

**BIOSOCIAL DIVERSITY OF SCOTS PINE
(PINUS SYLVESTRIS L.) IN A TREE STAND
IN RELATION TO CHOSEN HYDRAULIC
CONDUCTIVITY INDICATORS OF THE STEM**

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ABSTRACT

The research focused in determining the lignification indicator of fresh needled springs and the mass of fresh needles in reference to the lignin content in tracheid walls of peripheral area of the stem (MFT/LC and MFN/LC) of Scots pine differentiated as far as its biosocial position within the community expressed by Kraft's classification. The material for the analysis came from mature pine stands growing on North European Plain, on the territory of Poland. Chemical and structural analyses of wood encompassed the area of mature sapwood, i.e. thickness of the last 10 annual rings located at 1.3 m (DBH). It seems that the noticed differences values of both indicators (MFT/LC and MFN/LC) in pines belonging to the first three Kraft's biological classes are connected with physiological, physical and structural conditionings of water transport with minerals in xylem and are closely connected with competition for sunlight, water, nutrients and living space.

KEYWORDS: *Pinus sylvestris* L., mass of fresh needles, lignin content, tracheid walls, sapwood, peripheral area of stem.

INTRODUCTION

Xylogenesis is multistage process, which leads to the formation of xylem. Each of the stages is regulated by a network of correlations based on positive and negative influences of plant growth regulators. Among numerous tree species, phytohormones, particularly auxins and cytokinins, play a significant role in the process (Fajstavr et al. 2018). They affect certain proteins and genes, and force process, which contribute to the formation of various types of xylem, to take place (Goodwin 1978, Shininger 1979, Sudachkova et al. 2012).

Lignin, whose structure in itself is intriguing, is a significant component of lignified walls, and also above all contributes to the stiffness of cell walls. It is an organic polymer whose basic structural elements are derivatives of phenylpropane. A phenylpropane unit consists of a benzene ring composed of six carbon atoms and propane bonds composed in 3 carbon atoms (Fengel and Wegener 1989). The presence of lignin in the walls of the dead conductive cells of the xylem not only protects the wall against collapse at negative pressure while transporting water with minerals but also offers protection against embolism. Lignification of the cell wall provides a general mechanical resistance and stability of the entire plant organism, especially trees (Barnett and Jeronimidis 2003, Boerjan et al. 2003, Üner et al. 2011, Antonova et al. 2014, Kim and Daniel 2014, Tsuyama and Takabe 2014).

Lignin of deciduous trees in comparison with lignin of coniferous trees is characterised by higher percentage of content of methoxy groups and greater ratio of methoxy groups (-OCH₃) to hydroxy groups (-OH) (Fengel and Wegener 1989). In wood, lignin bonds with saccharides and together create lignin-hemicellulose compounds. Chemical bonds: ester, ether, glucosidic, or acetalic (Fengel and Wegener 1989) can occur between these compounds. Furthermore, lignin limits cell wall swelling of anatomical wood elements as well as increases immunity against microorganisms (Austin and Ballaré 2010, Shmulsky and Jones 2011). It also polymerises between polysaccharide components of cell walls and appears after the cell growth or at least a part of a cell wall. Lignin is found in the intercellular layer, primary wall and secondary wall. In dead wood cells such as tracheids, impregnation of the wall with lignin secures the wall polysaccharides against partial hydrolysis (O'Brien 1970). The biosynthesis of lignin was intensively researched over the last few years (Brown 1961, Boerjan et al. 2003, Austin and Ballaré 2010, Antonova et al. 2014). Phylogenetic origin of plants conditions various ratios of the three basic units in lignin, i.e. syringic alcohol, coniferyl alcohol, and p-coumaryl alcohol. Lignin which is present in cell walls of Scots pine wood consists of coniferyl units with some admixture of p-coumarylic and syringic units (de Stevens and Nord 1953). The common precursor for all derivatives of phenylpropane is shikimic acid (Tomaszewski 1964). In Scots pine, shikimic acid appears in small amounts as one of the first products of photosynthesis (Hasegawa 1962). By adding the radioactive shikimic acid to callus tissue culture of *Pinus strobus*, Hasegawa et al. (1960) noticed an effective incorporation of this compound into the lignin. Hasegawa (1962) achieved similar results also in reference to tracheids of the Scots pine.

