Acta Sci. Pol.
Silv. Colendar. Rat. Ind. Lignar. 4(2) 2005, 113-121

SELECTED BIOMETRIC TRAITS OF THE SCOTS PINE (*PINUS SYLVESTRIS* L.) STEMS AS THE BASIS FOR THE ASSESSMENT OF THE VOLUME AND PROPORTION OF MATURE WOOD

Arkadiusz Tomczak, Tomasz Jelonek, Witold Pazdrowski, Maciej Duma
Agricultural University of Poznań

Abstract. An attempt was made in the study to determine interrelationships between the volume, proportion of manure wood and selected easy-to-determine biometric traits of trees, i.e. breast height diameter, height and stem total volume. The analysis comprised pine stands of the ll, lll, lV and V age classes which developed in conditions of the fresh mixed coniferous forest site type. Correlations were found between the volume and the proportion of mature wood and the selected tree biometric traits. The observed interrelationships were expressed in different ways and with different intensity, depending on the compared traits.

Key words: Scots pine, proportion of mature wood, biometric traits, fresh, mixed coniferous forest

INTRODUCTION

Many morphological and physiological changes take place in trees during their ontogenesis. They go through phasic development, i.e. through the stages of embryonic and juvenile growth, maturation, maturity and aging. This development exerts a significant influence on the wood tissue forming during the consecutive stages of tree development and affects properties of wood as the renewable resource of plant origin [Pazdrowski and Spława-Neyman 2003]. The wood tissue which is formed in the part of stem or trunk away from the shoots with leaves (living tree crown) is characterized by a different structure than the wood which is formed in the crown [Haygreen and Bowyer 1996, Hejnowicz 1973, 2002, Rendle 1960, Thörnqvist 1993]. Mature wood is characterized by considerably better strength and physical parameters as confirmed by the results of investigations carried out on Norway spruce, Scots pine and black pine [Pazdrowski and Spława-Neyman 2003, Pazdrowski 2004]. This kind of wood exhibits

Corresponding author – Adres do korespondencji: mgr Arkadiusz Tomczak, Department of Forest Utilization of Agricultural University of Poznań, Wojska Polskiego 71A, 60-625 Poznań, Poland, e-mail: atomczak@au.poznan.pl

lower homogeneity than juvenile or intermediate (maturing) wood [Pazdrowski and Spława-Neyman 2003]. Bearing in mind the above-presented characterisation, it can be stated that the tissue of mature wood is characterized by distinctly higher technical values than juvenile wood and, consequently, it affects strongly both the quality and value of timber raw material.

The objective of the performed research project was to determine interrelationships between the volume and volume proportion of mature wood in the stems of Scots pine (*Pinus sylvestris* L.) trees and some selected tree biometric traits which are easy to determine, i.e. breast height diameter, height and stem total volume.

MATERIAL AND METHODS

Investigations were carried out in pine stands of the ll, lll, lV and V age classes which developed in conditions of the fresh mixed coniferous forest site type. The experimental stands were situated in the following forest divisions: Brynek, Choszczno and Miastko.

Table 1 presents a synthetic description of surfaces on which the experiments were conducted.

Table 1. Description of experimental stands
Tabela 1. Opis drzewostanów objętych badaniami

Forest Division Nadleśnictwo	Compartment and sub-compartment Oddział i pododdział	Species composition, age and stand density Skład gatunkowy, wiek i wskaźnik zadrzewienia	Mean (for Scots pine) Przeciętna (dla sosny)	
			breast height diameter pierśnica cm	height wysokość m
Brynek	15d	7So, 2 Brz – age 35, 1 Brz – age 25, std. 0.8, bon I	16	14
	13c	So, age – 35, std. 0.9, bon. Ia	17	16
	13g	9 So, 1 Brz – age 55, std. 0.9, bon. I	21	20
	5g	9 So, 1 Md – age 55, std. 0.9, bon. I	24	20
Choszczno	55a	So – age 37, std. 0.9, bon I a	16	17
	46c	So – age 37, std. 0.9, bon I a	16	18
	44a	So – age 61, std. 0.9, bon. I	25	21
	38o	9 So, 1 Brz – age 65, std. 0.9, bon I a	29	26
Miastko	408c	8 So, 2 Brz – age 40, std. 0.8, bon. I	14	16
	393g	7 So, 2 Brz, 1 Md – age 41, std. 0.7, bon. I	15	16
	408d	So age – 72, std. 0.8, bon. I	25	21
	407i	So age –72, std. 0.8, bon. I	28	22
	95f	So age – 77, std. 0.8, bon. I	28	24
	197 j	So age – 82, std. 0.4, bon. I	33	24
	93c	So age –102, std. 0.5, bon. I	36	26
	88j	So age –102, std. 0.9, bon. I	39	27

