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TRACHEIDS LENGTH VARIATION IN SCOTS PINE (*PINUS SILVESTRIS* L.) TREES BELONGING TO DIFFERENT TREE GROWTH CLASSES

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This investigation has been focused an the variation in length of early- and latewood tracheids in Scots pine wood belonging to different tree growth classes in even-aged forest stand (about 50 years old) growing in western Poland (52° 33'N and 16° 50'E). Variation of the tracheids length at different heights and distance from the pith could be studied. A total of 45000 tracheids have been measured. The juvenile wood tracheids are much shorter than mature according to Sanio's law. The lower the tree growth class the shorter period is necessary to reach maximum tracheid length. Maximum tracheids length tends to increase as tree growth classes rises up. Strong negative correlation exist between width of annual rings and tracheids length in lower half of the stem.

INTRODUCTION

Since Karl Sanio's research [17] much emphasis has been placed on investigations of length of anatomical elements, and especially the length variation of softwood tracheids within a tree has been taken into account [1, 7, 12, 16]. Research in this field is expanding in recent years [10, 18, 19, 20]. Variation in tracheids length among trees of the same species due to forest site and geographic locality has also been studied [2, 3, 7, 13, 15]. However, there are few research on variation of tracheids length between trees of the same uniform forest stand.

As it known, even-aged stand grown trees differ from each other in tree growth classes (location in the forest stand). Size and development of the crown, breast height diameter and height of tree are the main factors for dividing stand-grown trees into tree growth classes. Development of the crown is one of prime importance. The external factors (climate, micro-environment) exert their influence directly on the growth of the crown and only indirectly on the growth and quality of the wood [14]. The crown is not only the source but the regulating center responsible for formation and wood growth [22, 23].

A confusing picture seems to emerge with respect to effects of growth rate changes on cell length in conifers [24]. For example, for 7 of the 16 paper cited by Zobel and van Buijtenen [24] showed some decrease of tracheids length with growth rate (*Pinus radiata, P. echinata, P. ponderosa, P. taeda, Picea abies, P. rubens*). Three paper reported longer tracheids with faster growth (*Pinus silvestris, P. glabra, Picea abies*). Six papers found that growth rate differences did not effect tracheid length (*Pinus silvestris, P. echinata, P. strobus, Picea abies, Larix decidua, Pseudotsuga menziesii, Tsuga heterophylla*).

In order to get more information on properties and variablility of wood structure in relation to location of a tree in an even-aged stand, study has been taken on structure and density od *Pinus silvestris* of dominant, intermediate and suppressed trees origin. It was taken into account that the problem mentioned above is one of practical importance for silvicultural measures (thinning, pruning etc) effect on crown development. In this connection there are possibilities for limited modifications and control of width and growth rings structure, i.e. wood quality itself.

The aim of this paper which is a fragment of more extensive studies [8, 9] is to present the effect of position of Scots pine trees in uniform stand on their tracheids length with regard to growth increments width.

EXPERIMENTS

The investigative material was obtained from about 50 years old even-aged stand of Scots pine growing on the west part of Poland (52° 33'N and 16° 50'E): canopy class – 0.8, low-density stand. Each of the tree class location was

Table 1

Characteristic of the investigated pine trees
Charakterystyka badanych drzew sosny

Tree characteristic Charakterystyka drzewa	Tree growth classes (position of the tree in forest stand) Grupa wzrostowa drzewa (stanowisko drzewa w drzewostanie)		
	Dominant Dominujące	Intermediate Średnie	Suppressed Opanowane
Age on the stump cross section (years) Wiek na przekroju poprzecznym pniaka (lat)	48	47	45
Diameter at breast height D.i.b. (cm) Pierśnica w korze (cm)	28	22	14
Tree height (m) Wysokość drzewa (m)	24	22	19
Crown length (m) Długość korony (m)	8.8	5.5	2.0
Distance to the first living branch (m) Odległość do pierwszej żywej gałęzi (m)	15.4	16.5	17.0