Considering the role and significance of lignin in the functioning of trees and in the lignification process itself, there has been an attempt to determine the manner of shaping the quotient of mass of fresh needled sprigs and the mass of fresh needles to lignin content in tracheid walls of the peripheral area of the pine stem which represent first three Kraft's classes (I, II, III) which constitute the main tree stand, i.e. predominant trees (I), dominant trees (II) and co-dominant trees (III).

MATERIAL AND METHODS

The research encompassed mature pine stands which had been growing in optimal habitat conditions for this greenwoodogenic species on North European Plain. The sample areas were located over four stands of Scots pine (*Pinus sylvestris* L.) which were within the limits of natural habitats for that particular species in Europe. All the research areas were located in the North of Poland, and the research itself encompassed 36 sample trees, at the ages between 89 and 91. In each tree stand a 1-hectare sample area was established, where the measures of diameter at breast height (DBH) were taken among all pines and simultaneously they were divided into three Kraft's biosocial classes (Kraft 1884). The trees were classified into predominant, dominant and co-dominant categories. In each Kraft's biosocial class, the trees' heights were measured according to their number in the assumed 2 cm stages of thickness. The measurements of the sample trees were determined on the basis of their thickness class following the dendrometric method (Van Laar and Akça 2007). In each sample area 9 sample trees were selected and felled, hence a total of 36 model trees was harvested. From each sample tree, material for research, i.e. a disc-shaped sample was cut at DBH level (1.3 m). In the next step, for each of the tree, the annual volume was determined, as well as, the mass of fresh needled springs and the mass of fresh needles which was done through direct weighing process. The purpose of the disc was to ascertain the sapwood area (S_a) and the area of earlywood in sapwood (E_{as}).

The material used to mark lignin in tracheid walls was collected from the last 10 thickness increments, i.e. from the sapwood which is physiologically active. The measurements of the sapwood area (S_a) and the area of earlywood was conducted by using increment borer Preisser Digi-Met and a computer programme "Grube Comm". In the sapwood area, the width of earlywood in each annual ring was measured. The areas of earlywood in the peripheral area of the stem (sapwood) was determined as the total area of all annual rings. In addition, the data concerning the mass of fresh needles (N_{mass}) from sample trees and sapwood area (S_a) as well as the area of earlywood in sapwood zone (E_{as}) was used to determine a relative efficiency of conductive surface of the analysed tree samples. This was achieved by dividing sapwood area and the area of earlywood tracheids in the cross-sectional area of the trunk by the mass of fresh needles (Eqs. 1 and 2):

$$S_a/N_{mass} \text{ (mm}^2\cdot\text{kg}^{-1}\text{)} \quad (1)$$

$$E_{as}/N_{mass} \text{ (mm}^2\cdot\text{kg}^{-1}\text{)} \quad (2)$$

The lignin content L_c ($\text{mg}\cdot\text{g}^{-1}$) of dry mass) was marked spectrophotometrically (in three repetitions) following Doster's method (1988). At the first, the wood of the last 10 annual rings was treated with methanol for 48 hours, the adopted ratio was 1 ml of methanol per 1 g of xylem, and next it underwent the drying process. From each variant, i.e. Kraft's class, 20 mg of dry xylem was collected and was mixed with 5 ml of 2 N HCL and 0.5 ml of thioglycolic acid (Sigma-Aldrich). The samples underwent incubation at the temperature of 95°C for over 4 hours, next they were centrifuged at 3000 g for 20 min. The achieved precipitate was washed with deionised water and incubated with 5 ml 0.5 N NaOH over 18 hours in room temperature. After centrifuging at 15000 g, NaOH extraction was collected, and the precipitation was washed with 4 ml of deionised water and centrifuged once more. The obtained supernatant was mixed with NaOH extraction, 1 ml of concentrated HCL was acidified and left overnight at 5°C. The obtained precipitation after centrifuging (15000 g) was dissolved in 5 ml 0.5 N NaOH,

