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LUMBER YIELD FROM EUROPEAN WALNUT (*JUGLANS REGIA* L.) AND WILD CHERRY (*PRUNUS AVIUM* L.) SAWLOGS

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ABSTRACT

The goal of this research was to determine the lumber yield of European walnut (*Juglans regia* L.) and European wild cherry (*Prunus avium* L.) logs in Croatia. This research was conducted on 1st and 2nd grade European walnut and wild cherry logs according to Croatian norm regulation HRN D.B4.028, which is typically used in Croatian sawmills. Live sawing was the primary technique used and it was carried out on a band saw. All sawn boards were processed into dimension stock and flooring components using the rip-first sawing technique. Results of the log volume yield analysis in the form of dimension stock and flooring components indicate that the best yield was achieved with 1st grade European wild cherry logs, followed by 2nd grade European wild cherry logs, and then by 1st and 2nd grade European walnut.

The results of the dimension stock and flooring components value yield differ somewhat from the volume yield, here 1st and 2nd grade European walnut logs dominate. In total, the results indicate that 1st grade European walnut logs currently are financially more suitable for sawmill production. This is followed by 1st grade European wild cherry logs and then by 2nd grade European walnut and European wild cherry logs.

KEYWORDS: European walnut (*Juglans regia* L.), European wild cherry (*Prunus avium* L.), log volume yield, lumber yield, log value yield.

INTRODUCTION

Research on the impact of fruit trees in Croatian sawmill production has been given greater attention in the past few years, which includes European walnut (*Juglans regia* L.) and European wild cherry (*Prunus avium* L.). Prka et al. (2001) researched the success of sawmill and parquet production using European walnut. Volume yield and the financial returns of sawing these wood species is very similar to sawing Pedunculate oak (*Quercus robur* L.), Sessile oak (*Quercus petraea* Matt.) and common European beech (*Fagus sylvatica* L.). Volume yield in parquet production is closely correlated to volume yield in primary and secondary sawmills. Therefore, the volume of finished two-ply parquet, as the final product, increased in the plant where this research was conducted and also increased in the processing of higher-quality class sawlogs. Ištvanić (2001) discerned the possibility of successfully processing wild cherry in Croatian sawmills. Greater financial returns could be achieved by the further processing of dimension stock and flooring components into, for instance, wooden flooring such as solid parquet strips, finished parquet, finger jointed timber, and solid wood panels.

Wood from other genuses, *Juglans* sp. and *Prunus* sp. have very similar characteristics to the wood species presented in this research. Kersavage (1972) researched the impact of sawing black cherry (*Prunus serotina* L.) logs for the production of sawn boards and demonstrated that better financial results were achieved when the round sawing method was used as opposed to the live sawing method. Dunmire et al. (1972) researched the success of sawmill production with low-quality raw material from black walnut (*Juglans nigra* L.). Later, Rosen et al. (1980) conducted similar research using the live sawing method on short, low-quality raw materials using black walnut and black cherry. Both indicated that the volume yield and thereby the financial return in sawing these raw material types is much less than sawing standard raw material. Stewart et al. (1982) compared the sawmill production of the Bigtooth aspen (*Populus grandidentata* Michx.), black walnut, and black cherry into unedged sawn boards. They concluded that black walnut was the most economically viable, followed by black cherry, and lastly Bigtooth aspen. In their research, Phelps and Chen (1989) compared log features and sawn boards produced from black walnut cultivated on a plantation with naturally grown black walnut. They concluded that sawn boards from natural black walnut stands was of better quality. Similar research was conducted by Martinsson (2001) using wild cherry. His conclusion was that wild cherry, a fast growing wood species, yielded positive results when cherry was cultivated in a plantation for the purpose of sawmill production.

The objective of this study was to determine the lumber yield of European walnut and wild cherry logs in Croatia. This research was conducted on 1st and 2nd grade European walnut and wild cherry logs, which are typically used in Croatian sawmills.

