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TECHNICAL CHARACTERISTICS OF POPLAR WOOD AS RAW MATERIAL FOR WIDE USE IN TIMBER INDUSTRY

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Abstract:
Several heteroploid poplar clones on the basis of their growth, survival characteristics and wood quality were selected. These clones give the best results in the forest-steppe zone conditions and can be widely used as raw material for the lumber industry. The results suggest that the establishment of hybrid poplar plantations may become a promising area of forest cultivation.

Key words: *clone; density; hybrid; Poplar; structural characteristics; wood quality.*

INTRODUCTION

The creation of special purpose-oriented plantations of fast-growing and highly productive tree species is a promising direction in forestry that provides a significant reduction in operational load on natural forests.

Poplar is one of the most common fast-growing tree species. For its fast growth and early ripeness it has been named the "North Eucalyptus" (Ogievsky 1949). The creation of fast-growing poplar plantations enables us to grow larger volumes of wood per area unit and to conserve a balance between consumption and regeneration of wood volume. The plantation-based forestry is intended to create highly productive forest plantations and to meet the demand of the timber industry in raw material within the shortest possible time. It is the most promising solution to a problem of providing raw material for pulp and paper industry.

Populus genus of the Salicaceae family includes about 110 species divided into 6 sections. Each species has its own biological characteristics and shows high growing capacity only under certain specific soil and climate conditions. Poplar is wide-spread mostly in forest and forest-steppe zones. In the steppe and semi-desert zones it grows only in the river floodplains and along the lake banks.

Poplar has soft wood that is widely used in the pulp and paper industry, manufacturing industry, housebuilding, cabinet-making, timber industry etc., (Sivolapov 2005). Poplar wood is used for producing roundwood, saw timber, boards, roof frames, wood chip boards, wood-fibre boards and OSB boards. In Germany about 40% of aspen and poplar wood is molded into laminated densified sheets of various types (Tsivenkova 2005). Aspen and poplar laminated plywood is cheap and can be used as reusable formwork in monolithic construction. China produces such plywood in sufficiently great volume (Tsarev 1985).

Optimum indicators of the suitability of poplar wood for pulp and paper industry are its density, the cellulose concentration and the size of wood fiber. The wood density from 300 to 600kg/m^3 is considered to be the best. The cellulose concentration in poplar wood reaches 55-56%, and is on average higher than in coniferous wood. However, as for the fiber size poplar is considerably inferior to spruce which is the best coniferous species for pulp and paper industry. The average wood fiber length of poplar is 1.3-1.5mm while for spruce this figure is 2.5-2.8mm although the modern technologies for high-level process for conversion of wood into pulp and paper have made it possible to solve the problem of the use of poplar as pulpwood (Tsivenkova and Samylin 2005).

The modern history of poplar cultivation dates back for about 300 years in Europe, and about 200 years in Russia. The main feature that attracts the attention of foresters to poplar is its high productivity.

Poplar plantations productivity issues are being studied all over the world. Special research institutes and experimental stations in Italy, Turkey, Hungary, Bulgaria, the USA, Canada, Poland, Estonia, Sweden, Finland and Russia are currently devising the ways to increase productivity of poplar plantations.

The global trend indicates the increasing demand of the timber industry for high-quality raw materials (Zhigunov 2013). In the study of various poplar forms it is important to know not only their productivity but

also various wood quality characteristics. Among these characteristics density indicators, structural characteristics of fiber and chemical composition of wood are of great practical importance. The number of research works on forest breeding for wood quality conducted at the moment by various countries confirms the demand for the research in this area (Cleary 2014).

Some European countries give priority to stem quality and wood quality characteristics and resistance rather than to growth rates. At the moment the US, Canada, the EU and China are conducting field trials of genetically modified poplar with the aim of improving its wood quality, resistance to pests and ability to absorb and accumulate heavy metals as a way of soil detoxification (Wu 2014). As a result of the breeding work on wood quality a number of non-destructive monitoring techniques over the wood quality characteristics were devised/ developed.

OBJECTIVE

The objects of the study were:

1) Six fast growing and productive heteroploid white poplar hybrids: diploid (2n = 2x = 38) and triploid (2n = 3x = 57) at the age of 28 years obtained by OS Mashkina with the use of hybridization with unreduced diploid pollen, artificially synthesized at elevated temperature (13 trees in all): № 65/81, 136/82, 143/82 and 184/82, 22/83, 155/83, where the numerator is the plant number and the denominator is the year of origination of the parent plant.

The location of the plot – Voronezh region, Semiluki forest breeding nursery and its area is 0.3ha. Year of creation of the plot – 1986. Current age (2016) – 30 years. Soil – typical medium thick chernozem; the mechanical composition – sandy clay loam.

