

## **Dynamics of heartwood formation in mature Scots pine (*Pinus sylvestris* L.) trees origin from different site conditions**

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**Abstract:** *Dynamics of heartwood formation in mature Scots pine (*Pinus sylvestris* L.) trees origin from different site conditions.* The study was attempt to determine the difference of dynamics of heartwood formation in Scots pine stems between two different forest site type. The performed experiments comprised the analysis of woody disks taken from bottom of the 129 trees grown in four forest areas. Two of forest areas represents: fresh coniferous forest, and the other mixed broadleaved forest. Age of trees fluctuated from 105 years to 115 years. Dynamics of heartwood into bottom of the tree is highly variable between trees in the same sample plots, average dynamics of heartwood is slightly higher in mixed forest than coniferous forest.

**Keywords:** Scots pine, macrostructure, heartwood, sapwood,

### **INTRODUCTION**

Discussion about the function of heartwood in living trees and factors caused process of heartwood formation and variations of shape and area of heartwood in cross section of trees is still open. There were many publications on this topic in last decades and researches not found satisfactory solution. The comprehensive study concerning recent literature was presented by Taylor et al. (2002). Authors discuss the function of heartwood and sapwood, structure and wood properties, nutrients, repository for toxic substances, factors influencing the natural durability of heartwood, process of heartwood formation, variations of heartwood distribution and quality in trees and more. Heartwood in coniferous forests in Poland was subject of research of Pazdrowski (1988), Jakubowski (2004), Jakubowski and Koszewski (2004), Nawrot et al. (2008), Tomczak et al. 2009, Jelonek et al. (2010). Dynamics of heartwood formation in pines was subject of interests of Pazdrowski (1992). Pazdrowski and Szaban (2002) compared dynamics of hardwood formation in the stems of black pine (*Pinus nigra* Arnold) and Scots pine (*Pinus sylvestris* L.) growing in similar site conditions, authors found relevance between hardwood formation process and proportion of heartwood and sapwood in pine stems. Jelonek et al. (2010) state that age and social class of the tree position in the stand play significant role in the process of heartwood formation, biggest dynamics was found for trees after 50 years old and into dominant trees. Nawrot et al. (2008) that dynamics of heartwood formation increases with the age of a tree and with the improved social class of tree position in the stand. Greater dynamics of heartwood formation was found in trees growing in a more fertile site – fresh mixed forest. Research carried out by Pazdrowski et al. (2005) shows that European larch was characterised by a higher dynamics of heartwood formation than Douglas fir. Based on current literature suggestions we can state that favorable conditions for increasing dynamics of hardwood formation are: intensive growth of trees and fertile site conditions. The aim of that research was to find difference of heartwood dynamics formation between two forest site types: fresh coniferous forest and mixed broadleaved forest.

## METHODS

Sample material were collected from 4 forest stands grown under two types of forest site conditions. Two of stands were grown in fresh coniferous forest (less fertile) and the other on moist mixed broadleaved forest (more fertile). All forests were located in Forest District Babki (Regional Directorate of state Forest in Poznan). Trees came from round felling areas (sample plots). Age of trees fluctuated from 105 years (fresh coniferous forest) to 115 years (moist mixed broadleaved forest). Trees were determined randomly and accounted for about half of all fallen trees on the plot. Discs of thickness 5 cm were cut from the bottom of the trunk of each tree, discs were dried and a little polishing to reveal heartwood and annual rings. Annual rings were counted from pith to bark. Width of heartwood and sapwood were measured in four directions. Dynamics of heartwood were calculated as ratio of number of heartwood rings to number of sapwood rings.

## RESULTS

Trees growing on both forest site types differ in size of macrostructure elements. Average diameter of trees in fresh coniferous forest were smaller than diameter of trees growing in mixed forest (Tab. 1). Proportion of heartwood to sapwood also were higher in broadleaved forest. The minimum number of heartwood annual rings was 22 (coniferous forest) and 25 (mixed forest) which seems to be a small value for the above 100 year old forests. The maximum of heartwood rings was 64 (mixed forest) and 50 (coniferous forest) which is closely half of all annual rings in trunk (Tab. 2). Average number was higher for broadleaved mixed forest (43 rings) than fresh coniferous forest (34 rings). Variability of number of rings of heartwood is high in all four sample plots, even if trees are growing as neighbors in the same age. This is due to the wide annual growth rings in the juvenile period of growth of trees. The width of the heartwood will therefore depend primarily on the average width of the annual rings.

