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YIELD COMPARISON OF BEECH (*Fagus sylvatica* L.) AND FIR/SPRUCE (*Abies alba* Mill./*Picea abies* L.) LOGS IN THE SAWMILL PROCESSING INDUSTRY

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ABSTRACT

Sawmilling technology in Macedonia is primarily characterised by small- to medium-capacity sawmills, many of which operate with mixed species and variable equipment configurations. These sawmills typically process between 1500 and 5000 m³ of roundwood annually and play a crucial role in the domestic wood industry. The technology employed often includes vertical bandsaws for primary sawing and simple layouts for material flow. Beech *(Fagus sylvatica* L.) and fir/spruce (*Abies alba* Mill./*Picea abies* L.) are among the most commonly processed species, representing a significant share of the raw material input due to their abundance, accessibility, and economic relevance. Beech is predominantly used in furniture production, while fir/spruce is more common in construction and structural applications.

This paper presents a focused comparative analysis of raw material yield efficiency between beech and fir/spruce logs in a primary processing setting. The study was conducted at the MARKISTO sawmill in Leskoec, Ohrid, a representative facility within the North Macedonian context, operating with a capacity of 2,500–3,000 m³ per year. A total of 160 logs from two standardised lengths (4.0 m and 5.0 m) and I, II, and III quality classes—80 from each species—were analysed. The objective was to quantify and compare the percentage yield of sawn timber relative to log volume, under real production conditions, without altering existing workflows. Key influencing factors such as log diameter, taper, and wood defects were recorded and assessed.

Results indicated that fir/spruce logs generally achieved higher yield rates than beech, particularly in the higher quality classes. For instance, Class I fir/spruce logs yielded up to 10–15% more usable lumber compared to Class I beech logs, mainly due to more uniform structure and lower waste values. In contrast, beech logs, especially from lower quality classes, were more affected by natural defects like heart checks and curvature, reducing the quantitative yield despite similar or larger diameters. The study confirms that both species and log quality significantly affect sawmill efficiency and that careful log selection and classification are essential for optimising material recovery.

Keywords: beech, fir/spruce, quality class, sawmills, yield, efficiency.

1. INTRODUCTION

The ultimate objective of the primary processing of wood is the production of final products, characterised by appropriate dimensions, shape, and quality. In order for such products to be manufactured, a sequence of technological operations is required, whereby the initial system that begins with the natural form of the raw material (roundwood) is referred to as primary wood processing. The process of log conversion begins on the primary machines through sawing with various cutting tools, such as bandsaws, frame saws, or circular saws. In addition, combined methods in processing may also be employed, such as sawing-milling, among others. The log sawing process may be determined in several ways, and it depends on the wood species, the dimensions and quality of the logs, the dimensions of assortments, the assortment structure of the sawn products, their intended purpose, the quality class, and so forth.

The efficiency of sawmilling capacities is closely associated with the method of log sawing. The performance of operations is influenced by multiple factors, such as sawlog yield, the species of wood being processed, the level of equipment of the sawmill, the sawing method, etc. Among these factors, sawlog yield is directly linked to the economic profitability of a sawmilling capacity. Yield is defined as the degree of utilisation in the form of sawn lumber or as the quantity of sawn assortments obtained as the result of log processing. In addition to sawn assortments, the processing of logs yields other products, such as parquet blanks, wooden elements, laths, and other products. Yield can be examined from the perspectives of quantitative, qualitative, and value-based points. The notion of maximal quantitative yield refers to the quantity of sawn assortments obtained from the processing of a single log or a greater number of sawmill logs. Qualitative yield is a complex concept that implies obtaining assortments of the highest quality, while value-based yield is closely connected to both quantitative and qualitative yield. The focus of this paper will be directed toward quantitative yield, as the principal indicator of the rational use of sawlogs.

The rational use of sawlogs is significant from the perspective of planned exploitation of forest potentials and the ecological aspect of the environment. Through rational use of sawlogs, the quantity of waste generated in the process of log processing is reduced, thereby decreasing unnecessary tree felling within forest resources. For rational raw material utilisation, it is essential to prepare a sawing plan in advance and to be aware of sawlog quality, dimensions, and the final dimensions of the sawn assortments. The sawing plan, or the sawing pattern, denotes the arrangement of cuts on the transverse section of the log. Through proper selection of the sawing pattern, the unnecessary number of cuts is reduced, the formation of unnecessary fine and coarse waste is avoided, and thereby also the consumption of electrical energy required for powering sawing machinery is reduced.

