Mechanical Properties of Juvenile Wood of Scots Pine (*Pinus sylvestris* L.) on *Myrtillus* Forest Site Type

JAAK PIKK[1], REGINO KASK[2]
[1] Estonian Agricultural University, Forest Research Institute,
Kreutzwaldi 5, 51014 Tartu, Estonia, e-mail: jpikk@eau.ee
[2] Estonian Agricultural University, Faculty of Forestry,
Kreutzwaldi 5, 51014 Tartu, Estonia, regino@eau.ee

Pikk J., Kask R. 2004. Mechanical Properties of Juvenile Wood of Scots Pine (*Pinus sylvestris* L.) on *Myrtillus* Forest Site Type. *Baltic Forestry,* 10 (1): 72–78.

Variations in late wood percentage, juvenile wood and sapwood properties within trees and between stands of Scots pine from Northeast and South Estonia were analysed. The mean wood density of juvenile wood form 83,8% from sapwood density, static bending strength 62%, compression parallel to grain 68,6% and gross-surface strength 81,2% respectively. Investigations were conducted on the wood properties of trees from the 60-year-old stands determined the 5 year cambial age juvenile-mature wood transition in Scots pines in *Myrtillus* forest site type.

Key words: Pine, sapwood, late wood, bending strength, compressive strength, surface strength, density

Introduction

The properties of the pinewood differ in stems from pith to bark and from the roots to the top of the tree. To the same degree the amount of latewood and cells with thick walls increase from pith towards to the bark. During the cells and tissues formation process the structure and characteristics of the wood is influenced by the genetic, environmental (light intensity, nutrients, moisture) and anthropogenic factors (Stähl 1998, Saranpää 1999, Wodzicki 2001, Larson *et al.* 2001). For these reasons a material with different qualities can be obtained from same stem and the same wood for different users had different value. Earlier investigations discuss primarily the different qualities of heart- and sapwood and wood come of the crown. During recent years problems proceeding from properties of juvenile wood and superfluity of that in stem have become evident (Arlinger & Wlihemsson 1999, Larson *et al.* 2001, Jayawickrama 2001), as those factors decrease the general technical characteristics of the wood.

The juvenile wood forms a homogeneous cylinder in the central part of the stem and so almost all the top of the stem consists of the juvenile wood (Saranpää 2002). As the stem is getting older and diameter is increasing the heartwood is forming around the pith. The juvenile wood and also a part of the surrounding wood will change to heartwood, which is recognized by lower moisture level and higher containing of extractive matter.

The juvenile wood forms a little less than 10 annual rings around the spruce pith (Saranpää 2002), conifers have 5-25 annual rings (Lindström 2002), but the sources about pine tree are giving very different data. According to some authors the transition period of pines juvenile wood to the mature wood at cambial age approximately 22 years with the standard deviation of 5-7 years (Sauter *et al.* 1999). By E. Saarmann (1998) the juvenile wood is formed 10-20 nearest annual rings to the pith. S. Mattson (2002) remarks that variation was large for all wood property and the juvenile wood period seems to last for at least 16 years at 0,8 metre height. At the same time he has found out that there was no effect of the crown position in transition from juvenile to mature wood as judged by wood density and no evidence to support the concept that tree spacing and live-branch pruning have a significant effect on the cambial age in transition from juvenile to mature wood. (Gartner *et al*. 2002).

Sources give several constrained terms to juvenile wood that some authors have used synonymously (Amarasekara & Dene 2002). Also, there is no common position on how to determine the juvenile wood – should it be made according to density, modulus of elasticity or use acoustics approach when sorting out (Walker & Nakada 1999). For industry it is a question of utmost importance because for example the quality properties of paper (porosity, strength, density of sheets etc.) are affected by the raw material – as the butt log, middle log and top log have bigger differences in density and the juvenile wood as well as heartwood are playing there an important role (Duchesne *et al.* 1997). However, the top log of great pith consists lot of juvenile wood. First-thinning wood has different properties from the late- thinning wood (Hakkila *et al.* 1995). The reason comes from the great bunch of juvenile wood around the pith in a young tree with a small diameter. Early wood cells in such timber are short having thin walls, containing lots of lignin, having small amount of latewood and wood density is low. When drying wood, several increases and decreases cause lot of splits and timber can become warped. The most part of juvenile wood is not suitable material for construction works or building (Saarman 1998). As there are problems with many tree species used for economic purpose, the part of juvenile wood is tried to minimized by using forest selection and other methods of forestry, also the skillful sorting out of logs in mills are used (Jayawickrama 2001).

