WOOD RESEARCH
60 (1): 2015
11-24

INFLUENCE OF SILVICULTURAL STRATEGIES ON RED HEARTWOOD OCCURRENCE IN BEECH (PRELIMINARY STUDY)

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ABSTRACT

Heartwood in beech is a common phenomenon considerably reducing the round wood quality. The literature, however, is not giving enough information about how the occurrence of heartwood in beech stands can be influenced by various silvicultural strategies.

The aim of this paper is to assess the effects of silvicultural strategy and stand composition on the qualitative structure of beech raw material, as for heartwood occurrence and frequency.

The subject was studied in homogeneous beech stands and in mixed stands with dominant beech. As for age, one stand has diversified age structure, one has selection structure and the other stands are 100–120 years old. The silvicultural options used in the investigated stands were: selection felling (two stands), heavy crown thinning (one stand) and light crown thinning (four stands). From these stands we sampled logs and assessed them according to the standard EN 1316-1 (2012).

As for the silvicultural strategies, considerably higher quality was obtained for the logs from the first and the second group of stands. The stand species composition has not been confirmed as a significant factor for beech log quality.

According to our study, the type and intensity of silvicultural options can considerably influence the occurrence and extent of beech heartwoods, which has positive impact on the final raw material.

KEYWORDS: European beech, thinning from above, crown thinning, selection felling, red heartwood.

INTRODUCTION

Slovakia, with forests covering 41 % of its area, belongs to the most forested lands in central Europe. The leading species is European beech (*Fagus sylvatica* L.) with a proportion of 32 % (Anonymous 2012). In terms of the volume of round wood, beech is the most important woody plant for forestry and for wood industry in Slovakia. In the last decade, the share of beech has further increased by almost 1 %, due to wind, snow and bark beetle damage to spruce stands in the country. In the context of the current climate change, this trend may be supposed to continue also in the next years.

In the past, beech wood was not much used for industrial purposes in Slovakia. In the Slovak forestry, beech had only marginal importance. This was negatively reflected in poor quality of beech raw material. This had been true until the 1950s when the first industrial complexes for processing this raw material were built. The most common defects reducing the quality of beech roundwood are: knots, rots, growth stresses (Delphine et al. 2013) and facultative red heartwood (Knoke et al. 2006).

Heartwood (HW) types in beech are divided into (Sachsse 1991): Red heartwood, wounded heartwood, splashing heartwood or abnormal heartwood. However, the standards (EN 844-10 1998) and (EN 1316-1 2012) only define two types: „red heart" (RHW) - red or brown stain affecting the central portion of beech wood, sharply defined; and "dotty red heart or star red heart (SHW) "- unsound red heart of beech which appears at the ends of round wood in a star-like form.

Red heartwood often expands from the felling cut to the crown base. Thus, it can cover more than 50 % of the stem diameter. This causes considerable losses in the value of round timber. In fact, industrial processing, aimed at high value products, needs light coloured, "white" beech wood appearance (Wernsdörfer et al. 2005).

The literature concerning RHW size deals with external traits (injury and branch scars) on stem surface (Wernsdörfer et al. 2006), occurrence frequency from the viewpoint of tree characteristics and response to silvicultural intervention (Büren 2002). The last author observed that the heartwood occurrence was positively correlated with the stands age, tree height status and stem injuries.. Similar results were observed by more authors (Höwecke 1998; Mahler and Höwecke 1991; Richter 2001; Walter and Kucera 1991). Crown architecture is another important factor (Knoke 2003; Torelli 1974).

The impact of silvicultural strategy on stem quality and crown volume in beech trees has commonly been taken for granted. The rules of shelterwood system are different from the rules of selection system (Leibungut 1984; Schütz 1994). Stemwood quality and stem diameter growth are controlled by crown volume. Target beech trees are trees with large crowns promoted by heavy crown thinning, not older than 120 years, with $d_{1.3}$ 60 cm, rarely spoiled due to occurrence of red heartwood (Kladtke 2002). The influence of other woody species in beech stands on red heartwood occurrence in beech has been studied only marginally. Less abundant occurrence of red heartwood was observed (Bastien 1997) in stands of beech mixed with other species (cherry, sessile oak, sycamore maple, ash).