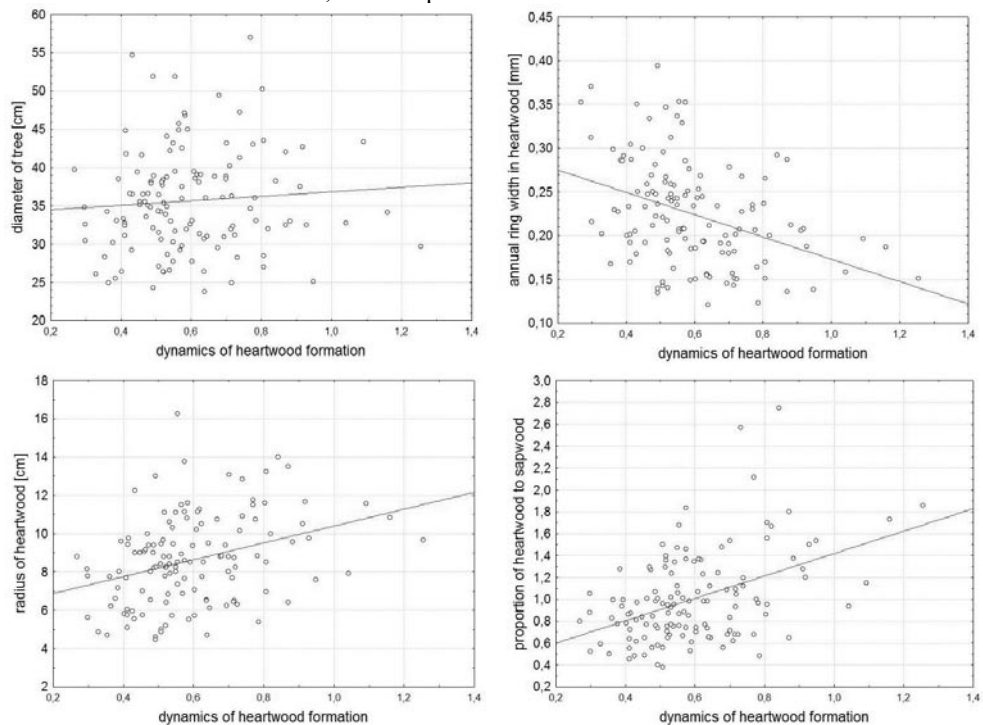
**Table 1.** The diameters of trees at the bottom of the trunk in mixed broadleaved forest (MBF) and fresh coniferous forest (FCF), basic statistics.

Forest site type	Mean [cm]	N	Std dev. [cm]	Min [cm]	Max [cm]	Q25 [cm]	Median [cm]	Q75 [cm]	Coefficient of variability [%]
MBF	38,4	68	6,5	25,1	57,0	34,1	38,1	42,3	17
FCF	32,5	61	5,4	23,8	51,9	28,6	32,1	35,1	17

**Table 2.** The number of heartwood and sapwood annual rings in mixed broadleaved forest (MBF) and fresh coniferous forest (FCF), basic statistics.

Forest site type	Mean	N	Std dev.	Min	Max	Q25	Median	Q75	Coefficient of variability [%]
heartwood annual rings									
MBF	43,00	68	8,22	25	64	37	43	49	19
FCF	34,87	61	6,03	22	50	30	34	39	17
sapwood annual rings									
MBF	69,62	68	8,51	50	93	65	69	75	12
FCF	65,18	61	6,45	48	87	62	65	67	10

The next characteristics of macrostructure is the average width of annual rings. Heartwood rings are almost to times wider (mean - 2.2 mm) than sapwood rings (mean - 1.3 mm). The average width of annual ring in the mixed forest is slightly higher (1.85 mm) than in the coniferous forest (1.76 mm). Similarly, the average width of annual ring of heartwood is higher in mixed forest (Tab. 3). The average width of annual ring in sapwood is similar in all plots. Similarly, median shows the same trends, in heartwood median is higher for mixed forest and lower for coniferous forest, but in sapwood shows similar value.



**Fig. 1.** Correlations between dynamics of heartwood formation and different biometric features of wood macrostructure in Sots pine stems at the bottom of trunk.