The aim of this study was to make evident the horizontal and vertical variation in some wood properties in *Myrtillus* site type of pine stems and to compare the characteristics of juvenile wood with mature wood and sapwood in the 60-year-old stands. There are relatively few data on raw material made of pole timber, but as the number of users has increased, the interest about the results is really high.

Material and methods

During the last decade when the felling extent is tripled more young wood have been started to from strong thinning and sanitation clearcut areas. This material should therefore contain more juvenile wood in comparison with the material cut from old forest. Taking that into account, the research objects with the 60-year-old pine trees in mixed stands on a *Myrtillus* site were chosen in North-East and South Estonia with the quality class I and II. The best strength properties were expected to get as according to the source pine forests on fresh soil and pine trees in mixed type forests have better strength qualities (Splawa-Newman 1994). On the other hand, it becomes evident that chosen trees have got relatively small diameter of juvenile wood in stem and number of annual rings (25) in sapwood, which makes a very big difference from the stands researched so far.

Twenty two model trees were chosen among the dominant trees, cutting of the testing disks and chopping blocks for preparing the testing samples of stem, from the highpoint of h1/4, h1/2, h 3/4. So the stub up to h ¾ was researched. In fresh cut trees the spreading of humidity was measured at above-mentioned levels. Room-dry dried and polished disks annual radial growth was measured, also the late wood percentage in the annual ring and heart- and sapwood relative importance as well as surface hardness in the three directions by the Janka method was measured. The program Win-Dendro was used for measuring the wideness of annual rings.

A total of 280 samples for measuring density and 764 experimental samples for determining the wood mechanical properties were made. Experimental samples of sapwood in cross-section were parcel out onto three groups by age of wood start from bark (sapwood 1, 2 and 3). All mechanical features in this research are explained at 12% of moisture level. All experimental data are processed using correlation and linear regression analyses with Microsoft Excel.

Experimental results

Physical characteristics

In mid October it was measured for the pine stems grown in North-East Estonia average sapwood relative moisture rate as 54,2±0,5% and heartwood 33,1±1,0% while the moisture rate of the juvenile wood (34,5±2,1) did not exhibit essential difference from the humidity rate of the heartwood. Humidity rate of the sapwood increased from the stump to the top of the stem statistically insignificant, but it was a remarkable increase in the case of heartwood.

At four levels of stems researched general width of annual ring (y) excluding 2-3 annual rings around pith, decreased linearly with increasing cambial age. It means the bigger the cambial age (x), then narrower is the annual ring in cross-section of the stem. The width of the annual ring at the level of h ¼ is explained as well:

$$y = 5{,}50049 – 0{,}09168x+0{,}547463*1/x, \quad R^2=0{,}79$$

Different situation is with relative importance of latewood (y), which in annual rings near the pith is small but starting from the 5-th year cambial age starts to increase linearly with age (x) (Fig. 1). In research object in Northeast Estonia the stem level of height h ¼ explains this as follows:

$$y = 17{,}88949+0{,}527125x – 17{,}4225*1/x, \quad R^2=0{,}69$$

In the case of stub and the level of h ¼ the results gained from the late wood relative importance were almost similar, but at the half way of the tree and at the level of h ¾ the importance of the late wood decreases. We can see in the figure how the late wood is divided in comparison with two different stands. The stand with second quality class the latewood distribution is more equal. In the stand with the higher quality class the importance of latewood is increases equally with increasing cambial age and this case: $R^2 = 0{,}81…0{,}86$.