it was centrifuged (15000 g) and the absorbance of the solution was measured at the wavelength of 380 nm using the UV-1202 Shimadzu spectrophotometer. The lignin content was expressed in relative units of absorbance. With the data concerning the mass of fresh needled springs, mass of fresh needles and lignin content in tracheid walls from last ten annual increment thickness from the peripheral area of trunks of chosen pines, it was possible to calculate the quotient of fresh needled springs mass divided by lignin content in tracheid walls as well as the quotient of fresh needles mass to the lignin content in tracheid walls in the last ten annual rings.

The research also determined the mean volume increase of the analysed standing trees by adopting volume tables, prepared in 1908. Moreover, the basic statistical characteristics of the analysed variables and correlations between them were established. The obtained empirical material was analysed by adopting the methods of mathematical statistics by using Statistica 13.0 statistical kit.

RESULTS AND DISCUSSION

The manner of shaping the measures of location and spread of relative conductivity surface (S_a / N_{mass} and E_{sa} / N_{mass}) of pine which represent different biosocial classes were depicted in Tab. 1.

Tab. 1: The characteristics of hydraulic conductivity indicators (S_a / N_{mass} , E_{sa} / N_{mass}) of Scots pine (*Pinus sylvestris* L.) depending on the biosocial position of the tree in the tree stand.

Kraft's class	S_a / N_{mass} (mm ² ·kg ⁻¹)				
	Mean	STD	Min	Max	CV (%)
I	1297.48	295.51	736.97	1668.37	22.78
II	1212.64	428.23	486.17	1983.84	35.31
III	1657.67*	668.06	751.71	3335.65	40.30
Total	1389.26	513.45	486.17	3335.65	36.96

Kraft's class	E_{sa} / N_{mass} (mm ² ·kg ⁻¹)				
	Mean	STD	Min	Max	CV (%)
I	767.26	160.81	510.06	995.92	20.96
II	750.26	295.70	294.43	1327.79	39.41
III	1015.56*	437.30	497.33	2246.90	43.06
Total	844.36	332.92	294.43	2246.90	39.43

*Statistically significant differences at the level of $p < 0.05$.

The relative area of hydraulic conductivity of the stem was expressed by the quotient of sapwood area (S_a) divided by the fresh needles mass (N_{mass}) and the quotient of the earlywood area in sapwood divided by the fresh needles mass (N_{mass}); it was diversified depending on the biosocial position of the tree in the tree stand. In both cases the relative area of hydraulic conductivity of the stem (S_a / N_{mass} and E_{sa} / N_{mass}) in pines which represent the third Kraft's biosocial class, which was statistically significant higher ($p < 0.05$) in comparison to predominant and dominant pines (Tab. 1). The mean of both indicators in the case of co-dominating pines (III Kraft's class) were respectively 1657.67 (mm²·kg⁻¹) (S_a / N_{mass}) and 115.36 (mm²·kg⁻¹) (E_{sa} / N_{mass}); however, in predominant trees it was 1297.48 (mm²·kg⁻¹) (S_a / N_{mass}) and 767.26 (mm²·kg⁻¹) (E_{sa} / N_{mass}) and in dominant pines 1212.64 (mm²·kg⁻¹) (S_a / N_{mass})

and 750.26 ($\text{mm}^2 \cdot \text{kg}^{-1}$) (E_{sa}/N_{mass}). The lowest variability of the S_a/N_{mass} indicator was noticed in pines from Kraft's I class (22.78%) and the highest in tress from Kraft's II class (tab. 1). In the case of the case of the indicator (E_{sa}/N_{mass}) the lowest coefficient of variability was among predominant trees and the highest was among dominant pines (Tab. 1).

