Source: Elferts D, Brumelis G, Gärtner H, Helle G, Schleser G (eds.) (2008) TRACE - Tree Rings in Archaeology, Climatology and Ecology, Vol. 6: Proceedings of the DENDROSYMPOSIUM 2007, May 3rd – 6th 2007, Riga, Latvia. GFZ Potsdam, Scientific Technical Report STR 08/05, Potsdam, p. 118 - 122.

Tree ring width and basic density of wood in different forest types

E. Přemyslovská, J. Šlezingerová & L. Gandelová

Department Wood Science, Mendel University of Agriculture and Forestry in Brno, Czech Republic
Email: premyslo@mendelu.cz

Introduction

Wood is important renewable raw material for energy generation, building, veneering, furniture making. Its mechanical and physical properties make the wood one of the most important structural materials, because of its big stiffness and strength and relatively low density. We can't omit its desirable acoustical properties. All physical and mechanical properties are defined by structure and density of wood, i.e. by amount and distribution of structural elements.

Wood structure and thus its properties are determined during tree ontogeny. Anatomical structure reflects all environmental (abiotic and biotic) and genetic factors operated on a tree during its life. The influence of the stand (growing conditions) on wood properties is to be examined for a long period.

The one year increment of spruce wood compounds from the layer of earlywood, created during the initial period of growing season and typical by the wide cells with thin cell wall, and latewood, that is created during and at the end of growing season and is characterized by substantially thicker cell wall but narrower radial dimensions than earlywood (Vavrčík 2002). The radial dimensions of a cell and dimension of cell wall is influenced by temperature and water availability. Increasing temperature during earlywood formation period causes shortage of phase of radial expansion of young wood cells and therefore the radial dimensions of cells are smaller than normal. If the tree experiences higher temperatures during latewood formation period, the phase of radial expansion is prolonged. The maturing period extends if the temperature of environment is high for both earlywood and latewood. That leads to the significantly thicker cell wall.

Precipitation affects positively the radial growth period and maturing period and causes prolongation of these (Vavrčík 2002). The thickness of cell walls in newly formed wood depends on the carbohydrates stock, and is therefore indicator of metabolic proceeds of a given year (Larcher 1988).

The wood density is one of the most basic parameters of wood quality. It affects substantially mechanical properties of wood. Due to different density of early- and latewood the treering width is very important factor of wood quality, because the portion of earlywood increases with increasing tree ring width (Kollmann 1951). The earlywood have lower density, lower strength and stiffness and have smaller shrinkage during moisture change (Horáček 1998).

The aim of this work is to determinate an average tree ring width and basic density of Norway spruce (*Picea abies* [L.] Karst.) growing in different vegetation forest zones. Norway spruce is the most important commercial specie in Czech Republic and its portion of forest stands is 53 %.

Material and Methods

Trial areas were selected and assessed by the typological classification of forest zones of Forest Management Institute (Plíva 1971). The typological system consists of horizontal and vertical division of zones. There are 9 forest vertical vegetation zones: (1) the oak zone, (2) the beech with oak zone, (3) the oak with beech zone, (4) the beech zone, (5) the silver fir with beech zone, (6) the Norway spruce with beech zone, (7) the beech with spruce zone, (8) the Norway spruce zone and (9) the mountain pine zone (Tab. 1). The horizontal zonation applies to each one vertical vegetation zone. The zoning is based on general characteristics of soil environment, soil nutrients content and sometimes on the topography of the region.

Table 1: Forest vegetation zones and its share on the Czech forests (Forest management Institute, Report on forestry of the Czech Republic, 2007.)