MATERIAL AND METHODS

Log selection and measurement

The study is based on European walnut and wild cherry trees harvested in northern Croatia. The logs were graded according to Croatian norm regulations HRN-D.B4.028 and HRN-EN-1315-1. A total of 140 European walnut and 120 European wild cherry logs were separated into two grades. The 1st grade consisted of 54 European walnut and 60 wild cherry logs. The 2nd grade consisted of 86 European walnut and 60 European wild cherry logs. The minimum log length was one meter (m), but they could also be longer. The minimum mid-diameter was 15-cm, but they could also be greater.

All sample logs were measured without bark by length, mid-diameter, top-end diameter and butt-end diameter. For log mid- diameter and length, the significant, difference in medium values and group of data were verified. Combined with log quality, these parameters enabled the analysis of raw material structure for experimental sawing. Individual log volume and log taper were calculated according to equations (1) and (2):

$$V_{\log} = \frac{D_{\text{mid}}^2 \cdot \pi}{4} \cdot L_{\log} \quad (1)$$

$$Taper = \frac{D_{\text{butt-end}} - D_{\text{top-end}}}{L_{\log}} \quad (2)$$

where: V_{log} – log volume (m^3), D_{mid} – mid diameter of the log (m), Taper – log taper ($cm.m^{-1}$), $D_{butt\text{-}end}$ – butt-end diameter of the log (cm), $D_{top\text{-}end}$ – top-end diameter of the log (cm), L_{log} – log length (m).

Processing logs in the primary sawmill

The primary sawmill, where this study was conducted, was located in northern Croatia. The major species sawed were Pedunculata oak, Sessile oak and European common beech. Mill equipment included a 1400 mm log band saw headrig, with automatic air-operated carriage, an edger, and a cross-cut circular saw.

Logs were processed individually on the log band saw using the live sawing method. All sawn boards produced in this research were intended for further processing at the same facility, and therefore were not separated according to quality. Boards were produced with a nominal thickness of 25 and 50 mm and with 22 % moisture content. Taking shrinkage into account, the target saw thickness was 27 and 55 mm. Since the boards were not edged, width oversize was not calculated. The oversize for the sawn board nominal length was at least 2 cm. The 25 mm boards were sawn from the outer portion or jacket of the log. Thicker boards were sawn from the center part of the log. All sawn boards produced from the sample logs were measured for thickness, width and length according to EN 1309-1 and EN 1313-2 and sawn board volume was calculated based on these parameters. The amount of coarse saw residue (slabs, log end off-cuts, edgings, trimmings etc.) and sawdust were not measured and were not included in the research.

In a primary sawmill, log volume yield is defined as the ratio of the sawn board volume and log volume according to equation (3):

$$Y_{\text{Volume log}\rightarrow\text{board}} = \frac{V_{\text{board }25} + V_{\text{board }50}}{V_{\log}} \quad (3)$$

where: $Y_{Volume\ log \rightarrow board}$ – volume log yield in the form of sawn boards; $V_{board\ 25}$ – sawn board volume of a nominal thickness of 25 mm (m^3), $V_{board\ 50}$ – sawn board volume of a nominal thickness of 50 mm (m^3).

Processing boards in a secondary sawmill

This study was conducted in a secondary sawmill equipped with a gang-ripsaw and CNC controlled cross-cut saw. Before the sawn boards are processed in the secondary sawmill, they undergo a 60-hour steaming process in order to diminish the color difference between sapwood and heartwood - this process yields uniform color. Subsequently, all sawn boards are then processed in the secondary sawmill into rough dimension stock and flooring components using the rip-first saw method.

Dimension and flooring components stock with a thickness of 25 and 11 mm were produced (calculated width of 48, 52, 62, and 78 mm). Taking into account oversize, the sawn thickness was 27 and 14 mm, while the sawn widths (with oversize) were 54, 58, 69 and 85 mm. The length of the oversize was 20 mm. These oversize dimensions are standard for dimension stock and flooring components intended for further processing. The thickness, width, and length of dimension and flooring stock were measured and used to calculate volume.

