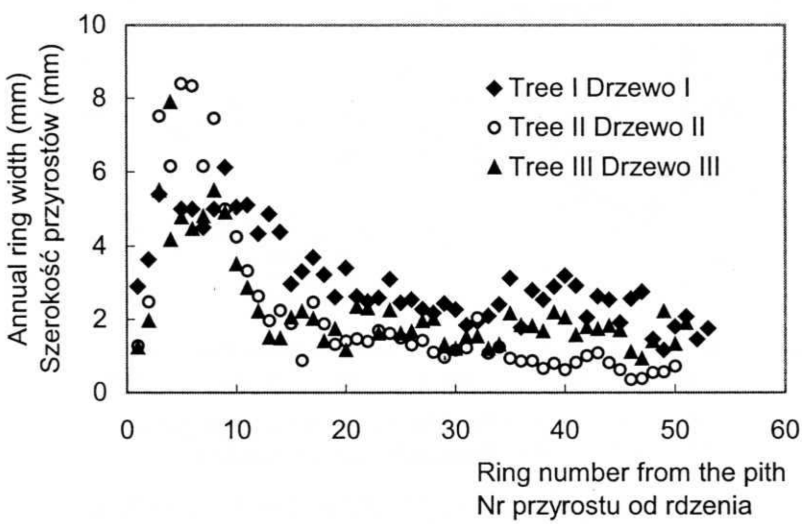

Fig. 1. The width of annual growth rings versus their cambial age of robinia trees
Rys. 1. Szerokość przyrostów rocznych w zależności od wieku kambialnego drzew robinii białej

Statistical analysis of measurement results has shown that the variation coefficients of the length and diameter of the anatomical elements measured are similar and equal to 10.1 (7.0-12.8)% for the fiber length and 11.2 (8.5-17.5)% for the vessel members length, while 9.5 (8.0-14.2)% for the fiber diameter and 12.5(10.5-18.9)% for vessel members diameter. These values are also close to the earlier data reported as results of similar studies by (Helińska-Raczkowska 1994, Helińska-Raczkowska and Fabisiak 1997).

According the histograms the distribution of frequency of the anatomical elements measure is close to the normal. The influence of cambial age of annual rings on the diameter of vessel members in early and latewood, determined on the basis of average values for the three robinia trees studied, is shown in Fig. 2.

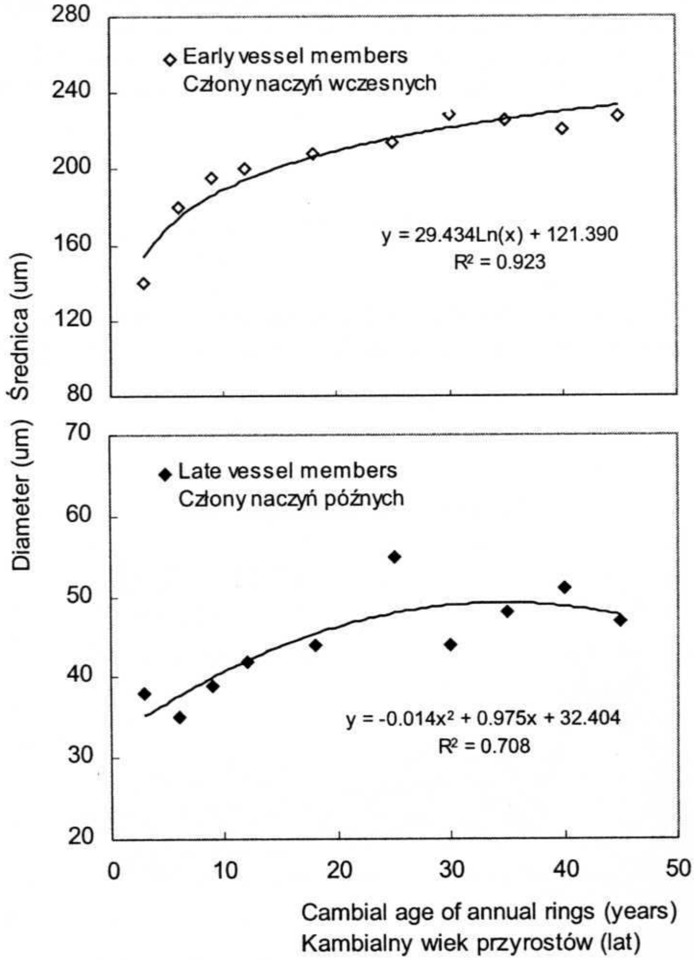

Fig. 2. Relationship between diameter of early and late vessel members and age of growth rings of robinia trees

