Comparison of the Structure of Juvenile and Mature Wood of *Larix decidua* Mill. from Fast-Growing Plantations in Poland

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The main objective of this study was to reveal variations in the wood structure and to define the location of the boundary between juvenile and mature wood *Larix decidua* Mill. from fast growing tree plantations. To reach these findings, the samples of wood from four short-rotation plantations in Central Europe (Poland) were selected and compared. The procedure used to determine the demarcation point between juvenile and mature wood resulted in strong correlations between the width of growth rings and the initial cambial age. It was found that the structure of wood from fast-growing trees differs from commercially available timber. The wood derived from plantations revealed wider annual rings than wood from natural forests. The analysis of the variability of wood structure resulted in defining the location of the boundary between juvenile and mature wood. Based on the analysis of structure of annual rings, the boundary of juvenile wood in fast-growing larch is placed between the 12th and 15th annual ring. The investigated material contained high proportions of juvenile wood, which makes up more than 70% of trunk volume. On the microscopic level, no visible changes, indicating the presence of a mature wood zone, were found.

Keywords: Fast-growing trees; Plantation wood; Larix decidua Mill.; Juvenile wood; Mature wood

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INTRODUCTION

The combination of two factors, *i.e.*, the worldwide intensification of forest harvesting and planting management to meet the demand for wood, and the considerable decrease of wood supply from natural forests over the past few years, has caused plantation forests to steadily increase their position as raw material sources. The development of large-scale plantations and agroforestry systems is important for meeting the demand and reducing wood shortages (Fujiwara and Yang 2000). An expected harvest from tree plantations in Central Europe is as high as 7 to 15 m^3 per ha, while one cycle-time is reduced to 40, even 30 years (20 years for larch); this is the reason why fast-growing trees are the subject of increased interest regarding their high productivity and conveniently distributed plantations. Fast-growing trees harvested at an early age contain a higher proportion of juvenile wood in comparison with currently collected material from natural forests (Nawrot *et al.* 2014). There is no universally accepted definition of juvenile wood, but usually the term juvenile wood is applied by technologists and foresters to wood with relatively wide growth rings and low density that is formed near the pith of the stem. The term is descriptive of the wood rather than indicative of a specific number of years of growth. Juvenile wood is followed by growth with a progressive reduction in ring width, which consists of a more normal, mature type of wood (Benson 1957).

The number of years involved in the change may differ in individual trees, and the changes that occur either in ring width or wood density may be large or small. This suggests that the wood properties of plantation-grown trees, to a large extent, depend on their juvenile wood contents and can thus be manipulated effectively through rotation age. In general, the longer the rotation age is, the lower the juvenile wood content is, and this results in stronger mechanical properties of wood from plantations (Bao *et al.* 2001). According to Bao *et al.* (2001), the amount of juvenile wood content determines the usage possibilities for wood processing. Then, the width of a juvenile wood zone has a considerable influence on the variability of wood properties (Bao *et al.* 2001; Gryc *et al.* 2011; Nawrot *et al.* 2014).

Trees produce juvenile wood at any age (Saranpää 2003). It is found mostly in the central part of the stem and also in the peripheral and upper parts (Panshin and Du Zeeuw 1980; Zobel and Sprague 1998). One of the first definitions of juvenile wood was formulated by Rendle (1959), who stated that juvenile wood is the secondary xylem formed during the early life of a tree. Taking into account anatomical aspect, juvenile wood is characterized by lower density, shorter cell length, lower latewood percentage, thinner cell wall, smaller radial cell dimension, and larger cell lumen. In general, juvenile wood and mature wood are less differentiated in terms of chemical composition than in the anatomical and physico-mechanical properties. Usually, juvenile wood has wider growth rings when compared with mature wood (Yang *et al.* 1986; Helińska-Raczkowska and Fabisiak 1999; Nawrot *et al.* 2014).

The width of the juvenile wood zone is usually quantified by the number of rings. However, there is no unified opinion concerning the number of rings of juvenile wood. According to Abdel-Gadir and Krahmer (1993), the determination of the boundary between juvenile and mature wood is complex and difficult, since anatomical changes take place gradually over a period of several years. The demarcation point between juvenile and mature wood varies in particular species (Bendtsen and Senft 1986), different genotypes (Abdel-Gadir and Krahmer 1993), and is dependent on the geographical origin (Clark and Saucier 1989). Most commonly, the boundary is set at 15 to 20 years in most *Larix* species (Shiokura and Sudo 1984; Keith and Chauret 1988; Zhu *et al.* 2000). However, fundamental knowledge of the wood properties of *Larix* trees grown in short-rotation plantations and their variation under different silvicultural management regimes is limited.