Traditional silviculture facilitates formation of HW, especially due to long rotation period, regeneration period and moderate improvement felling applied in beech stands (Rieder 1997). Vigorous beech trees profiting from silvicultural interventions show low probability of RHW occurrence (Knoke and Wenderoth 2001). Thus, the research has confirmed that appropriate silviculture can guarantee high quality of beech wood and considerably reduce the risk of its devaluation due to red heartwood.

The aim of this work is to assess how thinning intensity, silvicultural strategy and forest stand composition affect the quality of beech raw material, with the focus on RHW and SHW occurrence in stem of beech trees.

MATERIAL AND METHODS

Description of the compartments and their silvicultural programs

The material for analyses was sampled from the University Forest Enterprise of the Technical University in Zvolen. All sample plots have the same parent rock material, andesite, and the same soil type, cambisol. The group of forest types on the plots is Fagetum pauper. (The typological units used in Slovakia follow the Zlatník´s phytosociological system. A group of forest types in this system is defined as a set of geobiocenoses –plant communities with their environment; included are the developmental stages of these goebiocoenoses characterised by their woody plant compositions, structure of tree vegetation layer and species composition of the herbaceous vegetation). The stands are situated at 500–650 m a.s.l, the slope angle is 20–30 %, the slope orientation is SE to NE. The age of beech sample trees was assessed by dendrochronological analysis. They were 100–120 year-old. The sample trees were taken from the main stand layer, in the selection forest from the upper layer from four groups of stands specified according to the tending or selection felling intensity, and according to the species composition (Tab. 1).

Tab. 1 illustrates the intensity of silvicultural interventions applied during the particular periods. Silvicultural interventions in individual stands were as follows:

S-95 -the permanent research plot (PRP) in group of forest stands (513, 514a) was subject to selection felling once in a decade. In fact, there was carried out selection thinning in 1962–1981. Beech on the PRP represented over 95 % from the growing stock on the plot.

ST1-95 – the PRP in forest stand (514b) was treated by heavy crown thinning with positive selection until 1981. The intervention intensity was 17–19 % from the growing stock. In the last two decades, one crown thinning with removal of 25 % of the total stand volume. Beech represented over 95 % from the growing stock. .

ST2-95 - group of forest stands (432, 1102) was treated by light crown thinning from above, removed 12–16 % of the growing stock. In years 1992–2001, the stand 432 was subject to shelterwood felling; in 2001 was initiated Gayer's felling (Matthews 1989) in stand 1102. Beech represented over 95 % from the growing stock.

ST-50- group of forest stands (381, 603) was tended by light crown thinning from above, removed 10–15 % of the growing stock. Gayer's felling performed in 1992–2009, beech presence 50 %. The stands also contained sessile oak 35 %, European hornbeam 10 %, and European ash and sycamore maple accounting together for 5 %. The stand composition was assessed from the growing stock of stand.

The sample trees for our study were selected from the stands on the permanent research plots (PRP). In the stands 513, 514a and 514b, the sampling comprised target trees, and it were carried out in 2009. The sampling design- the number of target trees for a PRP was limited by the method used in subsequent research, which explains the small sample sets for these stands. In the other stands (silvicultural program ST2-95, ST2-50), sample trees were selected from high-quality dominant and pre-dominant trees (1:1) in years 2001–2002. These stands were in the phase of secondary felling. Altogether, there we sampled 7–16 trees from each stand. The selection was made throughout all the stands, the sample trees were without mechanical or

Tab. 1: Intensity of silvicultural interventions (in % of the growing stock) in particular forest stands and time periods.

Silvicultural strategy	Forest stand	Period				
		1962–1971	1972–1981	1982–1991	1992–2001	2002–2009
S-95	513	21 %+	22 %+	20 %+	20 %+	20 %+
	514 a	19 %+	22 %+	20 %+	21 %+	20 %+
ST1-95	514b	19 %++	17 %++	19 %++	25 %++	-
ST2-95	432	16 %++	13 %++	12 %++	17 %+++	23 %+++
	1102	13 %++	12 %++	15 %++	18 %+++	21 %+++
ST-50	381	15 %++	10 %++	14 %++	19 %+++	20 %+++
	603	14 %++	11 %++	10 %++	21 %+++	20 %+++

\+ Selection felling, selection thinning, ++ crown thinning with positive selection +++ regeneration felling

biological injury. On the sample trees, we measured the diameter at breast height (DBH), tree height (H), crown width (CW), crown length (CL), calculated the portion of crown length from tree height (CL/H), and determined the tree age (TA).