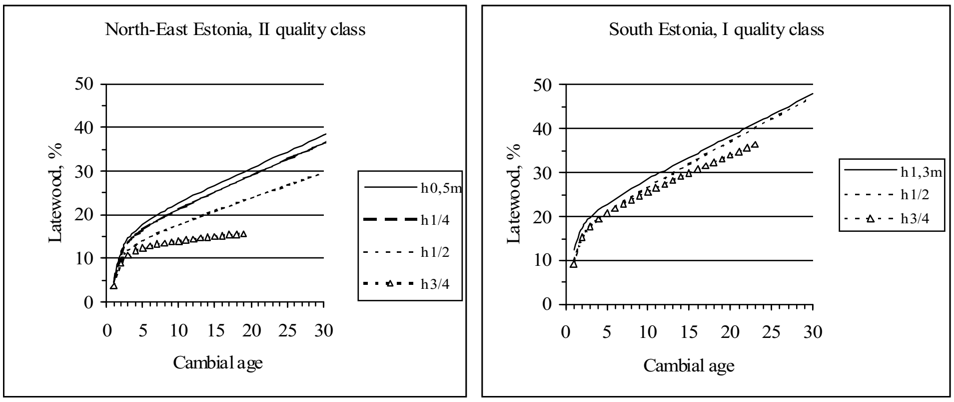

Figure 1. The distribution dynamics of latewood in different cross-sections of pine stem in Northeast and South Estonia on *Myrtillus* site

Density of the pinewood in stem decreases from the bark towards the pith and from stub towards the top (Fig. 2). The highest absolute dry density of sapwood was obtained under the bark from the butt log (535,2 kg/m³). Juvenile wood density at the same level was 448,6 kg/m³ e.g. 16,2% smaller.

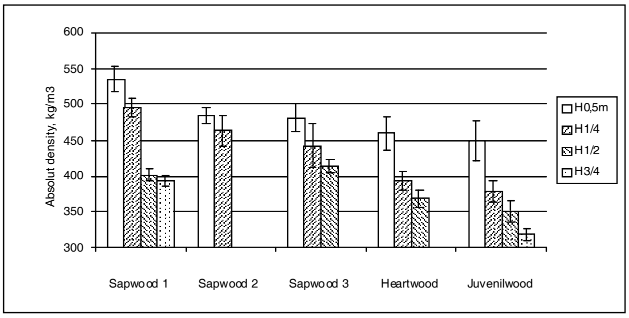

Figure 2. The pinewood absolute density at different height of stem from bark to pith

Density of the sapwood decreases towards the top and at the level of ¾ it was approximately 27% smaller than the density of butt examples. But even at that level the density of the sapwood is 1,2 times higher than in juvenile wood. Density of the juvenile wood in the stem decreases towards the top to the level h¾ even 29%. So the density of juvenile wood varies in the stem 318,3…448,6 kg/m³.

Mechanical properties

Static bending strength, compression strength parallel to grain, surface strength and impact strength are the most significant quality characteristics of the material (Tab. 1). Mechanical strength properties depend mainly on density as the trend of changes from the butt log towards the top log and from pith towards the bark are similar to the change of density as shown in Figure 2.

The average compression strength parallel to grain of juvenile wood was 30,7±2,4 MPa and 46,5±1,7 MPa in the outer layer of sapwood e.g. 1,5 times bigger. Variations range from 27,8 to 69,6 MPa and from 16,9 to 46,1 Mpa, respectively. It gave difference to compression strength along stem of sapwood 2,5 times and of juvenile wood 2,7 times.

Resistance of pinewood to impact strength does not qualify as main characteristics of wood and it is not taken into account when calculating wood constructions. But it is important characterizer for comparing wood material quality (Михайличенко, Садовничий 1983). Relying on experimental results it can be said that in juvenile wood of Northeast Estonian pine impact strength (37,8 ± 3,0 kJ/m³) in comparison with other wood layers in the stem on average (52,1±1,2 kJ/m²) was 27% smaller. In comparison with peripheral sapwood, the difference was 2,4 times. It means that impact strength in juvenile wood decreases towards the top faster than in sapwood.

