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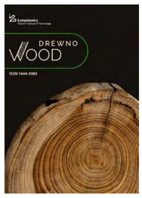

The Quality of Alder Raw Material from Stands Growing in Different Habitats

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A study was carried out to determine the quality of alder raw material growing in different forest habitat types. The research work was conducted in the Włoszczowa Forest District in Poland. Measurements were taken in eight stands growing on three types of forest site: alder moist forest, alder-ash moist forest, and moist forest. In the selected stands, 4-are sample plots were established. In each circular sample plot, the DBH and height of all trees were measured. In the selected trees, the quality of the wood and the type of defects that influenced the result of wood classification were determined in the trunk butt end (on a length of 4 meters). In every other plot, a core was taken from a height of 1.3 m in a randomly selected tree to determine the presence of latent defects. The black alder tested on each site attained very good technical quality. The dominant volume share was that of veneer wood, the largest amount of which was identified in moist forest. Very small amounts of wood of lower quality classes were found. It was found that in less humid habitats than typical alder forests, black alder produces better-quality wood. However, when the borings were taken into account, the proportion of each quality class changed dramatically. Hard rot and soft rot caused wood from the best quality classes to be degraded to lower classes. The percentage of the best-quality wood fell from 60% to 7.57%, while that of the worst-quality wood increased from 5.94% to 40.57%.

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Introduction

There are three species of alder in Poland: black alder (*Alnus glutinosa* (L.) Gaertn.), grey alder (*Alnus incana* (L.) Moench), and shrubby green alder (*Alnus alnobetula* (Ehrh.) K. Koch). Woody alders are mostly found in humid and wet forest habitat types, while green alder is found sparsely in the Bieszczady Mountains in the form of scrub [Białobok 1980]. In Polish forests, the percentage share of alder stands is about 5.5% and is steadily increasing, while the average volume of stand is about 279 m^3/ha, also with an increasing trend [Statistics Poland 2023]. Black alder is a species that overgrows almost every water body and river bank in Poland. It forms stand complexes in alder, ash-alder, riparian, mixed swamp and wet forest habitats, and less abundantly in lowland mixed deciduous forest habitats. Due to its scattered occurrence, it is a common species and an important element of the emerging landscape [Białobok 1980].

As regards the technical properties of black alder wood, it is light, soft, brittle, and highly splittable. It dries fairly quickly, exhibiting an average level of shrinkage. Slicing the wood is easy, and gluing it does not cause any major problems. Alder wood is renowned for its very good saturability and its ability to stain and polish.

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Unfortunately, it has little resistance to weathering. If not stored properly in the bark, it is often subject to steaming and rotting. Conditions in humid, very warm rooms without ventilation are unfavorable for alder wood. Stored in such places, the wood loses its natural durability after about two years. On the other hand, it achieves its greatest durability when continuously submerged in water, preferably ponds or lakes with a small depression, fulfilling its functions for hundreds of years [Białobok 1980]. When in water, alder wood takes on a brownish-red color and becomes stony. This phenomenon is the result of the wood being fully saturated with water, and has a positive effect on the mechanical properties and durability of black alder wood. After a prolonged period in water, the mechanical strength of alder is comparable to that of pine wood, and its durability to that of oak wood [Claessens et al. 2010]. Among other uses, it is applied as a shelling raw material and water-building material, in the production of fiberboard, particleboard, lumber, and pulp and paper, and as a biofuel [Białobok1980; Johansson 1999; Aydin and Colakoglu 2005; Usta et al. 2014; Rohumaa et al. 2021].

In its round form, it is used in hydraulic engineering in the form of piles to reinforce banks, in piers, or as building stakes. Nowadays, alder wood is also used to make carpentry boards. Due to its easy workability, it is used in the manufacture of milled and turned products. The relatively good machinability of alder wood is conducive to its use in woodcarving. Currently, alder is also used in the production of pencil slats, in the manufacture of musical instruments, furniture and packaging, and in model-making [Laurow 2003; Salca 2019].