Forest vegetation zone			Elevation above sea level	Average annual temperature	Annual precipitation	Growing season
code	prevailing species	%	m	°C	mm	days
0	pine	3.73	non-zonal			
1	oak	8.31	<350	>8.0	<600	>165
2	oak with beech	14.89	350-400	7.5-8.0	600-650	160-165
3	beech with oak	18.41	400-550	6.5-7.5	650-700	150-160
4	beech	5.69	550-600	6.0-6.5	700-800	140-150
5	beech with fir	30.04	600-700	5.5-6.0	800-900	130-140
6	beech with spruce	11.95	700-900	4.5-5.5	900-1050	115-130
7	spruce with beech	5.0	900-1050	4.0-4.5	1050-1200	100-115
8	spruce	1.69	1050-1350	2.5-4.0	1200-1500	60-100
9	dwarf pine	0.29	>1350	<2.5	>1500	<60

Primarily recognized are series, next on the basis of more detailed soil characteristics each series is subdivided into edaphic categories (Tab. 3). 124 stands located in Czech Republic were chosen for this research (Fig. 1). The age of stands in chosen areas was 70-100 years. On each trial area 20 trees were randomly selected, the wood cores have been taken using increment borer from each tree.

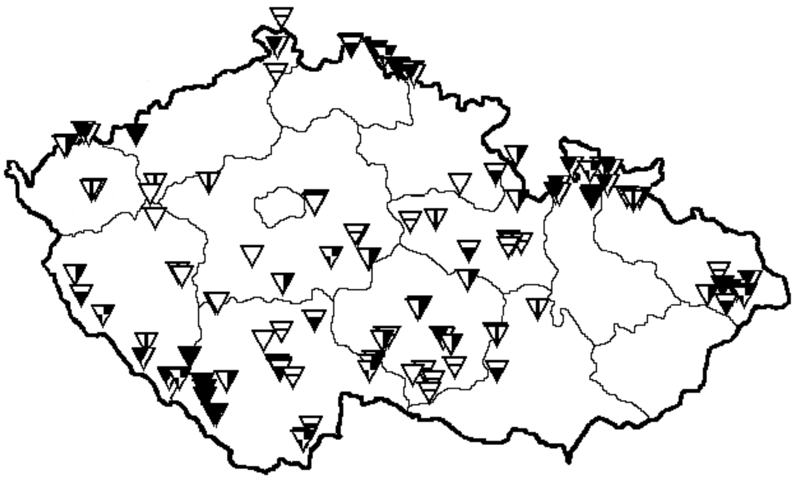

Figure 1: Map of Czech Republic with trial areas of this research marked by triangles

The Ericson's procedure (Ericson 1959) was applied to calculate basic density for the whole stem radius. Basic density of wood was determined by the method of Olesen (1971).

Basic density is defined as

$$\rho_k = \frac{m_0}{V_w}$$

where: ρ_k is basic density of wood, m_0 is mass of wood at moisture content 0 % and V_w is volume of wood above saturation point.

Finely, the average tree ring width for each sample was determined as length of core/number of tree rings.

Results and discussion

Relation between tree ring width and basic density was found for set of all tested samples. The assumption of decrease of wood density with increasing tree ring width has been validated as you can see in figure 2. This is caused by increasing portion of thin walled early wood in wide tree rings of gymnosperms.

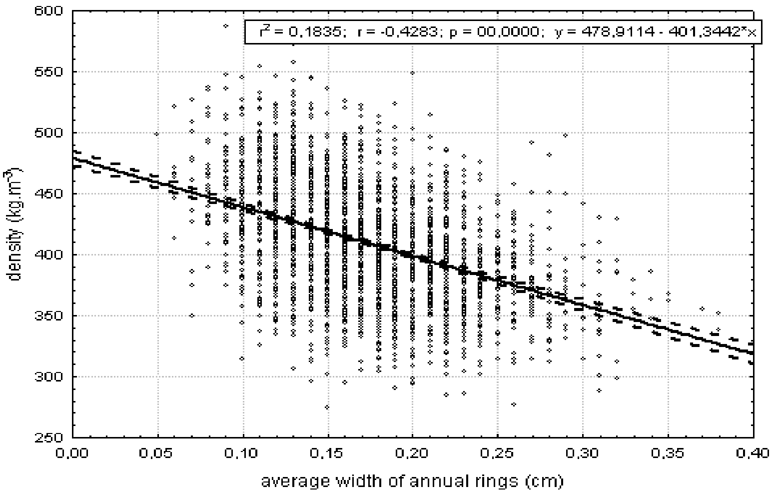

Figure 2: Relation between tree ring width and basic density.

The statistically significant differences between basic density values of samples from different vegetation zones and edaphic factors have been found. Resulting values of basic density and tree ring width are listed in the table 2 (according to vegetation zones) and table 3 (according to edaphic factors).