Surface strength by the Janka method was identified at three levels: along to grain (Tab. 1), radial surface and tangential surface. The average results in sapwood and heartwood were bigger on along to grain, followed by tangential surface strength and the weakest was radial surface. It was complicated to identify strength technically at along to grain and radial surface because the testing point on experimental material (50x50x50 mm) situated near the line of juve-

Table 1. Values of wood properties in different parts of stem

Quality, example level	Unit	Exterior sapwood	Intermediate sapwood	Interior sapwood	Heartwood	Juvenile wood
Bending strength						
h0,5m	MPa	101,5±3,1	87,9±2,4	88,9±2,6	77,9±5,7	61,0±6,9
h1/4	"	94,2±2,3	77,8±4,5	67,0±3,3	62,6±3,4	53,8±3,3
h1/2	"	70,6±2,0		65,7±2,0	51,7±2,0	43,7±3,6
h3/4	"	59,4±4,4				44,3±0,4
Compression strength						
h0,5m	"	52,6±3,1	47,1±1,8	50,1±2,0	40,5±2,3	38,1±8,0
h1/4	"	54,3±1,5	46,7±2,3	38,8±1,3	36,8±3,6	29,7±3,5
h1/2	"	38,5±1,2	38,7±1,8	35,9±2,6	31,0±3,0	27,0±3,6
h3/4	"	32,7±2,2				27,3±0,3
Cross-surface strength						
h0,5m	"	36,6± 1,0			30,3± 1,4	
h1/4	"	30,9± 1,3			25,5± 0,6	
h1/2	"	29,3± 0,4			22,9± 0,5	
h3/4	"	26,8± 1,4			21.5± 0.5	

nile and mature wood. Mean strength was 19,6±0,6 MPa and 21,0±0,5 Mpa, respectively. Tangential strength (30,3±1,0) was 5,9% smaller and radial strength (27,0±0,6) 16,1% smaller than sapwood surface strength (32,2±0,6). Tangential strength (21,0±0,5) of heartwood was 19,2 % smaller and radial strength (18,30,5) ± 29,6% smaller than surface strength along to grain (26,0±0,6). Those regularities are widely used in cutting theories and elaborating cutting regimes but absolute maximum of strength depends on lots of factors where the main one is density.

Discussion

Individual trees are remarkably different from other when comparing the moisture content of wood. Depending on the season and felling month the moisture level differs in outside and inside of sapwood and also it differs in highpoints (Seeling 2000). Most of these differences are caused by density of the wood (Uzunovic & Dickinson 1998). If we exclude the effect of basic wood density and using the percentage saturation method for measuring the humidity significant differences related to increased moisture content appear with increasing tree height as pointed out by above mentioned authors.

According to our data on stem crosscuts no differences of sapwood were noticed in the rate of moisture but remarkable change of moisture was noticed in relation to height. Humidity rate in mature heartwood crosscut was similar to that in juvenile wood.

Nutrition conditions, growing space and age of tree are most clearly indicated by the width of the annual ring. It is also one of the most important visual evidence when estimating the wood quality, because increased radial growth resulted in the reduced fiber length, fiber diameter, cell wall thickness, wood density and modulus elasticity (Mattson 2002). But exist investigations where growth rate did not appreciably influence the density and bending properties of timber, and so its utility as predictor of their mechanical quality of timber is very low (Seco & Barra 1996).

Taking into account the width of annual rings in our felled model trees we can say that those trees were grown in normal conditions, with no influences of thinning or hyper-density periods of stand. Juvenile wood period is not distinguishable in the width of annual rings, but percentage of latewood increases from pith until the 5-th year smoothly and after that increases proportionally to the age (Figure 1). On the basis of gained results it is possible to estimate the existence of juvenile wood in those stems only in the frame of 5 annual rings which forming a cylinder with a diameter approximately 50 mm of around the pith. Starting form the pith in the frame of 5 annual rings mean width and content of latewood from stub to the top change not much. Differences appear with increasing cambial age in relation to the height in the case of heartwood.