Up to a certain point, alder wood had a low level of use, due to the presence of a large number of more popular species. The problem of felling and skidding such wood from swampy areas, which proved impossible in many places, was an additional factor affecting the commonness of its use [Białobok 1980]. Today, due to increasing acreage and technological developments, interest in this wood and its use is constantly expanding.

Therefore, a study was performed to determine the quality of alder raw material growing in different forest habitat types. The research hypothesis was that the quality of alder wood would vary between habitats.

Materials and methods

The research work was conducted in the Włoszczowa Forest District, which is well-known in Poland for its very good-quality alder wood. Measurements were taken in eight stands growing on forest sites of three different types: alder moist forest (AMF) (habitat under strong and very strong influence of ground and precipitation water, occupying habitats with swampy soils), alder-ash moist forest (AAMF) (very fertile habitats on strongly moist mineral soils, periodically waterlogged and flooded), and moist forest (MF) (very fertile habitats on mineral and organic-mineral soils) (Table 1). All of the studied stands are managed by clear cutting, but to date, only tending cuts in the form of thinning have been carried out there. The same tending operations have been performed in all stands.

In the selected stands, temporary 4-are circular sample plots (radius r = 11.28 m) were established (a total of 69 plots with a total area of 2.48 ha), distributed in a grid of squares, the number of which was determined assuming an abundance determination error of 7–8% and a coefficient of variation in the range 18–25%. At the center of each plot was a Vertex transponder driven on a pole to facilitate movement within a defined radius. In each circular sample plot, the DBH of all trees in the plot and the height of each studied alder were measured.

After the dendrometric measurements, the quality of the raw material was determined in the first two alders of a given thickness class (thickness classes: I – 7–20 cm,

Table 1. Characteristics of the examined stands

Unit	Area (ha)	Forest site	Stand density index	Species composition	Age (years)	Resources (m^3/ha)
73-f	6.71	alder moist forest	0.8	10 Al	117	513
73-l	3.6	alder moist forest	0.8	10 Al	117	513
74-f	2.22	alder-ash moist forest	0.9	10 Al	93	581
78-f	2.28	alder-ash moist forest	0.7	10 Al	68	223
79-c	5.82	alder-ash moist forest	0.6	10 Al	63	320
80-g	2.8	alder-ash moist forest	0.9	10 Al	93	430
85-b	1.51	alder-ash moist forest	0.8	10 Al	72	446
89-j	11.95	moist forest	0.9	10 Al	108	568

Table 2. Principles of assessing alder wood

Features		**Classes**					
A1		**B**	**C**	**D**	**S2**	**S4**	
Minimum length [m]		2.4	2.5			1.0	1.0
Minimum end diameter under bark [cm]		35	20	18		7	5
Knots	open	diameter up to 5 cm - 2 pcs./1m	-			permitted	permitted
	sound	-	diameter up to: 5 cm	10 cm	permitted	permitted	permitted
	unsound	-	diameter up to: 5 cm	8 cm	15 cm	permitted	permitted
	burl	not pemitted	permitted up to 1 cm in height, higher permitted in number 1 / 2 m	permitted		permitted	permitted
	rose up to:	5 cm Ø	10 cm Ø	permitted		permitted	permitted
End shake		- 1/3 Ø butt	permitted up to:	permitted		permitted	permitted
Crack	edge end frost	permitted one, up to 1/10 Ø butt	not permitted	permitted one, up to 1/10 Ø butt	permitted	permitted	permitted
Simple sweep up to:		3 cm / 1 m	3 cm / 1 m	4 cm / 1 m	5 cm / 1 m	up to 8 cm/1m, for lengths over 1 m up to 10 cm along the entire length	permitted
Spiral grain [cm/m] up to:		permitted	12	permitted		permitted	permitted
Scars		up to 6 cm wide allowed on one straight line	up to 6 cm wide	up to 12 cm wide	permitted	permitted	permitted
Multiple pith		-	not permitted		permitted	permitted	permitted
False heart wood up to:		1/3 Ø butt	1/3 Ø butt	1/2 Ø butt	permitted	permitted	permitted
Rot	inner up to:	1/5 Ø butt	1/5 Ø butt	1/3 Ø butt	1/2 Ø butt	soft rot not permitted	hard rot allowed; soft rot not allowed up to 50% of face area
	surface	not permitted	not permitted	allowed for 1/4 of the circumference and up to 1/10 of the diameter	allowed for 1/2 of the circumference and up to 1/10 of the diameter		
Worm holes		not permitted	not permitted	allowed for 1/4 of the circumference	permitted	permitted	permitted
Foreign bodies		not permitted	not permitted		permitted by agreement of the parties	not permitted	permitted

