

## Proportion of heartwood and sapwood in Scots pine (*Pinus sylvestris* L.) stems grown in different site conditions

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**Abstract:** *Proportion of sapwood and heartwood in Scots pine (Pinus sylvestris L.) stems grown in different site conditions.* The study was attempt to determine the proportion of heartwood and sapwood in Scots pine stems grown on 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. Age of trees fluctuated from 105 years to 115 years. Two of forest areas represents: fresh coniferous forest, and the other mixed broadleaved forest. It was found more percentage of heartwood in mixed forest. The average area of sapwood represents 80% of cross section of the stem in coniferous forest and 72% in mixed forests.

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

### INTRODUCTION

Heartwood as a central part of the xylem occurs as a result of natural process of tree development. Understanding of heartwood formation allow the foresters to influence on that process by using various of silvicultural method. Heartwood in conifers was the object of many studies in previous years. Pazdrowski and Szaban (2002) examined hardwood formation in the stems of black pine (*Pinus nigra* Arnold) and Scots pine (*Pinus sylvestris* L.) growing in similar site conditions. Research shown relevance between hardwood formation process and proportion of heartwood and sapwood in pine stems. Similar study concerning radial changes of macrostructure and some biometric features of tree was present by Tomczak et al. (2009), authors analysed pine stems growing on post-agricultural land. It was found that trees growing in post-agricultural land shows high proportion of heartwood than trees growing in typical forest sites. Jakubowski (2004) found more proportion of heartwood to sapwood on fresh coniferous forest in compare with dry coniferous forest and fresh mixed coniferous forest. About correlation between annual width rings and proportion of heartwood to sapwood wrote Pazdrowski (1988), he found positive correlation in all tested site conditions.

Process of heartwood formation has been carefully discussed by Taylor et al. (2002), in a comprehensive study as review paper. More on this subject can be found also in research of Jelonek et al. (2008, 2010), Jakubowski and Koszewski (2004), Nawrot et al. (2008a, 2008b). The aim of that research was to find difference of heartwood and sapwood proportion between two forest site types: fresh coniferous forest and mixed broadleaved forest.

### METHODS

Sample material origin from 4 stands grown under two types of forest site conditions. We selected two types differ in fertility and soil moisture. Two of selected group of trees were grown in fresh coniferous forest (less fertile) and the other on two group on moist mixed broadleaved forest (more fertile). Sample plots were located in Forest District Babki (Regional Directorate of state Forest in Poznan). Trees came from round felling areas (sample plots) the distance between sample plots (forests) should be no more than 10 km. 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. Woody discs were dried and a little polishing to reveal heartwood and annual rings. Width of heartwood and sapwood were measured in four directions. Statistical analyzes were performed using two coefficients: the ratio of heartwood width to sapwood width (H) and ratio of heartwood area to sapwood area ( $H_A$ ).

## RESULTS

The average diameter of the trees ranged from 23 cm to 57 cm, and there it was found distinct difference between two of analysed sites. In the fresh coniferous forest (FCF) average diameter amounted 32 cm and in the mixed broadleaved forest (MBF) 38 cm (Tab. 1). Pines in the mixed forest were about 10 years older so real difference between diameter on two sites seems to be smaller. Range of diameter on two sites was similar 25-57cm, (MBF) and 23-51 cm (FCF) (Tab. 1). Width of heartwood was higher on mixed forest (19.8 cm) than on coniferous forest (14.7 cm). The smallest heartwood of the four areas was found in area No 1 (Tab. 2).

**Table 1.** The diameters of trees at the bottom of the trunk, mixed broadleaved forest – sample plot 1 and 2, fresh coniferous forest sample plot 3 and 4, basic statistics.

| Sample plot No | Mean [cm] | N  | Std dev. [cm] | Min [cm] | Max [cm] | Q25 [cm] | Median [cm] | Q75 [cm] | Coefficient of variability [%] |
|----------------|-----------|----|---------------|----------|----------|----------|-------------|----------|--------------------------------|
| 1              | 38,13     | 34 | 5,87          | 28,20    | 51,90    | 34,20    | 38,13       | 41,60    | 15                             |
| 2              | 38,73     | 34 | 7,22          | 25,10    | 57,00    | 34,15    | 38,50       | 42,70    | 19                             |
| 3              | 30,06     | 34 | 3,43          | 23,80    | 38,50    | 26,60    | 31,05       | 32,40    | 11                             |
| 4              | 35,64     | 27 | 5,87          | 24,90    | 51,90    | 31,50    | 35,10       | 38,70    | 16                             |

