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Review of Characteristics of Alnus Glutinosa Stands Quality According to Forest Ttypes and Ages

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***Abstract* - Due to the interest in Alnus glutinosa as the plantation species has increasesed in Latvia during last years, a structural unit "LVM Sēklas un stādi" of State Stock Company "Latvijas Valsts Meži" (Latvia's State Forests) offers to the local market Alnus glutinosa bare root seedlings with an advanced root system obtained from Alnus glutinosa seeds growed in planting such selected seedlings in cutovers and for land reforestation theorectically will allow the land owner to increase the value of forest and the profit from its management. Practically, this prospects should be evaluated from the perspective of forest health.**

Therefore, the purpose of this study were to: (1) estimate the incidence of heart colouring and stem decay in Alnus glutinosa stands in different forest types and ages, (2) identify and measure heart colouring area /heartwood hard rot stage area diameter and soft rot stage area diameter/ cavity diameter of the stumps, (3) evaluate the relationships between stand species composition (forest types) and Alnus glutinosa stands age on heart colouring/heartwood hard rot stage and soft rot stage/cavity incidence, (4) by analysing the results to work out the recommendations to improve the forest managment in forest stands where Alnus glutinosa stands from plantations are growing.

Keywords* - *Alnus glutinosa, Dryopterioso-caricosa, Myrtillosa, Myrtillosaturf.mel, Dryopterioso-caricosa, Oxalidosa, Myrtilloso-sphagnosa, Oxalidosa turf.mel.

I. INTRODUCTION

Stands of black alder (*Alnus glutinosa (L.),Gaertn.)* comprise 5.1% of the total forest area of Latvia. *Alnus glutinosa* typicaly grows on wet petlands, usually comprising pure stands or stands mixed with *Alnus incana (L.) Moench., Bertula spp., Populus tremula L.* and *Picea abies (L.) Karst.* [1], [16]. Specific characteristics of this treee species are frost and waterlogging tolerance, a strong root system that penetrates both vertically and horizontally, adaption to various soil conditions and ability to fix nitrogen in symbioyic root nodules with bacteria in the genus *Frankia* [1], [3]. The root system is adapted to very wet soils. Many strong, vertically growing, sinker roots ancor the tree on riverbanks, and they are able to penetrate deeply into wet and anaerobic soils reaching almost 5m deep [9].

Three main site types where *Alnus glutinosa* grows can be identified [5], [6] in relation to the type of water supply are:

- Marshy sites that have waterlogged subsoil throughout the year. On these, *Alnus glutinosa* forms pure stands owing to its physiological adaptions that allow it to grow in anaerobic soils.
- Riverside sites in which the soil in the rooting zone is well aerated during the growing season. On these, *Alnus glutinosa* is often mixed with species that are adapted to alluvial sites (*Alno-Padion* community).
- Plateau sites which high soil moisture contents where the stand is dominated by other species that are more competitive (*Carpinion* community).

Alnus glutinosa is regarded a short living tree species, starting to die out naturally at about 60 years of age under Central European conditions [18]. However, depending on the region and growth conditions, the species might reach age of 100-160 years [5]. *Alnus glutinosa* is usually attacked by a heartwood rot at the age of 50-70 years [5]. Some authors noted that *Alnus glutinosa* wood quality declines after 60-70 years because of heartwood rot [4], [17]. According to investigations made in Bavaria [7] the beginning of the phenomenon at about age 50. According to the results of investigaton [1] made in Latvia, the

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frequency of stem decay and heart colouring of 51-84 year old *Alnus glutinosa* stands are sequental "Table 1".

TABLE 1 CHARACTERISTICS OF ALNUS GLUTINOSA STEM QUALITY

Age, years	Species composition (%)	Forest site type	Sampled trees, no.	Decayed stems (%)
51	100 *Alnus glutinosa*	*Mercurialiosa*	100	98
74	80 *Alnus glutinosa* +20 *Alnus incana*	*Filipendulosa*	100	82
76	60 *Alnus glutinosa* +30 *Alnus incana* +10 *Picea abies*	*Oxalidosa turf.*	150	53
84	80 *Alnus glutinosa* +20 *Alnus incana*	*Oxalidosa turf.*	100	78
			Average	75

According to investigations [10] the frequency of heartwood rot differs with site but diagnosis from external characteristics is unreliable.