II – 21–26 cm, III – 27–38 cm, IV – 39–54 cm, V – 55–74 cm, VI – 75 cm and above). Measurements were taken moving from the 0° azimuth, clockwise. In the selected trees, the quality of the wood and the type of defects or absence of defects that influenced the result of wood classification [Technical conditions 2019a, b, c, d] were determined in the butt end (on a length of 4 meters) (Table 2). Up to a height of 2 meters all defects were measured with a tape, while above 2 meters the size of defects was estimated visually.

Since the measured trees were not felled, in every second plot, a core was collected from a height of 1.3 m in a random tree (37 cores in total), to determine the presence of latent defects. A total of 623 trees were measured, and quality was also determined in 263 pieces of alder. The following equipment was used during the survey: Vertex; Nikon Forestry Pro altimeter; Breaker meter; Garmin GPSMAP 64s; Suunto 14/360R busol.

After the field data had been transferred to Excel, the thicknesses of the 4-meter-long butt end parts of the trunk were determined. Log and long log volume tables [Czuraj 2000] were used to calculate the log volume.

On the basis of the volume obtained, the proportion of wood of each quality-dimensional class in a given habitat and the proportions of defects affecting the result of the wood classification were determined. In addition, the core obtained during the field work was measured and analyzed for the presence of hidden defects. Based on these, the bolts from which a given core was derived were reclassified (or not) into the appropriate quality class.

As the null hypothesis of the normality of data distribution was rejected on applying the Shapiro–Wilk test, the Kruskal–Wallis test was applied to analyze the statistical significance of the differences. Statistica 13.3 [Kot et al. 2007; Tibco Software Inc. 2017] was used for statistical analyses. A significance level of $p = 0.05$ was adopted.

Results and discussion

The investigation showed that in each of the habitats studied, class A1 wood (veneer wood) predominated, with smaller amounts of class C and D wood and the smallest amount of class B wood (Table 3). Low amounts

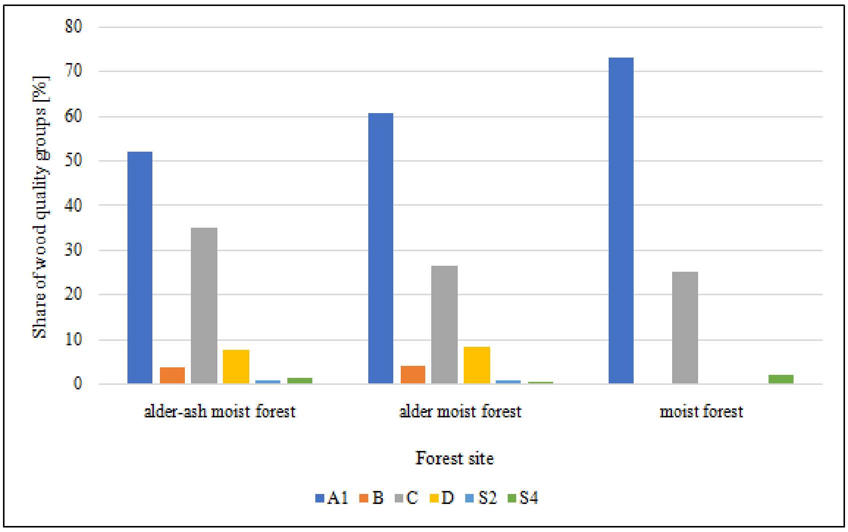

Fig. 1. Percentages of wood in quality classes in individual habitats
Key: A1 – veneer wood; B, C, D – large-size wood classes; S2 – stacked wood (pulpwood); S4 – firewood