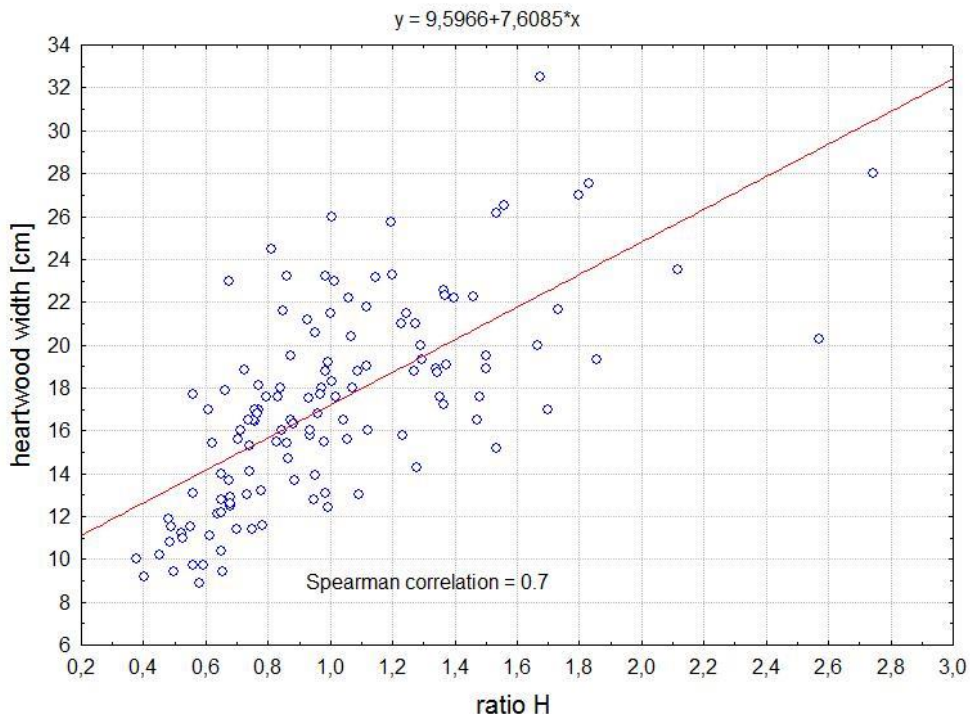
**Table 2.** The width of heartwood, mixed broadleaved forest – sample plot 1 and 2, fresh coniferous forest sample plot 3 and 4, basic statistics.

| Sample plot No | Mean [cm] | N  | Std dev. [cm] | Min [cm] | Max [cm] | Q25 [cm] | Median [cm] | Q75 [cm] | Coefficient of variability [%] |
|----------------|-----------|----|---------------|----------|----------|----------|-------------|----------|--------------------------------|
| 1              | 20,45     | 34 | 4,21          | 13,20    | 32,50    | 17,60    | 19,40       | 23,15    | 20                             |
| 2              | 19,17     | 34 | 3,21          | 14,30    | 27,00    | 17,00    | 18,75       | 21,50    | 19                             |
| 3              | 12,07     | 34 | 2,06          | 8,90     | 16,50    | 10,40    | 11,85       | 13,00    | 12                             |
| 4              | 17,27     | 27 | 3,54          | 11,50    | 26,00    | 15,50    | 16,50       | 19,10    | 17                             |

**Table 3.** The width of sapwood, mixed broadleaved forest – sample plot 1 and 2, fresh coniferous forest sample plot 3 and 4, basic statistics.