Assessment of log quality

The trees were felled, debranched, cut into pieces suitable for transport and transported to a timber yard. The logs were prepared according to the standards for qualitative assessment (EN 1316-1 2012). The logs were assorted into four qualitative classes (F-A, F-B, F-C, F-D). Measurement and typology of individual qualitative characteristics followed the standard (EN 1310 2000). Besides the main characteristics (log dimension, HW size and type) (Tab. 2), the classification also considered several additional ones (knots, cracks, curving, warping, eccentricity, rots, damage by insects, T-disease, etc.). The preliminary analysis, however, revealed that the influence of these additional characteristics did not manifest differences between the strategies, so these characteristics have been excluded from further examination.

The study has been limited to the influence of occurrence frequency and size of RHW and SHW in logs. The frequency of logs with RHW and SHW was calculated as the ration of the number of logs containing RHW and SHW and the number of all logs considered in the frame of the silvicultural strategy. The size of HW in the logs was assessed as the ratio of the maximum width of HW and the log end diameter, in % (EN 1310 2000).

Tab. 2: Main parameters for assessment of log quality, given by the standard (EN 1316-1 2012.)

Feature	Class			
	F-A	F-B	F-C	F-D
Minimum log length (m)	3	3	2	2
Minimum mid-log diameter (cm)	40	35	25	20
Size of RHW (% of the diameter)	≤15	≤30	permitted	permitted
Size of SHW (% of the diameter)	not permitted	≤10	≤40	permitted

Data analysis

There were calculated the basic statistical characteristics (arithmetic mean and standard deviation) for all dependent variables (Tabs. 3, 5). The subsequent evaluation comprised three steps.

The first step represented the comparison between particular silvicultural strategies as for the dendrometric characteristics of the trees (Tab. 4). The testing was performed with using one-way ANOVAs (with Duncan's post hoc tests). The independent explanatory variable (factor) was silvicultural strategy (S-95, ST1-95, ST2-95, ST-50), the dependent explained variables were dendrometric characteristics (TA, DBH, H, CL, CW, CL/H ratio).

The second step was analysis of silvicultural strategies in association with frequency (Tab. 5) and size of RHW and SHW (Tab. 6). The influence of this factor (independent variable) on the size of RHW and SHW (dependent variables) was tested with one-way ANOVAs (with Duncan's post hoc tests).

The third, final step was analysis of influence of silvicultural treatment on qualitative structure on final logs considering the frequency and size of RHW and SHW.

Percentages of heart-free logs and logs containing the studied HW types were compared in frame of silvicultural strategies and quality classes (Figs. 1, 2, 3).

RESULTS

Structure and dendrometric characteristics of the studied forest stands

Tab. 3 summarises the primary dendrometric characteristics of sample trees classified into groups according the silvicultural strategy. Tab. 3 shows that the ratio CL/H was significantly higher in the sample trees from the plots S-95 % and ST1-95 than in the other beech sample trees. The analysis has confirmed that heavy crown thinning and selection forest structure result in more growth space and better light conditions, which inhibit or slow down crown reduction in the main stand layer.

Tab. 3: Characteristics of beech sample trees in the studied forest stands.

Silvicultural strategy	Number of trees	TA	DBH	H	CL	CW	CL/H Ratio
		(year)	(cm)	(m)	(m)	(m)	(%)
S -95	7	111.9±4	46.4±3.4	30.5±1.6	17.1±4.5	5.1±0.7	55.7±12.2
ST1-95	7	103.1±4	43.1±5.7	29.5±2.2	18.3±3.4	4.8±0.8	61.8± 8.1
ST2-95	27	111.7±8	43.8±7.1	31.7±4.2	14.3±3.4	6.1±1.5	44.9± 7.7
ST -50	30	114.6±9	47.4±8.2	29.8±4.8	14.6±3.6	7.2±1.7	48.9± 9.7
Total	71	112.1±8	45.5±7.3	30.6±4.2	15.1±3.8	6.3±1.7	49.3±10.3