So – Scots pine, Brz – birch, Md – larch, std – stand density, bon – stand quality.
So – sosna, Brz – brzoza, Md – modrzew, std – zadrzewienie, bon – klasa bonitacji, age – lat.

Breast height diameters of all trees as well as measurements of tree heights (proportionally to their frequency in individual degrees of thickness) were taken on the selected experimental surfaces. On the basis of the obtained measurement results of the tree breast height diameters and heights, using the Urich ll method [Grochowski 1973], dimensions of three mean sample trees representing the main stand were calculated, i.e. pre-dominant, dominant and co-dominant trees according to Kraft's classification and then they were selected in stands. The total of 48 mean sample trees were marked out. Pine trees of healthy, straight and symmetrical stems and crowns well-developed appropriately to the given biological class were selected. After marking the North on stems of each tree, they were felled and discs were cut out from each one in order to assess their volume and the proportion of mature wood in the stems of mean sample trees. The discs were cut off the plane at which trees were felled and from the middle of two-meter sections of boles.

The disc surfaces were sanded and then two perpendicular lines were drawn along north-south and east-west directions. The perpendicular lines were used to measure the width of early and late wood zones in the consecutive annual rings in four world directions. In the case of the discs taken from the plane of felling of sample trees, the measurements started from the stem pith towards the stem circumference, whereas in the case of discs taken from the middle of 2 m bole sections, the measurements proceeded from the circumference towards the pith. The above-described procedure affected, later on, the determination of the true volume and proportion of mature wood in the stems of trees in the course of laboratory analyses.

Measurements were performed using an electronic increment meter coupled with a computer equipped in the program "Codima Increment meter".

Next, the value of the ratio of the width of the early to late wood zones in the consecutive annual rings on discs collected from mean sample trees was determined.

Values calculated in this way were used as the basis to delineate the occurrence on the diameter of consecutive discs of mature and juvenile wood. The share of late wood in the stem successive annual rings increased with the distance from the stem pith. It should be stressed that this change became more conspicuous when the trunk was situated outside the tree crown [Hejnowicz 2002]. A similar correlation was observed in the variability of a number of other timber traits [Hejnowicz 2002].

Juvenile wood was characterised by low values expressing the late wood to early wood zone ratio in the annual ring, while the mature wood was characterised by high numerical values of this trait.

The obtained measurement results were analysed employing methods of statistical analysis. Principal statistical characteristics of dependent and independent variables as well as curvilinear correlations were determined with the assistance of the statistical program STATISTICA 6.0 PL.

RESEARCH RESULTS

The obtained statistical characteristics of the selected biometric traits of tree stems and their volume and the proportion of the mature wood revealed their considerable variability, especially during the early stages of development of trees and stands, i.e. in the second age class. With the passage of time and as the trees moved to older

developmental stages (to higher age classes), a distinct decline in the variability of all dependent and independent traits analysed in this study was observed. A relatively high variability (value of the calculated variability coefficient) was found in relation to the volume of the mature wood and the stem volume. In the first instance, the value of the calculated variability coefficient, depending on the developmental phase of trees and stands, ranged from 28.1% to 66.7%, while in the second – from 27.7% to 58.0% (Table 2). The lowest variability was recorded with reference to the height of pine trees in relation to the developmental stage which ranged from 6.6% to 13.8%.