Juvenile and mature wood zones have been distinguished for years, taking into consideration different macrostructure, microstructure, and submicroscopic wood properties as well as its selected physical and mechanical properties. However, it needs to be stressed here that the boundary between these wood zones is not distinct, and different values are assumed within a given species, depending on the applied methods of identification (Cown 1992; Tasissa and Burkhart 1998; Fabisiak 2005; Alteryac *et al.* 2006). Furthermore, Yang *et al.* (1986) claim that the boundary between examined wood types may vary within a single tree as a result of individual differentiation and variations in external factors.

Relative changes in wood properties can be relevant for the forest industry (Tyrväinen 1995). According to Nawrot *et al.* (2014), in contrast to mature wood, juvenile wood is an undesirable element of the stem structures because it has several unfavorable properties that limit its potential applicability. Thus, to better understand the wood properties of plantation-grown trees, it is important to analyze the intrinsic differences in wood properties between juvenile and mature wood (Bao *et al.* 2001).

The main objective of this study was to reveal variations in the wood structure and to define the location of the boundary between juvenile and mature wood of *Larix decidua* Mill. from fast-growing tree plantations. This knowledge is necessary to determine the proportions of juvenile wood. To reach these findings, samples of the investigated wood species from four short-rotation plantations in Central Europe (Poland) were selected and compared. The analysis included criteria such as annual rings and tracheid sizes (length, radial diameter of lumen, and cell wall thickness).

Larch is an economically and traditionally important timber tree in Europe, due to its fast-growing nature, high adaptability, and its durable wood. This species is considered to be the future of the plantation of fast-growing trees (Ritchie 1991). Due to the shortage of wood in the European market as the raw material for particleboards and fibreboards industry and the increasing demand of the world economy on wood, an extensive research on harvesting wood from fast-growing trees plantations should be conducted (Keegan *et al*. 1992; Pilate *et al*. 1999; Johansson 2013). One of the possibilities to reduce the shortage of raw material could be wood production outside of forest ecosystems, mainly in plantations of fast-growing species such as larch.

EXPERIMENTAL

Materials

The research was performed on material from dominant larch trees (*Larix decidua* Mill.) in selected fast growing tree plantations located in Poland managed by The State Forests National Forest Holding. The experimental plantations for this research were in four distinct localisations:

- Jastrzębiec, located at 53°21′14"N 17°35′53"E,
- Wąkop, located at 53°28'00"N 19°20'48"E,
- Studzianki Pancerne, located at 51°42'01"N 21°21'14"E,
- Napromek, located at 53°30'26"N 19°51'23"E.

All four plots were located at an elevation range of 173 to 300 m a.s.l.. The plots were geographically close to each other (less than 250 km). The basic information for each planting site is summarized in Table 1.

During the stage of selecting the plantations, two groups of plantations were included: single-species plantations, where larch is 100% of the species composition of the first floor; and mixed plantations, where the share of larch is 50 to 90%. Among all plantations of fast-growing trees of European larch, plantations with a short production cycle were chosen. The analysis of available timber from plantations of fast-growing trees in the State Forests base has led to the use of another selection criterion – the type of forest habitat. For the larch plantations, the habitat types of forest such as fresh mixed coniferous forest, fresh mixed broadleaved forest, as well as fresh broadleaved forest are assumed as optimal. Therefore the decision for plantation growing in fresh mixed broadleaved forest and fresh broadleaved forest was made. The trees for the research were harvested in May of 2014. Obtained samples were left for drying for a period of six months.

Table 1. Main Information for the Planting Sites

Planting sites*	Tested trees number	Age of harvesting (years)	Trees diameter at breast height** (cm)	Temperature (°C)			Annual precipitation (mm)	Soil texture	Habitat type of forest
				Min	Mean	Max			
A	3	22	19.2	-32.0	8.6	37.9	5862	Silt-clay to clay-loam	Fresh broadleaved forest
B	3	21	16.9						Fresh mixed broadleaved forest
C	3	25	17.3						Fresh mixed broadleaved forest
D	3	21	19.0						Fresh broadleaved forest

* Planting sites: A - Jastrzębiec, B - Wąkop, C - Studzianki Pancerne, D - Napromek
** Average from plantation

All the trees selected for the research were straight with uniform crowns, and they were free from lean and visible defects. The tests were made on the disc-shape wood slices. Based on the research of Zhu *et al.* (2000) and Gryc *et al.* (2011), the discs were cut from the tree trunk at level breast height (1.3 m above the ground). The trees were aged 21 to 25 years. Before anatomical measurements, the discs were left at room temperature to dry to up to 12% of moisture content. After seasoning, transverse cross-sections of discs were sanded to make the wood structure more visible.