Given that a large number of sawn boards were processed into two different thicknesses, this calculation did not focus on the number of dimension stock and flooring components produced from the sawn boards (from which thicknesses the sawn boards arose). The reason was to simplify the research (the problem of organizing the research into the actual technological process).

Volume yield in the secondary sawmill was calculated from two viewpoints. First, volume yield was defined as a ratio between the volume of dimension stock and flooring components produced and sawn board volume according to equation (4). Second, volume yield was defined as a ratio between the volume of dimension stock and flooring components produced and log volume according to equation (5):

$$Y_{\text{Volume board} \rightarrow \text{dim.stock}} = \frac{V_{\text{d.s.}_1} \cdot N_{\text{d.s.}_1} + V_{\text{d.s.}_2} \cdot N_{\text{d.s.}_2} + \ldots + V_{\text{d.s.}_n} \cdot N_{\text{d.s.}_n}}{V_{\text{board}_{25}} + V_{\text{board}_{50}}} \tag{4}$$

$$Y_{\text{Volume log} \rightarrow \text{dim.stock}} = \frac{V_{\text{d.s.}_1} \cdot N_{\text{d.s.}_1} + V_{\text{d.s.}_2} \cdot N_{\text{d.s.}_2} + \ldots + V_{\text{d.s.}_n} \cdot N_{\text{d.s.}_n}}{V_{\text{log}}} \tag{5}$$

where: $Y_{\text{Volume board}\rightarrow\text{dim.stock}}$ – volume yield of sawn boards in the form of dimension stock and flooring components, $V_{\text{d.s.1...n}}$ – volume of dimension stock or flooring components (m^3), $N_{\text{d.s.1...n}}$ – number of dimension stock or flooring components of equal volume, $Y_{\text{Volume log}\rightarrow\text{dim.stock}}$ – volume log yield in the form of dimension stock and flooring components.

The goal was to produce as many high-quality dimension stock and flooring components as possible with the greatest volume yield (a greater price with restrictions given for the dimension stock specification).

Dimension stock and flooring components value yield is expressed as the average quality coefficient of all dimension stock and flooring components produced from the log (sawn boards according to equation (6). For quality index 1, first class dimension stock was selected as the most valuable product. The quality index for the other products was determined by their market price divided by the price of the most valuable piece. If the average dimension stock and flooring components value yield coefficient is multiplied by price, whose quality index is 1, we get the average dimension stock and flooring components value yield for all dimension stock and flooring components expressed in price value per dimension stock and flooring components volume according to equation (7):

$$Y_{\text{Value d.s.}} = \frac{V_{\text{d.s.}_1} \cdot k_{\text{d.s.}_1} + V_{\text{d.s.}_2} \cdot k_{\text{d.s.}_2} + \ldots + V_{\text{d.s.}_n} \cdot k_{\text{d.s.}_n}}{V_{\text{d.s.}_1} + V_{\text{d.s.}_2} + \ldots + V_{\text{d.s.}_n}} \tag{6}$$

$$Y_{\text{Value €/d.s.}} = Y_{\text{Value d.s.}} \cdot c_{\text{p}} \tag{7}$$

where: $Y_{\text{Value d.s.}}$ – dimension stock and flooring components value yield, $k_{\text{d..s.1....n}}$ – quality index of dimension stock and flooring components of the same quality group, $V_{\text{d.s.1...n}}$ – volume of dimension stock or flooring components (m^3), $Y_{\text{Value €/d.s.}}$ – monetary value of the dimension stock and flooring components value yield (€.m^{-3}) dimension stock and flooring components, c_p – price of dimension stock and flooring components whose quality index is selected as 1 (€.m^{-3}) dimension stock and flooring components.

Log value yield, in the form of dimension stock and flooring components, was expressed with the average coefficient value of all dimension stock and flooring components in relation to the log. This was calculated by multiplying the coefficients for volume log yield in the form of dimension stock and flooring components and dimension stock and flooring components value yield according to equation (8). If the log value yield coefficient is multiplied by the price value, whose quality index is 1, the average log value yield expressed monetarily per log unit volume according to equation (9):

$$Y_{\text{Value log}} = Y_{\text{Volume log}\rightarrow\text{dim.stock}} \cdot Y_{\text{Value d.s}} \qquad (8)$$

$$Y_{\text{Value €/log}} = Y_{\text{Value log}} \cdot c_{\text{p}} \qquad (9)$$

where: $Y_{\text{Value log}}$ – log value yield in the form of dimension stock and flooring components, $Y_{\text{Value €Ilog}}$ – monetary value of the log value yield in the form of dimension stock and flooring components (€.log m^{-3}).