Table 3. Volume of raw material in a given quality class with respect to forest site type

Forest site	Classes						
	A1 [m³]	B [m³]	C [m³]	D [m³]	S2 [m³]	S4 [m³]	V together [m³]
alder-ash moist forest	11.93	0.87	8.02	1.73	0.15	0.30	23.00
alder moist forest	33.04	2.08	14.32	4.42	0.38	0.25	54.49
moist forest	50.95	0.00	17.50	0.00	0.00	1.35	69.80

Key: A1 – veneer wood; B, C, D – large-size wood classes; S2 – stacked wood (pulpwood); S4 – firewood of medium-sized wood (S2 and S4) were also found. Analyzing the different habitats, it was found that the most best-quality wood occurred in the moist forest habitat (MF), less in the alder moist forest habitat (AMF), and the least in the alder-ash moist forest habitat (AAMF).

Analysis of the above results reveals the influence of selected inventory characteristics on the quantity and quality of alder raw material (Fig. 1). Taking into account the forest site type, it is evident that black alder grew very well on all of the examined sites, including typical alder moist forest, alder-ash moist forest and moist forest, and veneer-quality raw material (A1) dominated in each of them, its percentage share ranging from 50% in AAMF to over 70% in MF. It is nevertheless surprising to note the greater predominance of class A1 in moist forest than in the other forest site types. The second class with a significant share in volume was class C, which had 34%, 26% and 25% shares in AAMF, AMF and MF habitats, respectively. These values are quite close to each other. A surprisingly low proportion of class B material was found: its share in AAMF and AMF was only about 4%, and it was not found at all in MF. The proportion of class D was also not high. It was found only in the AAMF and AMF habitats (about 7% and 8%, respectively). In moist forest, like class B, it was not recorded. Medium-sized wood, mainly due to the diameters of the girdle zones, was detected in negligible amounts in all of the habitats studied. Among these classes, S4 was dominant, with a share of about 1%. In addition, an analysis was made of the significance of the differences in the shares of wood classes in the studied habitats. This was done using the Kruskal–Wallis test, which showed that there were no statistically significant differences in the amount of wood in individual quality classes between the studied habitats. (H = 2.024, p = 0.363). This fails to support

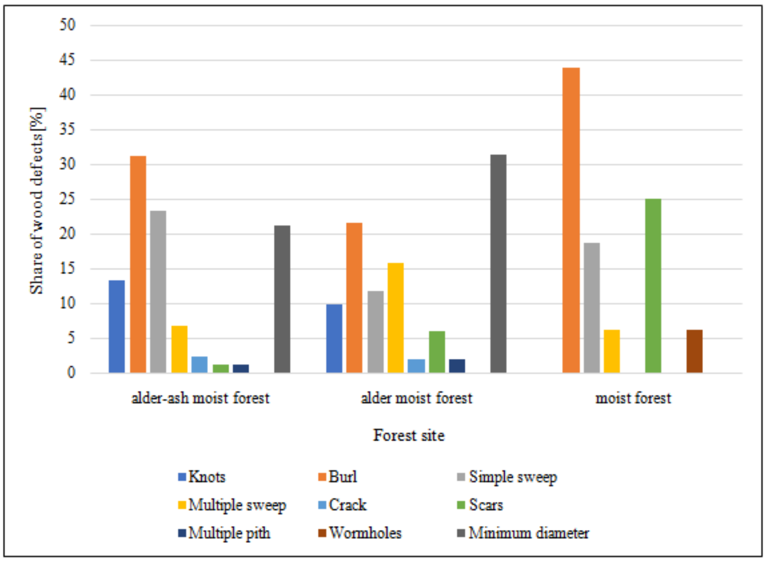

Fig. 2. Proportions of defects influencing the result of wood classification in different habitats