- Mean value ± Standard deviation

The differences in the mean values of particular dendrometric characteristics among the sample trees are in Tab. 4. The tests confirmed differences in crown length of the sample trees between the stands ST1-95 in comparison with beech trees from the stands ST2-95, and between ST1-95 and ST-50. An important crown parameter the CL/H seems to be influenced by the silvicultural strategy. This has been confirmed based on significant differences between S-95 and ST2-95, between ST1-95 and ST2-95 and between ST1-95 and ST-50.

Tab. 4: ANOVAs (with Duncan´s tests) - Influence of dendrometric characteristics in individual groups of forest stands.

Silvicultural strategy	Dendrometric characteristics					
	TA (year)	DBH (cm)	H (m)	CL (m)	CW (m)	CL/H ratio (%)
S-95 x ST1-95	0.0149 **	0.3199 ns.	0.5901 ns	0.4351 ns.	0.7312 ns.	0.1199 ns.
S-95 x ST2-95	0.9636 ns.	0.4052 ns.	0.5090 ns.	0.0829 ns.	0.1230 ns.	0.0085 **
S-95 x ST-50	0.4101 ns.	0.7351 ns.	0.6948 ns.	0.1017 ns.	0.0020 **	0.0801 ns.
ST1-95 x ST2-95	0.0127 *	0.8193 ns.	0.2645 ns.	0.0166 *	0.0751 ns.	0.0001 ***
ST1-95 x ST-50	0.0018 **	0.2059 ns.	0.8542 ns.	0.0225 *	0.0009 ***	0.0019 **
ST2-95 x ST-50	0.4150 ns.	0.2724 ns.	0.3241 ns.	0.8431 ns.	0.0830 ns.	0.2992 ns.

level of statistical significance, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, ns. - not statistically significant, $p > 0.05$

Heartwood occurrence and size in the studied forest stands

The mean HW proportion in the logs taken from the studied stands was rather high, ranging 47–73 % (Tab. 5). In the stands tended by heavy positive crown thinning (ST1-95) and by light crown thinning followed by regeneration felling (ST2-95), the HW share was higher by 7–26 % than in the stands formed by selection felling (S-95) or by light crown thinning at 50 % presence of beech trees (ST-50).

Tab. 5: Characteristics affecting the final quality of logs from the studied beech forest stands.

Feature		Silvicultural strategy				
		S-95	ST1-95	ST2-95	ST-50	Total
Number of logs (n)		26	22	112	121	281
Log length (m)		4.3±1.6	4.6±1.9	4.9±1.3	4.9±1.3	4.9±1.4
Mid-log diameter (cm)		37.0±6.1	35.9±6.2	34.3±8.1	34.5±8.9	34.8±8.2
RHW	Frequency (n)	6	9	48	42	105
	Frequency (%)	23	41	43	35	37
	Size (%)	17.0±8.2	15.6±8.6	33.4± 8.4	29.3±8.8	29.3±10.5
SHW	Frequency (n)	8	7	20	15	50
	Frequency (%)	31	32	18	12	18
	Size (%)	10.6±6.1	10.9±4.1	28.5±15.6	20.4±11.9	20.7±14.1
Total (RHW+SHW)	Frequency (n)	14	16	68	57	155
	Frequency (%)	54	73	61	47	55
	Size (%)	13.3±9.3	13.5±8.5	32.0±11.1	26.9±10.4	26.5±12.4

- Mean value ± Standard deviation

The stand with selection structure (S-95) showed more logs with small SHW, contrarily, in the other stands (ST1-95, ST2-95 and ST-50) more logs with RHW were observed. While in the stand ST1-95 the rate between the logs with RHW and SHW was 1.3, in the stands ST2-95 and ST-50 it was by 2.4 and 2.9, respectively.

For log quality assessment is important the HW size and type. The mean HW size in the stands S-95 and ST1-95 was 2–2.5 times smaller than in the stands ST2-95 and ST-50 (Tab. 5). At the same time, the RHWs in the studied stands were 1.2–1.6 times larger than the SHWs in these stands.