Tab. 2: Statistical characteristics of MFT/LC and MFN/LC coefficients in Scots pine (*Pinus sylvestris* L.) depending on the biosocial position of the tree in the tree stand.

MFT/LC ($\text{g} \cdot (\text{mg} \cdot \text{g}^{-1})^{-1}$)					
Kraft's class	Mean	STD	Min	Max	CV (%)
I	226.43*	65.50	122.16	327.83	28.93
II	158.95*	48.64	96.16	253.70	30.60
III	99.64*	36.18	52.73	165.16	36.31
Total	161.67	72.54	52.73	327.83	44.87

MFN/LC ($\text{g} \cdot (\text{mg} \cdot \text{g}^{-1})^{-1}$)					
Kraft's class	Mean	STD	Min	Max	CV (%)
I	147.95*	40.97	83.11	208.46	27.69
II	102.33*	26.55	63.49	146.35	25.95
III	67.73*	23.41	37.92	109.34	34.56
Total	106.00	45.07	37.92	208.46	42.52

*Statistically significant differences at the level of $p < 0.05$.

Statistical characteristics of the quotient of fresh moisture springs mass divided by lignin content in tracheid walls in the peripheral area (MFT/LC) and the quotient of fresh needles mass divided by the lignin content in tracheid walls of the peripheral area of the stem (MFN/LC) was presented in Tab. 2. The lowest mean value ($226.43 \text{ g} \cdot (\text{mg} \cdot \text{g}^{-1})^{-1}$) of the indicator (MFT/LC) was noticed in predominant trees representing I Kraft's class, lower (158.95) in pines from II Kraft's class, and the lowest ($99.64 \text{ g} \cdot (\text{mg} \cdot \text{g}^{-1})^{-1}$) in co-dominant pines (Tab. 2). The variable expressed by the coefficient of variability in the case of (MFT/LC) and the lowest value was noticed in predominant trees (28.93%), in dominant pines (30.60%) and in co-dominant trees (36.31%) (Tab. 2). As far as the quotient of fresh needles mass divided by the lignin content in tracheid wall of ten annual rings of the peripheral area of the stem in concerned, the highest value of the indicator (MFN/LC) was observed in pines from I Kraft's class ($147.95 \text{ g} \cdot (\text{mg} \cdot \text{g}^{-1})^{-1}$), lower ($102.33 \text{ g} \cdot (\text{mg} \cdot \text{g}^{-1})^{-1}$) in trees from II class whereas the lowest ($67.73 \text{ g} \cdot (\text{mg} \cdot \text{g}^{-1})^{-1}$) in co-dominant pines (Tab. 2). The standard variation ranged between $23.40 \text{ g} \cdot (\text{mg} \cdot \text{g}^{-1})^{-1}$ to $40.97 \text{ g} \cdot (\text{mg} \cdot \text{g}^{-1})^{-1}$ (Tab. 2). The coefficient of variability of the described indicators was in the range 25.94% to 34.55% (Tab. 2). The statistical characteristics of the mean increase of the volume in pine trunks which represent the main tree stand, i.e. predominant trees, dominant trees and co-dominant trees have been collected and presented in Tab. 3. The highest value of mean increase of tree volume was noticed in trees from I Kraft's class (predominant trees); however, as the biosocial position progressively deteriorates in the tree stand, the value of mean increment of trees clearly lowers (Tab. 3). The standard deviation and coefficient of variability have also indicated this regularity (Tab. 3). The standard ranged from 0.0009 to 0.0025 whereas the coefficient of variability was from 19.40% to 25.25%.

Tab. 3: Statistical characteristics of the mean increment of the pine stems in each Kraft's biosocial class.