RESULTS AND DISCUSSIONS

Volume yield of logs in the form of sawn boards

A total of 11.260 m^3 of 1st grade and 11.360 m^3 of 2nd grade European walnut logs were sawn. Also, a total of 24.731 m^3 of 1st grade and 24.921 m^3 2nd grade wild cherry logs were sawn. Comparison of log mid-diameter and length are shown in Figs. 1 and 2. Results of the log mid-diameter and length significance tests are shown in Tabs. 1 and 2.

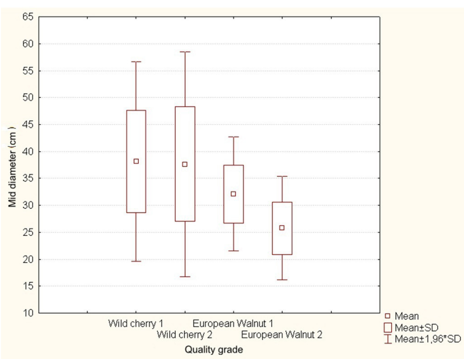

Fig. 1: Comparison of average log mid diameter values

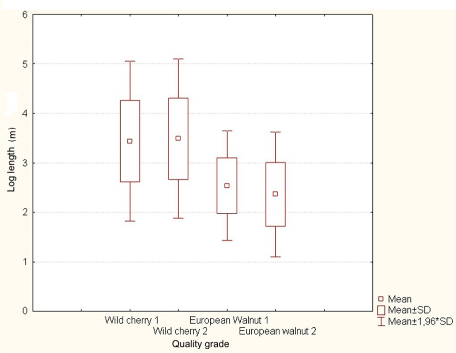

Fig. 2 Comparison of average log length values

Tab. 1: Results of significant differences in testing log mid diameter

Mid diameter (cm)	Cherry 1st vs. Cherry 2nd	Cherry 1st vs. Walnut 1st	Cherry 1st vs. Walnut 2nd	Cherry 2nd vs. Walnut 1st	Cherry 2nd vs. Walnut 2nd	Walnut 1st vs. Walnut 2nd
Mean Group 1	38.15000	38.15000	38.15000	37.63333	37.63333	32.08967
Mean Group 2	37.63333	32.08967	25.75118	32.08967	25.75118	25.75118
t-value	0.28117	4.14079	10.33396	3.45130	9.07719	7.16203
df	118	112	144	112	144	138
p	0.77908	0.00007	0.00000	0.00079	0.00000	0.00000
Valid N Group 1	60	60	60	60	60	54
Valid N Group 2	60	54	86	54	86	86
Std.Dev. Group 1	9.45968	9.45968	9.45968	10.63567	10.63567	5.38825
Std.Dev. Group 2	10.63567	5.38825	4.90700	5.38825	4.90700	4.90700
F-ratio Variances	1.26409	3.08218	3.71639	3.89614	4.69783	1.20577
p Variances ($p < .0500$)	0.37067	0.00005	0.00000	0.00000	0.00000	0.43699