The width of annual ring in the stem that has been growing fast has smaller late wood than in a stem that has been growing slower. Longer fibers are in outward annual rings (Saranpää 1999). So the annual ring gets suddenly wider when the thinning takes place and density of wood decreases in negative correlation between the width of annual rings (Morling 2002). After thinning in an average tree the density might be smaller than 17% (Минин, Москалева 1986). That is why it has become evident that younger stands must be kept thick because the best pinewood grows in light thinned stand where grow 1300-1400 trees per hectare at the age of 43-47 (Литаш, Рябоконь 1984).

According to the sources wood density is most influenced by the frequency of annual rings and percentage of latewood (Wilhelmsson *et al.* 2002). The width of annual rings has less influence (Seco & Barra 1996) that also fits with our results where the relation of density to the annual rings is characterized by the correlation coefficient R= -0,44 and latewood percentage R= 0,80 (Tab. 2). Density may have strong connection with the annual rings in a freely grown tree, but in periodically thinned and fertilized soil the density varies. According to the some sources (Veermets 1963) wider annual rings do not decrease mechanical characteristics but the importance of latewood percentage remains. Here we cannot exclude that during faster growth building and resistance of wood cells change as also has called attention P. Saranpää (1999) and T. Morling (2002).

Table 2. Correlation coefficients between wood properties

Quality	1	2	3	4	5	6
1. Wood density	1					
2. Impact strength	0,41	1				
3. Compression strength	0,87	0,55	1			
4. Annual ring width	-0,44	-0,62	-0,58	1		
5. Latewood %	0,80	0,43	0,77	-0,53	1	
6. Bending strength	0,95	0,41	0,86	-0,42	0,79	1

Carrying out investigations about properties between juvenile and mature wood among 10 tree species in China considerable differences were found (Bao *et al.* 2001). Comparing in our research juvenile wood density with a beside growing heartwood no remarkable statistical changes were identified except some tendency in increase of density toward bark can be assumed as shown in the Figure 2. Therefore, the relationship of outer sapwood density with juvenile wood density remains constant (1,2) over three-quarters of stem height, is notable.

When characterizing the construction materials then bending strength is one of the most important properties. Reducing all researched bending strength data of crosscuts to butt log's crosscut (Figure 3) we get a row with linear characteristics where bending strength of juvenile wood forms only 62% of the bending strength of the wood near the bark. So the bending strength factor in juvenile wood has 1.2 times bigger relative standard error of middle value that can be explained by existence of stronger latewood in experimental pieces because of wider rings of juvenile wood.

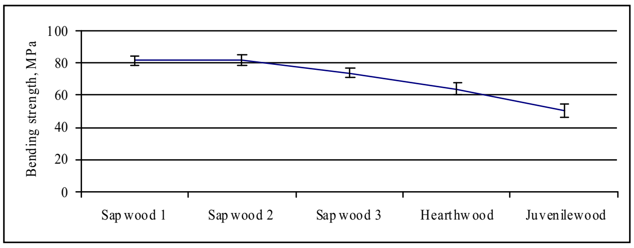

Figure 3. Mean static bending strength (with standard error) in cross-section of stem from bark to pith

According to K. Veermets (1960) the relation between wood mechanical properties (moisture W=15%) and density appears in parabolic equation as the curve of parabolic is usually small the direct line that could be used in practice for the 120-year-old pinewoods the bending strength (B) and density (m) is: $B=2500m-450$. But according to our data the relation between bending strength (y) and density (x) compared with direct line (Fig. 4) and is better explained by equation as follows:

$y=-212{,}765+0{,}473484x+33500{,}86*1/x$, $R^2= 0{,}90$

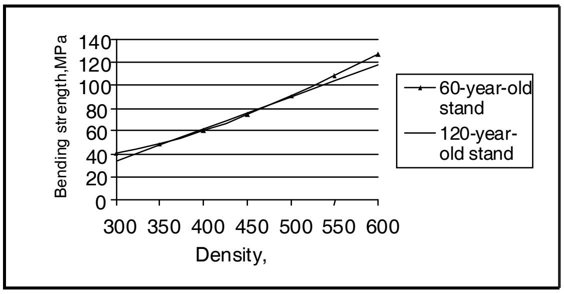

Figure 4. Relation between bending strength and density of the 60-year-old (Northeast Estonia) and 120-year-old (South Estonia) pine stands on *Myrtillus* site

The larger part of the curve in the graphic characterizes the part with lower density in the juvenile wood. Despite that the results of the investigations in the 120- and 60-year-old pinewoods match and exclude the age as a determinative factor, and the density is of utmost important.