Methods

Based on the literature (Yang *et al.* 1986; Helińska-Raczkowska and Fabisiak 1999; Nawrot *et al.* 2014), the boundary between juvenile and mature wood was determined using the criterion of the width of annuals rings and latewood proportion in annual rings. Furthermore, based on previous studies (Yang *et al.* 1986; Bao *et al.* 2001), the differences in anatomical structure, especially the differences in structural elements' size, tracheid wall thickness, and the radial lumen diameter in earlywood and latewood, were also taken into account as additional criteria.

Annual rings were analyzed from wood discs. The analysis of the annual growth rings was performed using the WINDENDRO^{TM} (Ver. 2002a, Regent Instruments Inc., Quebec, Canada) – semi-automatic image-analysis software, and a high definition optical scanner to measure tree rings width and density variables (based on Campbell *et al.* 2011). WINDENDRO^{TM} is an image analysis system for tree-rings analysis. The width of annual rings, the width of earlywood and latewood, and latewood proportions were determined. For ring-width measurements, sanded discs were scanned (600 dpi resolution), and the images were saved as TIFF (tagged information file format) files. The WINDENDRO^{TM} software measures the selected tree-ring parameters using a line of sensors traced along the imported image profile. The measurement paths were selected in order to detect each ring boundary at right angles (four measurement paths were appointed for each wooden disc).

Anatomical structure was analyzed with the wood images observed using an Olympus BX40 light microscope (Olympus Corporation, Tokio, Japan), which was equipped with a camera connected to the computer software Cell B, which allows for the analysis of the dimensions of the structural elements. Cell B is a basic image-acquisition and archiving software for various microscopy applications. During microscopic measurements, radial locations based on cambial age were analyzed (Luostarinen 2012). The studied radial parts were as follows: from the pith to the 2nd annual rings, 3rd to 4th annual rings, 5th to 7th annual rings, 8th to 12th annual rings, and from the 13th annual ring on. The sample size was approximately 5 x 5 x 10 mm^3 (dimensions along radial, tangential, and axial directions). For each tree, approximately 40 samples were obtained.

Before microscopic measurements, wood specimens were soaked for three months in a mixture of water, glycerol, and 96% ethanol to soften the wooden tissue (volume ratio 1:1:1) (Luostarinen 2012). A sledge microtome (Reichert, Vienna, Austria) was used to cut samples in slices of 10- to 30-µm thickness each. Microscopic preparations were stained with 5% safranin solution in ethyl alcohol (96%). Anatomical parameters were measured using an image transverse and radial cross section (Fig. 1). At least 60 measurements were performed for each sample per parameter.

