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The effect of annual ring width on density of axial resin canals in pine wood (*Pinus sylvestris* L.)

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Abstract: Relation between number of axial resin canals at the cross stem section and the width of annual rings were studied. The trees were selected from different age classes (IV, V and VI), harvested from the same stand. Experimental trees were characterised by a varied width of annual rings, ranging from 7.2 mm to 0.2 mm. In this study it was determine the surface number of resin canals (no. of canals/cm^2). The mean density of axial resin canals, for a given tree, ranges from 48 to 73. However, within a single tree it was much higher, since it ranged from 20 to 140 and depended on the total width of annual rings.

Keywords: pine wood, annual rings width, density of occurrence of axial resin canals

INTRODUCTION

Increment in diameter in trees occurs thanks to the cell division in cambium, repeated periodically in the vegetation period and the formation of annual rings. The width of annual rings is determined by numerous external and internal factors. Internal factors may include genetic predispositions, physiological singularities and the activity of cambium (Wodzicki, Zajączkowski 1983). External factors affecting the fluctuations in annual rings include first of all the climate (temperature, precipitation, light) and site factors (soil, nutrition, position of the tree in the stand) (Hejnowicz 2002).

In case of coniferous species the formation of growth rings consists first of all in the differentiation of cells in early and late wood (axial tracheids - early and late, ray tracheids, parenchyma cells in wood rays). Resin canals are permanent components of wood in certain coniferous species (*Pinus, Picea, Pseudotsuga* and *Larix*). In *Abies, Cedrus* and *Tsuga* they are formed as a consequence of wounding and are referred to as traumatic resin canals. Resin canals are divided into axial and radial and they are found simultaneously in wood of the same trees, forming a uniform system of resin canals. Traumatic (secondary) canals are exceptions in this respect, belonging usually to the axial system (Zimmermann, Brown 1981).

Resin substances have a paramount effect on wood colour, natural durability and toxicity. The above mentioned substances, particularly when found in a raw material in greater amounts, prevent depreciation during storage, delaying the development of destructive fungi, other microorganisms and insects. These substances pose technological problems during wood pulping into fibrous substances. Resin substances hinder impregnation of chips, i.e. the process of delignification. They also influence the consumption of chemicals used during wood pulping (Libby 1992). Their primary components include resin acids (terpenoids), terpenes, fats, lignans, and they may be extracted from wood by certain solvents (ethanol, acetone, etc.). They are the so-called extractive compounds, found at amounts ranging from 2 to 10%, while in tropical species at 20-25%. They are formed inside epithelial cells, they fill the resin canals and to a greater or lesser extent saturate cell walls. The amount of extractives affects the fluctuations in certain physical properties, such as e.g. equilibrium moisture content, fibre saturation point and the degree of wood swelling. It was found that species with a high content of extractives exhibit lower values of boundary moisture content of cell walls, which shows that these substances serve the role of fillers of empty spaces in the cell walls, thus preventing the penetration of water into these spaces (Boiciuc and Petrician 1970). Extractive compounds also have an effect on the course of sorption isotherms, particularly in the range of relative humidity from approx. 60 -70 % to 100%. Equilibrium moisture content is dependent on the volume occupied by extractives and it is always higher in case of extracted wood (Mantanis et al. 1994, Wangaard and Granados 1967).

Studies conducted on the presence of resin substance in wood have been discussed in many research publications. They concerned mainly the effect of different factors on the yield of resin (Antkowiak 1996, Walker 2006). Those studies were limited to the circumference zone comprising approx. 10 annual rings. In contrast, there is no detailed information on the number of axial resin canals at the cross stem section, depending on the width of annual rings. Such knowledge is essential for the determination of suitability of wood for specific applications.

METHODS

Analyses were conducted on two trees each from different age classes (IV, V and VI), harvested from the same stand. The trees were selected carefully to ensure that they did not have visible defects or damage, had a straight stem and no signs of resin blaze. An experimental disc was collected at breast height from each tree. Analyses were conducted on slats cut from discs along the north ray. Characteristics of experimental trees are presented in Table 1. Prior to measurements slats were smoothed using a microtome knife and determinations were performed accurate to 0.01 mm using an electronic increment meter coupled with a computer. In this study it was decided to determine the surface number of resin canals (no. of canals/cm^2). For this purpose an eyepiece grid micrometer with a 100 mm^2 field of vision was used. Measurements were performed using an image analyser and a Motic Mot 2000 computer programme. On each experimental slat the number of axial resin canals was determined on the surface of individual annual rings in the field with the height of the side of the eyepiece micrometer square and next it was referred to the area of 1 cm^2.