The average bending strength in Estonian *Vaccinium vitis-idaea* and *Myrtillus* site type pinewoods have been compared. In 55-90-year-old felled trees it is 84,8±0,7 MPa (Kask 2003). At the age of 120 the bending strength is 902 kg/cm² (101,0 MPa if w=12%) (Веэрметс 1959).

The bending strength of mature pine stands in Lithuania is generally 87,7 MPa, in Byelorussia 87,3 MPa and in North-west Russia 84,5 MPa (Боровиков, Уголев 1989). Based on above - mentioned data our bending strength of the pinewood is already similar to those at the age of 60. One of the increasing factors may be generally smaller consistence of juvenile wood in stem as of neighbours.

After the static bending strength density has also strong correlation with compressive strength parallel to grain (R=0,87) but much weaker connection with impact strength (R=0,41).

Compression strength parallel to grain has good connection (R=0,77) with the percentage of latewood and weak correlation (R=0,58) with the width of the annual rings. Mean compression strength of juvenile wood makes up only 68,6% of the strength of outer layer of sapwood.

In a great part the surface strength of the wood dictates the possibilities for use and the last touch of wood surface. More frequently the surface strength parallel to grain is described in the literature. Strength of the radial and tangential surface is directly connected with the surface strength parallel to grain. For example, according to A. Mihailitšenko and F. Sadovnitšij (Михайличенко, Садовничий 1983) the surface strength parallel to grain that forms up to 40% of tangential and radial surface strength.

According to our data surface strength parallel to grain (y) of sapwood decreases in line with the height of stem crosscut (x):

$y= 29{,}0791-1{,}04403x+8{,}507463*1/x$, $R^2=0{,}99$ and in juvenile wood correspondingly:

$y= 23{,}43433-0{,}99552x+7{,}880597*1/x$, $R^2=0{,}82$

The most varying is surface strength parallel to grain that is confirmed by annual ring weakest connection to the surface strength (Tab. 3). In the case of wide annual rings the results are influenced by the

Table 3. The correlation coefficients characterise the relation between growth ring width and pinewood strength of radial, tangential and cross surface

Quality	1	2	3	4
1. Gross-surface strength	1			
2. Radial surface strength	0,84	1		
3. Tangential surface strength	0,86	0,86	1	
4. Annual ring width	-0,50	-0,62	-0,61	1

testing part that may be totally in early wood or partly in latewood.

Differentiation of pinewood properties influenced by geographical heritage is clearly defined by several researchers (Saarman 1998, Jayawickrama 2001) but in Estonia there are few data on it. In the framework of this research no remarkable differences in the mechanical properties in collected testing materials between Northeast and South part of Estonia were identified. This can be taken as normal as the distance between the areas is only 220 km.

Conclusions

Summing up the results it can be said that the juvenile wood is less favoured in most areas of wood use because of weaker strength characteristics. Density of the juvenile wood makes up 83.8% of the sapwood near the bark, bending strength 62% and surface strength 81,2% in the 60-year-old stands. Compression strength parallel to grain in juvenile wood decreases faster towards the top log as than in sapwood.

In comparison with the southern neighbouring states, Estonia has good possibilities for growing pinewood with low content of juvenile wood and good properties because of the tested model trees had it relatively few annual rings. It is not possible to avoid juvenile wood in pine stems but definitely it can be reduced by forest growing methods.

Acknowledgements

This study was supported by the Estonian Scientific Foundation (grant No 4968) and the Ministry of Education (project No. 0432486s03). The authors are thankful to everyone who helped to prepare this paper.

References

Amarasekara, H., Denne, M. 2002. Effect of crown size on wood characteristics of Corsican pine in relation to definitions of juvenile wood, crown formed wood and core wood. - Forestry - Oxford. 75,1, 51-61.