Rys. 2. Zależność między średnicą członów naczyń wczesnych i późnych a wiekiem przyrostów rocznych drzew robinii białej

As follows from these data, the diameter of vessel members in earlywood takes the lowest values for the elements localized near the pith, and then increases by about 35% up to the ring number 14. For the rings with further increasing numbers, the diameter also shows an increase but much smaller, by about 8%. The observed dynamics of increase of this parameter can be used for discernment between the juvenile and mature wood. Similar dependencies between the diameter of vessel members in earlywood on the cambial age have been obtained for ash tree (Helińska-Raczkowska and Fabisiak 1999). The diameter of vessel members in latewood does not depend on the cambial age of the rings, although in the vicinity of the pith it is much smaller than in the growth rings further from the pith.

It should be mentioned that the wood of robinia tree is characterized by a gradual development of the ring-porous structure of annual growth rings (Tsuomis 1968). In the first rings around the pith the vessels are finer and do not form a distinct ring at the beginning of the ring. The vessel system is similar to that of diffuse-porous wood. Literature on the subject is scarce.

Analysis of the length of vessel elements in early and latewood shows that it increases linearly as a function of cambial age (Fig. 3) up to the circumference. The diameter of fibers in early and latewood (Fig. 4) varies in the range 17 – 22 μm and practically does not depend on the cambial age of annual growth rings.

Fig. 5 presents the length of fiber from earlywood as a function of cambial age of annual rings. As follows from the data in Fig. 5, the average length of fibers in earlywood increases by about 40% up to the ring 14, and for farther rings this increase is

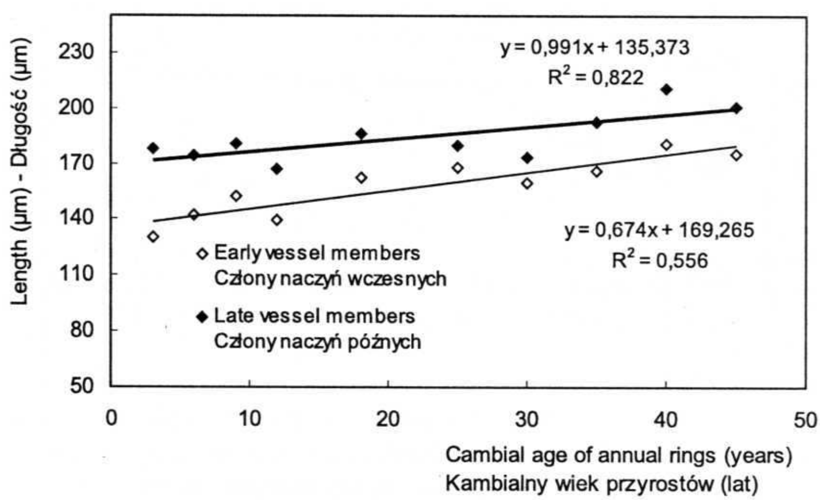

Fig. 3. Radial variation of the length of early and late vessel members versus cambial age of robinia trees

Rys. 3. Promieniowa zmienność długości członów naczyń wczesnych i późnych drzew robinii białej

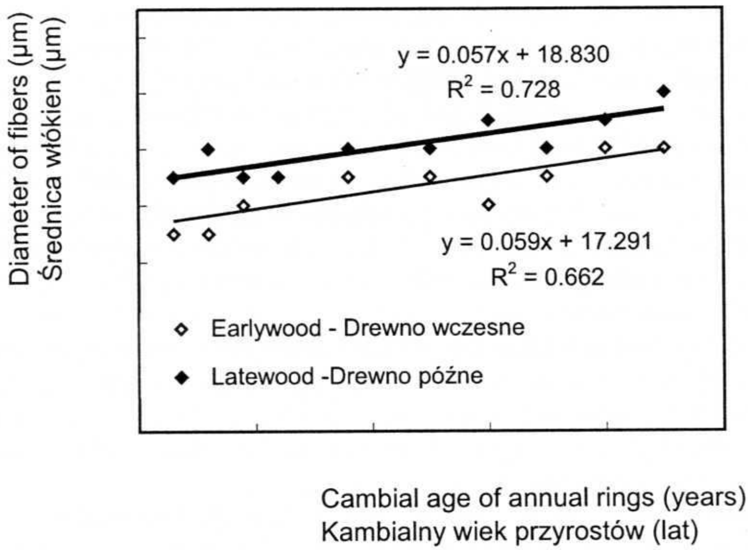

Fig. 4. The diameter of fibers of robinia wood as a function age of annual growth rings