In practice, the maximal quantitative yield of logs depends upon numerous factors, such as log diameter, assortment dimensions, thickness allowance of assortments, kerf width, and many other factors. The listed factors define the geometry of maximal quantitative yield. The geometry of maximal quantitative yield is reduced to the assumption that the log at its thin end is circular in shape, while the coverage of the circle's surface is by assortments in the form of quadrilaterals – the prism model (Rabadjiski 2019). Under practical conditions, the formation of sawing patterns is not limited solely to the transverse section of the log. When forming these patterns, the dimensions of assortments (width and thickness), as well as shrinkage allowance, must be taken into consideration. For these reasons, in theory, apart from the geometry of maximal quantitative yield, optimisation methods are also devised when forming sawing patterns (Nikolić 2010). Knežević (1968) provides a method for creating sawing patterns of logs by means of the coefficient method, wherein the thickness of assortments is reduced to the nearest thickness of boards or planks in accordance with the prescribed standard. This method represents a mathematical model, but its shortcoming lies in the approximate thickness of assortments or the inability to obtain an exact value. Considering such factors, Knežević (1955) established a method for forming sawing patterns, whereby the process begins with the thinnest assortment on the lateral sides of the transverse section, with the thickness of assortments increasing toward the central portion of the log. According to this method, assortments of greatest thickness are positioned in the middle of the cross-section.

Each wood species is distinguished by different anatomical characteristics. Consequently, these characteristics include the form of the stem, its length, and its cross-section. The geometry of the logs also determines the quantitative yield. In the formation of patterns, diameter taper is also taken into account. Taper denotes the gradual reduction of diameter from the thin toward the thick end of the log, which represents a deviation from the cylindrical form. Within sawmilling capacities, both coniferous and deciduous logs are processed, possessing various diameters, lengths, and quality classes. Consequently, the percentage of quantitative yield also varies. Under production-exploitation working conditions, according to Rabadjiski (2019), the percentage of quantitative yield ranges within rather wide limits, averaging between 48.0 and 70.0%. In the processing of beech logs of I/II quality class, with diameters from 26.0 to 58.0 cm on a bandsaw, quantitative yield ranges from 46.0 to 57.0% (Rabadjiski 1991). In the processing of logs with identical characteristics on a vertical frame saw, the author states that yield falls within the limits of 46.0 to 57.0%. Šoškić and Popović (2004), in processing beech logs of quality class I, report that yield ranges from 47.0 to 62.0%, averaging 60.0%; for quality class II, 54.0%; and for the third class, 49.0%. According to Чернаев (1960), in the processing of coniferous logs, yield ranges from 53.0 to 64.0%. Brežnjak (2000) reports that the average quantitative yield for fir/spruce logs amounts to 65.0%. Based on the mentioned research, it may be concluded that coniferous wood species yield a higher quantitative percentage. Apart from the sawing pattern, important factors influencing yield include the quality class and the applied sawing technology.

The paper presents data derived from research conducted under production-exploitation working conditions. A comparative analysis has been carried out of the quantitative yield in beech logs and fir/spruce logs of equal lengths and quality class.

2. MATERIALS AND METHODS

The subjects of research in this paper are sawlogs of beech (*Fagus sylvatica* L.) and fir/spruce (*Abies alba* Mill./*Picea abies* L.) of I, II, and III quality class. As the research facility, the sawmill MARKISTO, located in the village of Leskoec, Ohrid, was selected. The raw material used in the company MARKISTO is supplied from the Public Enterprise Macedonian Forests. Within the chosen sawmilling capacity, logs of both deciduous and coniferous origin are processed. Among the deciduous species, beech wood predominates in processing. Additionally, logs of walnut (*Juglans regia* L.) are included in small quantities. The coniferous logs are from fir/spruce (*Abies alba* Mill./*Picea abies* L.).

Based on the overall statistics, it can be concluded that beech is the most common deciduous species in primary processing in the Republic of North Macedonia. This type of wood is abundant throughout the state, and the industry makes use of what is most easily accessible. Sawn lumber from beech is predominantly employed in the furniture industry, particularly in the production of tables and chairs.

Fir and spruce are marketed as a single wood species, commonly known as čam. They are classified as one species owing to their similar anatomical structure and technical properties. This wood is primarily applied in construction. It demonstrates exceptionally favourable load-bearing properties, and it is likewise utilised for roofing and flooring structures. For flooring and roofing structures, wooden laths are commonly employed.

The availability of these species in the sawmilling capacity at the time of data collection was taken into consideration while choosing the wood species. For the analysis, a dominant deciduous species (beech) and a coniferous species (fir/spruce) were chosen, with the aim of conducting a comparison of the percentage of maximal quantitative yield between deciduous and coniferous species.

The research described in this paper was conducted using a methodology suitable for this kind of study. The investigations were conducted in two phases:

1. determination of maximal quantitative yield of beech sawlogs, and
2. determination of maximal quantitative yield of fir/spruce sawlogs.

The factors that primarily influence the maximal quantitative yield of sawlogs may be of both technological and economic nature. The technological factors that significantly affect the yield of wood mass are:

- selection of raw material;
- selection of saw thickness;
- selection of sawing pattern;
- determination of shrinkage allowance;
- determination of the degree of processing of sawn timber;
- determination of the quantity of coarse waste;
- determination of wood moisture content;
- selection of the concept of sawmilling technology.