Nowadays *Alnus glutinosa* is becoming increasly important as a plantation species. Aside from commeercial forestry, this tree species is important for riparian ecosystems and their biodiversity, providing habitants for specific wetland flora and fauna and stabilising riverbanks [1], [15].

If *Alnus glutinosa* is planted in a cutover where a heartwood rot has already been established [5], there will be no positive effect, as the young trees will become infected when their roots contact with the roots of the rotten stumps [13].

It is believed that deciduous tree in pure stands are generally resistant to *Heterobasidion* root rot. On the other hand, the results of studies performed in Lithuania show that *Bertula* stands planted in previously severely affected areas of *H. annosum* (*Pinus sylvestris*) is also infected with *H. annosum* [11]. However, it is possible that no suitable planting material has been selected in this case [8].

The vegetative method plays a very important role in the propagation of many deciduous tree species. *Alnus glutinosa* has great strain-healing abilities. A forest derived from seeds differs in many biological characteristics from a forest derived from coppice. In large forest stands, trees are often taller at the end of their lives compared to trees growed brom coppice. For example, oak forests continue to grow intensively until the age of 120-150 years, live 300-400 years and reach a height of 30-40 m. Oak shoots grow intensively for 70-80 years, live for 150-200 years and reach a height of 20-30 m.

II. STUDY GOAL

The goal of this study was to synthesize the existing experience and knowledge about the silviculture of *Alnus glutinosa* on suitable sites in relation to the production of high quality and valuable timber and to work out the recommendations to improve the forest managment in forest stands where *Alnus glutinosa* stands from plantations are growing.

The following objectives were set to achieve the study goal:

The third important difference between a large forest and a coppice is that the wood structure of a large forest is more even and correct than that of a coppice tree. Big forest trees differ much more radically from coppice trees in that the carcasses damage trees much less in stand stands than in coppice trees. In stands formed vegetatively, the stems and roots of the mother trees gradually die. Through the parts of the dying roots, the fungal filaments penetrate the coppice and develop freely in the new generation of forest.

Because of that foresters must ensure the regeneration of the forest with seeds, seedlings, not coppice [13].

The early stage of forestry is cruical for successful and sustainable forest managment. One third of the reforested forest in Latvia is regenerated by planting with different kinds of tree seedings. The success of forest regeneration by planting depends on correctly prepared soil and chouice of the right seeding material. Reforestation by *Alnus glutinosa* in Joint Stock Company "Latvia State Forests" (LVM) have been conducting by bare roots, containerized and with improved root system. The main aim in forestry is to achieve higher tree seeding establishment and promote their growth and improve fixation in soil. Practically, this procpects should be evaluated from the perspective of forest health.

In order to ensure and improve the ecological stability of forests, the ability to adapt to various pathogenic microorganisms and resistance to stress factors caused by anthropogenic effects, the territory of Latvia is divided into two regions for (*Alnus glutinosa Gaertn.)* reforestation. Seedlings obtained from clone seeds in West region "Fig. 2", "Table 4" can be planted only in West region of Latvia "Fig. 2". The same methodology applies to East and North regions.

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- To identify the origin of the clones in the West region of Latvia.
- To estimate the incidence of heart colouring and stem decay in *Alnus glutinosa* stands in different forest types and ages in all regions of Latvia.
- To identify and measure the diameter of heart colouring and stem decay area.
- To evaluate the relationships between stand species composition (forest types) and *Alnus glutinosa* stands age on heart colouring/heartwood rot incidence.

III. MATHERIALS AND METHODS

3.1. Field Measurements.

- Sampling stumps of *Alnus glutinosa* in different forest type and age class felling areas after commercial thinning and final felling for estimating the frequency of decay and heart colouring.
- Measuring the diameters of the stumps, the diameters of heart colouring areas, and diameters of heartwood rot areas according to the scheme "Fig. 1".