Table 1. Characteristics of experimental pine trees (*Pinus sylvestris* L.)

Tree characteristics	Tree number					
	I	II	III	IV	V	VI
Tree age (years)$^{*)}$	65	66	83	90	101	112
Breast height diameter in the bark (cm)	45	41	41	28	32	51
Number of rings in heartwood	51	39	38	43	51	47
Number of rings in sapwood	14	27	45	47	50	65

$^{*)}$ The number of growth rings on butt-end cross-section

RESULTS

Analysed trees were characterised by a varied width of annual rings, ranging from 7.2 mm (tree III) to 0.2 mm (tree VI). The range of this value over the length of a ray within a single tree varied from 2.5 mm in tree IV to 7.1 mm in tree III. Statistical characteristics of analysed properties are presented in Table 2.

The performed analysis of variance ANOVA for mean widths of annual increments in 5-year increment zones of the experimental trees showed that they are significant. The value of the calculated test statistics was 3.408, while the critical value $F_{(22;83;0.01)} = 0.409$ (Fig. 1).

Table 2. Statistical characteristics of mean annual rings in pine wood

Tree number	Cambial age of annual rings (years)	Statistical parameters						
		Value			Range	Standard deviation	Standard error	Coefficient variation
		mean	min	max				
		mm						%
I	65	3.41	1.10	6.51	5.41	1.3207	0.1638	38.7
II	66	3.06	1.08	4.77	3.69	0.9610	0.1183	31.4
III	83	2.22	0.23	7.24	7.01	1.7596	0.1931	79.2
IV	90	1.48	0.48	2.94	2.46	0.5446	0.0574	36.8
V	101	1.51	0.37	5.16	4.79	0.8216	0.0817	54.4
VI	112	2.33	0.20	5.95	5.75	1.4670	0.1386	62.9

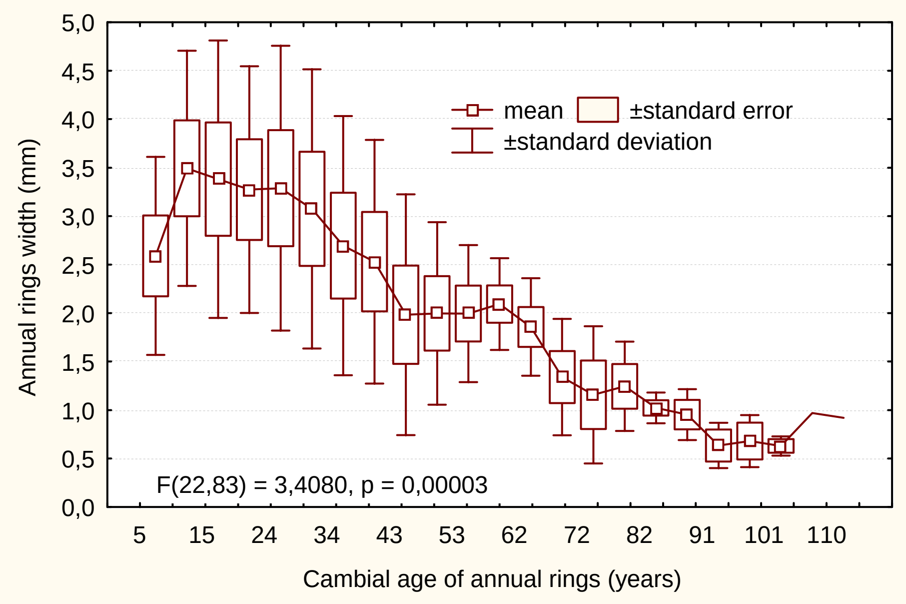

Fig.1. The effect of cambial age on mean width of annual rings in five-year growth ring zones for all trees

Density of axial resin canals in the function of annual ring width is presented in Fig. 2, while statistical characteristics of the analysed values are given in Table 3.

Table 3. Statistical characteristics of density resin canals in transverse section of pine wood

Tree number	Cambial age of annual rings (years)	Statistical parameters						
		Number			Range	Standard deviation	Standard error	Coefficient variation (%)
		mean	min	max				
I	61	50	14	114	100	20.5151	2.6266	41.0
II	66	48	30	65	35	7.6585	0.9427	16.0
III	83	70	22	146	124	27.0357	2.9675	38.6
IV	90	68	11	136	125	25.9809	2.7386	28.9
V	101	73	16	122	106	23.4846	2.3368	32.2
VI	112	63	22	141	119	24.4279	2.3082	38.8