Tab. 2: Results of significant differences in testing log length

Mid diameter (cm)	Cherry 1st vs. Cherry 2nd	Cherry 1st vs. Walnut 1st	Cherry 1st vs. Walnut 2nd	Cherry 2nd vs. Walnut 1st	Cherry 2nd vs. Walnut 2nd	Walnut 1st vs. Walnut 2nd
Mean Group 1	3.43833	3.43833	3.43833	3.48833	3.48833	2.53889
Mean Group 2	3.48833	2.53889	2.36582	2.53889	2.36582	2.36582
t-value	-0.33347	6.73984	8.83207	7.13341	9.26235	1.62610
df	118	112	144	112	144	138
p	0.73937	0.00000	0.00000	0.00000	0.00000	0.10621
Valid N Group 1	60	60	60	60	60	54
Valid N Group 2	60	54	86	54	86	86
Std.Dev. Group 1	0.82279	0.82279	0.82279	0.81969	0.81969	0.56214
Std.Dev. Group 2	0.81969	0.56214	0.64266	0.56214	0.64266	0.64266
F-ratio Variances	1.00757	2.14230	1.63912	2.12621	1.62681	1.30698
p Variances ($p < .0500$)	0.97700	0.00547	0.03664	0.00594	0.03960	0.29558

In analyzing the results of log volume yield (in the form of sawn boards), results indicated that the best yield came from 1st grade wild cherry logs, followed by 1st grade European walnut logs, and then equally by 2nd grade European walnut and European wild cherry logs (Tab. 5). These results appear to be correlated to the quality and dimensional structure of the log being sawn. Statistical analysis indicates that wild cherry logs, in both quality grades, have somewhat greater dimensions in terms of diameter and length (Tabs. 1, 2 and Figs. 1, 2). In producing unedged sawn boards, these factors can have a significant effect on the volume yield. This was reflected in the results of the 1st grade wild cherry logs.

On the other hand, even though they were of lower value in terms of dimension, the quality of 1st grade European walnut logs yielded better results than 2nd grade wild cherry logs with larger dimensions. The most difficult findings to explain are the results of the 2nd grade European walnut and European wild cherry logs, as they are equivalent. Statistical analysis shows there was a difference in dimension, which was greater in wild cherry. Assuming equal log quality, one would presume that wild cherry would have resulted in greater yields. This however did not happen. The reason for this is that initial log quality, which is determined by visual examination of the log exterior, cannot fully detect defects inside the log. Defects were discovered during sawing and these defects were removed from the sawn boards, thus decreasing the total number of sawn boards and subsequent volume produced from the sample logs. The primary defect found was decay (rot) in the central portion of the log and decay occurred in logs with larger diameters. Decay occurs when a fungus enters through the knots of dead branches.

Volume and value yield of logs in form of dimension stock and flooring components

Assessing sawn board and log volume yields, in the form of dimension stock and flooring components, further indicates small changes in respect to the grading sequence. Again the best results were obtained in 1st grade wild cherry logs, followed by 2nd grade cherry logs, and then by 1st and 2nd grade walnut logs (Tab. 5). These results were significantly influenced by the structure of the dimension stock and flooring components produced, in addition to the sawn board quality. They were not identical due to actual work orders and market demand. Data on dimension stock and flooring components produced from sawn boards are shown in Tabs. 3, 4. In the production of larger dimension stock this certainly influenced better optimization and offers potential for producing this type of dimension stock.

Tab. 3: Dimension stock and flooring components sawed from 1st and 2nd grade European walnut logs

Thicknes (mm)	Width (mm)	Length (mm)	1st grade		2nd grade		Price (€.m-3)	Quality index
			Quantity pieces	Volume (m3)	Quantity pieces	Volume (m3)		
25	78	490	2205	2.107	1293	1.235	937.00	1
25	62	300	2003	0.931	2112	0.983	720.00	0.76841
25	52	250	2013	0.654	1998	0.649	720.00	0.76841
11	62	300	163	0.033	233	0.048	492.00	0.52508
11	52	250	866	0.124	891	0.127	492.00	0.52508
Σ			7250	3.849	6527	3.042		

Tab. 4: Dimension stock and flooring components sawed from 1st and 2nd grade wild cherry logs

Thickness (mm)	Width (mm)	Length (mm)	1st grade		2nd grade		Price (€.m⁻³)	Quality index
			Quantity pieces	Volume (m^3)	Quantity pieces	Volume (m^3)		
25	78	700	862	1.176	1113	1.519	817.00	1
25	78	490	5760	5.504	3843	3.672	712.00	0.87148
25	52	250	10098	3.282	8829	2.869	540.00	0.66095
25	48	250	468	0.140	550	0.165	540.00	0.66095
11	52	250	3103	0.444	3425	0.489	369.00	0.45165
11	48	250	170	0.022	432	0.057	369.00	0.45165
Σ			20461	10.569	18192	8.772		