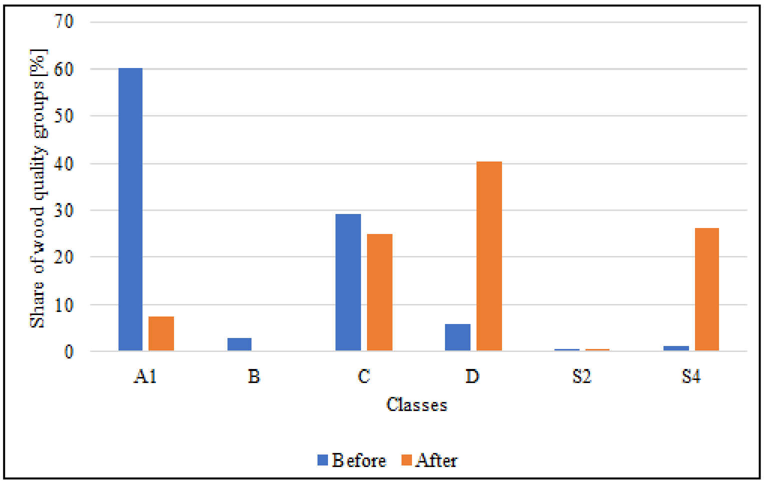

Fig. 3. Proportions of wood in quality classes before and after taking into account defects in cores
Key: A1 – veneer wood; B, C, D – large-size wood classes; S2 – stacked wood (pulpwood); S4 – firewood

the assumption stated in the research hypothesis that there will be differences in the quality of alder wood growing in different habitats.

The results obtained are similar to those of Claessens et al. [2010], who also found that alder produces the best-quality wood in riparian areas and areas on plateaus with high soil moisture levels. Although alder is the only tree that will grow in swamps, the rate of production is often slow and the wood of low quality.

The analysis of the influence of defects on the result of wood classification showed that the distribution of defects was different in each studied habitat (Fig. 2). On the AMF sites, the main defect influencing the classification result was insufficient diameter at breast height (31.37%), while on the ash-alder and MF sites, the greatest influence came from burls (31.11% and 43.75%, respectively). The AMF habitat was also subject to the high influence of burls (over 20%), multilateral curvature (15.69%), unilateral curvature (11.76%) and knots (15.69%). AAMF also exhibited the significant influence of single-sided curvature (23.33%), insufficient diameter (21.11%), and knots (over 13%). Occasionally, defects such as cracks, healed knots and multi-core appeared. The distribution of defects in moist forest, in addition to burls as already mentioned, included a high share of healed knots (25%) and one-sided curvature (18.75%). The shares for multilateral curvature and wormholes were both 6.25%.

In relation to the proportions of defects in each habitat, the significance of differences was also analyzed, but the Kruskal–Wallis test showed the absence of statistically significant differences ($H = 0.838$, $p = 0.658$). Again, this does not support the assumption expressed in the research hypothesis that the quality of alder wood will vary between habitat types.

A large effect of knots on the quality of alder wood was also reported by Karaszewski et al. [2015]. They found that in an older stand (96 years old) 35% of the wood was of reduced quality due to the presence of overgrown knots, and in a younger stand (87 years old) 28% of the wood was of reduced quality. Healthy knots were also found to have a large influence, affecting 29% of the wood in the older stand and 47% in the younger stand. The result of wood classification was also significantly influenced by curvature.

In the final stage of the study, the proportions of quality-dimensional classes were compared after analyzing the sampled cores (Fig. 3). No internal defects were found in 5 cores only. Hard incipient decay, soft incipient decay, and false heartwood were found in 15, 11, and 6 cores, respectively.