Fig.1. Dst- diameter of the stump; Dhr- Heart colouring area /Heartwood hard rot stage area diameter; Dc –Heartwood soft rot stage area diameter/ Cavity diameter

3.2. Statistical Analyses.

The sequental data were collected and analysed:

- Block area-Forest block-Forest compartment; Area (ha) ; Stock nr; Average tree (m^3); Stock (m^3); County; Coordinates X/Y; Forest type; Age class; Age decade; Species composition; Sampled stumps (pcs.); Decayed (Heartwood soft rot/ Cavity) stems(%); Stump diameter (mm)/ Average/Median/Stdev; Heart colouring area diameter/Heartwood hard rot stage diameter (mm); Average/Median/Stdev; Heartwood soft rot stage diameter/Cavity diameter(mm) Average/Median/Stdev

IV. RESULTS AND DISCUSIONS

In order to ensure and improve the ecological stability of forests, the ability to adapt to various pathogenic microorganisms and resistance to stress factors caused by anthropogenic effects, the territory of Latvia is divided into regions of origin of *Alnus glutinosa*, which must be observed in the processes of reforestation [12].

Fig.2. Regions of origin of *Alnus glutinosa* [12]

The Latvian State Forest Research Institute "Silava" has confirmed that the identification of 50 clones (*Alnus glutinosa Gaertn*.) of Platene (West region of Latvia) seed plantations and operations has been done with molecular passporting methods that ensure the acquisition of these plants in the forest reproductive material identification to be at the stage of production, trade or use. The results of the identification are given in "Table 2".

TABLE 2 MOLECULAR PASSPORT OF THE CLONES

Clone, no.	Sample, no.	Makers																	
		be 14		be1		be10		be12		be13		be5		be6		be8		be9	
1	43	189	189	335	340	247	247	116	116	233	233	242	246	151	157	230	247	190	190
2	10	189	193	344	348	247	247	116	120	225	233	242	256	157	157	247	247	132	134
3	21	0	0	337	344	247	247	116	118	225	236	246	246	151	187	226	247	0	0
4	28	0	0	318	346	247	247	116	118	225	233	248	248	157	157	0	0	0	0
5.-53.																			

Reforestation by *Alnus glutinosa* in LVM in West region "Fig. 2" have been conducting by bare roots, containerized and with improved root system. The scheme of manufacturing of seedings with improved root system is given "Fig. 3. "

Fig. 3. The scheme of manufacturing of seedings with improved root system

Reforestation by *Alnus glutinosa* in LVM in West, North and East region in 2021 will be conducted according to the plan of growing seedling "Table 3. "

TABLE 3 PLAN OF GROWING SEEDLING

Plantation	Region	Plan in 2020 (pcs.)	Sown in 2020 (pcs.)	Realization plan in 2021(pcs.)
Strenči	North	250000	479830	180000
Podiņi	East	693450	1729450	485415
Mazsili	West	328300	328300	229810

The origin of *Alnus glutinosa* clones for refrostation in West region were obtained in 2002. The characteristic of origin of the clones are given in "Table 4. "

TABLE 4 ORIGIN OF THE CLONES

Parameter	Data				
Block area-Forest block-Forest compartment	703-204-14	703-204-15	703-214-8	703-204-2	703-214-7
Area (ha)	2.39	4.27	8.8	2.96	2.94
County	Dundaga				
Age (Age decade) years	78 (8)	98 (10)	88 (9)	98 (10)	73 (8)
Species composition	9 *Alnus glutinosa 1 Bertula 78 +F.excelsior 78+P.Abies 71*	10 *Alnus glutinosa 98+ Bertula 98 +P.Abies 91*	8 *Alnus glutinosa* 2 *Bertula 88 + P.Abies 88*	10 *Alnus glutinosa* 98 *+Bertula 98*	10 *Alnus glutinosa* 73 *+Bertula 91+*
Specie	04-*Bertula*				
Age (years)	78		88		
Height (m)	26		27		
Diameter (cm)	27		29		
Basal area (m^2)	2		6		
Stock (m^3/ha)	23		72		
Specie	06-*Alnus glutinosa*				
Age (years)	78		88		
Height (m)	26		26		
Diameter (cm)	30		31		
Basal area (m^2)	25		26		
Stock (m^3/ha)	309		321		