The sawlogs were processed on a bandsaw. The method of processing was appropriate for the wood species and their characteristics. After processing, sawmill assortments with appropriate dimensions were produced from the sawlogs.

The research was performed under production-exploitation working conditions. The working and sawing conditions were left unchanged. These conditions were merely observed, as were the results.

Measurements were taken of the logs' length, the diameter of the thin end, and the diameter of the thick end of the log. Classification of the logs was conducted in accordance with Macedonian standards MKS EN D.B4.028/1:1990, MKS EN D.C1.022, and MKS EN 1316-1:2013.

The method of work consisted of:

- measurement of logs (length, diameter of the thin end, and diameter of the thick end);
- calculation of:

a) mean diameter,

b) volume of the log,

c) diameter taper,

d) maximal quantitative yield;

- using statistical methods to process the data from measurements and computations.

The measurement of the logs was performed in the log yard. For the measurement of the required dimensions of the logs, a wooden calliper (Figure 1) and a steel tape were used. The wooden calliper was employed for measuring the diameters of the logs intended for processing. The calliper's scale is graduated in centimetres. The steel tape has a length of 10 metres, divided into metres, centimetres, and decimetres, with the first metre divided into millimetres. The steel tape was used for measuring the length of the logs. All measured parameters were recorded in pre-prepared tables for documentation.

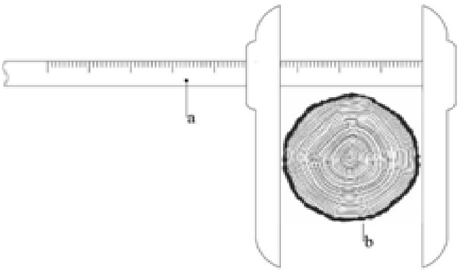

Figure 1. *Wooden caliper,*
a – caliper, b – sawlog.

In total, 40 beech logs with a length of 4.0 m were analysed. The total volume of these logs amounts to 25.929 m³. The logs are grouped into 6 thickness classes, according to their mean diameter, with an interval of 5 cm between each group. The analysed logs belong to the I, II, and III quality classes. The diameter of the thin end (d_1) ranges from 31.0 to 56.0 cm; the diameter of the thick end (d_2) ranges from 33.0 to 60.0 cm; while the mean diameter (d_{sr}) ranges from 52.0 to 58.0 cm. The taper (S), as an important indicator for the maximum quantitative yield of the logs, varies from 0.25 to 2.75 cm/m. The beech logs are presented in Figure 2. With a length of 5.0 m, a total of 40 logs were analysed, belonging to the I, II, and III quality classes. The total volume of these logs amounts to 32.169 m³. The classification was carried out into 6 groups, according to the mean diameter, with a difference of 5 cm between the groups. The diameter of the thin end (d_1) ranges from 28.0 to 56.0 cm; the diameter of the thick end (d_2) ranges from 31.0 to 56.0 cm; while the mean diameter (d_{sr}) ranges from 30.0 to 59.0 cm. The taper (S) ranges from 0.40 to 2.20 cm/m.

Figure 2. *Beech sawlogs (Fagus sylvatica* L.*)*

Figure 3. *Fir/spruce sawlogs (Abies alba* Mill*/Picea abies* L.*).*

A total of 40 fir/spruce logs were analysed, which belong to the I, II, and III quality classes. The total volume amounts to 25.562 m³. The diameter of the thin end (d1) ranges from 29.0 to 56.0 cm; the diameter of the thick end (d2) ranges from 32.0 to 60.0 cm; while the mean diameter (dsr) is from 30.0 to 58.0 cm. The taper (S) is from 0.50 to 2.75 cm/m. With a length of 5.0 m, a total of 40 logs were analysed, distributed across 6 thickness groups. Their total volume amounts to 32.444 m³. The logs belong to the I, II, and III quality classes. The diameter of the thin end (d1) is from 28.0 to 56.0 cm; the diameter of the thick end (d2) is from 33.0 to 60.0 cm; while the mean diameter (dsr) ranges from 30.0 to 58.0 cm. The taper (S) is within the range of 0.20 to 1.60 cm/m. The fir/spruce logs are presented in Figure 3.

The logs are sawn with specialised sawing (their final intention is known in advance), with predetermined dimensions of assortments. The assortments are intended for furniture production, while the large waste is utilised for parquet blanks. The wooden elements are intended for the production of tables and chairs. Boards are commonly used for the manufacture of solid furniture. The logs are most frequently sawn according to the live sawing pattern (Figure 4). The sawing of fir/spruce logs is also specialised. The timber is used for construction purposes. From the peripheral zone of the log, boards and planks are obtained, while from the central zone of the log, beams, scantlings, and laths are produced. Because it is thought that this method produces a larger output, these logs are sawn using a live sawing pattern (Figure 5). The percentage of fine waste rises using this sawing technique, and in certain situations, it may almost match the percentage of coarse waste. This is a typical feature of lath sawing.