The influence of strategy on size in the both studied HW types was found significant only comparing the stands S-95 and ST2-95; and the stands ST1-95 and ST2-95 (Tab. 6). Between the stands S-95 and ST-50 and between the stands ST1-95 and ST-50, statistically significant differences were only observed for RHW size. No significant differences in the HW size of either the first or the second type were found among the other stands.

Tab. 6: ANOVA (with Duncan's tests) – Influence of silvicultural strategy on HW size ratio.

Silvicultural strategy	HW type	
	RHW	SHW
S-95xST1-95	0.7120 ns.	0.9552 ns.
S-95xST2-95	0.0001 ***	0.0030 **
S-95xST-50	0.0009 ***	0.0922 ns.
ST1-95xST2-95	0.0000 ***	0.0029 **
ST1-95xST-50	0.0004 ***	0.0853 ns.
ST2-95xST-50	0.2515 ns.	0.1380 ns.

– level of statistical significance, *p < 0.05, **p < 0.01, ***p < 0.001, ns. - not statistically significant, p > 0.05

Quality structure of assortments in the studied forest stands

Fig. 1 shows that quality structure of logs taken from the stands with selection structure (S-95) and the stands subject to heavy crown thinning (ST1-95) was distinctly different from the structure of the stands subject to light crown thinning only (ST2-95 and ST-50). In case of the first and the second group of forest stands, the total share of logs belonging to the high quality classes (F-A and F-B) attained 50 and 40 %, respectively; with almost one quarter of logs belonging to the highest quality class (F-A). On the other hand, in the stand groups tended only by light crown thinning from above and subject to understorey felling in the final phase (ST2-95 and ST-50), the proportions of the F-A and F-B were only 12 and 16 %, respectively.

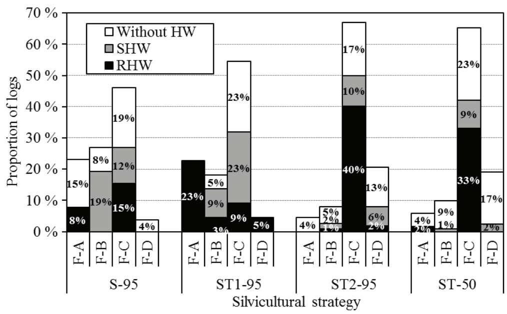

Fig. 1: Proportions of logs without heartwood, and logs containing RHW and SHW in particular quality classes and according to the silvicultural strategy.

The major part of the logs obtained from the studied stands ST2-95 and ST-50 was in the quality class F-C. The stands tended by light crown thinning from above and subject to shelterwood felling in the final phase manifested up to 67 and 65 % of logs of quality F-C. In case of the stands formed by selection felling and the stands tended by free crown thinning with positive selection, the proportions of the logs belonging to the quality class F-C were 46 and 55 %, respectively.

The proportion of logs of lowest quality (F-D) in the stand formed by selection felling (S-95) and the stand tended by crown thinning with positive selection (ST1-95) was above 5 %. On the other hand, the proportion of these logs in the stands tended by light crown thinning followed by shelterwood felling (ST2-95 and ST-50) levelled about 20 %.

Logs are assorted into the quality classes based on their dimensions (minimum diameter and length), quantity and quality of knots, cracks, rots, red and star-shaped heartwood, and several other less important characteristics (EN 1316-1 2012). The forestry practice has been accepted HW (RHW and SHW) quality and quantity as the main criteria for assorting beech logs into particular quality classes. Our analysis (Fig. 1) resulted in finding that from the selection stand (S-95) and the stand tended by crown thinning with positive selection (ST1-95), only a few of the logs classified into the highest classes (F-A, F-B) were heart-free (15 and 8, and 0 and 5 %, respectively). The most of the highest-quality logs contained a small RHW or SHW (Fig. 2), not being in contradiction with criteria for these two highest classes (size under 15, and 30 %, respectively for RHW diameter and 0, and 15 % respectively, for SHW diameter). The biggest numbers of heart-free logs assorted to the class F-C were in the stands S-95 and ST1-95. These logs did not meet criteria for a higher class, due to their small average diameter. In case of the stands tended by light crown thinning followed by shelterwood felling (ST2-95 and ST-50), the most abundant in F-C class were logs with RHW (40 and 33 %, respectively). Also in this class, there were 17 and 23 %, respectively, heart-free logs not possible to classify in a higher class due to their small average diameter. The most abundant in this class were again heart-free logs with an average diameter of 20 – 25 cm (13 and 17 %).