Before the analysis of the cores, the 4-meter-long butt end fragment showed a predominance of wood of quality classes A1 (60%) and C (almost 30%), a much smaller share of wood of quality classes D (5.94%) and B (2.90%), and a negligible amount of medium-sized wood. When cores were taken into account, the shares for individual quality classes changed dramatically. Hard and soft incipient decay caused wood from the highest quality classes to be degraded to lower ones. The share of veneer class A1 dropped to just 7.57%, that of class B remained unchanged, and that of class C decreased slightly, by approximately 4%. On the other hand, there was a very large increase in the shares of class D – from 5.94% to 40.57% – and firewood (S4) – from 1.15% to 26.11%. The share of the remaining medium-sized wood group (S2) was almost unchanged.

When classifying the wood in standing trees, one must also take into account the impact of hidden defects (decays and false heartwood), which were present in most of the tree trunks from which cores were taken. Comparing the results, it is evident how strongly they affected the estimated wood quality classes. These defects are often present in older stands, such as the ones studied in this case. This phenomenon has been pointed out by many researchers.

The phenomenon of decay occurring in older alder was studied by Claessens et al. [2010] and Karaszewski et al. [2015]. They found that older alders (around 60–70 years old) develop decay rapidly, which significantly affects the quality of the raw material. Therefore, they recommend that alder should be removed at the latest at the age of felling, i.e. around 70–80 years. Miklašēvičs [2021], in a study conducted in Latvia, also found that the age of alder is the main factor affecting wood quality. The highest quality wood is obtained from trunks up to 30 years old. For trees harvested in stands older than 70 years, the proportion of stems with decay exceeded 69%. For those harvested in stands older than 80 years, the proportion of such stems exceeded 81%, and for those older than 90 years it was more than 88%. In other research in Latvia, Arhipova [2012] and Arhipova et al. [2012] found that the proportion of trees affected by decay was already very high in much younger stands (50 years old) and increased with age, and the average proportion of wood affected by decay in the volume of a single stem was 66%. A study by Bleive et al. [2022], again in Latvia, showed high variability in the occurrence of trunk decay in mature stands of black alder, ranging from 6.7% to 93.3%. However, they demonstrated that with increasing age and dimensions, the risk of trunk degradation due to internal decay is higher, and the incidence of decay within alder trunks increased sharply in stands older than 60 years. The largest proportion of wood affected by decay is within the heartwood, at the bottom of the trunk, indicating that this disease poses a serious threat to the commercial use of wood in the production of high-quality products.

Conclusions

After synthesizing and analyzing our results, we concluded that:

1. The investigated black alder achieved very good technical quality in each habitat. The largest volume share was that of veneer class A1, with the highest amount identified in moist forest. Very small amounts of inferior-quality classes such as D (not found in MF) or medium-sized wood were found. It is therefore evident that the species composition matches the habitat type of the forest. It is also found, however, that black alder produces better-quality wood in habitats that are less humid than typical alder forests. This means that in order to obtain very good-quality alder wood, alder should be introduced into less humid habitats. However, statistical tests did not confirm the research hypothesis concerning differences in the quality of alder wood growing in different habitats.
2. From analysis of the proportions of defects affecting the result of wood classification, it was found that burls had the greatest influence. This occurred in the alder-ash moist forest and moist forest habitats. In the typical alder moist forest habitat, on the other hand, the most frequent cause of decrease in wood quality class was undersized diameter, which may be indicative of the poorer growth of trees in this habitat compared with the other aforementioned habitats. Defects such as single-sided and multilateral curvature, as well as knots, were also present in high proportions. This is probably due to the fact that, as the trees are younger, the knots have not had time to overgrow and turn into burls. In this case, statistical tests also failed to confirm the research hypothesis of different quality of alder wood growing in different habitats.
3. When the borings were taken into account, the proportion represented by each quality class changed dramatically. Hard rot and soft rot caused wood from the highest quality classes to be degraded to lower classes. The share of the best-quality wood fell from 60% to 7.57%, while the share of the worst-quality wood increased from 5.94% to 40.57%. By comparing the quality classes of wood estimated in the field with those indicated by cores taken from randomly selected tree trunks, it can be concluded that internal defects significantly change the quality classification of trees. Therefore, when performing the classification of alder wood on standing trees, great care should be taken to ensure that there are no significant differences in classification after felling.

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