In order to estimate the incidence of heart colouring and stem decay in *Alnus glutinosa* stands in different forest types and ages, to identify and measure the diameter of heart colouring and stem decay area and to evaluate the relationships between stand species composition (forest types) and *Alnus glutinosa* stands age on heart colouring/heartwood rot incidence, during 2020-2021, incidence of butt rot in *Alnus glutinosa* stands and the presence of fungi responsible for it were investigated

TABLE 5 CHARACTERISTICS OF INVESTIGATED FOREST SITE TYPES

Parameter	**Data**						
Block area-Forest block-Forest compartment	503-443-46-0 503-443-18-0	107-421-2	107-443-5	107-438-11	803-307-2	501-119-4	501-110-13
Area (ha)	0.77	0.8	1.99	1.75	4.03	0.85	0.8
Stock nr,	JD1071	AE1828_01	AE 1805_01	AE 1805_01	BS 1960_01 BS 1960_02	JN 0036	
Average tree (m^3)		0.45	0.4	0.4	0.4		
Stock (m^3)		163.11	372.56	372.56	372.56		
County	Pļaviņas		Alūksne		Madona	Ogre	
Parish	Aiviekste		Liepna		Vecumnieki	Jugla	
Coordinates X/Y		708934/366266	708846/366207			549831/302173	
Forest type	*Dryopterioso-caricosa Myrtillosa*	*Myrtillosa turf.mel.*	*Dryopterioso-caricosa*	*Dryopterioso-caricosa*		*Mercurialiosa mel.*	
Age class		Mature stand				Overmature stand	
Age decade	8 (1942.)	9	8	8	9 (1931)	10	
Species composition	8 *Alnus glutinosa* 1*P.abies* 1*Bertula* 78	8 *Bertula* 3 *Alnus glutinosa* 88+*Pinus sylvestris* *P.tremula* 88	7 *Alnus glutinosa* 3*Bertula* 73+*P.tremula* 71 *P.abies* 73	5 *Bertula* 4 *Alnus glutinosa* 1P.abies 78+Pinus sylvestris78 *P.tremula* 70	6 *P.abies* 2 *Alnus glutinosa* 1 *P.tremula* 89 +*P.abies* 67	5 *Bertula* 4 *Alnus glutinosa* 1 *P.tremula* 92+*P.Abies* 65	4 *Bertula* 3 *Alnus glutinosa* 2P.Abies 92+1*P.tremula* 50
Specie	04-*Bertula*		*Oxalidosa*		08-*P.tremula*	04-*Bertula*	
Age (years)	78				89	92	92
Height (m)	29				30	27	29
Diameter (cm)	25				36	29	31
Basal area (m^2)	2				9	11	11
Stock (m^3/ha)	23				128	132	142
Specie				06-*Alnus glutinosa*			
Age (years)	78					92	92
Height (m)	26					26	29
Diameter (cm)	25					30	30
Basal area (m^2)	20					8	7
Stock (m^3/ha)	247					99	97
Sampled stumps (pcs.)	85	48	92	68	53	55	38
Decayed soft rot/ cavity) stems (%)	75	88	48	55	82	88	87
Stump diameter (mm) Average/Median/Stdev	342/330/79	394/390/73	330/340/58	340/345/75	340/338/44	375/265/64	372/272/58
Heart colouring diameter*//Hard rot stage diameter (mm) Average/Median/Stdev	40/40/39* // 124/110/56	120/126/45	125/115/44	85/90/21	145/152/33	156/165/42	150/158/38
Soft rot stage diameter/Cavity diameter (mm)Average/Median/Stdev	126/100/73	185/185/46	150/146/46	110/110/57	173/167/28	186/190/43	192/188/45
Specie			03-*P.abies*			08-*P.tremula*	
Age (years)	78				89	92	50
Height (m)	27				31	29	29
Diameter (cm)	32				36	36	35
Basal area (m^2)	3				23	2	6
Stock (m^3/ha)	38				325	28	83