Table 2. Statistical characteristics of selected biometric traits of mean sample tree stems as well as volume and proportion of mature wood
Tabela 2. Charakterystyka statystyczna wybranych cech biometrycznych strzał drzew próbnych oraz miąższości i udziału drewna dojrzałego

Age class Klasa wieku	Measures of location and dispersion Miary położenia i rozproszenia	Height Wysokość m	Breast height diameter Pierśnica cm	Stem volume Miąższość strzały m^3	Mature wood volume Miąższość drewna dojrzałego m^3	Ratio of the mature wood volume to stem volume Stosunek miąższości drewna dojrzałego do miąższości strzały
II	mean – średnia	16.73	15.88	0.141	0.087	0.6298
	standard deviation odchylenie standardowe	2.30	4.12	0.082	0.058	0.1498
	variability coefficient, % współczynnik zmienności, %	13.77	25.96	58.05	66.69	23.79
	minimum – minimum	11.80	8.50	0.050	0.030	0.2829
	maximum – maksimum	20.40	22.00	0.290	0.230	0.8846
III	mean – średnia	22.45	23.42	0.421	0.363	0.8373
	standard deviation odchylenie standardowe	1.86	4.87	0.225	0.214	0.0750
	variability coefficient, % współczynnik zmienności, %	8.26	20.80	53.39	59.00	8.96
	minimum – minimum	20.30	17.00	0.160	0.110	0.6875
	maximum – maksimum	26.70	32.00	0.860	0.800	0.9302
IV	mean – średnia	22.61	25.46	0.493	0.382	0.7646
	standard deviation odchylenie standardowe	1.86	4.93	0.217	0.188	0.0548
	variability coefficient, % współczynnik zmienności, %	8.21	19.38	43.99	49.16	7.16
	minimum – minimum	19.40	18.10	0.172	0.130	0.7003
	maximum – maksimum	25.80	32.25	0.824	0.752	0.9126
V	mean – średnia	26.40	33.27	1.108	0.931	0.8410
	standard deviation odchylenie standardowe	1.75	3.73	0.307	0.262	0.0365
	variability coefficient, % współczynnik zmienności, %	6.61	11.21	27.68	28.14	4.34
	minimum – minimum	23.80	27.40	0.705	0.597	0.8021
	maximum – maksimum	28.30	37.20	1.488	1.281	0.9011

Figures 1 and 2 show the dependence of the stem volume and the mature wood volume on the breast height diameter and tree height. The dependence of the mature wood volume in the tree stem on the total volume is shown in Figure 3, whereas interrelationships between the share of the mature wood (expressed by the ratio of the mature wood volume to the stem total volume) and the stem total volume, breast height diameter, tree height and stem volume are shown in Figures 4 to 6. The above-mentioned interrelationships were characterised by determination coefficients and regression equations. These relations were of curvilinear nature. High values of determination coefficients were found while analysing dependences of the stem total volume and mature wood on the tree height and breast height diameter as well as the dependence of the mature wood volume on the tree total volume. The above values reached: $R^2 = 0.8829$, $R^2 = 0.87$, $R^2 = 0.9362$, $R^2 = 0.8655$ and $R^2 = 0.9627$, respectively. The obtained results indicate that the dependent variables (stem total volume and mature wood volume) were affected by the analysed independent variables (tree height and breast height diameter) by about: 88%, 87%, 94%, 86% and 96%, respectively.

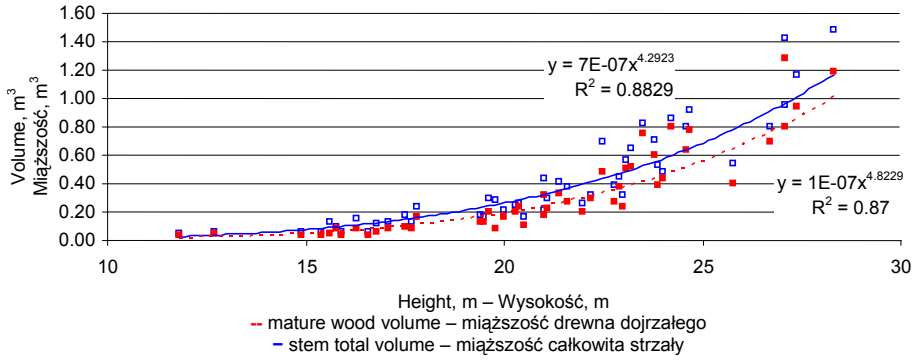

Fig. 1. Dependence of stem and mature wood volume on tree height
Rys. 1. Zależność miąższości strzały oraz drewna dojrzałego od wysokości drzewa