Rys. 4. Średnica włókien drzewnych robinii w funkcji wieku kambialnego przyrostów rocznych

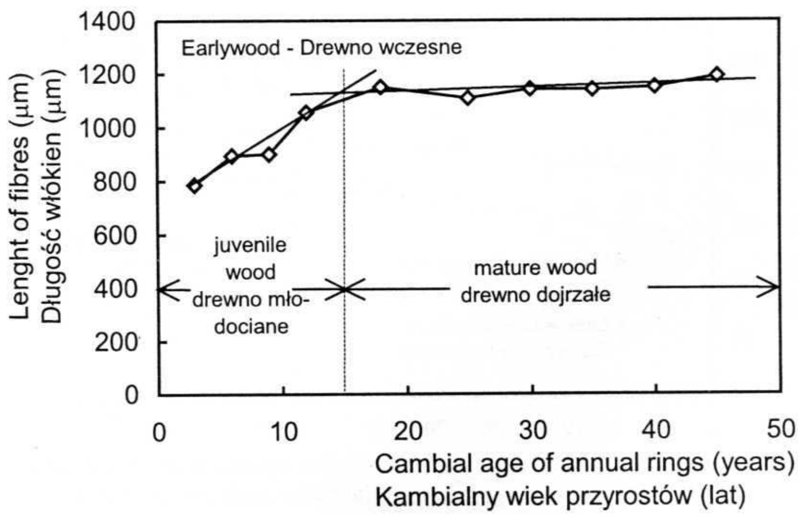

Fig. 5. Relationship between fibers length in earlywood and age of growth rings of robinia trees

Rys. 5. Zależność między długością włókien drewna wczesnego a wiekiem przyrostów rocznych drzew robinii białej

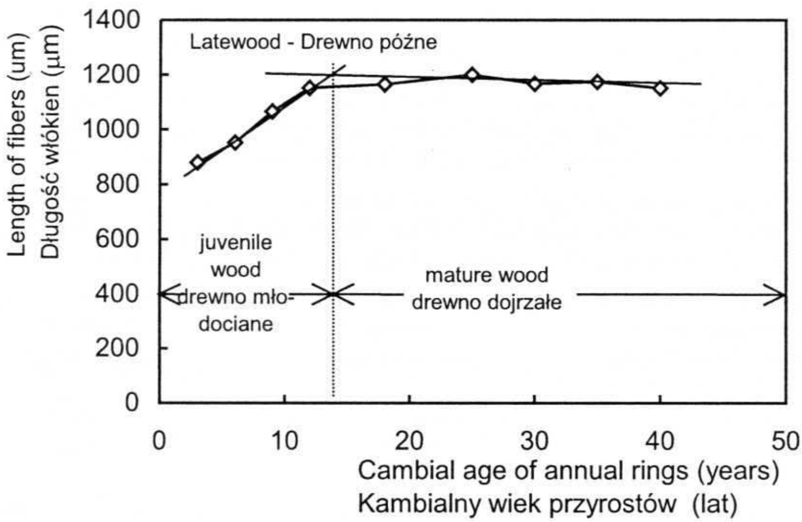

Fig. 6. Relationship between fibers length in latewood and age of growth rings of robinia trees
Rys. 6. Zależność między długością włókien drewna późnego a wiekiem przyrostów rocznych drzew robinii białej

much smaller. The average length of fibers in latewood (Fig. 6) also increases but to a lesser extend (by about 30%) up to the ring 14, and for farther rings the fiber length practically does not change, apart from a slight decrease near the circumference.

The fibers of latewood are somewhat longer than those in earlywood: in the absolute values the average length of the fibers increases from 785 µm to 1180 µm in earlywood and from 900 µm to 1200 µm for latewood.