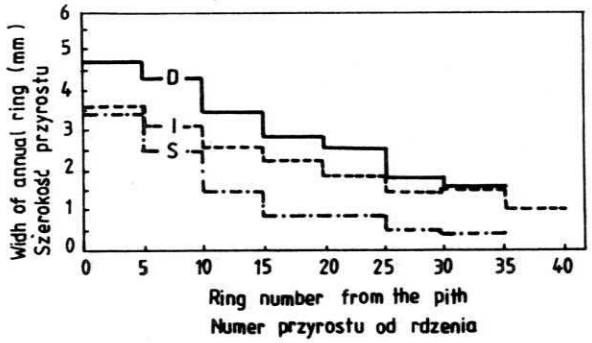

Fig. 1. Variation in width of growth rings at 1/4 height level of the pine trees belonging to different classes; D – dominant, I – intermediate, S – suppressed trees

Rys. 1. Zmienność szerokości przyrostów rocznych na 1/4 wysokości drzew sosny należących do różnych klas wzrostu; D – dominujące, I – średnie, S – opanowane

represented by a group of three trees. Total height (h) and diameter at breast height (DBH) of selected trees were as folow: dominant (h=22...24.2 m, DBH=28...32 cm), intermediate (h=21...23.3 m, DBH=14...15 cm). In each class trees which had been marked by number "2" were designed for measurement of tracheid length variation with height and distance from pith.

Data on the investigated pine trees is listed in Table 1. Growth rates of tested trees at 1/4 height level can be seen on Fig. 1. Cross-sectional discs from tested trees were taken at a 1/4, 2/4, 3/4 and 4/4 height level of the tree. Along the northern-southern diameter of each disc, strips 20 mm in width along the tangential direction and 20 mm in depth along the grain were cut out. For measurement early- and latewood material were taken from the folowing annual rings along the northern radius: 3, 6, 9, 12, 15, 20, 25, 30, 35 and 40. This strips of early- and latwood were macerated in a mixture of hydrogen peroxide solution (commercial ca. 30%) and glacial acetic acid 1:1 at temperature of 60°C. Duration of maceracion was about 44...48 hours.

Traiched length's measurement were made on projection microscope "Zeiss MP 320" conected with electronic recorder of fiber length histogram [21]. It consist of an electronic recording system and a hand-operated sensor--converter which converts the length values into impuls quantities. Measurement was performed by moving sensing device over fiber slide and a result was assigned to a proper fiber length's class. Then number of fibers in each length class was counted. The electronic recorder of fiber length histogram used in this study possessed 13 class register. Usually 300 early and late tracheids have been tested in a single experiment series but there have also series in which 600 tracheids were measured. A total 45 000 tracheids have been measured.

DATA ANALYSIS

Mean length values of pine early and late tracheids collected from trees of various location in forest stand in relation to stem height level are shown in Fig. 2. Tracheids length increase from pith to bark on

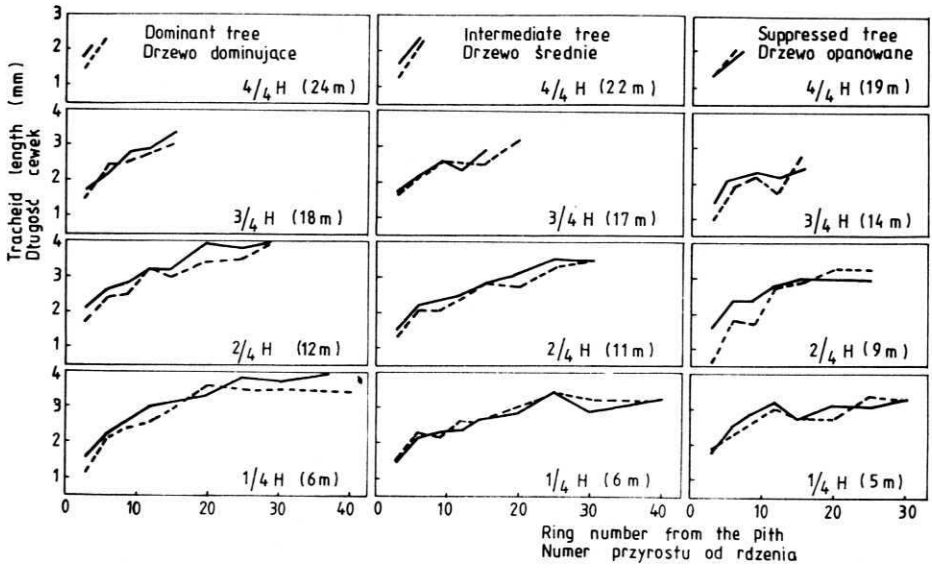

Fig. 2. Mean length of pine earlywood (broken line) and latewood (solid line) tracheids on different height levels of dominant, intermediate and suppressed trees