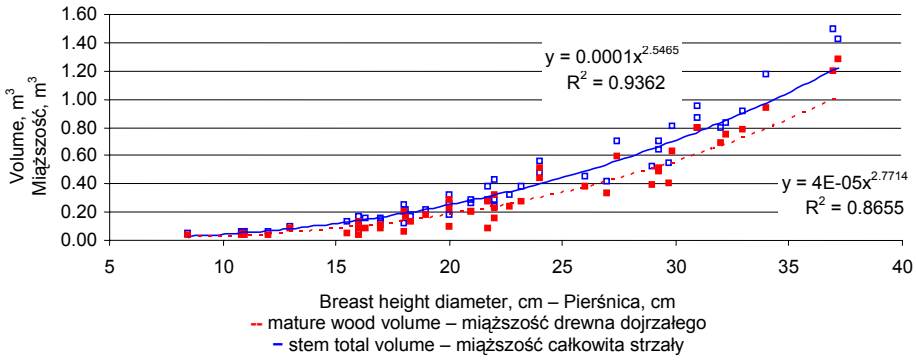

Fig. 2. Dependence of stem and mature wood volume on tree breast height diameter
Rys. 2. Zależność miąższości strzały oraz drewna dojrzałego od pierśnicy drzewa

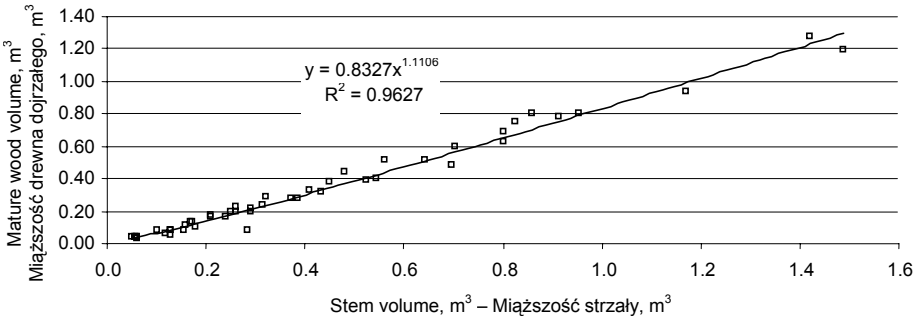

Fig. 3. Dependence of the mature wood volume on the stem total volume
Fig. 3. Zależność miąższości drewna dojrzałego od miąższości całkowitej strzały

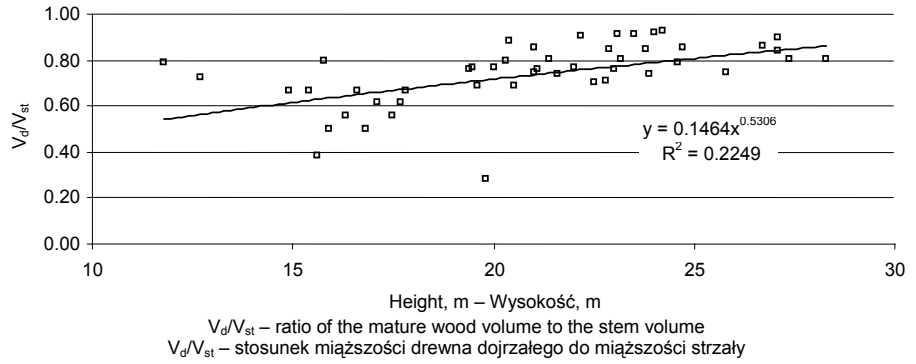

Fig. 4. Dependence of the proportion of the mature wood on tree height
Rys. 4. Zależność udziału drewna dojrzałego od wysokości drzewa