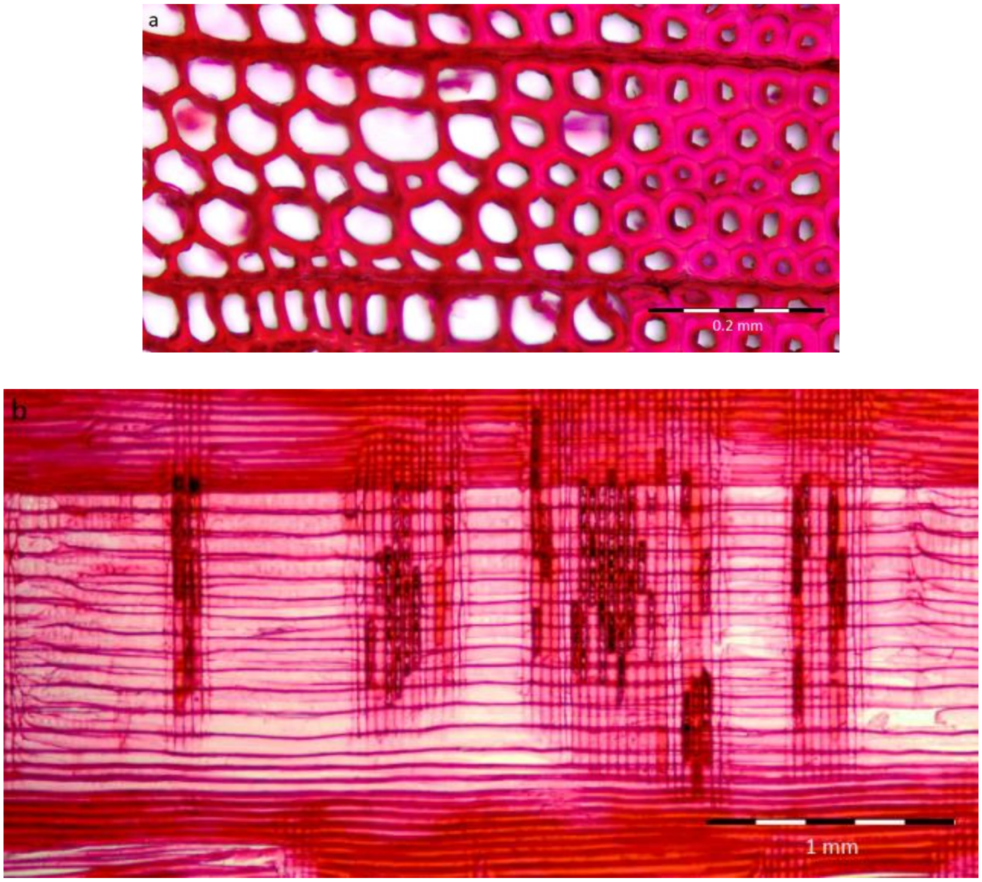

Fig. 1. Microscopic images: (a) transverse cross section (measuring of cell wall thickness and lumen diameter); (b) radial cross section (measuring of tracheid length)

Statistical analysis of the results was carried out using Statistica v. 10 software (StatSoft, Inc., Tulsa, OK). Data were analyzed and provided as the mean ± standard deviation, the median, scatterplot of results around the median, and minimum and maximum values. To evaluate the relationship of the measured properties and to compare different series, one-way analyses of variance (ANOVA) was used (α=0.05 significance level). When an analyzed factor (*e.g.*, cambial initial age) was found to be significant in the ANOVA, a *post hoc* Tukey's HSD test was used to determine which groups were significantly (α = 0.05) different (pair-wise comparisons made between different radial locations).

RESULTS AND DISCUSSION

Radial Development of Width of Annuals Rings and of Latewood Proportion in Annual Rings

Examination of the width of annual rings showed that all wood specimens from plantations displayed similar tendencies in the radial direction. The ring-width profiles were constructed using the width of annual rings from pith to bark against the corresponding ring number. Radial profiles of ring width provide the opportunity to observe the growth of a tree over the time.