Rys. 2. Średnia długość wczesnych (linia przerywana) i późnych (linia ciągła) cewek sosny na różnych poziomach wysokości drzew dominujących, średniach i opanowanych

all height levels according to Sanio's law [17]. The obtained results confirmed that the length of earlywood tracheides was smaller than that of the latewood. It is interesting, however, that growth rate of tracheids length depends on the tree classes. In order tracheids length to be doubled at 1/4 height level of the stem periods of 12, 20 and 25 years are required for dominant, intermediate and suppressed trees, respectively. Similar relationship hardly exist on the upper parts of the stem.

It has been observed that the age at which tracheids reached maximum length is related to growth classes of a tree. The higer the tree class is, the longer period required to reach maximum length. Herein in dominant tree maximum length of tracheids occured in about the 15th growth ring while in intermediate and suppressed trees within the range of 25th and 30th growth increment, respectively. According to report by Sanio [17] *Pinus silvestris* tracheids attained maximum length from the 25 to 60th growth ring. Tracheids length of Swedish pine increased up to 20th annual

Table 2

Variation in tracheids length at various stem height levels of the pine trees of different tree growth classes
Zmienność długości cewek na różnych poziomach wysokości drzew sosny należących do różnych grup wzrostu

Tree growth class Grupa wzrostowa drzew	Relative stem height – (H) Względna wysokość drzewa 1/4	2/4	3/4	4/4
	Mean tracheids length – (mm) Średnia długość cewek			
	Early tracheids – cewki wczesne			
Dominant Dominujące	1.2-3.6	1.7-4.1	1.6-3.0	1.5-2.3
Intermediate Średnie	1.5-3.5	1.3-3.5	1.6-3.2	1.3-2.2
Suppressed Opanowane	1.9-3.4	0.6-3.3	1.0-2.7	1.3-2.0
	Late tracheids – cewki późne			
Dominant Dominujące	1.6-4.0	2.1-4.1	1.7-3.3	1.9
Intermediate Średnie	1.5-3.3	1.5-3.5	1.7-2.9	1.6-2.3
Suppressed Opanowane	1.8-3.3	1.6-3.0	1.4-2.4	1.3-1.9

Table 3

Averaged tracheid length of pine wood at 1/4 tree height level in relation to cross-section zones
Uśredniona długość cewek sosny na poziomie 1/4 wysokości drzew w zależności do strefy przekroju poprzecznego

Cross-section zone Strefa przekroju poprzecznego	Average tracheids length (mm) Uśredniona długość cewek (mm) Tree class – grupa wzrostowa drzew		
	Dominant Dominujące	Intermediate Średnie	Suppressed Opanowane
Juvenile wood (<10*) Drewno młodociane	2.01	2.16	2.33
Transition zone (10-20*) Strefa przejściowa	3.08	2.73	2.95
Mature wood (>20*) Drewno dojrzałe	3.63	3.30	3.20

* rings from pith – liczba przyrostów od rdzenia

ring [1]. Similar relation were observed for other species of pine, i.e. *P. taeda* [5], *P. radiata* [6].

Data on variation in early- and latewood tracheids length within the range of stem radius at various height levels is presented in Table 3. As shown in this table maximum length of tracheids in dominant tree was 4.1 mm, while only 3.1 mm in suppressed tree. These values correspond to results reported recently by Laurow [15], Atmer and Thörnqvist [1], Bauch et al. [4] where average tracheids length of Scots pine was found to be 3.3 mm, 3.5 mm, 3.7 mm, respectively.