The observed change in the length of fibers has confirmed earlier opinions about importance of the radial gradient of this anatomical element for demarcation between the juvenile and mature wood (Helińska-Raczkowska and Fabisiak 1995). The changes in the fiber length as a function of cambial age can be used for determination of the borderline between the juvenile and mature wood on the cross-section of the tree trunk. Aiming at objective determination of the border between the juvenile and mature wood, (Abdel-Gadir and Krahmer 1993, Gartner et al. 1997) we have used the so-called segmental linear regression (Draper and Smith 1973). Assuming two-segmental linear regression, we have used the relation $y_1=a_1+b_1x$ for the segment corresponding to the juvenile wood and $y_2=a_2+b_2x$ for that corresponding to mature wood. The parameters of the respective regression equations are given in Table 2.

The borderline between the juvenile and mature wood is determined as the abscissa of the point of intersection of the two regression lines (X') (in Fig. 5 and 6). The age of the tree corresponding to the border between the growth rings of juvenile and mature wood (X') determined from the changes in the gradient of the length of fibers in early and latewood and the diameter of vessel members in earlywood has been consistently approximated as 14 years (Table 2, Figs. 5 and 6).

Table 2

Tabela 2

Parameters of regression equations describing the length of fibers in the juvenile and adult wood (y,μm) as a function of cambial age (x, years) for robinia tree. X' is the abscissa of the point of intersection of the two regression lines

Parametry równań regresji długości włókien drewna wczesnego i późnego (y,μm) w funkcji wieku kambialnego (X, lat) robinii dla drewna młodocianego i dojrzałego. X' – odcięta punktu przecięcia obydwu równań regresji liniowych

Regression parameters Parametry równań regresji	Earlywood Drewno wczesne	Latewood Drewno późne
a_1	27,21	31,119
b_1	704,35	778,84
a_2	2,849	-0,814
b_2	1050,1	1196
X'	14,2	13,6
R^2	0,900	0,993

According to the study by Stringer and Olson (1987) performed on young robinia trees of 10-12 years of age, the time of the juvenile increase in diameter is of about 8 years. These authors determined the limiting age of juvenile wood on the basis of the changes in the gradient of the length of fibers and wood density. On the other hand, the age of corresponding to juvenile wood zone estimated from the radial changes in the fibers length in one experimental robinia tree aged 36 years (Hejnowicz and Hejnowicz 1959) is of about 10-12 years.

Similar dependencies have been established, for robinia (Hejnowicz and Hejnowicz 1959) and for a few other ring-vascular trees (Panshin and de Zeeuw 1980, Helińska-Raczkowska and Fabisiak 1997).

In the 50 year old robinia trees studied, the juvenile wood forms a cylinder of about 13cm in diameter, which covers from 15 to 25% of the whole cross-section of the trees at the level of 1/4 of their height (6m.).

CONCLUSIONS

1. The border between the juvenile and mature wood, determined on the basis of the cambial age dependence of the gradient of the length of fibers in early and latewood and the diameter of early vessels, is delineated by the growth ring 14 (corresponds to 14 years of age).

2. The juvenile wood zone makes a cylinder of about 13 cm in diameter and covers about 15-25% of the cross-section of 50-year old robinia trees at the level of 1/4 of their height (6 m.).
3. The juvenile growth zone is characterized by a rapid increase in the length of fibers in earlywood (by about 40%), in latewood (by ~35%) and the diameter of vessels in earlywood (35%).
4. The juvenile wood is structurally heterogeneous relative to the mature and this is the reason for qualitative inhomogeneity of wood as raw material.

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PROMIENIOWA ZMIENNOŚĆ WYBRANYCH PARAMETRÓW STRUKTURALNYCH JAKO WSKAŹNIK MŁODOCIANEGO WZROSTU ROBINII AKACJOWEJ (*Robinia pseudoacacia* L.)

Oznaczono zmienność długości i średnicy włókien drzewnych oraz segmentów naczyń w drewnie wczesnym i późnym w funkcji wieku kambialnego przyrostów. Mierzono zmienność wymienionych parametrów w 3, 6, 12, 18, 25 i dalej w co 5-tym przyroście aż do obwodu. Krążki do badań pochodziły z poziomu 1/4 wysokości trzech drzew doświadczalnych w wieku 50 lat. Na podstawie uzyskanych wyników wyznaczono granicę między drewnem młodocianym a dojrzałym, która odpowiada 14 przyrostowi. W strefie drewna młodocianego występuje gwałtowny wzrost długości włókien drzewnych drewna wczesnego o ok. 40%, oraz późnego o 30% a także średnicy segmentów naczyń wczesnych o ok. 35%.

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