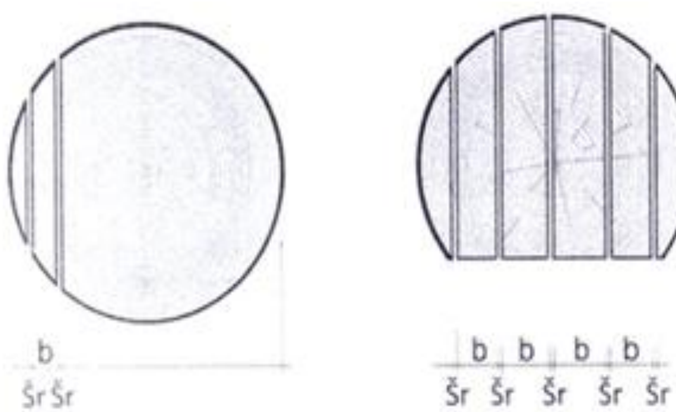

Figure 4. *Sawing pattern for the beech sawlogs,*
b – assortments thickness (mm), $\check{s}_r$ *– kerf width of the bandsaw.*

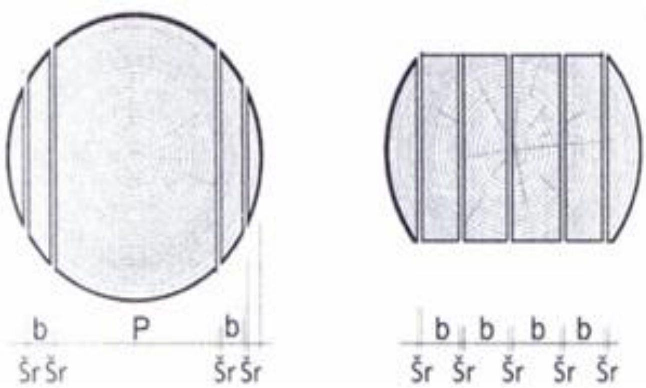

Figure 5*. Sawing pattern for fir/spruce sawlogs,*
b – assortments thickness (mm), $\check{s}_r$ *– kerf width.*

For the purposes of statistical processing of the data from this research, descriptive statistics and regression analysis were used. The data analysis employed relative values, which are expressed as percentages. Simple (linear or curvilinear) regression and correlation analysis are used to examine the relationships between two occurrences; multiple (linear and curvilinear) regression and correlation analysis are used for numerous occurrences. The data processing was conducted in the software Microsoft Excel.

3. RESULTS AND DISCUSSION

The analysis of the maximum quantitative yield in beech sawlogs was carried out separately for logs with lengths of 4.0 m and 5.0 m. According to the results obtained for both lengths, a comparative analysis was performed between the yields. With the purpose of comparing the yield of beech logs and certain parameters that influence the yield, an analysis was conducted for both log lengths. The analysis was carried out depending on the length and thickness group. The objective of the analysis was to investigate the effect of the length and thickness group on the percentage of maximum quantitative yield. For the analysis, descriptive statistics and regression analysis were employed. Table 1 presents the statistical values of the quantitative yield of beech logs with lengths of 4.0 m and 5.0 m.

***Table 1**. Statistical values of the quantitative yield of beech (Fagus sylvatica* L.*) logs with lengths of 4.0 m and 5.0 m.*

Thickness group	Length	Mean value	Standard deviation	Standard error	95% confidence interval		Minimum	Maximum
					Lower bound	Upper bound		
[cm]	[m]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
1	2	3	4	5	6	7	8	9
1. 30.0 - 34.0	4.0	46.62	2.85	1.16	43.63	49.61	43.79	51.67
	5.0	46.10	1.96	0.80	44.04	48.16	43.28	48.47
2. 35.0 - 39.0	4.0	41.16	5.04	1.90	36.50	45.82	35.91	48.39
	5.0	51.24	5.56	2.10	46.10	56.38	44.21	59.54
3. 40.0 - 44.0	4.0	46.09	3.91	1.48	42.48	49.70	40.29	51.52
	5.0	52.84	2.35	0.89	50.66	55.02	50.22	56.39
4. 45.0 - 49.0	4.0	49.08	2.95	1.50	45.99	52.17	45.54	53.08
	5.0	53.60	2.66	1.08	50.81	56.39	50.73	57.93
5. 50.0 - 54.0	4.0	49.57	4.23	1.60	45.66	53.48	43.37	56.41
	5.0	56.48	2.78	1.05	53.91	59.05	53.28	60.08
6. 55.0 - 59.0	4.0	52.07	4.01	1.51	48.36	55.78	45.38	56.29
	5.0	59.52	3.24	1.22	56.52	62.52	54.88	64.69