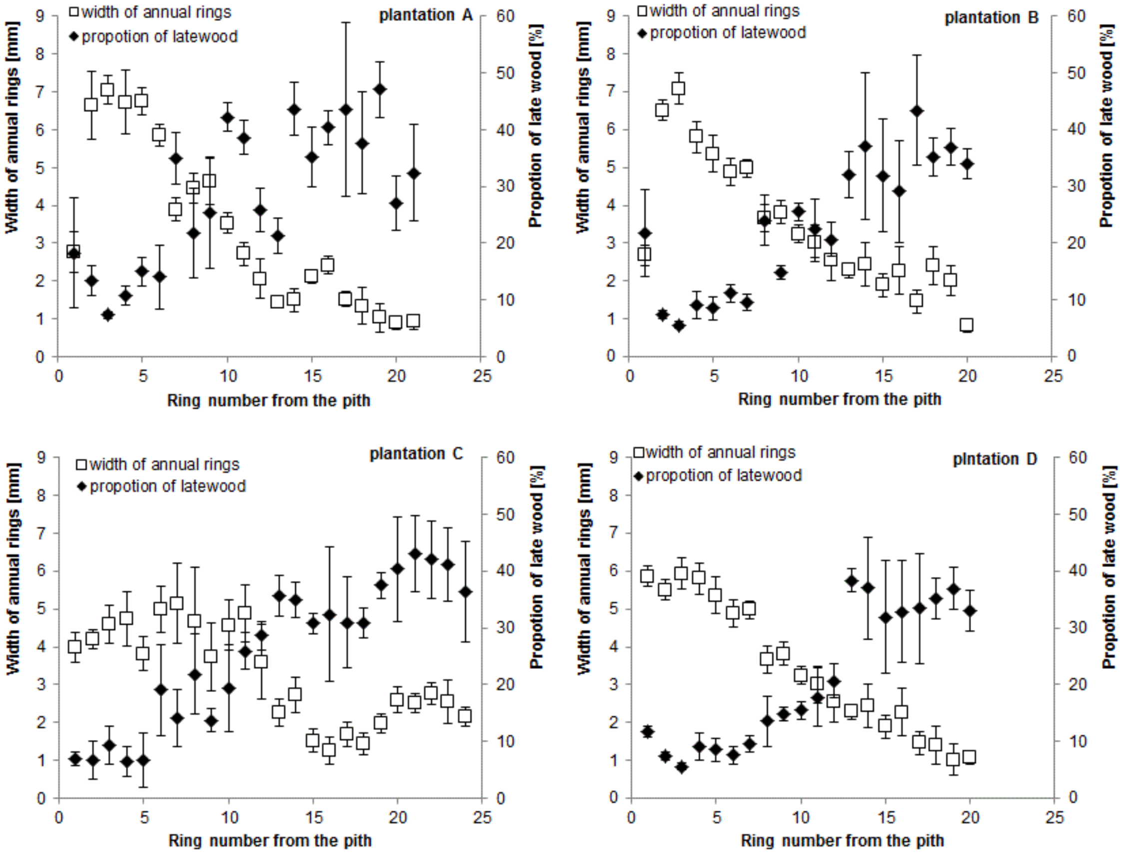

Fig. 2. The average width of annual rings and the contribution of latewood in *Larix decidua* Mill. wood from different Polish plantations

The tested material was free of false rings and compression wood. As can be seen in Fig. 2, the annual rings near the pith were relatively wide and decreased rapidly in width during the early years of growth. They levelled off after approximately 12 years of growth. In contrast, the percentages of latewood were lower near the pith.

The age at which the proportion of latewood in annual rings became constant was between 12 and 15 years. Depending on tree plantation, significantly different groups of average latewood content were found between the pith and 15th annual rings (Tukey's HSD test was used at an α level of 0.05).

Whether it was ring width, or percentage of latewood, the interval between the 12th and 15th annual ring seemed to be an important point during the growth process of *Larix decidua* Mill. from fast-growing trees plantations. Therefore, it seems reasonable to consider this area as the boundary of juvenile and mature wood. Such a zone width of juvenile wood of larch confirms the results reported by Zhu *et al.* (2000). Usually, the age of demarcation point between juvenile and mature wood is considered to be the age at which the ring width stays constant (Tasissa and Burkhart 1998). Using growth-ring width as criteria for determining the boundary of juvenile wood and mature wood, this indicated that juvenile wood covered approximately 12 to 15 annual rings.

The width of the growth rings is strongly correlated with the cambial initial age, as shown in Fig. 2. Correlation coefficients above -0.7577 were determined for all the tested samples. The P-value from the ANOVA was below 0.05, indicating a statistically significant relationship between the width of annual rings and the cambial initial age, as well as between the latewood proportion and cambial initial age. In the case of latewood content, a strong positive linear correlation with the cambial initial age was found. R^2 coefficients above 0.7225 were determined for all the tested series. The P-value from the ANOVA was below 0.05.

The width of first annual rings was close to 7 mm. In each of the tested larch populations, wood was characterized by very high homogeneity of annual rings within the mature wood zone. The width of annual rings in the mature wood zone was 2 to 3 mm. For the analyzed wood samples, we found annual growth rings much wider than those in the wood commercially available in the current domestic market. Gryc *et al.* (2011) reported for European larch from Czech Republic, the width of annual growth rings at the level of 2.42 mm (mature wood) to 4.89 mm (juvenile wood). According to Bijak (2013), typical European larch wood from Poland is characterized by the width of annual growth rings at the level of 3.12 mm (no distinction between juvenile and mature wood was given). Similarly, as in the case of the present study, much wider growth rings were reported by Fabisiak and Moliński (2007a,b) during testing of European larch wood from plantation culture, even 12 mm in juvenile wood zone, and up to 4 mm in mature wood zone. Therefore, taking into account the width of annual rings and determined boundary between juvenile wood and mature wood, it can be noted that juvenile wood in tested *Larix* trees (harvested at the age of 21 to 25) makes up approximately 70% (average for all tested trees). It renders a core diameter of 13 to 17 cm.