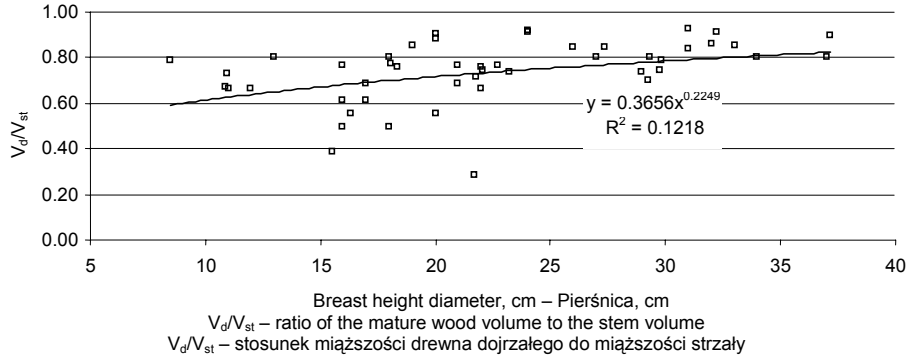

Fig. 5. Dependence of the proportion of the mature wood on breast height diameter
Rys. 5. Zależność udziału drewna dojrzałego od pierśnicy drzewa

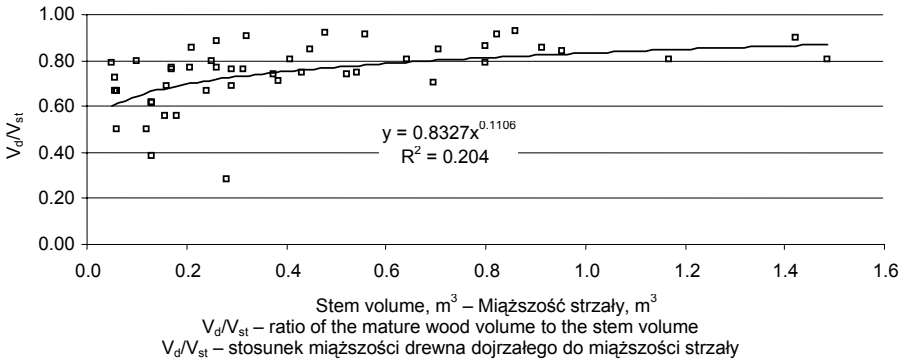

Fig. 6. Dependence of the proportion of the mature wood on the stem total volume
Rys. 6. Zależność udziału drewna dojrzałego od miąższości całkowitej strzały

On the other hand, when analysing the dependence of the mature wood volume ratio to the stem volume on the tree height, breast height diameter and stem total volume it is evident that the above-mentioned independent variables affected the value of the dependent variable. All the discussed correlations were of direct proportional nature. The calculated determination coefficients (R^2) were low and ranged from 0.1218 to 0.2249 (Figs. 4-6).

DISCUSSION

During the initial phase of wood tissue production, juvenile wood is manufactured in the tree stem. Most commonly, it develops in the course of some to several years of the life of the tree under a strong influence of its assimilation apparatus (tree crown) [Hejnowicz 1973, 2002, Niedzielska and Wąsik 2000, Zobel and Stage 1998]. The wood that develops later on is called mature wood. The two wood zones, i.e. mature and juvenile, occur in different proportions in the tree stem and this proportion depends on several factors, in particular on the age of trees, site conditions as well as the tree species [Thörnqvist 1993].

A comprehensive knowledge of interrelationships occurring between the volume and the volume proportion of mature wood in pine stems and the tree height, breast height diameter and stem total volume, i.e. easily determined biometric traits, is of fundamental cognitive and practical importance. The application significance of the obtained research results is closely associated with the rationalisation of the processing and utilisation of timber raw material harvested within the framework of planned intermediate (thinnings) and final cuttings.

CONCLUSIONS

1. Correlations were found to occur between the volume and proportion of the mature wood found in stems of pine trees growing in conditions of fresh mixed coniferous forest and selected tree biometric traits. They found their expression in different manners and with different intensity, depending on the compared traits.