According to Table 1, it may be concluded that the highest yield is achieved in the sixth thickness group, for both lengths. The first thickness group exhibits approximate values of quantitative yield, and this trend continues across all thickness groups, except in the second group, where the difference amounts to about 10.00%. The lowest value of yield was recorded in the second thickness group (35.91%) for the length of 4.0 m, while the highest value was recorded in the sixth thickness group (54.88%) for the length of 5.0 m. It can therefore be concluded that with an increase in both the diameter and the length of the log, the percentage of quantitative yield also increases. Based on the data presented in the table, it may be inferred that with a difference of 1.0 m in length, at the same mean diameter, the yield may increase by as much as 10.00%. When drawing conclusions regarding the increased percentage of yield, other factors must also be taken into consideration, such as anatomical defects, taper, curvature of the log, and quality class. The percentage of maximum quantitative yield is a complex concept, particularly in the case of beech. The complexity is due to the specific anatomical structure, namely the presence of false heartwood in this wood species, which can significantly reduce the yield percentage. Heartwood is incorporated into as few assortments as possible while constructing the sawing patterns. The assortments obtained from the central zone, which contain this defect, represent a challenge during the process of artificial drying. In order to increase yield in beech, parquet blanks are manufactured from coarse waste and lower-quality log zones. For better visualisation of the data from the table, a graph has been created illustrating the relationship between the thickness group of beech sawlogs and the percentage of quantitative yield for both analysed lengths, presented in Figure 6.

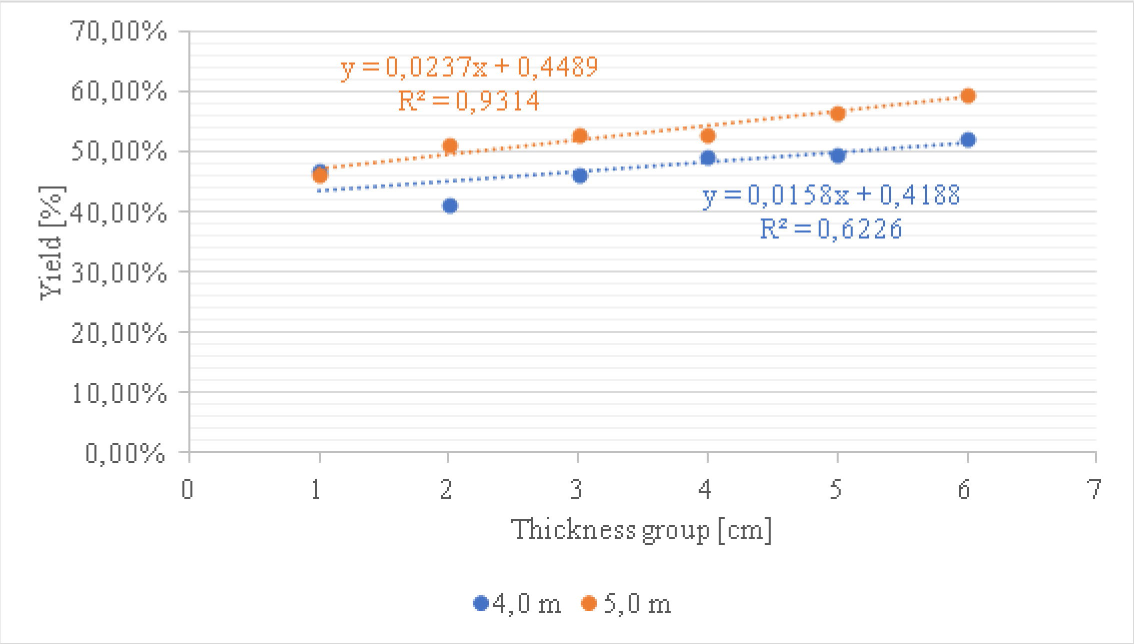

Figure 6. *Relationship between thickness group and quantitative yield of beech (Fagus sylvatica* L.*) sawlogs.*

According to the correlation coefficient (R), it may be concluded that for beech sawlogs of 4.0 m length, with an increase in mean diameter, the percentage of quantitative yield also increases. The value of coefficient R for sawlogs of 5.0 m length indicates a weaker correlation. To put it another way, a few other factors affect the proportion of quantitative yield in these sawlogs.

Table 2 displays the statistical values for the quantitative yield of fir/spruce sawlogs with lengths of 4.0 m and 5.0 m. Table 2 indicates that yield increases as one increases the diameter in 4.0-meter-long fir/spruce logs. For logs of 4.0 m length, the lowest percentage of yield was recorded in the first thickness group, amounting to 50.33%, while the highest percentage was recorded in the sixth thickness group, amounting to 74.78%. Smaller-diameter logs were processed into beams and scantlings, while larger-diameter logs yielded boards, planks, and laths. The sawmill products from fir/spruce are intended for the needs of the construction industry.