Radial Development of Structural Element Sizes

During the research, the differences in anatomical structure (especially the differences in the size of the structural elements, the tracheid wall thickness, and the lumen diameter in earlywood and latewood) were examined. Table 2 lists values of anatomical parameters measured for early and latewood in the 4 plantation-grown *Larix* *decidua* Mill. According to one-way ANOVA test results, there were no significant differences between wood parameters from the plantations when tracheid length, lumen diameters, and cell wall thickness were compared within radial locations based on the cambial age. The P-value was below 0.01. Therefore, regardless of the plantation, larch wood revealed the presence of similar structural elements.

Table 2. Anatomical Parameters Measured for Earlywood and Latewood in Four Plantation-Grown *Larix decidua* Mill. Trees (Standard deviation is given in parentheses) and One-Way ANOVA Results

Cambial age group		Tracheid length (mm)				Radial lumen diameter (µm)				Cell wall thickness (µm)			
		Plantation											
		A	B	C	D	A	B	C	D	A	B	C	D
Earlywood													
0-2		2.42 (0.30)	2.49 (0.29)	2.56 (0.27)	2.56 (0.37)	24.45 (4.63)	32.16 (5.16)	34.18 (5.75)	33.23 (5.26)	2.13 (0.38)	2.21 (0.49)	2.33 (0.56)	2.34 (0.70)
3-4		2.47 (0.32)	2.43 (0.32)	2.38 (0.32)	2.59 (0.40)	31.25 (4.71)	37.27 (7.13)	40.91 (5.92)	41.86 (8.86)	2.26 (0.52)	2.53 (0.62)	2.69 (0.45)	4.86 (1.40)
5-7		2.52 (0.34)	2.67 (0.40)	2.81 (0.46)	2.87 (0.27)	34.79 (6.11)	39.54 (6.99)	41.27 (6.14)	47.83 (9.25)	2.49 (0.63)	3.07 (0.89)	2.78 (0.81)	5.23 (1.23)
8-12		2.66 (0.47)	2.64 (0.37)	2.62 (0.22)	2.78 (0.46)	46.61 (9.15)	45.12 (7.25)	42.64 (7.51)	64.67 (9.30)	2.61 (0.69)	2.88 (0.87)	2.13 (0.36)	3.34 (0.99)
13-		2.67 (0.31)	2.75 (0.30)	2.72 (0.29)	2.71 (0.27)	47.06 (7.22)	49.00 (8.01)	48.76 (6.84)	53.47 (8.94)	3.24 (0.87)	3.04 (0.80)	2.33 (0.38)	3.49 (1.17)
ANOVA	F-value	15.21				64.77				20.15			
	Sig. level	P<0.01				P<0.01				P<0.01			
Latewood													
0-2		2.57 (0.31)	2.52 (0.27)	2.46 (0.18)	2.72 (0.34)	10.56 (5.56	8.28 (2.74	6.92 (1.05)	7.16 (2.13)	3.73 (0.91)	4.71 (0.82)	5.01 (0.89)	4.43 (0.60)
3-4		2.73 (0.28)	2.60 (0.25)	2.46 (0.17)	2.76 (0.45)	7.96 (2.55)	6.28 (1.99)	6.29 (2.52)	5.90 (1.95)	4.30 (1.20)	5.99 (1.03)	6.57 (1.90)	5.89 (1.57)
5-7		2.77 (0.29)	2.72 (0.25)	2.66 (0.19)	2.82 (0.34)	6.94 (2.57)	7.45 (2.67)	8.11 (2.58)	9.86 (2.25)	7.56 (1.58)	7.42 (1.54)	7.21 (1.13)	7.80 (1.65)
8-12		2.99 (0.31)	2.90 (0.35)	2.83 (0.34)	2.99 (0.44)	7.43 (2.38)	7.59 (2.42)	4.96 (1.71)	4.75 (1.70)	8.48 (1.26)	8.69 (1.42)	7.47 (1.35)	8.94 (1.73)
13-		3.16 (0.31)	3.10 (0.35)	3.07 (0.36)	3.01 (0.28)	4.49 (2.17)	5.15 (1.14)	5.02 (1.38)	5.72 (2.11)	10.20 (2.16)	9.83 (1.90)	8.18 (2.01)	10.57 (2.35)
ANOVA	F-value	22.18				78.26				6.64			
	Sig. level	P<0.01				P<0.01				P<0.01			

A, B, C, D - plantation according to Table 1

Some of the tracheid's parameters were found to be correlated with the cambial initial age. Correlation coefficients above 0.8185 were determined for tracheid length, radial diameter of lumen, and earlywood cell wall thickness. The results are presented in Fig. 3. The diameter of tracheid lumen in latewood did not vary along the radial direction. The Tukey HSD test did not indicate significant differences among the determined values (element's size) within the tested years of growth.