Kraft's class	Mean	STD	Min	Max	CV (%)
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I	0.0098*	0.0025	0.0057	0.0136	25.25
II	0.0069*	0.0015	0.0047	0.0089	21.58
III	0.0048*	0.0009	0.0033	0.0065	19.40
Total	0.0072	0.0027	0.0033	0.0136	37.72*

* Statistically significant differences at the level of $p < 0.05$.

On the basis of the conducted statistical analyses, it was observed that there is a clear relationship between hydraulic conductivity indicators (S_a / N_{mass} and E_{as} / N_{mass}) and the quotient of the mass of fresh needled springs divided by the lignin content in tracheid walls of the peripheral area of the stem (MFT/LC), and the quotient of the fresh needles mass divided by the lignin content in the tracheid walls in the peripheral area (MFN/LC) and the annual increase of stem volume of the trees from the main tree stand. The mean volume increase is a dependent variable whereas the hydraulic conductivity indicators (S_a / N_{mass} and E_{sa} / N_{mass}) and (MFT/LC and MFN/LC) indicators are independent variables.

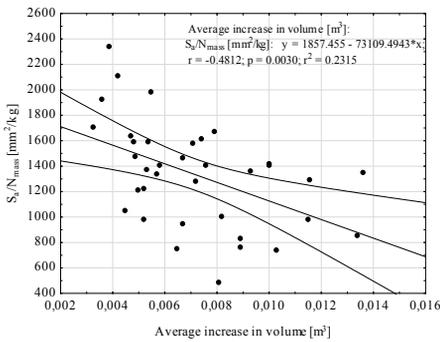


Fig. 1: The mean increase in volume of pine stems in reference to hydraulic conductivity indicator expressed by the quotient S_a / N_{mass} .

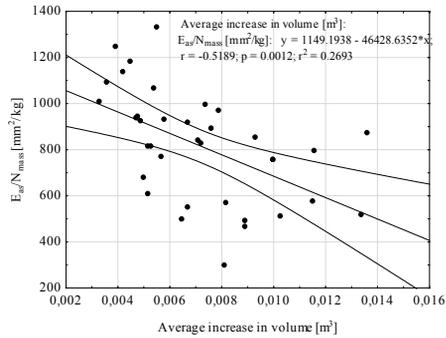


Fig. 2: The mean increase in volume of pine stems in reference to hydraulic conductivity indicator expressed by the quotient E_{as} / N_{mass} .

The mean increase in volume of the pine stems from the sapwood area which referred to the mass of fresh needles (S_a / N_{mass}) correlated negatively. The correlation coefficient assumed the values on the significance level $p < 0.05$ value $r = -0.4812$ (Fig 1). The earlywood area in sapwood was referred to the mass of fresh needles (E_{as} / N_{mass}), and it also assumed values on the level of significance $p < 0.05$ and correlated negatively, and the value of correlation coefficient was $r = -0.5189$ (Fig. 2). The mean increase in volume of pine wood in the main tree stand was conditioned significantly by the MFT/LC and MFN/LC coefficients; as a result, the calculated correlation coefficients were $r = +0.94852$ in the first one and $r = +0.95083$ in the second case (Figs. 3 and 4).

Discussion

In the introduction it was mentioned that xylogenesis is a multistage transformation process which eventually leads to the formation of secondary xylem. Each of the stages is regulated by a network of interdependencies based on positive, or negative, interactions with growth regulators (Fajstavr et al. 2018). Among the entire range of regulators, phytohormones, especially auxins and cytokinins, play a significant role in growth and development processes of plants, including trees. The influence of some proteins and genes by coercing particular transformations to take