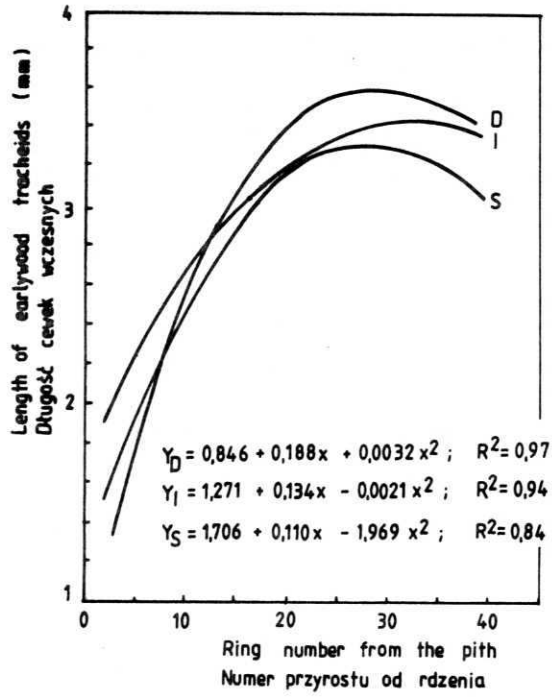

Fig. 3. The effect of pine tree location in forest stand on the radial gradient of earlywood tracheids length in 1/4 stem height levels; D – dominant, I – intermediate, S – suppressed trees

Rys. 3. Wpływ stanowiska drzew sosny w drzewostanie na promienowy gradient długości cewek wczesnych na poziomie 1/4 wysokości drzewa; D – dominujące, I – średnie, S – opanowane

The effect of location of pine trees in forest stand on the earlywood tracheids lenght in 1/4 stem height levels is presented in Fig. 3. Tracheids length, as shown by the curves tends to increase as tree position in stand is rises up.

Average results of tracheids length (without distinction on early and latewood tracheids) in relation to wood cross-section zones are listed in Table 3. As shown in Table 3 tracheids lenght slighty declines in juvenile wood zone (from pith to 9th growth ring) as socjological standing of a tree increases. In the case of transition wood zone (from the 10th to 20th growth ring), and particular in mature wood zone (up from 20th growth ring) tracheids length continues increase as tree location in stand rises up. However it is rather slight increase. When mature wood (from the 20th to 40th growth ring) is consider tracheids are about 12 percent longer on the average in dominant tree than in suppressed tree.

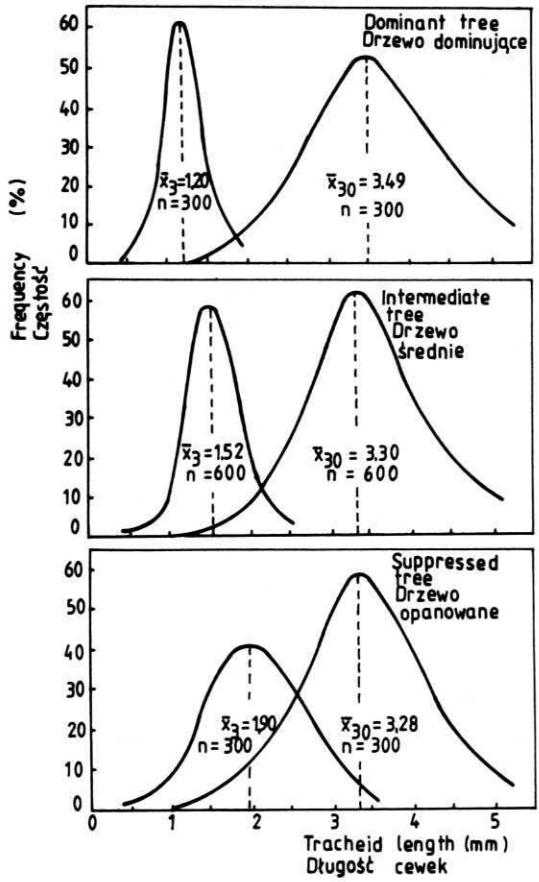

Fig. 4. Frequency histogram illustrating juvenile wood (3th annual ring) and mature wood (30th annual ring) population of earlywood tracheids lenght in pine of various tree growth classes

Rys. 4. Histogram obrazujący długość wczesnych cewek sosny w drewnie młodocianym (3 przyrost) i w drewnie dojrzałym (30 przyrost) drzew sosny należących do różnych klas wzrostu

The better is the position of a tree in the forest stand the larger difference occur in tracheids length between juvenile (3th growth ring) and mature wood (30th growth ring). These differences are 2.3 mm, 1.8 mm, 1.4 mm in dominant, intermediate and suppressed trees, respectively (Fig. 4).