Parameter	Data					
Block area-Forest block-Forest compartment	803-305-23	807-71-4	202-454-8	202-453-29	313-42-25	312-228-18
Area (ha)	2	2.32	1.54	1.01	1.84	1.96
Stock nr,	AA2323	BS 1933	HT1840_01	HT1906_01	BT 2007_01	BT 2020_01
Average tree (m^3)	0.6	0.44	0.79	0.6	0.72	0.1
Stock (m^3)	795.57	292	512.4	262.5	367.8	91.14
County	Madona	Kārsava	Renda	Renda	Svente	Svente
Coordinates X/Y	661455/282037	697466/31613	396397/321503	398896/322313	668075/183534	658119/179698
Forest type	*Oxalidosa*	*Myrtilloso-sphagnosa*	*Oxalidosa*	*Myrtilloso-sphagnosa*	*Oxalidosa turf.me*	*Dryopterioso-caricosa*
Age class			Mature stand			Middle age stand
Age decade	8 (1946)	8	8	9	9	3
Species composition	8 *Alnus glutinosa* 1*P.tremula* 1 *Bertula 74 +P.Abies 56*	6 *Bertula* 1 *Alnus glutinosa 2 P.Sylvestris 1P.Abies 74 +P.Abies* 63	4 *Bertula* 4P.Abies 1 *P.Sylvestris* 1 *Alnus glutinosa*	4 *Bertula* 2 *Alnus glutinosa* 2 *P.Sylvestris* 1 *P.Abie* s 86 1 *Alnus glutinosa* 66 +*Bertula* 66	4 *Alnus glutinosa* 2 *Bertula* 2 *P.Abies* 1*P.tremula* 89	4Alnus glutinosa 3Bertula 28 +P.tremula28
Specie			04-*Bertula*			
Age (years)	74	74	71	86		28
Height (m)	25	23	25	23		16
Diameter (cm)	29	25	25	28		15
Basal area (m^2)	3	14	15	7		4
Stock (m^3/ha)	33	144	167	72		31
Specie			06-*Alnus glutinosa*			
Age (years)	74	74	71	86		28
Height (m)	26	21	21	23		16
Diameter (cm)	27	25	25	27		18
Basal area (m^2)	30	2	6	4		9
Stock (m^3/ha)	371	20	60	44	120	71
Sampled stumps (pcs.)	50	35	48	56	32	42
Decayed (soft rot/ cavity) stems(%)	88	83	79	67	92	4
Stump diameter (mm)/ Average/Median/Stdev	317/310/59	341/320/71	315/295/65	335/315/78	325/331/69	200/195/38
Heart colouring diameter/Hard rot stage diameter (mm) Average/Median/Stdev	152/160/30	133/140/39	115/135/42	142/155/42		
Soft rot stage diameter/Cavity diameter (mm)Average/Median/Stdev	167/160/27	138/145/37	108/120/40	145/150/40	152/149/48	
Specie	08-*P.tremula*	01-*P.sylvestris*	03-P.abies	01-*P.sylvestris*		
Age (years)	74	74	71	86		
Height (m)	26	26	24	26		
Diameter (cm)	44	27	28	32		
Basal area (m^2)	5	6	10	6		
Stock (m^3/ha)	62	71	114	71		
Specie				03-P.abies		
Age (years)				86		
Height (m)				23		
Diameter (cm)				27		
Basal area (m^2)				6		
Stock (m^3/ha)				66		
Specie				06-Alnus glutinosa		
Age (years)				66		
Height (m)				20		
Diameter (cm)				23		
Basal area (m^2)				2		
Stock (m^3/ha)				19		

Surveyed were altogether 13 felling areas in Vidusdaugava, Dienvidkurzeme, Zemgale, Ziemeļlatgale, Dienvidlatgale, Austrumvidzemes Forest Districts the results of the investigation are given in "Table 5". Characteristics data of investigated *Alnus glutinosa* stands are given in "Table 6. "