place, which in the end leads to formation of (Little and Pharis 1995). Xylem is optimised to various degrees as far as their functions are concerned, such as tree growth conditions and strategies allowing its survival. As a result, the characteristic features of the formed xylem are, among others, a complex chemical composition and anatomical structure which is characteristic for each tree species, from which the physical and mechanical properties of wood as a material, including building and construction material, directly results (Barnett and Jeronimidis 2003, Jelonek et al. 2012). Even within a single species there can be differences in structure and properties of xylem, for instance resulting from the geographical location (Martínez-Vilalta 2009, Fernandes et al. 2016), habitat conditions (Eilmann et al. 2011, Matisons et al. 2019), age or biosocial position within in the stand (Pazdrowski et al. 1993, Nilsson and Albrektson 1993, Mäkinen 1996, Vanninen and Mäkelä 2000, Eriksson 2006). The growth and increase of tree species are determined, to a great extent, by the size of their crown, which provides information about the size of the transpiration and assimilation apparatus. The mass of leaves or needles, including the participation of the lighted and shaded crown, intensiveness of the assimilation process, fertility of the habitat and access to water rich in minerals determine xylem production. The amount of biomass collected in various tissues, organs or tree components is known as allocation (Litton et al. 2007). It is usually expressed mathematically as a share of the biomass of a given fraction (Poorter and Sack 2012, Poorter et al. 2012) or as a ratio of biomass of various components, i.e. above-ground biomass to underground biomass (Poorter and Sack 2012). In Franklin et al. (2012) the five basic theories explaining the biomass allocation process have been distinguished. In forestry, allometric model is widely used, which assumes that the absolute size of the biomass of a single organ is a dimension function of a different one and the relationship is described by power function (Gayon 2000). However, it should be emphasised that allometric relationships do not consider the influence of internal and environmental factors on the biomass allocation including dendromass, which is significantly conditioned by the tree growth factors (Kellomäki 1981, Oleksyn et al. 1999, Poorter et al. 2012).

The article attempts to analyse the process of establishing the relationship between the mass of fresh needled sprigs to the lignin content in the tracheid walls in the last ten annual increment thickness rings of the peripheral area of the stem of mature Scots pine (*P. sylvestris* L.) and the relationship of mass of fresh needles to lignin content in tracheid walls of the peripheral area of trees of various biosocial position in the tree stand. The volume mass flow of water with minerals takes place through conducting elements of the xylem from the roots to the transpiration and assimilation apparatus, the so-called long-distance transport. Moreover, the short-distance transport, inner water evaporation and transpiration takes place from higher water potential to lower water potential. The long-distance transport of water in xylem, which is against gravitation, results from the under pressure created by transpiration and also from overpressure generated by root pressure supported by cohesion and adhesion as well as capillary action (Steudle 2001).

The growth and tree increment, including wood production, are determined by preserving the equilibrium between the conducting surface of the stem and the surface of transpiration and the assimilation apparatus in specific (optimal) habitat conditions. The issue, in the work, was expressed by hydraulic conductivity indicator which was expressed by the quotient of the sapwood area and the earlywood tracheid area in sapwood divided by the mass of fresh needles of pines S_a / N_{mass} ($\text{mm}^2\cdot\text{kg}^{-1}$), E_{as}/N_{mass} ($\text{mm}^2\cdot\text{kg}^{-1}$) representing the main tree stand (predominant, dominant and co-dominant trees).

The obtained results indicate a clear differentiation of the relative conductive area S_a / N_{mass} ($\text{mm}^2\cdot\text{kg}^{-1}$) E_{as}/N_{mass} ($\text{mm}^2\cdot\text{kg}^{-1}$) in Scots pine (*P. sylvestris* L.) depending from