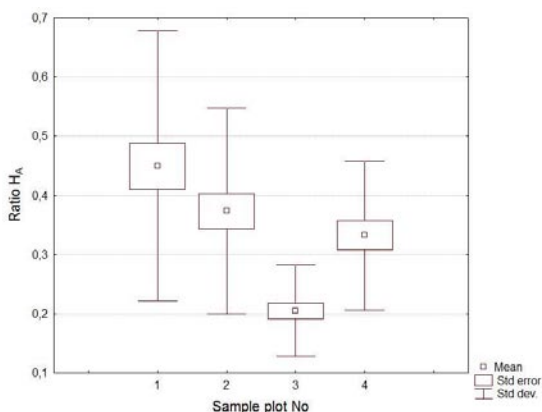
| Sample plot No | Mean [cm] | N  | Std dev. [cm] | Min [cm] | Max [cm] | Q25 [cm] | Median [cm] | Q75 [cm] | Coefficient of variability [%] |
|----------------|-----------|----|---------------|----------|----------|----------|-------------|----------|--------------------------------|
| 1              | 17,68     | 34 | 4,35          | 7,90     | 27,00    | 14,90    | 17,85       | 20,20    | 25                             |
| 2              | 19,56     | 34 | 6,20          | 9,90     | 34,00    | 15,00    | 19,10       | 22,30    | 32                             |
| 3              | 17,99     | 34 | 3,21          | 11,90    | 26,40    | 15,80    | 17,90       | 19,70    | 18                             |
| 4              | 18,37     | 27 | 4,33          | 11,20    | 25,90    | 14,30    | 18,50       | 22,40    | 24                             |

The little differentiation of width of heartwood was found on all sample plots, range of quartiles (Q25-Q75) show max 6 cm. All tested plots shows the same average sapwood width - about 18 cm, but the range of width shows high value from 7.9 cm to 34 cm (Tab. 3). Percentage of heartwood and sapwood was different in analysed two site conditions. Heartwood relative area on broadleaved forest was slightly high than in coniferous forest.



**Fig. 1.** Relation between ratio H (heartwood width to sapwood width) and heartwood width in all tested trees

This was probably caused by the faster growth of trees in better conditions especially in the juvenile stage of development of trees. The consequence of this situation are wider annual increments and width of heartwood. This is confirmed by positive and quite strong correlation (Spearman = 0,7) between heartwood width and ratio H (Fig. 1). For practical and technical objectives can be used ratio H, as easy to obtain, but for scientific purposes we can use ratio  $H_A$ . Ratio  $H_A$  may be more useful in the study of biomechanics of the tree (Fig. 4). Width of heartwood on rich site



**Fig. 2.** Variation of ratio  $H_A$  on tested sample plots, mixed broadleaved forest – plots No1 and 2, fresh coniferous forest – plots No 3 and 4.

conditions are relatively high (more than width of sapwood) but area of heartwood represents below 40% of the area of sapwood. On poorer sites this proportions are smaller, heartwood is narrower than sapwood and represents 20-30% of the area of sapwood. The differences between ratio H on FCF and on MBF are statistically significant. Coniferous site conditions allow to produce more stable forests and with thinner knots and area of heartwood are relatively low. Trees with higher area of sapwood could be more useful also for chemical wood impregnation.

## CONCLUSIONS

1. There were significant differences in the proportion of sapwood and heartwood between two analysed sites: fresh coniferous forest and moist mixed broadleaved forest. Higher proportion of heartwood was observed in broadleaved mixed forest.
2. The average area of sapwood represents 80% of cross section of the stem in coniferous forest and 72% in broadleaved forests. Forests grown in coniferous site condition seems to be more useful for chemical wood impregnation in order to higher area of sapwood.

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**Streszczenie:** *Udział twardzieli i bielu w strzałach sosen zwyczajnych (Pinus sylvestris L.) wyrosłych w różnych warunkach siedliskowych.* Materiał badawczy stanowiły 4 drzewostany wyrosłe w ramach dwóch typów siedliskowych lasu. Wybrano typy siedliskowe różniące się żyznością i wilgotnością siedliska. 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. Przeciętne średnice drzew w obu badanych typach siedliskowych lasu różniły się wyraźnie. W warunkach lasu mieszanego przeciętna średnica drzew wynosiła 38cm i 39cm (powierzchnia 1 i 2), w warunkach boru świeżego 30cm i 35cm (powierzchnia 3 i 4). Stwierdzono istotne różnice we względnym udziale drewna twardzielowego i bielastego na siedliskowych typach lasu: bór świeży i lasu mieszany. Większy udział twardzieli notowany był na siedlisku lasu mieszanego. Przeciętna powierzchnia drewna bielastego na siedlisku boru świeżego zajmowała około 70-80% przekroju poprzecznego w odziomkowej części pnia, na siedlisku lasu mieszanego 60%. Siedliska borowe jako optymalne dla sosny z uwagi na większą powierzchnię bielu mogą być bardziej użyteczne w nasycaniu drewna.

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