The value yields of dimension stock and flooring components indicate different results in contrast to log volume yields. The quality and price of dimension stock and flooring components are the driving factors. The quality and size of the dimension stock and flooring components were the same, and in Croatia the current price of European walnut products is slightly higher than for European wild cherry (give Euro price and amount). Therefore, the results from the value yield analysis of the dimension stock and flooring components, where 1st and 2nd walnut logs predominate, is understandable (Tab. 5).

Tab. 5: Log volume and value yield

Wood species	Quality of logs	Volume yield					
		$Y_{Volume\ log \rightarrow board}$		$Y_{Volume\ board \rightarrow dim.stock}$		$Y_{Volume\ log \rightarrow dim.\ stock}$	
		coeff.	(%)	coeff.	(%)	coeff.	(%)
European walnut	1st grade	0.7223	72.23	0.4733	47.33	0.3419	34.19
	2nd grade	0.6932	69.32	0.3863	38.63	0.2678	26.78
Wild cherry	1st grade	0.7623	76.23	0.5606	56.06	0.4273	42.73
	2nd grade	0.6968	69.68	0.5051	50.51	0.3520	35.20

Wood species	Quality of logs	Dimension stock and flooring components value yield		Log value yield	
		$Y_{Value\ d.s.}$	$Y_{Value\ €/d.s.}$	$Y_{Value\ log}$	$Y_{Value\ log}$
		coeff.	(€.m⁻³)d. s.	coeff.	(€.m⁻³)logs
European walnut	1st grade	0.88526	829.49	0.30267	283.60
	2nd grade	0.84843	794.98	0.29008	271.80
Wild cherry	1st grade	0.79910	652.87	0.34149	279.00
	2nd grade	0.79475	649.31	0.27975	228.56

However, when the log value yield (dimension stock and flooring components) is considered with the log volume yield (dimension stock and flooring components), a plausible explanation is derived. When assessing the log value yield as a product of volume and a value yield coefficient, the best results were obtained from 1st grade European wild cherry logs; followed by 1st grade European walnut logs; followed by 2nd grade European walnut logs; and then by 2nd grade European wild cherry logs (Tab. 5). In the analysis of the relationship between log volume yield and the value yield, the decisive factor was the significantly greater volume yield from European wild cherry logs in contrast to European walnut logs. Comparing the monetary value of this yield, the best results are from the 1st grade European walnut logs, as a result of the higher average price of dimension stock and flooring components obtained in the marketplace at the time of this research.

CONCLUSIONS

In conclusion, the results indicate that 1st grade European walnut logs are financially more suitable for sawmill production in this current market. This is followed by 1st grade European wild cherry logs and then by 2nd grade European walnut and European wild cherry logs. This research discerned an unexpected smaller volume yield for European wild cherry logs in the larger dimension class. The yield was less due to the unexpected defects found inside the logs, which were revealed during sawing. In this particular analysis, the measurement of and determination of defect type was not foreseen. It is obvious that defects must be addressed in future research.

Given the complexity and technical constraints of this research, it was not possible to statistically analyze different production components and statistically assess those components, which may have helped in the interpretation of the investigation. Thus, in order to get more reliable statistical results, further research should be conducted with an experimental design, where the technological execution would involve more production components. This technological assessment would allow complete monitoring of each individual log and product produced. In this manner, sufficient data would be collected to conduct both a qualitative and quantitative statistical analysis.

Even though the trees that produced the logs used in the experimental sawing were from a close proximity to the mill, more attention should be given to the defects that may occur in trees based on their exact geographical location. In this manner, the cause for the detection and frequency of certain defects can be determined based on the geographical location and characteristics of the habitat. Subsequent research also should be expanded to include assessing the yield of processed roundwood from smaller dimensions and the species included in this research.

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