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Duration of juvenile period in diameter growth of trees selected coniferous species

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Abstract: The result of the tests was determination of the width of the juvenile wood zone in trees of various coniferous species, originating from even-aged stand and from the same biosocial class. The boundary between juvenile wood and mature wood was determined based on the measurements of the tracheid length variability. Thirty measurements of the length of earlywood and latewood tracheids were carried out for each tested ring. For all tested wood species the tracheids of earlywood were shorter, compared to latewood tracheids. The zone of juvenile wood was determined based on a two-segment linear regression. In all tested species this zone was formed within a similar period and encompassed the first 25 to 28 annual rings.

Keywords: juvenile wood, mature wood, pine, larch, spruce

INTRODUCTION

On the cross-section of trees one may distinguish juvenile wood and mature wood. Juvenile wood is present not only in fast-growing trees, as initially suggested (Paul 1960). Its production depends on the age of a tree, therefore it is present in every tree (Rendle 1960). In even-aged stand, the juvenile wood zone is the widest in dominant trees, and the narrowest in suppressed trees. The width of the juvenile wood zone is affected by, inter alia, habitat or climate conditions (Yang et al. 1986; Zhu et al. 2000; Fabisiak 2005; Koubaa et al. 2005). Research on many species indicates genetic determination of the length of the juvenile wood creation period (Szymański, Tauer 1991; Gapare et al. 2006).

In the case of coniferous species, juvenile wood is characterised by, inter alia, a higher content of lignin and lower content of cellulose, compared to mature wood (Gierlinger, Wimmer 2004), less steep course of cellulose microfibrils in relation to the cell longitudinal axis, shorter cells, lower density, and worse mechanical properties. On the other hand, longitudinal deformations of this wood, are several times greater and transverse deformations by half smaller than in the case of mature wood (Clark et al. 2006; Ivkovič et al. 2009). The above-mentioned differences between the properties of juvenile wood and mature wood are the reason for heterogeneity of raw wood material. Therefore, determination of the share and width of the juvenile wood zone within trees or saw logs is important from the cognitive and practical perspective, due to its effect on the wood quality and the value of wood products.

The boundary between juvenile wood and mature wood can be determined based on various wood properties, i.e. cell length, the gradient of microfibrils in layer S2 of the secondary cell wall, wood density, the share of latewood (Sauter et al. 1999; Koubaa et al. 2005; Fabisiak et al. 2006; Gapare et al. 2006; Mansfield et al. 2009). The width of the juvenile wood zone, determined based on various properties, may vary. Many authors say, that these differences are connected with the interaction between the genetic and environmental factors participating in the process of juvenile tissue creation (Clark et al. 2006; Gapare et al. 2006). Literature reports suggest, that cell length is most often used to determine the demarcation line between these zones (Fabisiak, Moliński 2002a; Mansfield et al. 2009).

The above-mentioned properties change rapidly in juvenile wood, to stabilise at a specific level or fluctuate insignificantly in the mature wood zone (Zobel, Spraque 1998; Fabisiak 2005].

The aim of this study was to determine the width of the juvenile wood zone in trees of various coniferous species, originating from even-aged stand and from the same biosocial class, thus growing in the same climate and habitat conditions.

MATERIALS

The material for testing was Norway spruce (*Picea abies* L.), Scots pine (*Pinus sylvestris* L.) and European larch (*Larix decidua* Mill.). Tests were carried out on wood from dominant trees at the age of 104-106 years, originating from a stand growing in the habitat of mixed spruce forest. The stand was located in forest division of Łopuchówko, commune of Murowana Goślina. Approximately 5 cm thick test discs were cut out at the diameter breast high, and then approx. 4 cm wide slats were cut out from the discs along the north-south radius. The tests were conducted on the north parts of the slats. The tests were conducted on macerated material from annual rings 3, 6, 9, 12, 15, 20, 25, 30, 40, and further from every 10^{th} ring up to the sample's circumference. Maceration was carried out for 48 hours using a mixture of ice-cold acetic acid and 30% peroxide (1:1) at a temperature of 60ºC. Radial gradient of the tracheid length was used to determine the juvenile period. The measurements were carried out using a imaging analyser composed of a microscope fitted with a CCD camera and hooked up to a computer, using the Micro Scan Plus imaging processing system. Thirty measurements of the length of earlywood tracheids and latewood tracheids were taken from each tested annual ring.

RESULTS

The lengths of earlywood and latewood tracheids from the studied annual rings of tested species are presented in fig. 1. Each point of the diagram is an average from 30 measurements. Statistical analysis of the obtained results proved, that the variability coefficients of the studied property were similar, and their average for individual species was 9% for larch, 10% for spruce, and 17% for pine. Numerical values of these coefficients were within the ranges of variability coefficients published for the length of prosenchymatic elements of coniferous species (Panshin de Zeeuw 1980).