Based on previous studies, it can be seen that the tested larch wood samples from the plantations in Poland exhibited features typical for wood from natural forests from this climate zone. The average length of tracheid ranges from 2.4 to 2.8 mm and from 2.4 to 3.0 mm for earlywood and latewood, respectively. Similar tracheid length was reported by other researchers (*i.e.* Galewski and Korzeniowski 1958; Wagenführ 2007; Farsi and Kiaei 2014).

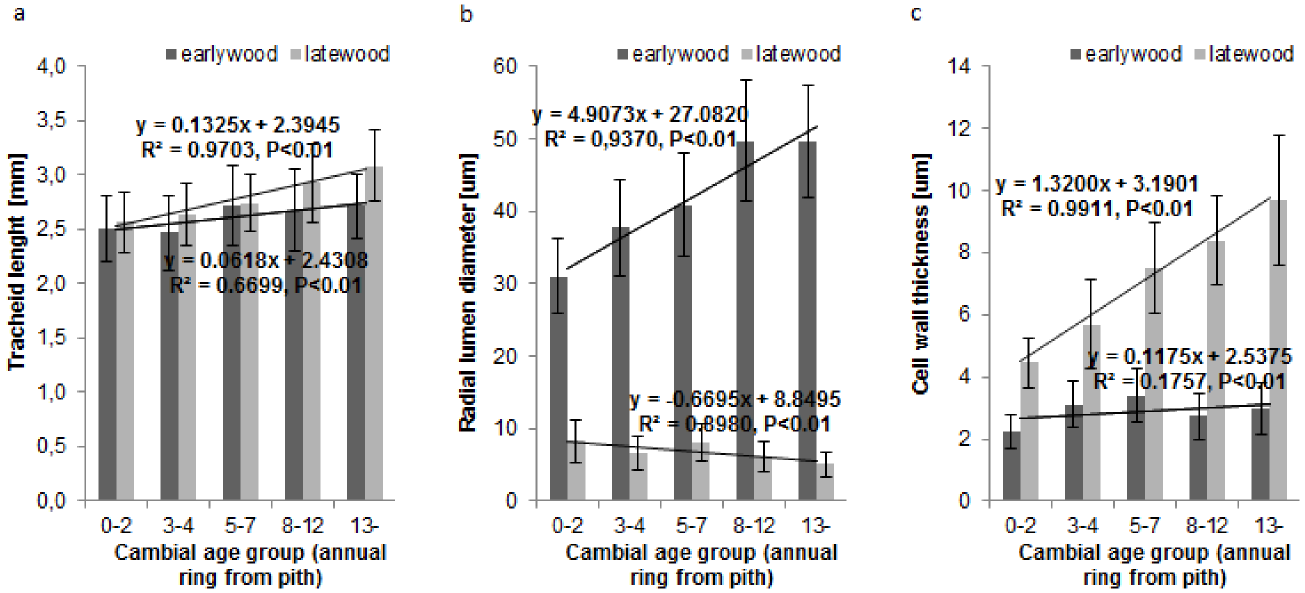

Fig. 3. The combined results of measurements of structural element size of *Larix decidua* Mill. wood from different plantations in Poland: (a) length of tracheid; (b) radial diameter of lumen; (c) cell wall thickness (y - variable correlation equation, R^2 - coefficient of determination, P - significance level)

As illustrated in Fig. 3., regardless of the plantation, tracheids in earlywood were observed to be shorter than those in latewood. Moreover, in this study, the radial diameter of the lumen in earlywood (31.2 to 48.4 µm) was noticeably different from that in latewood (4.3 to 10.7 µm) for cultivated fast-growing *Larix decidua* Mill. The tracheid diameter of *Larix decidua* Mill. has previously been reported to range from 35.5 to 55.0 µm in earlywood and 4.6 to 51.4 µm in latewood (Wagenführ 2007; Farsi and Kiaei 2014), and these values are close to those presented in this study.