For logs of 5.0 m length, a slight deviation from the linear increase of yield may be observed. The second thickness group demonstrates a higher percentage of yield than the third, while the fourth has a higher percentage than the fifth. This is due to the lower quality of the logs being sawn, given that the majority of the processed sawlogs belonged to the third quality class. The deviation from linear increase, however, is minor and does not exceed 3.00%. The lowest yield among the 5.0 m logs was observed in the third thickness group, amounting to 59.99%, while the highest yield was in the sixth thickness group, amounting to 75.70%. It can be concluded that in fir/spruce sawlogs, as the mean diameter increases, the yield also increases. With an increase in length by one meter, at the same mean diameter, the yield increases from 1.32% to 11.32%, with an average increase of 6.04%. The increase in yield percentage with growth in length is particularly pronounced in smaller diameters. Due to their straightforward anatomical structure, small taper, and low curvature, fir and spruce sawlogs have excellent yield percentages because they have fewer anatomical faults. Since the lumber is intended for construction, when sawing beams, a greater portion of the cross-section is utilised, fewer cuts are required, and consequently the proportion of both fine and coarse residues is waste. The high percentage of yield is attributed primarily to the small taper.

Table 2. *Statistical values of the quantitative yield of fir/spruce (Abies alba* Mill./*Picea abies* L.) *logs with lengths of 4.0 m and 5.0 m.*

Thickness group [cm]	Length [m]	Mean value [%]	Standard deviation [%]	Standard error [%]	95% confidence interval Lower bound [%]	95% confidence interval Upper bound [%]	Minimum [%]	Maximum [%]
1	2	3	4	5	6	7	8	9
1. 30.0 - 34.0	4.0	52.68	1.65	0.67	50.95	54.41	50.33	54.71
	5.0	63.49	2.65	1.08	60.71	66.27	60.09	66.62
2. 35.0 - 39.0	4.0	54.74	3.16	1.20	51.82	57.66	50.86	60.08
	5.0	66.06	2.01	0.76	64.20	67.92	63.25	68.85
3. 40.0 - 44.0	4.0	62.20	3.09	1.17	59.35	65.05	57.03	66.68
	5.0	64.84	4.77	1.80	60.43	69.25	59.99	70.90
4. 45.0 - 49.0	4.0	64.96	4.01	1.64	60.75	69.17	58.85	69.52
	5.0	71.12	2.23	0.91	68.78	73.46	67.84	74.37
5. 50.0 - 54.0	4.0	66.48	4.97	1.88	62.42	70.54	60.63	72.48
	5.0	70.76	2.09	0.79	68.83	68.83	68.25	73.25
6. 55.0 - 59.0	4.0	71.67	3.63	1.37	68.31	75.03	65.31	74.78
	5.0	72.99	2.66	1.01	70.53	75.45	69.27	75.70

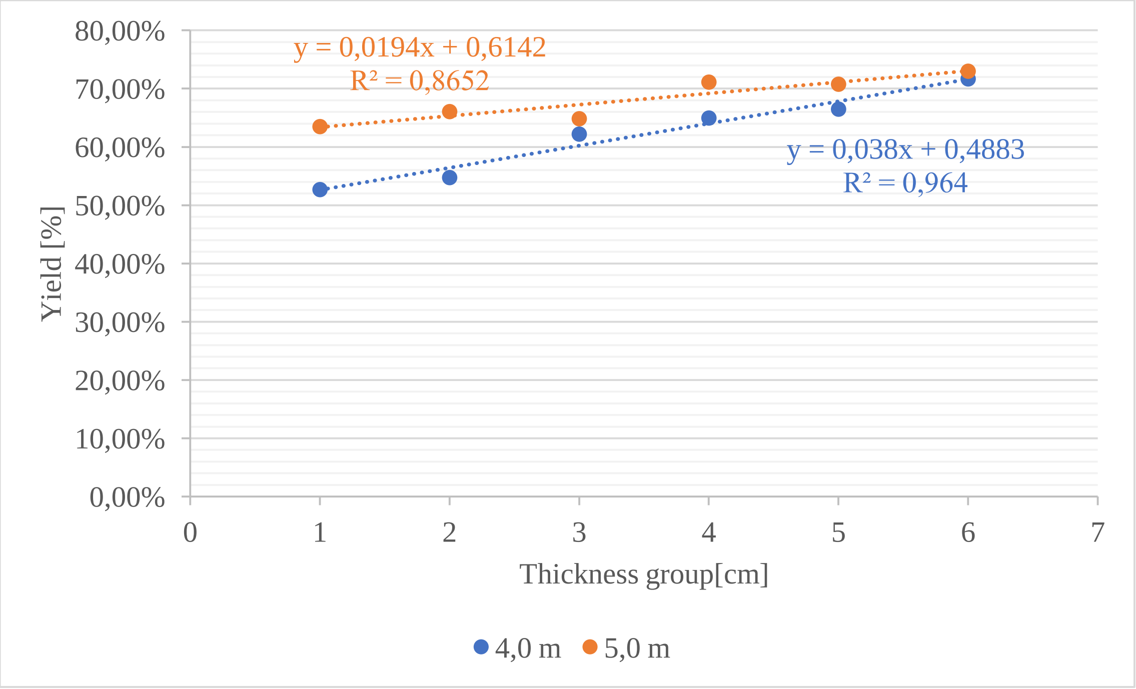

Figure 7. *Relationship between thickness group and quantitative yield in sawlogs of fir/spruce (Abies alba* Mill./*Picea abies* L.).