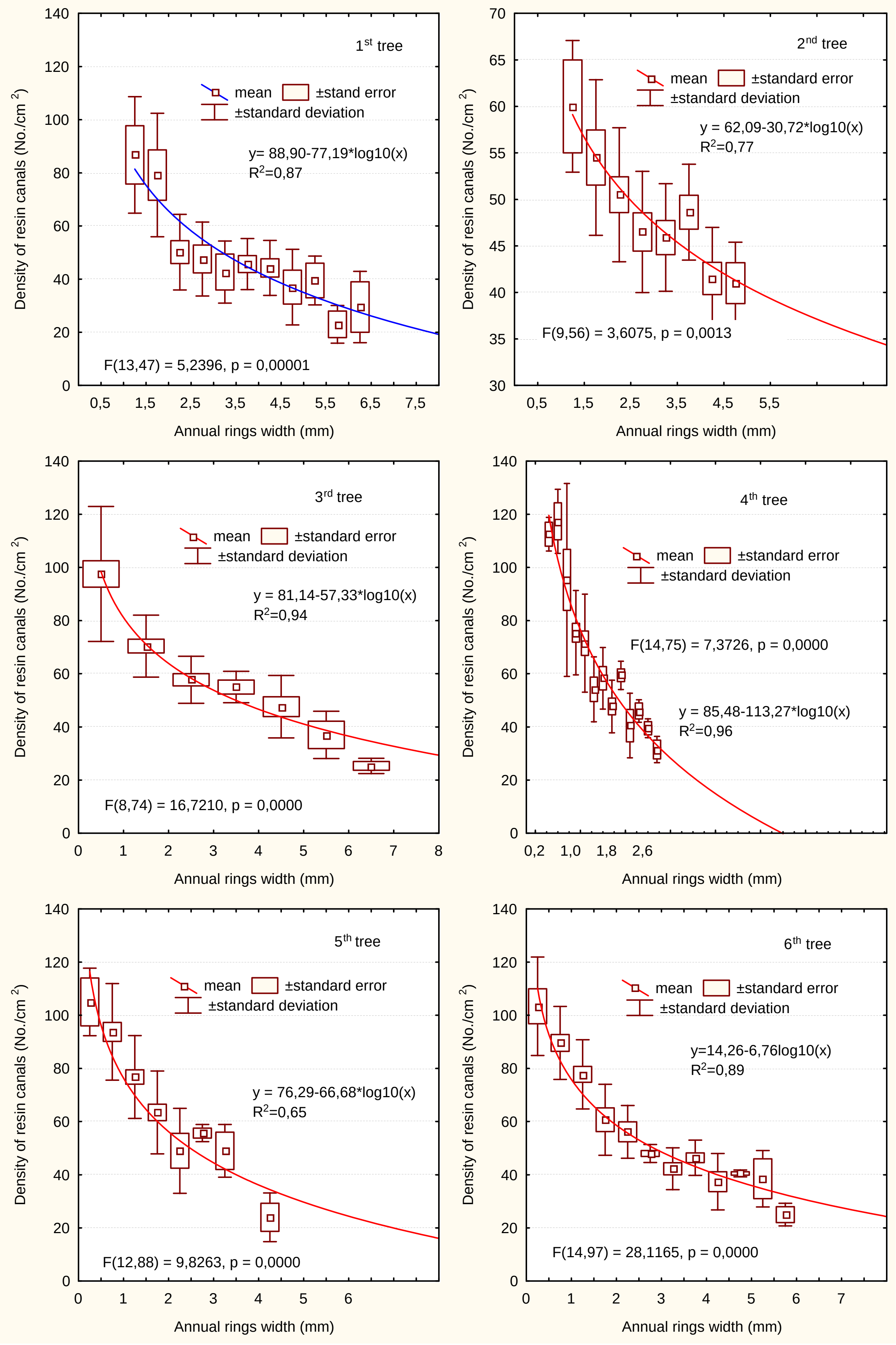

Fig. 2. Relationship between density of resin canals and annual rings width of pine wood

Mean density of resin canals for the analysed trees ranged from 48 to 73. A much higher variation in the analysed property was found within individual trees. The coefficient of variation ranged from 16 to 41%. When analysing the above mentioned dependencies it may be stated that the frequency of occurrence of resin canals fell within a wide range from 11 to 146. The lowest values were found in the increments of 6 - 7 mm in width. Such a wide annual rings were observed in three trees (I , III and VI). It was found that the density of resin canals does not depend on the age class of trees. This dependence was described by an equation y = a lnx +b. Münch (1919) developed a formula used to determine the density of resin canals (d) per 1 cm^2, which takes the form y = 40 + 30/b, (b - the width of an annual ring). Graph 3 was prepared in order to compare the density of occurrence of axial resin canals calculated from all the analysed trees according to Münch's formula and the density determined experimentally.