In the case of all studied trees, the length of earlywood tracheids and latewood tracheids grew until a certain cambial age of annual rings, in accordance with the law of Sanio (1872). With further growth of the trees, said dimension stabilises at a certain level and demonstrated insignificant fluctuations to the trunk's circumference. In each of the species, tracheids created in the first part of the vegetative period were shorter than the tracheids created in summer, irrespective of the location of the annual ring on the trunk's cross-section. These differences all along the tree radius were the smallest for spruce and pine wood, for they were approx. 11% and 12%, respectively, and the greatest in the case of larch wood, where they reached 16%.

The greatest growth dynamics of the tracheid length was observed for spruce wood, where doubling of this dimension was observed already for the 15^{th} annual ring. Within this zone, pine wood was characterised by the shortest tracheids (2260 μm), while in the case of spruce the tracheids were approx. 16% longer, and for larch they were approx. 32% longer, compared to pine. The width of juvenile zone was determined based on the variability of average tracheid length within the analysed annual rings. In order to do so, so-called two-segment linear regression was carried out (Abdel-Gadir, Krahmer 1993). The parameters of the regression equations for the juvenile wood zone and the mature wood zone of the analysed species are presented in table 1. The boundary between juvenile wood and mature wood is determined by the abscissa of the point of junction of both regression equations for a given species. The demarcation lines between these zones were located within the area from the 25th to the 28th annual ring (they are marked with a bold line in fig. 1). In connection with the above, it may be assumed that, for the analysed species, the period of juvenile wood creation is practically the same. The average tracheid length in these years of tree growth was the smallest in the case of pine wood and equalled 2350 µm. In the case of spruce wood, tracheids were 2760 µm long on average, within a comparable zone of the trunk cross-section, and in the case of larch wood they were the longest with a length slightly exceeding 3100 µm. Comparing the dynamics of the length growth of the analysed cells in juvenile wood, it was observed that in the case of pine and larch the increase of this dimension was 80%, while in the case of spruce it was 130%. On the other hand, in the case of the mature wood zone, spruce was characterised by the longest cells, whose average length was 4230 µm, while the shortest cells were observed for pine wood and their average length was 3310 µm. In the case of spruce wood further growth of the length of tracheids, especially late ones, was observed in the last vegetative periods (above the 80th annual ring), while in the case of the other species a downward trend was noticed. The downward trend in the length of tracheids, and sometimes also in other properties (e.g. wood density), in old trees was demonstrated for many tree species (Pearson, Ross 1984; Zobel, Spraque 1998).

Table 1. Parameters of the regression equations (y=ax+b) describing the relationship between the length of tracheids (y, mm) and cambial age of annual rings (x, year) of juvenile wood (JW) and mature wood (MW) of larch, pine and spruce trees belonging to dominant classes

Species	Cross-sectional zone	Regression equation parameters		R^2
		a	b	
larch	JW	38.2	2692	0.8307
	MW	-1.24	3796	0.0304
pine	JW	56.1	1754	0.9827
	MW	0.825	3283	0.0160
spruce	JW	59.2	2209	0.9520
	MW	15.9	3316	0.8210

The determined width of the juvenile wood zone was similar to that given by Koizumi (2003), who, based on the variability of the tracheid length in *Larix sibirica*, determined it to have encompassed 20 annual rings. Similarly Karlman et al. (2005), in their literature-based research, assumed that the period of juvenile wood creation for pine (*Pinus sylvestris* L.) and several species of larch (*Larix* sp.) was 20 years. Many research suggests that the better the biosocial position of a tree in the stand, the longer the period of juvenile wood creation. Fabisiak (2005) as well as Fabisiak and Moliński (2002a, 2002b) demonstrated, that for 45-year old dominant trees of Douglas fir and pine the age of transition from juvenile to mature tissue was 25 years, and for larch 20 years.