Arlinger, J., Wilhelmsson, L. 1999. Wood analysis - an aid to meeting the needs of the mills.- Results SkogForsk. 1, 4.

Bao. F. C., Jiang, Z. H., Jiang, X. M., Lu, X. X., Luo, X. Q., Zhang, S. Y. 2001. Differences in wood propeties between juvenile wood and mature wood in 10 species grown in China. - Wood Science and Technology, 35, 4, 363-375.

Duchesne, I., Wilhelmsson, L., Spangberg, K. 1997. Effect of in-forest sorting of Norway spruce (Picea abies) and Scots pine (*Pinus sylvestris*) on wood and fibre properties. - Can. J. F. R. 27, 5, 790-795.

Gartner, B. L., North, E. M., Johnson, G. R., Singleton, R. 2002. Effects of live crown on vertical patterns of wood density and growth in Douglas-fir. - Can. J. F. R. 32, 3, 439-447.

Hakkila, P., Kalaja, H., Saranpää, P. 1995. Etelä-Suomen ensiharvennusmänniköt kuitu- ja energialähteenä [First-thinned pine stands as the fibre and energy source in South Finland]. Metsätutkimuslaitoksen Tiedonantoja 582, 100 s. (in Finnish)

Jayawickrama, K. J. S. 2001. Breeding radiata pine for wood stiffness: review and analysis. - Australian Forestry, 64, 1, 51-56.

Kask, R. 2003. Physical and mechanical properties of Scots pine (Pinus sylvestris) on bilberry and cowberry forest site types. Abstract of M.Sc. Thesis. Tartu. 24.

Larson, P. R., Kreutschmann, D. E, Clark, A., Isebrands, J. G. 2001. Formation and properties of juvenile wood in southern pines: a synopsis. General technical report forest products laboratory, USDA Forest Service. FPL-GTR-129, iii, 42.

Lindström, H. 2002.Intra-tree models of juvenile wood in Norway spruce as an input to simulation software. Silva Fennica 36(2): 521-534.

Mattsson, S. 2002. Effects of site preparation on stem growth and clear wood properties in boreal Pinus sylvestris and Pinus condarta. - Acta Universitatis Agriculturae Sueciae -Silvestria. 240, IXXXVII, 37

Morling, T. 2002. Evaluation of annual ring width and ring density development following fertilization and thinning of Scots pine. - Annals of forest science. 59, 1, 29-40.)

Saarman, E. 1998. Puiduteadus [Wood science]. 247.

Saranpää, P. 1999. Effect of forest management on wood quality.-Metsäalan tutkimusohjelma. Raportti 2. Helssinki, 178-185.

Saranpää, P. 2002. Kuusen kuituominaisuuksein vaihtelu [Exchanges of fibre properties of spruce]. Työtehoseuran metsätiedote. 3(646), 1-4. (in Finnish)

Sauter, U. H, Mutz, R., Munro, B. D. 1999. Determing juvenile-mature wood transition in Scots pine using latewood density. - Wood and Fiber Science. 31, 4, 416-425.

Seco, J. I. F. G., Barra, M. R. D. 1996. Growth rate as a predictor of density and mechanical quality of sawn timber from fast growing species. Holz als Roh- und Werkstoff 54, 3, 171-174.

Seeling, U. 2000. Ausgewählte Eigenschaften des Holzes der Fichte (Picea abies (L.) Karst.) in Abhängigkeit vom Zeitpunkt der Fällung. - Schweizeische Zeitschrift für Forstwesen, 151, 11, 451-458.

Splawa-Neumann, S. 1994. Selected properties of Scots pine (Pinus sylvestris L.) wood in dependence upon forest stand type and age of the trees. Prace Institutu Technologii Drevna. 38, 1-2, 19-28.

Stähl, Erik-G. 1998. Changes in wood and stem properties of Pinus sylvestris caused by provenance transfer. -Silva Fennica, 32(2):163-172.

Uzunovic, A., Dickinson, D. I. 1998. Measuring and expressing moisture content in green timber. - Material und Organismen, 32, 3, 217-225.