their biosocial position in the stand. The trees representing Kraft's III class (co-dominant) in both cases indicated the highest value of analysed indicators, however pre-dominating pines (Kraft's I class) and dominating ones (Kraft's II class) had definitely lower values. It means that in the trees from Kraft's III class, for 1kg of fresh needles falls unequivocally the largest conductive area of sapwood (1491.00 mm^2) and the conductive area of tracheid in earlywood in sapwood ($932,22 \text{ mm}^2$) than in predominating and dominating pines. In the former ones, the values of the discussed indicators were respectively (1297.48 mm^2) and (767.26 mm^2) and in the latter ones (1212.64 mm^2) and (750.26 mm^2). The matter can be explained with Pipe Model Theory as described by Shinozaki et al. (1964a,b), which holds that in a physiologically healthy tree the optimisation of the xylem's conductive surface is closely correlated with the size and efficiency of the assimilation and transpiration apparatus of the tree, as well as its height (Jelonek et al. 2008). Analysing the quotient values of the mass of fresh needled springs divided by the lignin content in tracheid wall of the peripheral area of the stem (MFT/LC) and the quotient value of mass of fresh needled divided by the lignin content in tracheid walls of the peripheral area (MFN/LC), clearly reveals the differentiation of values in both indicators in pines belonging to the first Kraft's biosocial class. The predominating trees (Kraft's I class) in the case of both indicators showed their highest value, which was MFT/LC – $226.43 \text{ g} \cdot (\text{mg} \cdot \text{g}^{-1})^{-1}$ and MFN/LC – $147.95 \text{ g} \cdot (\text{mg} \cdot \text{g}^{-1})^{-1}$; whereas the values for dominating pines (Kraft's II class) and co-dominating (Kraft's III class) were definitely lower. In the former, the values of the discussed indicators were respectively ($158.95 \text{ g} \cdot (\text{mg} \cdot \text{g}^{-1})^{-1}$ and $102.33 \text{ g} \cdot (\text{mg} \cdot \text{g}^{-1})^{-1}$); whereas in the latter class it was $99.64 \text{ g} \cdot (\text{mg} \cdot \text{g}^{-1})^{-1}$ and $67.73 \text{ g} \cdot (\text{mg} \cdot \text{g}^{-1})^{-1}$.

The social differentiation of the trees in the tree stand is a result of competition for light and living space. The instances of greenwoodogenic species, including pines, occupy a lower position within the altitudinal structure of a tree stand, hence they suffer more from the lack of sunlight, water and also nutrients. The direct result of the struggle for environment resources is the diversification of tree sizes and the changes in xylem structures, conducting surface in xylem and phloem and also the changes in the tree crown (Mátyás and Varga 2000, Sowiński and Szczepaniak 2015). Mäkinen (1996) has noticed that the spring and needle biomass of Scots pine (*P. sylvestris* L.) decreases with the increase of competition.

A special attention should be paid to the relation between the hydraulic conductive indicator (S_a/N_{mass} and E_{sa}/N_{mass}), and the mean increase in tree cubic volume and the quotient of the mass of fresh needled springs divided by the lignin content in the tracheid walls of peripheral areas of the stem (MFT/LC) and the quotient of mass of fresh needles divided by the lignin content in tracheid walls of peripheral areas of the stem (MFN/LC), and the mean increase in tree volume. In the case of the relative conductive surface, i.e. hydraulic conductivity of stems (S_a/N_{mass} and E_{as}/N_{mass}), the increase in volume correlates negatively in both cases. The value of the calculated correlation coefficients was respectively -0.4812 and -0.5189 . However, the MFT/LC and MFN/LC coefficients correlated positively but in the case of the latter the coefficient was $+0.9485$ and in the case of the former $+0.9508$. The upturn in hydraulic conductivity indicator's value S_a/N_{mass} and E_{as}/N_{mass} in pines will result in lowering the mean tree volume increase; however, lowering the value of relative conducting area will result in the mean volume increase. In the case of MFT/LC and MFN/LC coefficients, together with their increase in the value, also there was a significant increase in mean volume of pines from the main tree stand, i.e. predominating trees, dominating trees and co-dominating trees.