The width of annal ring is correlated with average tracheids length in the lower half of stem. It is stron negative correlation (Fig. 5). An emphasis should be placed on the fact that at definite width of annual ring the tracheids are longer the better position of a tree in the stand. Variation in tracheid length amount to over 1 mm in suppressed and dominant trees and is independent

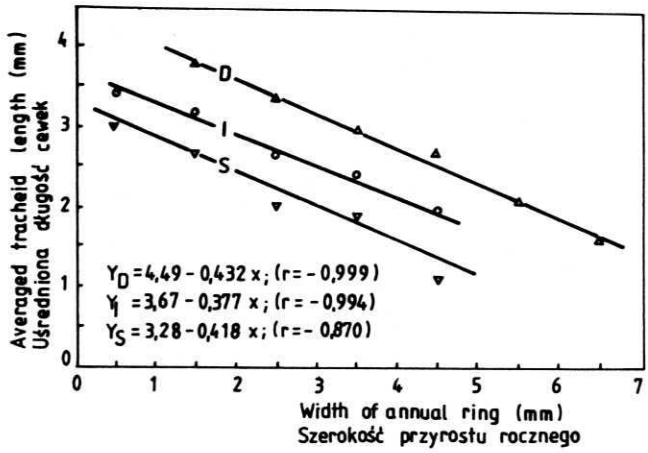

Fig. 5. Averaged length of earlywood and latewood tracheids from the lower half of the stem in relation to the width of annual ring; D – dominant, I – intermediate, S – suppressed trees

Rys. 5. Uśredniona długość wczesnych i późnych cewek w dolnej połowie długości strzał sosny w zależności do szerokości przyrostów rocznych; D – dominujące, I – średnie, S – opanowane

from width of annual ring. One should admit there is no evidence of distinct relationship between width of growth ring and tracheids length in the upper half of stem.

CONCLUSION

Tracheids length of Scots pine trees (*Pinus silvestris*) collected in about 50 years old even-aged stand is related to position of a tree in forest stand. The lower the tree growth class the shorter period is necessary to reach maximum tracheid length. Maximum tracheid length are reached in about 15th, 25th, 30th in suppressed, intermediate and dominant trees, respectively. Generally, maximum tracheids length tends to increase as tree growth class rises up. Maximum length of tracheids in dominant tree found to be 4.1 mm, while only 3.1 mm in suppressed tree. In mature wood differences in length of latewod tracheids amount to 1 mm between dominant and suppressed trees. In mature wood (from 20th to 40th growth ring) averaged length values of late- and earlywood tracheids varry but sligtly in relation to a tree classes because mean tracheids length in dominant tree is only 12% longer than that in suppressed tree. The better position of a tree in forest stand the larger differences take place in tracheids length between juvenile wood (3th growth ring) and mature wood (30th growth ring). These differences amout to 2.3 mm, 1.8 mm, 1.4 mm in dominant, intermediate and suppressed trees, respectively. Strong negative correlation exist between width of annual rings and tracheids lenght in lower

half of the stem ($r = -0.870 \ldots -0.999$). An emphasis should be placed on the fact that trees of better classes poses longer tracheids at definite width of annual ring. Thus the width of annual rings plays singificant role in tracheids length formation.

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ZMIENNOŚĆ DŁUGOŚCI CEWEK DRZEW SOSNY ZWYCZAJNEJ (*PINUS SILVESTRIS* L.) NALEŻĄCYCH DO RÓŻNYCH KLAS WZROSTU

Streszczenie

Badano zmienność długości wczesnych i późnych cewek drzew sosny zwyczajnej należących do różnych klas wzrostowych w jednowiekowym drzewostnie (w wieku ok. 50 lat) rosnącym w zachodniej części Polski (53°33'N i 16°50'E). Analizowano zmienność długości cewek na różnych poziomach wysokości drzew i w różnej odległości od rdzenia. Łącznie zmierzono 45 000 cewek. Cewki drewna młodocianego są zgodnie z prawem Sanio znacznie krótsze niż cewki drewna dojrzałego. Im niższa jest klasa wzrostu drzew, tym krótszy jest okres niezbędny do osiągnięcia przez cewki maksymalnej długości. Maksymalna długość cewek wykazuje tendencję wzrostową wraz z polepszeniem się warunków wzrostu drzewa w drzewostanie. Zaobserwowano wysoką negatywną korelację pomiędzy szerokością przyrostów rocznych i długością cewek w dolnej połowie długości strzał.

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