The share of sapwood and heartwood as well as the dynamics of heartwood formation in Scots pine (Pinus sylvestris L.) growing on forest and former farmland soils

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The aim of this study was to determine the share of sapwood and heartwood as well as dynamics of heartwood formation in stems of Scots pines (Pinus sylvestris L.) grown on forest and former farmland soils. The investigations were conducted in the Trzcianka Forest Division administered by the Regional Directorate of the State Forests in Piła. They were carried out in stands of age classes II, III and IV, grown in fresh coniferous forest and fresh mixed coniferous forest sites on forest and former farmland soils. Twelve experimental sites were established, from which a total of 36 mean sample trees were collected based on the diameter class Uricha I method. Mean sample trees represented the main stand, i.e. predominant, dominant and codominant trees according to the classification by Kraft. From each mean sample tree discs were collected, which made it possible to determine the share of sapwood and heartwood as well as the dynamics of heartwood formation. Discs were collected from centres of 2-metre sections. Analyses showed that pines grown on former farmland were characterised by greater dynamics of heartwood formation and a greater share of heartwood than trees grown on forest soils.

Sapwood, heartwood, dynamics of heartwood formation, Scots pine, annual rings, forest site type, biological class according to Kraft, forest soils, former farmland

Introduction

Forests growing on former farmland account for a considerable proportion of total forested area in Poland. This is a result of the programme of intensive afforestation of former farmland implemented on a broad scale after WWII, from the late 1940's to the 1960's, in order to increase the forest area in Poland. The Act on forests of 28 September 1991 specifies that forest economy should be based on the general protection of forests, sustainability and continued yielding, as well as the practice to increase forest resources thanks to afforestation of former farmland with the lowest soil quality classes, which agricultural utilisation is not economically viable (Radecki 1992).

The National programme to increase the forest area for the years 1995 - 2020 was prepared and approved by the resolution of the Council of Ministers of 24 June 1995 promotes an increase in the area of forests growing on former farmland. Rational utilisation of wood from these stands requires a comprehensive analysis of broadly understood properties of this raw material. This paper is an attempt to determine fluctuations in selected macroscopic characteristics of wood, i.e. the share of sapwood and heartwood in stems of pines, as well as fluctuations in the dynamics of heartwood formation in trees grown on forest soils and soils of former farmland.

Methods

The analyses were conducted in the Trzcianka Forest Division administered by the Regional Directorate of the State Forests in Piła. Investigations covered pine stands of age classes II, III and IV grown on forest soils and on soils of former farmland. A total of 12 experimental plots were established (Table 1).

After the stands had been selected, in each stand 1-hectare experimental plots were established. In each plot diameters at breast height were measured on all growing pines at 2-cm diameter subclasses. Moreover, tree height was measured in proportion to the frequency of trees in individual diameter subclasses. Next all the measured trees were divided into three diameter classes. In each class dimensions of mean sample trees were calculated applying the Uricha I method (Grochowskiego 1973). Trees selected for felling and further measurements represented the main stand, i.e. predominant, dominant and codominant trees according to Kraft (Kraft 1884).

Table 1. Characteristics of experimental plots

Class of age	Forest site type	Boni-tation	Soil /Forest plot No/	
			Forest	Former farml.
II	Ffs MFfs	II I	199i 200d	183d 246a
III	Ffs MFfs	II I	180i 237Ab	210f 182a
IV	Ffs MFfs	II I	194b 196i	226f 197b

Ffs - Fresh forest site (Bśw), MFfs – Mixed fresh forest site (BMśw)

In each experimental plot three mean sample trees were felled, yielding a total of 36 trees. Each mean sample tree was divided into 2-m sections, from the centre of which discs of 2-3 cm were cut for further measurements. Moreover, discs were also cut from the kerf plane of these pine trees.

Each disc was marked and next widths of the heartwood cylinder and the ring of sapwood were measured and the number of annual rings in both wood types was counted.

Recorded data made it possible to calculate the total volume of the trees and the volumes of sapwood and heartwood in the stems, as well as the resulting heartwood formation dynamics. In this paper heartwood formation dynamics were expressed in the ratios of the number of sapwood rings to the number of heartwood rings (Duda, Pazdrowski 1975, Pazdrowski 1992, Pazdrowski, Szaban 2002). The lower the ration, the greater the rate of replacement of sapwood rings with heartwood rings.

In this study arithmetic means of analysed characteristics were used, expressed in absolute and relative values, along with the calculated measures of position and scatter.

Results

The quantitative ratio of sapwood to heartwood in trunks or stems of trees is a major criterion in the assessment and classification of large-sized pine wood assortment. In the plywood industry pine wood with a large share of sapwood is considered desirable, since a wide layer of this wood yields considerable amounts of light, uniformly coloured veneer to be used as face layers in plywood. In turn, the fermentation industry needs such wood to build vats and the chemical industry requires heartwood to build wooden barrels due to its lower permeability (Krzysik 1978, Mućk 1984, Hejnowicz 2012). Sapwood is readily saturated with antiseptic liquids, while heartwood is sparsely saturated (Mućk 1984). For this reason, depending on the intended use of wood material, properties of both wood types may be sometimes considered a positive and sometimes a negative property.