The highest value of basic density has been found for fourth (beech) vegetation zone – 445 $kg{\cdot}m^{-3}$ Together with that, the smallest average tree ring width 1.57 mm has been found for this group. After Tukey test of multivariate comparison there are statistically significant differences between sub-categories of edaphic series gleyic and between and between sub-categories P and B. Interesting is basic density of wood in sub-category P (462 $kg{\cdot}m^{-3}$) and generally higher values of basic density on stands with lower pH.

Similarly high values of basic density and small average tree ring widths are typical for second (beech with oak) vegetation zone (444 $kg{\cdot}m^{-3}$, 1.65 mm) and third (oak with beech) vegetation zone (438 $kg{\cdot}m^{-3,}$ 1.69 mm), whereas the difference between values of basic density and average tree ring width in vegetation zones 2 – 4 are not statistically significant.

High values of basic density can be caused by effect of high temperatures and by longer vegetation period. If the tree experiences high temperature, the phase of radial growth of earlywood tracheids is shorten and of latewood tracheids is prolonged, simultaneously the phase of maturing is prolonged. The production of latewood is therefore boosted up and the earlywood tracheids have thicker cell wall and smaller radial dimension the those growing in colder environment.

Tab. 2 Results according vegetation zones (main value in cell is mean, first value in brackets is number of samples, second value is stand. deviation)

Prevailing species	oak with beech	beech with oak	beech	beech with fir	beech with spruce	spruce with beech	spruce	Mean
Vegetation zone code	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
Basic density ($kg.m^{-3}$)	443.98 *(200; 37.29)*	437.57 *(340; 41.87)*	445.00 *(282; 35.96)*	413.98 *(589; 43.96)*	392.34 *(465; 37.33)*	377.66 *(219; 34.37)*	374.14 *(400; 36.13)*	409.61 *(2495; 47.17)*
Tree ring width (mm)	1.65 *(200; 0.46)*	1.69 *(340; 0.51)*	1.57 *(282; 0.41)*	1.81 *(589; 0.58)*	1.99 *(465; 0.48)*	1.76 *(219; 0.44)*	1.59 *(400; 0.68)*	1.75 (2495; 0.55)

On the other hand, the smallest values of basic density can bee observed in eighth (spruce) vegetation zone (374 kg·m^{-3}), where is, however, narrow tree ring width (1.59 mm). It can be caused by production of latewood tracheids with thin cell wall, or perhaps by decreased production of latewood caused by lower average temperature during vegetation period in higher elevation. In the seventh vegetation zone (beech-spruce), on the contrary, the low value of basic density (378 kg·m^{-3}) seems to be caused by raised portion of earlywood, because the average tree ring width is big (1.76 mm).

There is significant difference between basic density in N and T edaphic category and others.

Economically the most important is fifth (beech with fir) vegetation zone, that takes 30 % of the total forest area. The average value of the basic density is 414 kg·m^{-3}, and the average tree ring width is 1.81 mm. Statistically significant differences between edaphic categories can be found for M-I categories of acid series, where the values of the basic density higher, one exception is category gleyic – nutrient-poor with average value of basic density 460 kg·m^{-3}. Similar to the pattern of results of 5th vegetation zone are results of sixth (spruce with beech), where the average value of basic density is 392 kg·m^{-3} and simultaneously the highest value of the average tree ring width 1.99 mm.

Table 3: Results according edapfic categories (main value in cell is mean , first value in brackets is number of samples and second value is stand. deviation)