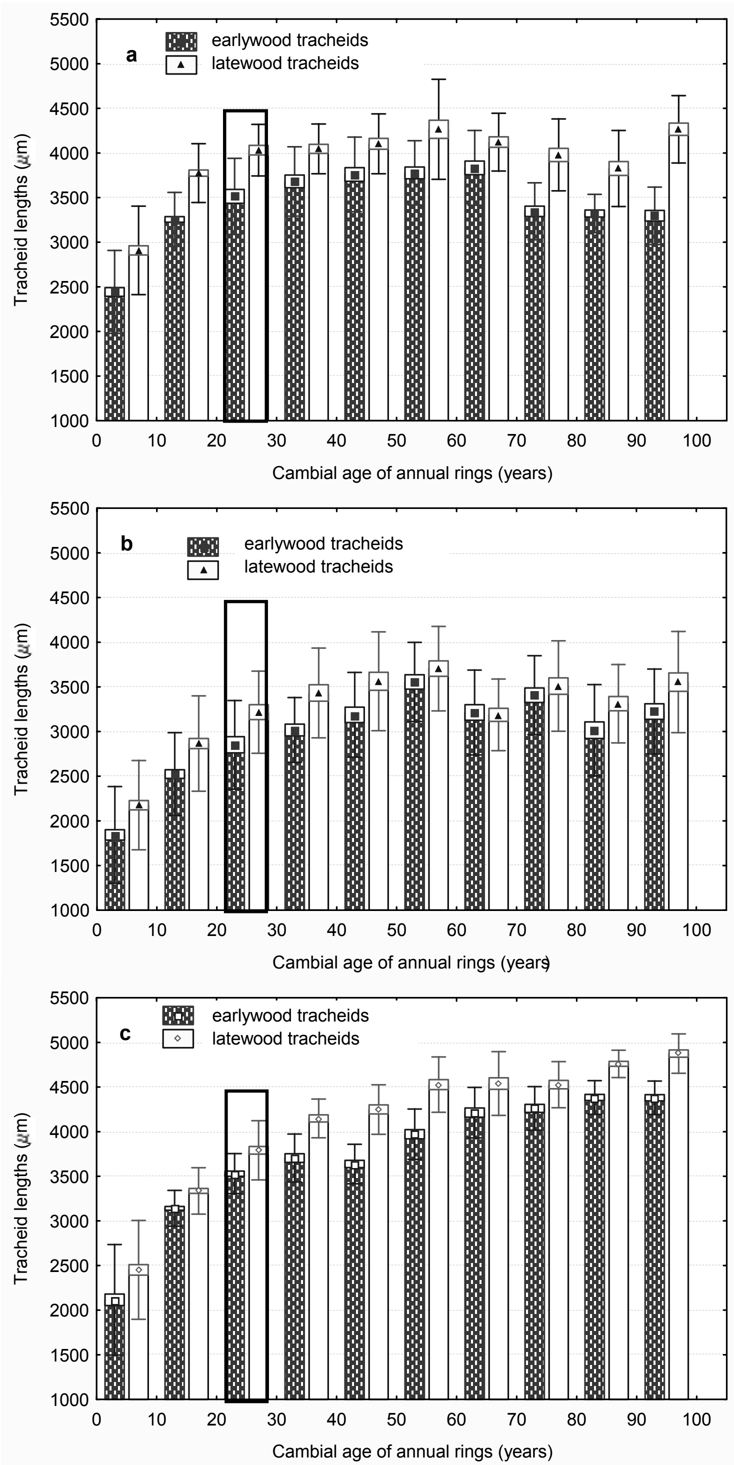

Fig. 1. Average lengths of earlywood and latewood tracheids in: a) larch, b) pine, and c) spruce

CONCLUSIONS

1. Earlywood tracheids were shorter than latewood tracheids in each analysed annual ring of the trees of pine, spruce and larch, originating from the dominant tree class. The average differences in the lengths of these cells within a single annual ring of 100-year old trees ranged from 11% to 16%.
2. The juvenile wood zone was determined based on the variability of the tracheid length (average for the whole annual rings), using two-segment regression. It was demonstrated, that the width of this zone for the analysed species was similar and encompassed the first 25 to 28 annual rings.
3. Pine wood was characterised by the shortest tracheids in the juvenile wood zone and mature wood zone, where the average length of tracheids was 2350 μm and 3310 μm, respectively. In the case of mature wood, the longest cells were observed in spruce, where their average length was approx. 4230 μm.

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Streszczenie: *Długość młodocianego okresu przyrostu na grubość drzew wybranych gatunków iglastych.* W badaniach określono szerokość strefy drewna młodocianego w drzewach różnych gatunków iglastych (sośnie, świerku i modrzewiu), pochodzących z jednowiekowego drzewostanu, z tej samej klasy biosocjalnej. Granicę między drewnem młodocianym a dojrzałym wyznaczono na podstawie pomiarów długości cewek. W każdym badanym przyroście wykonano po 30 pomiarów długości cewek drewna wczesnego i późnego. We wszystkich doświadczalnych gatunkach drewna cewki drewna wczesnego były krótsze w porównaniu z cewkami drewna późnego. Na podstawie dwusegmentowej regresji liniowej wyznaczono granicę między drewnem młodocianym a dojrzałym, która we wszystkich badanych gatunkach uformowała się w podobnym okresie między 25 a 28 przyrostem rocznym. Porównując dynamikę wzrostu długości analizowanych komórek w drewnie młodocianym stwierdzono, że w sośnie i modrzewiu wymiar ten wzrasta o 80%, natomiast w świerku aż o 130%.

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