Quantitative ratios of sapwood and heartwood in stems or trunks of trees are significantly affected by the dynamics of heartwood formation (Krzysik 1978, Pazdrowski 1992). Results of analyses are given in tables 2 and 3 and presented graphically in Figs. 1 to 3.

Table 2. Statistical characteristic of share of different types of wood of Scots pine growing on forest and former farmland soils

Soil	Measures of position and scatter		Tree steam volume		
			Total	Sap-wood	Heart-wood
Forest	Arithmetic mean	m^3 %	0,1919 100,0	0,1700 88,5	0,0222 11,5
	SD	m^3	0,1177	0,0986	0,0197
	Coeff. of variation	%	61,3	58,1	89,0
Former farml.	Arithmetic mean	m^3 %	0,2679 100,0	0,2160 80,6	0,0519 19,4
	SD	m^3	0,1490	0,1139	0,0390
	Coeff. of variation	%	55,6	52,7	75,2
Forest and Formr farml and	Arithmetic mean	m^3 %	0,2299 100,0	0,1929 83,9	0,0370 16,1
	SD	m^3	0,1340 1	0,1044	0,0333
	Coeff. of variation	%	58,3	54,1	89,9

In pine stands grown on forest soils the average stem volume was lower than in pines grown on former farmland soils (tab. 2). The shares of sapwood and heartwood in the former amounted to 88.5% and 11.5%, while in the latter they were 80.6% and 19.4%, respectively. Variation in the shares of sapwood and heartwood on forest soils amounted to 58.1% and 89.0%, while on former farmland it was 52.7% and 75.2%, respectively (tab. 2). Recorded values of the coefficients of variation (tab. 2) characterising volumes of sapwood and heartwood in stems of pines grown on forest soils and on former farmland soils indicate the effect of soil type on volume in both types of wood. Since in both analysed soil types, i.e. forest soil vs. former farmland soil, growing pines differed in stem volume and contents of both wood types, in order to eliminate these elements having a potential effect on variation in the shares of sapwood and heartwood it was decided to compare the ratio of heartwood to sapwood (Table 3).

Table 3. Statistical characteristic of share of volume of heartwood and sapwood in stems of Scots pine growing in conditions of forest soil and former farmland soil

Soil	Measures of position and scatter		Heartwood / Sapwood
Forest	Arithmetic mean	% %	0,1033 68,1
	SD		0,05864
	Coeff. of variation	%	56,8
Former farml.	Arithmetic mean	%	0,2000 131,9
	SD		0,1376
	Coeff. of variation	%	68,8
Forest and Former farmland	Arithmetic mean	%	0,1516 100,0
	SD		0,1110
	Coeff. of variation	%	73,2

Values denoted in bold indicate that the ratio of heartwood volume to that of sapwood in pines grown on forest soils is low (0.1033), while in trees from former farmland it was almost two-fold greater (0.2000). This definitely confirms that pines grown on former farmland soils have markedly more heartwood than trees grown on forest soils. Values of the coefficient of variation characterising variation in the ratio of heartwood to sapwood in stems of pines grown on forest soils was 56.8%, while for those grown on former farmland soil it was 68.8% (Table 3).

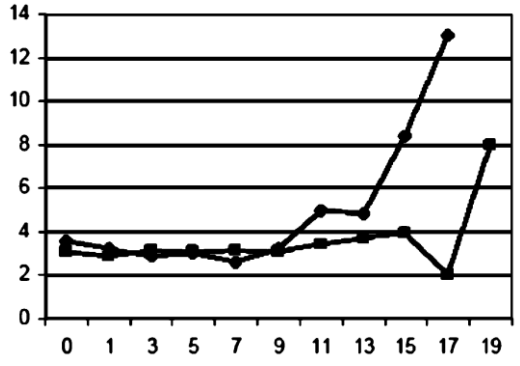

Fig.1. Mean dynamics of heartwood formation of Scots pines (*Pinus sylvestris* L.) growing on former farmland and forest sites in conditions of fresh forest site (◆ Forest, ■ Former farmland, OY - No of sapwood rings / No of heartwood rings, OX – height of measurement)

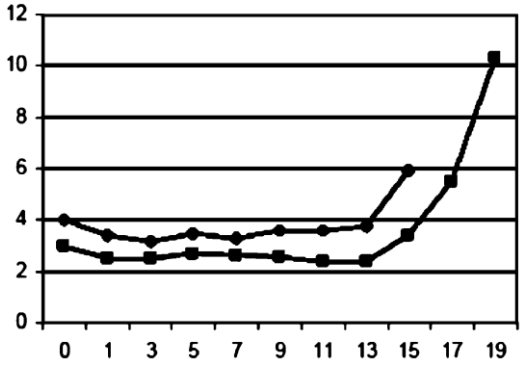

Fig. 2. Mean dinamics of heartwood formation of Scots pine (*Pinus sylvestris* L.) groving of former farmland and forest sites in condition of fresh mixed forest sites (◆ Forest, ■ Former farmland, OY - No of sapwood rings / No of heartwood rings, OX – height of measurement)

A graphic interpretation of the recorded results characterising the dynamics of heartwood formation showed the fastest replacement of sapwood rings with heartwood in pines grown on former farmland soils, which was particularly evident in the fresh mixed coniferous forest sites (Fig. 2).