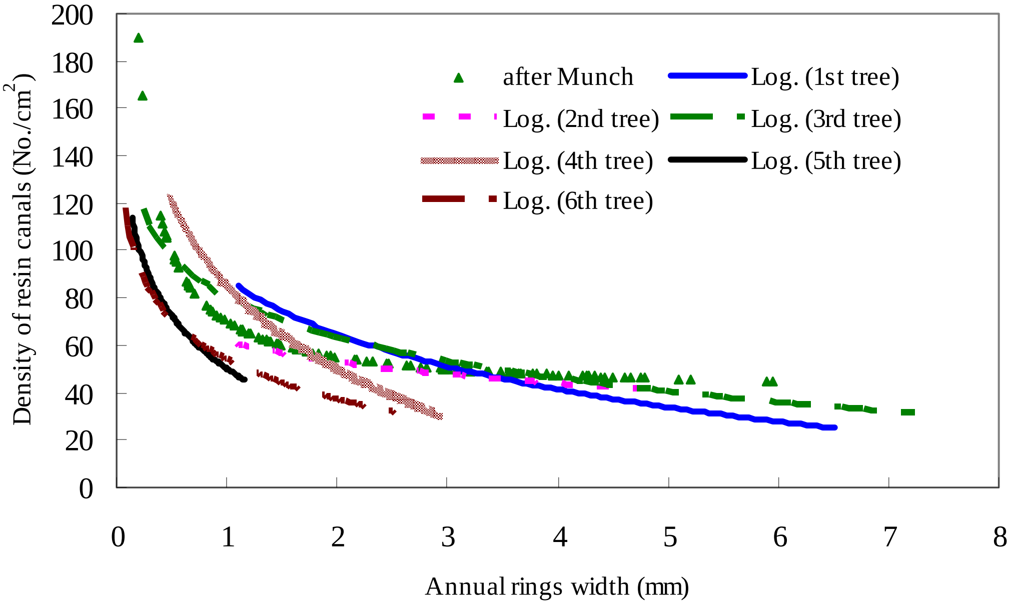

Fig 3. Relationship between density of resin canals and annual rings width in pine wood

It results from the presented dependencies that the narrower the rings are in a tree, the more canals it contains per unit area. Thus it may be stated that all factors affecting the fluctuation in width of annual rings determine the occurrence of axial resin canals.

When analysing the obtained dependencies it may be stated that in rings with the same width a variable density of resin canals is observed in the examined trees and the difference may be as high as approx. 40%. Thus it may be concluded from the above that in some years of tree growth there were conditions conducive of the formation of resin canals. Similar observations were reported by Antkowiak (1996), when investigating the effect of weather conditions, temperature and relative humidity on the formation of resin canals in the circumference zone.

It results from the literature on the subject that the surface number of axial resin canals for Scots pine falls within the range of 50 - 60. However, it needs to be added that studies conducted to date concerned only the circumference zones, covering from several to around a dozen annual rings. In this section of the tree cross-section wood is generally narrow-ringed, thus the such a limited variation in the density of resin canals in that area. In this study this variation is slightly bigger, since analyses were conducted on all annual rings from the pith to the tree circumference.

CONCLUSIONS

1. Analysed experimental trees were characterised by the varied width of annual rings. The mean width over the length of the entire tree ray ranged from 1.48 mm in tree IV to 3.41 mm in tree I.
2. Analysis of variance ANOVA performed for mean widths of annual rings in 5-year increment zones of individual trees showed that these differences are significant at the level of 0.0001.
3. The density of axial resin canals, average for a given tree, ranges from 48 to 73. However, within a single tree it was much higher, since it ranged from 20 to 140 and depended on the total width of annual rings. The density of resin canals decreases with an increase in the width of the annual ring. This dependence may be described by an equation $y = a \ln x + b$.

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Streszczenie: *Wpływ szerokości przyrostów rocznych na gęstość pionowych przewodów żywicznych w drewnie sosny (Pinus sylvestris* L.*).* W pracy przedstawiono wyniki pomiarów gęstości występowania pionowych przewodów żywicznych na przekroju poprzecznym pnia. Drzewa doświadczalne pochodziły z różnych klas wieku i charakteryzowały się zróżnicowaną szerokością przyrostów rocznych. Stwierdzono, że im drewno jest bardziej wąskosłoiste, tym ma więcej przewodów żywicznych na jednostce powierzchni i odwrotnie, w drewnie szerokosłoistym zagęszczenie tych elementów anatomicznych maleje.

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