TABLE 6

CHARACTERISTICS OF INVESTIGATED ALNUS GLUTINOSA STANDS

Age (Age decade), years	Species composition (%)	Forest site type	Sampled stumps, no.	Decayed stems (%)	Stump diameter *Average* (mm)	Soft rot stage /Cavity diameter *Average* (mm)
28 (**3**)	4 *Alnus glutinosa* 3 *Bertula* 28 +*P.tremula* 28	*Dryopterioso-caricosa*	42	**4**	**200**	
74 (**8**)	8 *Alnus glutinosa* 1*P.tremula* 1 *Bertula 74* +*P.Abies 56*	*Oxalidosa*	50	88	317	167
74 (**8**)	6 *Bertula* 1 *Alnus glutinosa 2 P.Sylvestris 1P.Abies 74* +*P.Abies* 63	*Myrtilloso-sphagnosa*	35	83	341	138
79 (**8**)	4 *Bertula* 4*P.Abies* 1 *P.Sylvestris* 1 *Alnus glutinosa*	*Oxalidosa*	48	79	315	108
78 (**8**)	8 *Alnus glutinosa* 1*P.abies* 1*Bertula* 78	*Dryopterioso-caricosa Myrtillosa*	85	75	342	126
73 (**8**)	7 *Alnus glutinosa* 3*Bertula* 73+*P.tremula* 71 *P.abies* 73	*Dryopterioso-caricosa*	92	48	330	150
78 (**8**)	5 *Bertula* 4 *Alnus glutinosa* 1P.abies 78+Pinus sylvestris78 *P.tremula* 70	*Dryopterioso-caricosa*	68	55	340	110
			Average	**69**	**332**	**133**
86 (**9**)	4 *Bertula* 2 *Alnus glutinosa* 2 *P.Sylvestris* 1 *P.Abie*s 86 1 *Alnus glutinosa* 66 +*Bertula* 66	*Myrtilloso-sphagnosa*	56	67	335	145
89 (**9**)	4 *Alnus glutinosa* 2 *Bertula* 2 *P.Abies* 1*P.tremula* 89	*Oxalidosa turf.mel.*	32	92	325	152
88 (**9**)	8 *Bertula* 3 *Alnus glutinosa* 88+*Pinus sylvestris P.tremula* 88	*Myrtillosa turf.mel.*	48	88	394	185
89 (**9**)	6 *P.abies* 2 *Alnus glutinosa* 1 *P.tremula* 89 +*P.abies* 67	*Oxalidosa*	53	82	340	173
			Average	**81**	**345**	**164**
92 (**10**)	5 *Bertula* 4 *Alnus glutinosa* 1 *P.tremula* 92+*P.Abies* 65	*Mercurialiosa mel.*	55	88	375	186
92 (**10**)	4 *Bertula* 3 *Alnus glutinosa* 2*P.Abies* 92+1*P.tremula* 50		38	87	372	192
			Average	**88**	**373**	**188**

V. CONCLUSIONS AND RECOMENDATIONS

1. To ensure the quality of *Alnus glutinosa* wood, reforestation must be carried out with seeds, seedlings, not coppice.
2. In the processes of reforestation the regions of origin of *Alnus glutinosa* must be observed.
3. The main factor influencing the quality of wood is the age of the stems of *Alnus glutinosa*. The highest quality wood is up to 30-year-old stems.
4. When harvesting has been managed in stands older than 70 years, the proportion of decayed stems exceeds 69%, heartwood rot diameter reaches 133 mm at an average stump diameter of 332 mm.
5. When harvesting has been managed in stands older than 80 years, the proportion of decayed stems exceeds 81%, heartwood rot diameter reaches 164 mm at an average stump diameter of 345 mm.
6. When harvesting has been managed in stands older than 90 years, the proportion of decayed stems exceeds 88%, heartwood rot diameter reaches 188 mm at an average stump diameter of 373 mm.

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