2. Values of determination coefficients (R^2) which characterise the relationship between the volume of the mature wood in the stem and tree height, breast height diameter and total volume amounted to: 0.8700, 0.8655 and 0.9627, respectively. However, in the situation when the dependent variable was the ratio of the mature wood volume to the stem total volume and the independent variables comprised: tree height, breast height diameter and stem total volume, the determination coefficients reached the following values: 0.2249; 0.1218 and 0.2040.

3. The obtained statistical characteristics of the selected biometric traits of the pine tree stems as well as the mature wood volume and proportion indicate their considerable differences, especially during tree early developmental phases, i.e. in the second age class. As trees passed into older developmental stages (higher age classes), the analysed traits were found to become more stable.

4. Bearing in mind the obtained high values of the determination coefficients (R^2) which characterise the relationship between the mature wood volume in the stem and the tree height, breast height diameter and stem total volume, it is reasonable to utilise this regularity as a way of the estimation of the mature wood volume in pine tree stems growing in conditions of fresh mixed coniferous forest.

REFERENCES

Grochowski J., 1973. Dendrometria. PWRiL Warszawa.

Hejnowicz Z., 1973. Anatomia rozwojowa drzew. PWN Warszawa.

Hejnowicz Z., 2002. Anatomia i histogeneza roślin naczyniowych. PWN Warszawa.

Haygreen J.G., Bowyer J.L., 1996. Forest products and wood science. An introduction. Iowa State University Ames.

Niedzielska B., Wąsik R., 2000. Badania zmienności cech drewna jako podstawa do racjonalnego kształtowania jego jakości. In: Mater. III Konf. Leśnej IBL. 30-31 marca, Warszawa, 259-267.

Pazdrowski W., Spława-Neyman S., 2003. Stage growth of Trees and its effect on selected properties of Norway spurce wood (*Picea abies* (L) Karst). EJPAU 6. Ser. For. www.ejpau.media.pl, 1-7.

Pazdrowski W., 2004. The proportion and some selected physical and mechanical properties of juvenile maturing and adult wood of Black pine and Scots pine. EJPAU 7. Ser. For. www.ejpau.media.pl, 1-8.

Rendle B.J., 1960. Juvenile and adult wood. J. Inst. Wood Siena 5, 58-61.

Thornquist T., 1993. Juvenile wood in coniferous trees. Document D.13. Uppsala.

Zobel B.J., Stage J.R., 1998. Juvenile wood In forest Trees. Springer-Verlag Berlin, 300.

WYBRANE CECHY BIOMETRYCZNE STRZAŁ SOSNY ZWYCZAJNEJ (*PINUS SYLVESTRIS* L.) JAKO PODSTAWA OCENY MIĄŻSZOŚCI I UDZIAŁU DREWNA DOJRZAŁEGO

Streszczenie. W pracy podjęto próbę określenia zależności między miąższością, udziałem drewna dojrzałego w strzałach sosen zwyczajnych a wybranymi cechami biometrycznymi drzew łatwymi do określenia, tj. pierśnicą, wysokością i miąższością całkowitą strzały. Analizą objęto drzewostany sosnowe II, III, IV i V klasy wieku, które wyrosły w warunkach boru mieszanego świeżego. Stwierdzono występowanie zależności między miąższością i udziałem drewna dojrzałego w strzałach sosen a wybranymi cechami biometrycznymi drzew. Zależności te wyrażały się w różny sposób i z różną intensywnością, odpowiednio do porównywanych cech.

Słowa kluczowe: sosna zwyczajna, udział drewno dojrzałego, cechy biometryczne, bór mieszany świeży

Accepted for print – Zaakceptowano do druku: 01.08.2005 r.

For citation – Do cytowania: Tomczak A., Jelonek T., Pazdrowski W., Duma M., 2005. Selected biometric traits of the Scots pine (Pinus sylvestris L.) stems as the basis for the assessment of the volume and proportion of mature wood. Acta Sci. Pol., Silv. Colendar. Rat. Ind. Lignar. 4(2), 113-121.