The maximum and minimum shows also similar values in all sample plots. Somewhat surprising is the wide variation of increment width in heartwood versus sapwood. In mixed forest coefficient of variability in heartwood is 20% and in sapwood 27%. There is a reverse situation in coniferous forest, 31% in heartwood and 21% in sapwood. Fluctuations of the width of annual rings are difficult to interpret, because it is influenced by many factors.

**Table 3.** Width of heartwood and sapwood annual rings in mixed broadleaved forest (MBF) and fresh coniferous forest (FCF), basic statistics.

Forest site type	Mean [mm]	N	Std dev. [mm]	Min [mm]	Max [mm]	Q25 [mm]	Median [mm]	Q75 [mm]	Coefficient of variability [%]
heartwood annual rings									
MBF	2,36	68	0,49	1,38	3,53	1,98	2,34	2,66	21
FCF	2,12	61	0,67	1,21	3,94	1,53	2,01	2,43	32
sapwood annual rings									

MBF	1,34	68	0,36	0,59	2,62	1,10	1,27	1,52	27
FCF	1,40	61	0,30	0,84	1,99	1,19	1,34	1,63	21

**Table 4.** Dynamics of heartwood in mixed broadleaved forest (MBF) and fresh coniferous forest (FCF), basic statistics.

Forest site type	Mean [cm]	N	Std dev. [cm]	Min [cm]	Max [cm]	Q25 [cm]	Median [cm]	Q75 [cm]	Coefficient of variability [%]
MBF	0,64	68	0,19	0,27	1,25	0,51	0,60	0,75	30
FCF	0,55	61	0,15	0,30	1,04	0,45	0,52	0,63	27

Dynamics of heartwood is slightly higher in mixed forest. Variability of heartwood dynamics is slightly higher for mixed forest (30%) than for coniferous forest (27%) (Tab. 4). In summary, the differences in mean dynamics of heartwood between the examined forest site types are small, while large is the variability in all sample plots, coefficient of variability shows value 29%. It was found only weak correlation between dynamics of heartwood formation and biometric features of heartwood (average annual ring width, heartwood width, proportion of heartwood to sapwood) (Fig. 1). Based on this study, we can risk the statement that dynamics of heartwood is highly variable between trees in the same forest site type and it slightly increase in fertile site conditions.

## CONCLUSIONS

1. Dynamics of heartwood into bottom of the tree is highly variable between trees in the same forest site type, average dynamics of heartwood is slightly higher in mixed forest than coniferous forest.
2. It was found a large variation in average annual ring width different in heartwood and sapwood. . In mixed forest coefficient of variability in heartwood was 20% and in sapwood 27%, in coniferous forest was 31% in heartwood and 21% in sapwood.

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**Streszczenie:** *Dynamika twardzielowania drewna sosny zwyczajnej (Pinus sylvestris L.) wyrosłej w różnych warunkach siedliskowych.* W badaniach dokonano porównania dynamiki twardzielowania w 4 drzewostanach wyrosłych w ramach dwóch typów siedliskowych lasu. Dwa drzewostany wyrosły w ramach boru świeżego pozostałe dwa na lesie mieszanym. Powierzchnie znajdowały się na terenie nadleśnictwa Babki (RDLP Poznań). Drzewa pochodziły z wycinanych gniazd z drzewostanach rębnych w wieku od 105 do 115 lat. Drzewa do badań wyznaczane były losowo i stanowiły one około połowy wszystkich drzew na wycinanym gnieździe. Minimalna liczba słoików drewna twardzielowego była tylko nieco większa niż 20 (22 dla Bśw i 25 dla BMśw), co stanowi niewiele dla ponad stuletnich drzewostanów. Maksymalna liczba słoików wynosiła 64 (LM) i 50 (Bśw) czyli blisko połowy wszystkich przyrostów rocznych. Przeciętnie były to 43 słoje dla LM i 34 dla Bśw. Nie wiadomo dokładnie co jest przyczyną takiej zmienności liczby słoików przypadających na drewno twardzielowe u drzew w tym samym wieku. Dynamika twardzielowania na badanych powierzchniach podlega dużej zmienności, jest ona nieco wyższa w warunkach lasu mieszanego wilgotnego niż boru świeżego.

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