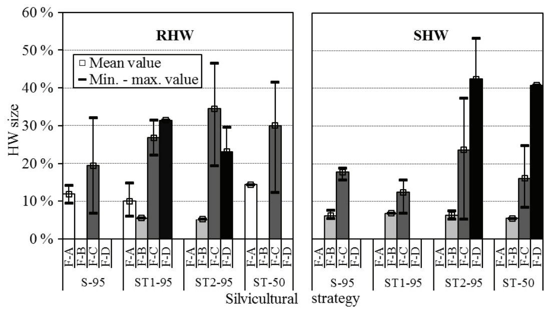

Fig. 2: Mean values and variation ranges for RHW and SHW sizes in the studied stands and quality classers.

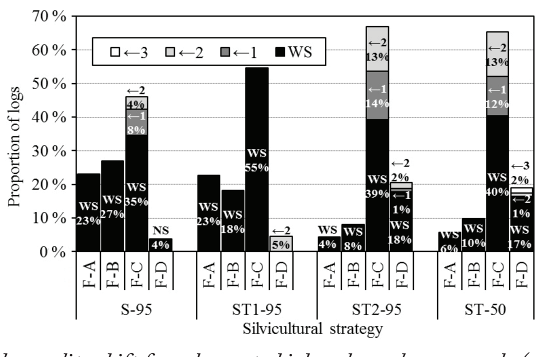

Fig. 3: Potential for the quality shift from lower to higher classes by one grade (←1), two grades (←2), three grades (←3) and without shift (WS).

The re-classified logs fulfilled the dimension criteria of higher quality classes; however, they were not suitable from the viewpoint of HW size and type.

According to our analysis, even 25.3 % of logs could have assigned higher quality class if they had contained less or no HW. From this amount, in 11.7 % the positive shift could be by one grade, in 12.7 % by two grades and in 0.7 % even by 3 grades. The highest shift potential in the quality class F-C was in the stands with selection structure (S-95) and in the stands tended by light crown thinning followed by shelterwood felling (ST2-95 and ST-50) (Fig. 3). Especially in the stands ST2-95 and ST-50, the heart size was a primary limit factor controlling the log quality. From the viewpoint of size, 14 and 12 % logs could have met the criteria for the class F-B and 13 % for the class F-A. In the stands with selection structure (S95 %), the proportions of similar logs were only 8 and 4 %, respectively. In the groups of forest types ST1-95, ST2-95 and ST-50, several logs (1-5 %) belonging into the class F-D could be classified better – by one to three grades.

DISCUSSION

The study material was sampled from stands with very similar growth conditions (parent rock, group of forest types, altitude, aspect, age structure), to eliminate the site effect (Schmidt et al. 2008). Thus we can suppose in this work that forest management is the chief factor controlling the quality of beech raw material production assessed from the viewpoint of HW occurrence, size and type. There were not observed significant differences in proportion of logs containing HW among the studied groups of forest types (the stand tended by crown thinning from above with positive selection ST1-95 manifested even the highest proportion of logs containing HW). Contrarily, the HW size was clearly smaller (2–2.5 times) in the stand groups formed by selection felling (S-95) and positive crown thinning (ST1-95) than in the stands tended by light crown thinning (ST2-95 and ST-50).

The HW size and type are significant traits for classifying logs according to their quality. The effect of forest management strategy was distinct in quality of logs assessed according to the standard (EN 1316-1 2012). The yield of logs of high quality classes (F-A, F-B) in the case of the stand with selection structure (S-95) and the stand tended by positive heavy crown thinning (ST1-95) was about 50, with almost 25 % of logs belonging to the highest quality class F-A. At the same time, the proportions of logs of the same quality in the stands tended only by light crown thinning and finalised by Gayer's felling were 12 and 16 %, respectively, thus representing more than three-times reduced production of the highest-quality assortment in this group of forest types. The biggest deal of the total production in all the studied stands was ranked into the class F-C. The poorest quality was observed in the stand tended by light crown thinning and finalised by shelterwood felling (ST2-95). The major part of log production in this stand was in the class F-C (67 %) and F-D (21 %), the lowest in the classes F-A and F-B (4 and 8 %, respectively).