It seems that the variation in both indicators (MFT/LC and MFN/LC) in pines representing the main tree stand is connected with physiological, physical and structural conditioning of transporting water and minerals in the stem. The trees from Kraft's I class indicated the highest

values of the analysed indicators (MFT/LC and MFN/LC), whose mean value was respectively 226.43 $\text{g}\cdot(\text{mg}\cdot\text{g}^{-1})^{-1}$ and 147.95 $\text{g}\cdot(\text{mg}\cdot\text{g}^{-1})^{-1}$. In pines from Kraft's II class the mean values in both indicators were lower from predominating trees and was 158.95 $\text{g}\cdot(\text{mg}\cdot\text{g}^{-1})^{-1}$ and 102.33 $\text{g}\cdot(\text{mg}\cdot\text{g}^{-1})^{-1}$; whereas in co-dominant individuals it was 99.64 $\text{g}\cdot(\text{mg}\cdot\text{g}^{-1})^{-1}$ and 67.73 $\text{g}\cdot(\text{mg}\cdot\text{g}^{-1})^{-1}$. It can be assumed that this is a result of a significant variability of the mass of fresh needled sprigs, mass of fresh needles, lignin content in tracheid walls of peripheral areas of the pine stems belonging to different biosocial classes in the tree stand. Moreover, it would seem that the noticed values of both indicators are adjusted to the intensity of the assimilation and transpiration process which may result in diversified efficiency of transporting water with minerals. The pines which occupy lower positions in the altitude structure of the tree stand are considerably more vulnerable to sunlight, water and nutrients deficiency rather than the trees from higher biosocial positions. The direct effect of the struggle over environmental resources is the diversification of tree sizes and changes in crown structure (Mátyás and Varga 2000). Mäkinen (1996) noticed that the biomass of sprigs and needles of the Scots pine lowers with the increase of competition. Naidu et al. (1998) researched allocation of biomass in *Pinus taeda* tree stands and indicated that in intermediate trees the share of the biomass of the stem (75.9%) of the total tree biomass is higher in comparison to dominating trees (63.4%). Furthermore, the intermediate pines are characterised by a higher ratio of biomass of heterotrophic parts, i.e. roots, stem and sprigs, than the autotrophic parts (needles). According to research conducted by Kellomäki (1981) concerning the influence of the available sunlight on the structure of the current increment of Scots pine, it appears that with greater access to sunlight there is a considerable shift of the current increment of biomass to the sprigs at the expense of the stem and needles. The greatest part of the annual production of biomass reaches the stems of trees which grows in conditions with a moderate access to sunlight, but the trees growing in shade direct their greater part of the increment in assimilation apparatus. Vanninen and Mäkelä (2000), as well as Vanninen (2004) have noticed that in pine tree stands, the intermediate trees most part of their current increment locate in stem biomass in comparison to dominating trees.

CONCLUSIONS

(1) On the basis of conducted research of shaping the quotient of the mass of fresh needled sprigs, mass of fresh needles divided by the lignin content in tracheid wall of the peripheral area of stem (MFT/LC and MFN/LC) of Scots pine (*Pinus sylvestris* L.) varied as far as the biosocial positioning in the tree stand are concerned, diversification of values of analysed indicators in reference to biosocial class of the trees was observed. (2) The predominating trees possessed both indicators (MFT/LC and MFN/LC) which were considerably higher, and whose mean value was respectively 226.43 $\text{g}\cdot(\text{mg}\cdot\text{g}^{-1})^{-1}$ and 147.95 $\text{g}\cdot(\text{mg}\cdot\text{g}^{-1})^{-1}$ than pines representing II and III Kraft's biological class. Both values of the discussed indicators in dominating trees was 158.95 $\text{g}\cdot(\text{mg}\cdot\text{g}^{-1})^{-1}$ and 102.33 $\text{g}\cdot(\text{mg}\cdot\text{g}^{-1})^{-1}$, whereas in co-dominating pines it was 99.64 $\text{g}\cdot(\text{mg}\cdot\text{g}^{-1})^{-1}$ and 67.73 $\text{g}\cdot(\text{mg}\cdot\text{g}^{-1})^{-1}$. (3) The noticed differences in the values in both analysed indicators (MFT/LC and MFN/LC) in pines belonging to the first three Kraft's biosocial classes constituting the main tree stand are connected with physiological, physical and structural conditioning of transporting water with minerals in the xylem and are closely related with competition for sunlight, water, nutrients and living space.

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