According to Table 2, for a clearer overview of the data, a regression analysis has been performed, presented in Figure 7. Based on the correlation coefficient R, for both the 4.0 m and the 5.0 m logs, it may be concluded that with the increase of the mean diameter, the percentage of quantitative yield also increases. In logs of 5.0 m length, the correlation is somewhat weaker than in those of 4.0 m. In these logs, a slight decline in yield can be observed in the third thickness group, as well as a deviation from the linear increase of yield. This is due to the lower quality of the 4.0 m logs and the greater taper, as one of the main factors influencing the percentage of quantitative yield. With the increase of log length, the taper also increases, which explains the reduction of quantitative yield in the third thickness group of logs with a length of 5.0 m. In the logs with a length of 5.0 m, the correlation coefficient R demonstrates a strong correlation. It can be concluded that for these logs, with the increase of the mean diameter, the percentage of quantitative yield increases.

The study starts with the finding found in the literature that the yield percentage of deciduous wood species is lower than that of coniferous species. In order to examine this hypothesis, identical lengths of sawlogs were selected for both analysed wood species. The logs were divided into six identical thickness groups, based on their mean diameter. The comparison of quantitative yield in beech and fir/spruce is presented in Table 3 and Figure 8.

Table 3. *Comparison of yield in logs of beech (Fagus sylvatica L.) and fir/spruce (Abies alba* Mill.*/Picea abies* L.*).*

Thickness group (cm)	Wood species	Diameter taper (cm/m)	Quantitative yield (%)	Coarse waste (%)	Fine waste (%)	Shrinking allowance (%)	Total waste (%)
1	2	3	4	5	6	7	8
1. 30.0 - 34.0	beech	0.87	**46.36**	31.48	13.91	8.11	53.50
	fir/spruce	0.99	**57.83**	20.47	14.15	6.80	41.42
2. 35.0 - 39.0	beech	1.34	**45.92**	30.59	16.00	8.04	54.63
	fir/spruce	0.98	**60.13**	16.36	14.90	7.07	38.33
3. 40.0 - 44.0	beech	1.55	**49.35**	26.89	14.62	8.64	50.16
	fir/spruce	1.14	**63.51**	15.26	14.93	7.46	37.65
4. 45.0 - 49.0	beech	0.98	**51.29**	24.52	14.96	8.98	48.46
	fir/spruce	0.89	**67.97**	9.71	14.10	7.94	31.74
5. 50.0 - 54.0	beech	1.31	**52.91**	23.91	13.49	9.26	46.66
	fir/spruce	1.06	**68.59**	8.38	14.10	8.05	16.44
6. 55.0 - 59.0	beech	1.18	**55.67**	20.10	13.15	9.74	43.00
	fir/spruce	1.09	**72.33**	5.97	13.08	8.49	27.54

From the data presented, it may be concluded that the percentage of yield in fir/spruce sawlogs is significantly higher in all thickness groups. The difference between the yield of fir/spruce and beech, for each thickness group, ranges from 11.47% to 16.66%. This difference is considerable and is clearly observable through the volume of sawn products. The comparison between yields is relevant since the same thickness groups and identical sawlog lengths are being considered. The percentage of coarse waste is significantly lower in fir/spruce than in beech. In terms of fine waste, the values are approximately equal, with small, negligible differences. The percentage of coarse and fine waste depends primarily on the sawing pattern and the presence of defects. The taper largely dictates the percentage of coarse waste. It is important to note that in sawing both wood species, the objective is to achieve the maximum quantitative yield, and therefore the coarse waste is additionally utilised. From the coarse waste of beech sawlogs, parquet blanks are produced. The coarse waste of fir/spruce sawlogs is minimised as much as possible through the sawing of laths. Concerning fine waste, it is important to emphasise that the kerf width in the primary sawing machine for beech sawlogs amounts to 3.5 mm, whereas in fir/spruce sawlogs it amounts to 4.0 mm. The shrinkage allowance is more favourable in fir/spruce sawlogs due to the physical-mechanical properties of this wood species and its low volumetric shrinkage. In beech, volumetric shrinkage amounts to 17.5%, whereas in fir/spruce it amounts to 11.8% for each sawn product individually. With regard to taper, although the general observation holds that coniferous logs exhibit smaller taper, we were nevertheless unable to establish a relevant relationship for either of the two wood species.