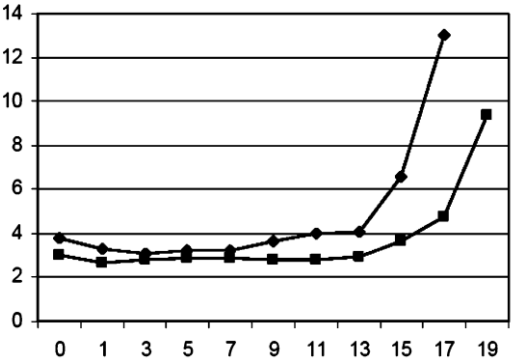

Fig. 3. Mean dinamics of heartwood formation of Scots pines (*Pinus sylvestris* L.) growing on forest and former farmland soils (◆ Forest, ■ Former farmland, OY - No of sapwood rings / No of heartwood rings, OX – height of measurement)

Figures 1 to 3 present dynamics of heartwood formation in pines (Pinus sylvestris L.) grown on forest and former farmland soils. In this study the dynamic of heartwood formation was characterised based on the ratio of the number of annual rings in sapwood to the number of heartwood rings. Thus it may be concluded that with an increase in the quotient (value) the dynamic of heartwood formation is lower, while in the case when the ratio of the number of sapwood rings to heartwood rings decreases, the dynamic is greater.

According to Hejnowicz (1974, 2012), heartwood formation is inseparably connected with the death of parenchyma cells. This may be caused by cell ageing, i.e. a physiological process, or such factors as the action of fungi, frost and damage caused by other causative factors.

Wood, until the age of the trunk or stem does not exceed the lifespan of parenchyma cells, is composed solely of sapwood (Hejnowicz 1974). It results from studies by Granier (1981), Vomperski and Ivanow (1984) and Pazdrowski (1988) that the share of sapwood and heartwood is determined to a considerable degree by the fluctuations in the size of the live crown and the maintenance of the equilibrium between the conductive area of the trunk or stem (sapwood) and the transpiring area of the tree. In this respect a particularly important role is played by the light crown.

Conclusions

1. Pines grown on former farmland soils had a greater share of heartwood in stem volume than it was in trees grown on forest soils. The mean share of heartwood expressed in relative values was 19.4% in the former and 11.5% in the latter. Variation in the share of heartwood in stems of pines from forest soils was greater, amounting to 89.0% in comparison to trees grown on former farmland, where the calculated coefficient of variation for this trait was 75.2%.
2. In relation to sapwood an opposite trend was observed for its share in stem volume than that observed for heartwood. The mean share of sapwood in pines from forest soils was 88.5%, while in trees from former farmland it was markedly lower, amounting to 80.6%. Variation in the share of sapwood in stem volume, expressed in the coefficient of variation, in pines from forest soils reached 58.1%, while in trees from former farmland it was 52.7%.
3. A greater dynamic (rate) of the heartwood formation process was observed in stems of pines grown on former farmland, while it was lower in trees grown on forest soils, as evidenced by the calculated values of the ratio of the number of sapwood rings to that of heartwood rings.
4. Analyses showed a definite relationship between the dynamics of heartwood formation and the share of both wood types in stems of pines grown both on former farmland and forest soils.

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Участие заболони и ядра, а также динамика формирования ядровой древесины у сосны обыкновенной (Pinus sylvestris L.) растущей на лесных почвах и почвах бывших земельных участков

Резюме

Целью исследований была попытка определить участие заболони и ядра , а также динамику формирования ядровой древесины в стволах сосны обыкновенной (Pinus sylvestris L.) растущей в условиях лесных почв и почв поземельных участков. Исследования проводились в низменной местности. Они охватывали насаждения II, III и IV класса возраста, растущие в условиях местопроизрастания бора свежего и бора смешанного свежего на лесных и поземельных почвах. Было выделено 12 исследовательских участков , на которых загатовлено 36 модельных деревьев по методу классов толщины Уриха I. Модельные деревья представляли главное насаждение по классификации Крафта. От каждого модельного дерева были взяты кружки из середины 2-метровых секциЙ, которые предоставили возможность определить участие заболони и ядра , а также динамику процесса формирования ядровой древесины . Исследования показали, что сосны выросшие на бывших земельных участках отличались большей динамикой процесса формирования ядровой древесины и большим участием ядровой древесины, чем деревья растущие на лесных почвах.

Древесина заболонная и ядровая, динамика процесса формирования ядровой древесины, сосна обыкновенная, годичные кольца, тип условий произрастания, биологический класс Крафта.

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