An appropriate tending intervention can improve the tree's vitality (enhanced space for crown growth, accelerated growth increment, thicker sapwood, relatively reduced dry-wood zone), on the other hand, it may cause stem wounds. A thinning purposed for releasing the crowns of the target trees, can reduce considerably HW formation in terms of both occurrence and size, also at the presence of the just mentioned wounds due to silvicultural interventions. From this aspect, the most appropriate silvicultural management seems in the stand with selection structure (S-95). From this stand, there were acquired logs with the highest quality. The amount of hartwood-free logs obtained from the stand ST1 tended by heavy crown thinning with positive selection was lower. However, the higher frequency of HW occurrence had not a proportional impact on the log quality, because the HW size in logs was small. As such, these logs did not need to shift into lower quality classes.

Logs containing HW need to shift into lower quality classes than these corresponding to the log length and diameter. This fact has negative commercial consequences. Our analysis has resulted in degrading almost one quarter of logs by one or two quality grades. The biggest, but practically equal losses (30 and 28 %, respectively) were recorded in the stands tended by light crown thinning followed by shelterwood felling (ST2-95 and ST-50). The quality losses in the stands formed by selection felling and by heavy crown thinning (S-95, ST1-95) were significantly lower (12 and 5 %, respectively).

The beech stands with a 50 % beech proportion (ST-50) were tended by light thinning. The beech trees in these stands manifested noticeable diversity in crown width. The stand variability was the biggest in the age structure of the beech sample trees analysed. In case of beech sample trees, the difference in log quality between ST-50 and the homogeneous beech stands ST2-95 tended by the same silvicultural method has not been found significant. However, this result contrasts with the finding Bastien (1997).

The results of our research on impact of crown thinning or selection felling intensity on the diameter structure and crown parameters of beech sample trees have confirmed the former knowledge obtained by several authors (Altheer 1971; Büren 2002; Freist 1962; Kladtke 2002; Saniga 1998). All these authors agree that heavy crown thinning from above by employing the method of target trees affects positively the crown volume and accelerates reaching of the target stem diameter in these trees. The structure of selection beech forests is favourable for trees in the upper stand layer. These trees have high-quality stems and free crowns with the length representing 40–45 % of the total tree height. Such conditions are favourable for high assimilation rate and accelerated diameter increment (Dittmar 1990; Gerold and Biel 1992; Saniga 1996, 1998; Schmidt et al. 2008). In even – aged forest, the management principle for beech trees is releasing their crowns at age over 60 years, with the aim to enhance the activity of their assimilatory apparatus (Schütz 1994).

High assimilation performance of tree crown is a presupposition for maintaining vigorous vitality of reserve tissues and transport system in the tree stem. On the other hand, the dry central zone in the stem is limited in size, which lowers the tree's predispositions for RHW formation (Sachsse 1967; Torelli 1974, 1984). As for the SHW size, the vitality of reserve tissues is of primary importance, too. At the same time, bacteria and fungi associated with this type of heartwood increase the risk of its enhancement (splashing and abnormal heartwood) (Sachsse 1991). Our research results well correspond to this fact: the low RHW and SHW size values in the stand with selection structure (S-95) and the stand tended by heavy positive crown thinning (ST1-95) (Tab. 5) correlate with higher CL and CL/h ratio values. The values of these two parameters in the other analysed stand types tended by light crown thinning from above (ST2-95 and ST-50) were lower.

ACKNOWLEDGMENT

This paper was processed in the frame of the projects No. 1/0163/12 and No. 1/0381/12 as the result of author's research at significant help of Scientific Grant Agency of Ministry of Education of the Slovak Republic and Slovak Academy of Sciences.

We would like to thank the Forest Enterprise of Technical University administration for the good cooperation and the help in our field work. Special thanks to Dagmar Kúdela for the translation and language correction of the manuscript.

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