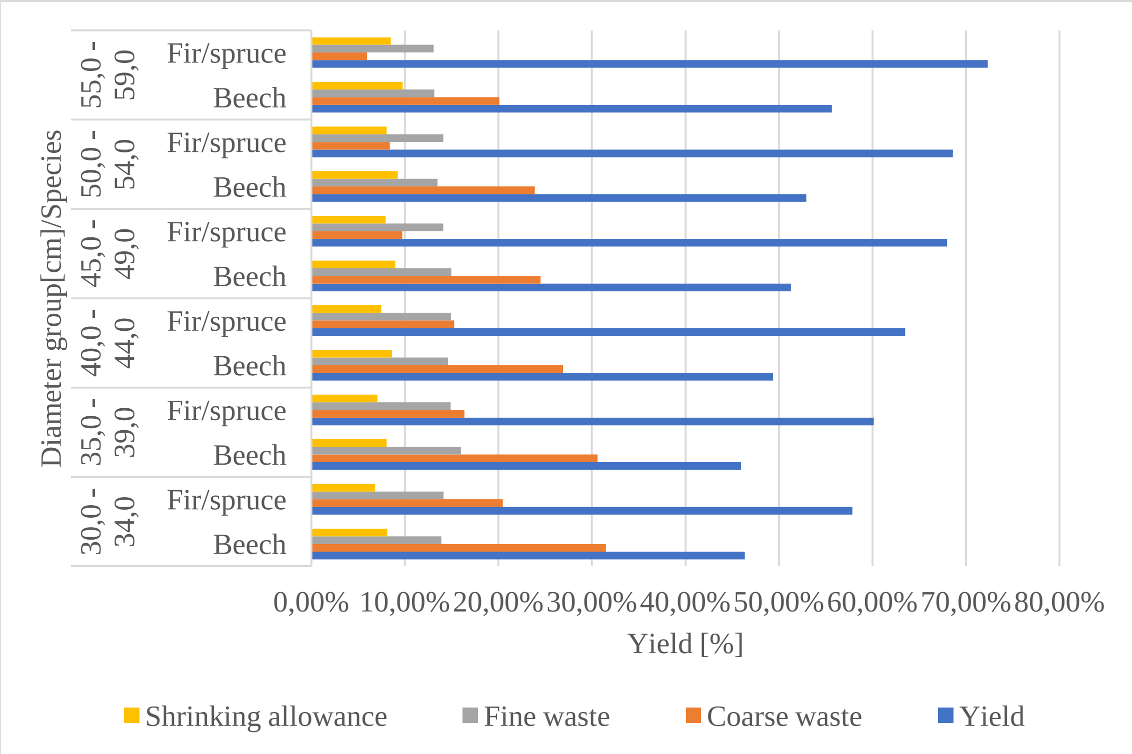

Figure 8. *Comparison of yield in logs of beech (Fagus sylvatica* L.*) and fir/spruce (Abies alba* Mill.*/Picea abies* L.*).*

4. CONCLUSIONS

The quantitative yield of sawmilling raw material constitutes a broad and complex domain which exerts a direct influence upon the economic performance of a sawmilling facility. Beyond economic performance, yield also represents an important concept for the ecology of sawmilling processes and the planned exploitation of forest resources. Several factors affect the percentage of quantitative yield, among which the most significant are the type of raw material and its properties, the characteristics of the processing technology, and the choice of sawing pattern. An inadequately arranged sawing pattern leads to increased amounts of waste and unplanned use of sawlogs, resulting in economic losses.

In the research, an attempt was made to compare the yield of sawlogs of beech and fir/spruce. Beech was selected as a characteristic and dominant deciduous species in domestic sawmilling facilities, while fir/spruce was chosen as a dominant species of coniferous origin. The selection of wood species was also made based on their availability within the analysed research facility. A total of 160 logs were analysed, 80 from each wood species. The logs were grouped according to length (4.0 and 5.0 m) and according to mean diameter. The grouping according to mean diameter was carried out in six diameter classes, with an interval of 5.0 cm between each class. The cutting was performed on identical primary and secondary machines.

Based on the available collected data, it can be concluded that the yield of fir/spruce sawlogs is significantly higher than that of beech sawlogs, which also confirms the general statement, widely available in the literature, that coniferous species provide a higher percentage of quantitative yield compared to deciduous species. For the beech logs, the results correspond with those of Rabadjiski

(1991) and Šoškić and Popović (2004), with the note that in some groups the percentages are lower (especially for Class II and smaller diameters), yet still within the range of 46.0–57.0%. For fir/spruce logs, the results are higher than those of Чернаев (1960) (53–64%) and close to, or even above, those of Brežnjak (2000) (average 65.0%), with maximum values reaching up to 75.0%, which confirms the tendency that conifers yield significantly better percentages.

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