edaphic factor			basic density (kg.m^{-3})	tree ring width (mm)
extreme	xerothermal *(xerothermica)*	**X**		
	scrub *(humilis)*	**Z**	378.57 *(40; 35.30)*	1.49 *(40; 0.36)*
	skeletal *(saxatilis)*	**Y**		
acid	nutrient-poor *(oligotrophica)*	**M**	454.89 *(181; 36.36)*	1.22 *(181; 0.36)*
	acidic *(acidophila)*	**K**	403.19 *(429; 49.6)*	1.54 *(429; 0.64)*
	stony-acidic *lapidosa acidophila)*	**N**	427.34 *(121; 37.0)*	1.56 *(121; 0.37)*
	compacted-acid *(illimerosa acidophila)*	**I**	440.34 *(120; 41.22)*	1.65 *(120; 0.36)*
rich in nutrients	fresh, nutrient-medium *(mesotrophica)*	**S**	393.97 *(281; 41.98)*	1.87 *(281; 0.46)*
	slope (stony) nutrient-medium *(lapidosa mesotrophica)*	**F**	383.78 *(40; 43.23)*	2.29 *(40; 0.30)*
	water-deficient *(subxerothermica)*	**C**		
	nutrient-rich *(eutrophica)*	**B**	403.69 *(141; 44.29)*	2.14 *(141; 0.47)*
	limestone *(calcaria)*	**W**		
	loamy (compacted, nutrient-rich) *(illimerosa trophica)*	**H**	421.39 *(80;39.3)*	2.06 *(80; 0.38)*
enriched with humus	enriched-collurial *(deluvia)*	**D**	407.38 *(40; 45.76)*	2.08 *(40; 0.40)*
	stony-colluvial *(lapidosa acerosa)*	**A**	400.60 *(40; 26.23)*	2.15 *(40; 0.36)*
	talus *(saxatilis acerosa)*	**J**	449.97 *(20; 36.21)*	1.57 *(20; 0.45)*
enriched with water	floodplain *(alluvialis)*	**L**		
	valley *(vallidosa)*	**U**		
	mast to wet *(humida hygrophila)*	**V**	399.86 *(101; 37.40)*	2.05 *(101; 0.37)*
gleyic	nutrient-medium *(variohumida trophica)*	**O**	407.94 *(241; 40.7)*	1.95 *(241; 0.49)*
	acidic *(variohumida acidophila)*	**P**	427.07 *(162; 46.42)*	1.78 *(162; 0.47)*
	nutrient-poor (varihumida oligotrophica)	**Q**	417.21 *(180; 49.4)*	1.45 *(180; 0.44)*
water-logged	nutrient-poor, wet *(paludosa oligotrophica)*	**T**	400.31 *(60; 42.46)*	1.46 *(60; 0.36)*
	nutrient-medium, wet *(paludosa mesotrophica)*	**G**	373.34 *(120; 35.39)*	2.04 *(120; 0.51)*
peaty	nutrient-medium *(turfosa)* nutrient-poor *(turfosa)*	**R**	379.35 *(98; 35.26)*	1.92 *(98; 0.46)*
mean			409.61 *(2495; 47.17)*	1.75 *(2495; 0.55)*

Conclusions

Significant influences of environment on wood formation (basic density, tree-ring width) have been proved. The highest value of basic density has been found for fourth (beech) vegetation zone and generally we can say that higher values of basic density are on stands with lower pH. Relation between tree ring width and basic density was found. To conclude, the research results of environment impact to properties of wood can improve forestry and wood industry management.

Acknowledgements

The project was financially supported by the research project of the Forest Faculty of the Mendel University in Brno, MSM 6215648902 and MZP CR VaV SP/2d1/93/07.

References

Vavrčík, H. (2002): Analýza xylému na buněčné úrovni s využitím fluorescenční mikroskopie, Disertation thesis, 145 p.

Larcher, W. (1988): Fyziologická ekologie rostlin, Academia Praha, 359 p.

Horáček, P.(1998): Fyzikální a mechanické vlastnosti dřeva I., MZLU Brno, 124 p.

Plíva, K. (1971): Typologický systém ÚHÚL, Cyklostylovaná příručka pro služební potřebu pracovníků ÚHÚL Brandýs n.L., 29 p.

Ericson, B. (1959): Mercury Immersion method for Determining the Wood Density of increment Cora Sections, *For. Res. Inst. o Sweden*, 1, p. 1-31.

Olesen, P.O. (1971): The Water Displacement Method, The Royal Veterinary and Agricultural University of Copenhagen, 18 p.

Kollmann, F. (1951) Technologie des Holzes und Holzwerkstoffe, Berlin – Gottingen – Heidelberg, 1050 p.

Forest Management Institute, (2007): Report on forestry of the Czech Republic by December 31, 2006, FMI, 128 p.