The cell wall thickness in tracheids varied from 2.2 to 3.0 µm in earlywood and 4.4 to 9.7 in latewood. These values are higher than those reported in literature for *Larix decidua* Mill., but they are similar to the size of the tracheid of *Pinus sylvestris* L. (Farsi and Kiaei 2014). This knowledge is important from technological point of view in the context of the wood-based panel industry in Europe because pine wood is the main raw material.

According to Abdel-Gadir and Krahmer (1993) and Fabisiak (2005), determination of the boundary between juvenile and mature wood is complex and difficult. Fabisiak (2005) reported that identification of juvenile wood at the cross-sectioned stem was difficult, particularly in coniferous trees, because of the presence of transition traits between juvenile and mature wood. Because of that, as shown in previous studies on *Pinus taeda* L. wood (Abdel-Gadir and Krahmer 1993), it is not possible to find the exact locus of this boundary. Based on analysis of density, static bending, and compression along the grain, Bendtsen and Senft (1986) determined the juvenile period to be 12 years; on the basis of tracheid length, it was identified as 18 years; while in the case of the cellulose fibril angle, it was established at 30 years. Therefore, no distinction between juvenile and mature wood can be indicated based on the structural element size because observed changes in the tracheid length, lumen diameter, and cell wall thickness were very small. Probably, it is necessary to conduct research on 10- to 20-year-older trees to find changes in wood anatomical structure indicating the boundary between juvenile and mature wood at the anatomical level. However, it must be emphasized that the investigated material is dedicated to the wood-based panel industry, so that the raw material derived from short-rotations plantations is equally valuable.

Analysis of Amount of Juvenile Wood

Taking into account growth ring width as a criterion for determining the boundary between juvenile and mature wood, it has been indicated that juvenile wood covered approximately 12 to 15 annual rings. These observations are consistent with earlier published data (Fabisiak 2005), where the juvenile wood zone in *Larix decidua* Mill. from the experimental Forestry Station in Poland comprised the first 10 annual rings counted from the pith.

A similar number of annual rings of juvenile wood was determined based on the analyses of basic density in a study by Tasissa and Burkhart (1998) in stems of taeda pine (*Pinus taeda* L.). Juvenile wood on the basis of tracheid length was also distinguished by Fabisiak (2005). The author established the boundary age in 35-year-old dominant larch trees at 20 years, in medium trees at 15 years, and in intermediate trees at 12 years. The observed radial variation for width of annuals rings and latewood proportion in annual rings led to distinct boundaries between juvenile and mature wood. Regarding the size of structural elements of *Larix decidua* Mill. from Polish plantations, no distinction between juvenile and mature wood can be indicated.

The important information is the determined boundary between juvenile and mature wood. Larch wood from fast-growing trees harvested in short rotations contained a high proportion of juvenile wood; taking into account wide annual increments, it makes up approximately 70% of trunk volume (core diameter 13.0 to 17.0 cm). It is expected that a high content of juvenile wood will have an influence on the material properties and will determine the possibility of use in wood processing.

CONCLUSIONS

1. For the examined trees, *Larix decidua* Mill. from Polish fast-growing tree plantations, the procedure used to determine the point between juvenile and mature wood resulted in strong correlations of the width of growth rings and the initial cambial age.
2. The investigated larch wood samples from the Polish plantations are characterized by typical features of wood from natural forests. Moreover, it was found that the structure of wood from fast-growing trees differs from commercially available timber.

3. The wood derived from four plantations in Poland revealed wider annual rings when compared with wood from natural forests.
4. The analysis of the variability of wood structure resulted in defining the location of the boundary between juvenile and mature wood. It was concluded from the analysis of the structure of the annual rings (width, latewood proportion) that the boundary of juvenile wood in fast-growing larch is located between the 12th and 15th annual rings.
5. On a microscopic level (after analysis tracheid's length, radial diameter of lumen and cell wall thickness), there were no visible changes indicating the presence of a mature wood zone.
6. Knowledge in this area is important from a technological and economical point of view, especially with respect to the wood-based panel industry. The larch wood from fast-growing plantations contained high proportions of juvenile wood, making up more than 70% of trunk volume. The influence of juvenile wood on material properties and on wood processing will be examined in future research.

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