Veermets, K. 1960. Seaduspärasusi männipuidu tehnilistes omadustes [Relationships between technical properties of pine wood]. EPA teaduslike tööde kogumik 17. Tartu, 77-89. (in Estonian)

Veermets, K. 1963. Kuusepuidu mehhaanilistest omadustest [About mechanical properties of spruce wood]. EPA teaduslike tööde kogumik 33. Tartu, 164-179. (in Estonian)

Walker, J. C. F., Nakada, R. 1999. Understanding corewood in some softwoods: a selective review on stiffness and acoustics. - International Forest Review. 1: 4, 251-259; 284-285.)

Wilhelmsson, L., Arlinger, J., Spangberg, K., Lundqvist, S. O., Grahn, T., Hedenberg, O., Wodzicki,T. J. 2001. Natural factors affecting wood structure. - Wood Science and Technology, 35,1/2, 2-26.

Боровиков, А.М., Уголев, Б.Н. 1989. Справочник по древесине[The Wood Handbook]. Москва, 296. (in Russian)

Веэрметс, К. 1959. О технических свойствах сосновой древесины [About technical properties of pine wood]. - Сборник научных трудов ЭСХА 11б. Тарту, 70-80. (in Russian)

Литаш, Н.П., Рябоконь, А.П. 1984. Физико-механические свойства древесины в сосновых древостоев в связи с рубками ухода различной интенсивности [Physical and mechanical properties of the wood in Scots pine stands in relation to thinnings of different intensity]. – Лесное хозяйство, 7, 66-68. (in Russian]

Минин, Н.С., Москалева, С.А. 1986. Влияние рубок ухода на физико-механические свойства древесины культур сосны [Effect of thinning on the physical and mechanical properties of wood in Scots pine plandations]. – Лесной журнал, 2б 68-71. (in Russian)

Михайличенко, А.Л., Садовничий, Ф.П. 1983. Древесиноведение и лесное товароведение [Science of wood and forest product]. Москва, 206. (in Russian)

Received 20 October 2003

МЕХАНИЧЕСКИЕ КАЧЕСТВА ЮВЕНИЛЬНОЙ ДРЕВЕСИНЫ СОСНЫ ОБЫКНОВЕННОЙ (*P. SYLVESTRIS* L.) В СОСНЯКАХ ЧЕРНИЧНИКАХ

Я. Пикк, Р. Каск

Резюме

По литературным данным ювенильная древесина образуется вокруг серцевины из 5–25 годичных слоев. Относительно большой объем ювенильной древесины в деловой древесине приводит к неблагоприятным явлениям для потребителей в деревообрабатываемом производстве. Феномен ювенильной древесины и возможности сокращения влияния ювенильной древесины в сырье в Эстонии вообще мало изучены.

Целью данного исследования является изучения варьирования некоторых показателей качества в стволах деревьев 60-летних сосняков-черничников в Северовосточной и Южной Эстонии. У господствующих деревьев были вырезаны кряжи на высоте 0,5 м, h1/4, h1/2 и h3/4. Для определения абсолютной плотности было подготовлено 280 образцов и для определения механических свойств древесины -764 образца.

Одной из основных характеристик качества древесины является содержание поздней древесины в годичном слое. Содержание поздней древесины пяти годичных слоев вокруг сердцевины ниже чем у остальных слоев до коры. Плотность древесины снижается в направлении от коры до серцевины и по стволу от пня до верхушки. Прочность ювенильной древесины при статическом изгибе (при влажности 12%) на высоте h1/4 значительно ниже чем у заболони. Статический изгиб (y) тесно связан с плотностъю (x) древесины: $y= -212{,}765+0{,}473484x+33500{,}86*1/x$, $R^2=0{,}90$. Довольно тесная связь имеется между плотностью и прочностью на сжатие вдоль волокон и мало связано с ударной вязкостью. Ширина годичного слоя в какой-то степени связана со статической твердостью. Установлено, что плотность ювенильной древесины составляет соответственно 83,8% от заболони, изгиб 62% и сжатие вдоль волокон 68,6%.

Ключевые слова: сосна, заболонь, поздняя древесина, статический изгиб, прочность на сжатие, плотность.