Plant spacing – 4×4m in Fig. 1;

2) A naturally selected highly productive triploid gray poplar clone – cultivar Khopersky (Sivolapov 2005) at the age of 30 years (female specimen). A noteworthy detail is that we managed to propagate this cultivar only by *in vitro* culture;

3) White and gray poplar clones propagated by *in vitro* culture from the Semiluki forest breeding nursery (D - clone rameta 155/83; G - clone rameta 11/83, F - clone rameta 101/83; E - clone rameta 22/83, A - clone rameta Khopersky; the age is 18 years). The originators of the plot is OS Mashkina. Year of creation of the plot – 1997. Its area – 0.3ha. The site type – D_3 according to Pogrebnyak's classification which means mesohydrophytic (humid) deciduous forest. The location of the plot – Voronezh region, Semiluki forest breeding nursery. The purpose of the experience is to study the effect of the vegetative propagation method (*in vitro* or *in vivo*) of the white and gray poplar triploids which don't respond well to vegetative reproduction on their preservation, growth and productivity.

Planting material: annual regenerated plants obtained by *in vitro* clonal micropropagation (through meristem culture) and by traditional cuttings of selected polyploid poplar (*in vivo*) in plastic greenhouse with the use of root stimulants.

The starting material for cutting: 8-10-year-old white poplar hybrids pre-selected for their growth rates.

4) 3x-1 and 3x-2, ES38 (Voronezh giant) – 30-year-old artificially obtained productive allotriploid hybrids of *Populus deltoides Marsh* × *Populus balsamifera L*. The plot was established in order to test the two allotriploid (2n=3x=57) male poplar clones (№1 and №2), obtained by pollinating the *Populus deltoides* with artificial diploid pollen of *Populus balsamifera* synthesized with the use of colchicine (Gulyaeva 1980). The location of the plot – Voronezh region, Semiluki forest breeding nursery, its area is 0,25ha, the year of creation – 1984. Soil – typical medium thick chernozem; the mechanical composition – sandy clay loam. The plot was planted by 1-year-old seedlings grown from stem cuttings. There were 3 replications of 5 plants each. There were 75 plants of 5 poplar clones in total planted in a random order with 4×4m. spacing.

MATERIAL, METHOD, EQUIPMENT

The microstructural characteristics and physical characteristics of tested wood were studied using core samples, which were taken from 50 trees in each plot at the height of 1.3m from the root collar.

For relatively small samples we used the high humidity method of measuring the basic wood density. Wood density when dry was measured by the stereometric method. The volume of the samples was measured by stereometric formula, their weight – with the use of analytical scales with an accuracy of 0.001g.

Maceration of wood samples for the determination of their wood fiber structural characteristics was conducted using the Franklin's method. According to this method of maceration the wood samples (~ 1g) have to be softened by boiling for 1 hour at reflux in a solution of glacial acetic acid and 34% hydrogen peroxide at the ratio 1:1.

Resulting product then was used to prepare specimens for microscopic examination. The length and thickness of the wood fiber was measured by the use of MBS-9 microscope fitted with micrometer eyepiece, the number of repetitions for each specimen was 30.

Statistical analysis of the data was performed with the use of the software package Statistica.

a. *b.* *c.*

Fig. 1.

Perspective heteroploid poplar hybrids at the age of 29 years. Semiluki forest breeding nursery, 2015. Photo by O.S. Mashkina: a – Diploid hybrid of white poplar № 184/82; b – autotriploid hybrid of white poplar № 65/81; c - allotriploid hybrids № 1 (on the left) and № 2 (on the right) of Populus deltoides and Populus balsamifera.

RESULTS AND DISCUSSION

The results of the wood quality analysis of previously selected promising heteroploid white poplar hybrids are presented in Table 1 and Fig. 2. As a control we took reference data for the white poplar in the central region of the European part of Russia: wood density when dry - 393kg/m^3, standard wood density - 416kg /m^3, the basic density - 334kg/m^3.

Table 1

Wood quality characteristics of the promising heteroploid white poplar hybrids at the age of 29

№	Clone number	Tree number	Wood density, kg/m^3						Structural characteristics of wood fibers		
			standard ρ_{12}		oven-dry ρ_0		basic $\rho_{баз}$		fiber length, mm		fiber thickness, mμ
			ρ_{12}	mean ρ_{12}	ρ_0	mean ρ_0	$\rho_{баз}$	mean $\rho_б$	length, mm	mean, mm	mean, mμ
1	65/81	14	473	465	444	435	363	358	1,37±0,21	1,34±0,19	23,8±4,8
2		15	457		425		352		1,33±0,17		
3	143/82	16	458	474	427	447	354	363	1,37±0,19	1,37±0,15	25,0±5,2
4		17	456		426		353		1,38±0,18		
5		41	508		488		383		1,32±0,16		
6	22/83	20	439	439	404	404	336	336	1,33±0,20	1,33±0,20	25,4±3,6
7	184/82	38	446	462	415	430	341	356	1,27±0,16	1,33±0,19	22,2±4,1
8		39	477		445		371		1,37±0,21		
9	136/82	40	455	455	425	425	355	355	1,26±0,15	1,26±0,15	24,3±3,5
10	155/83	18	335	332	363	359	304	300	1,26±0,25	1,33±0,22	23,5±3,0
11		19	329		355		296		1,39±0,15		
12	Khopersky poplar	22	429	445	398	414	334	356	1,45±0,23	1,46±0,20	26,4±4,1
13		23	466		437		367		1,46±0,18		
14		7т	445		414		362		1,47±0,16		
15		8т	441		408		362		1,45±0,23		

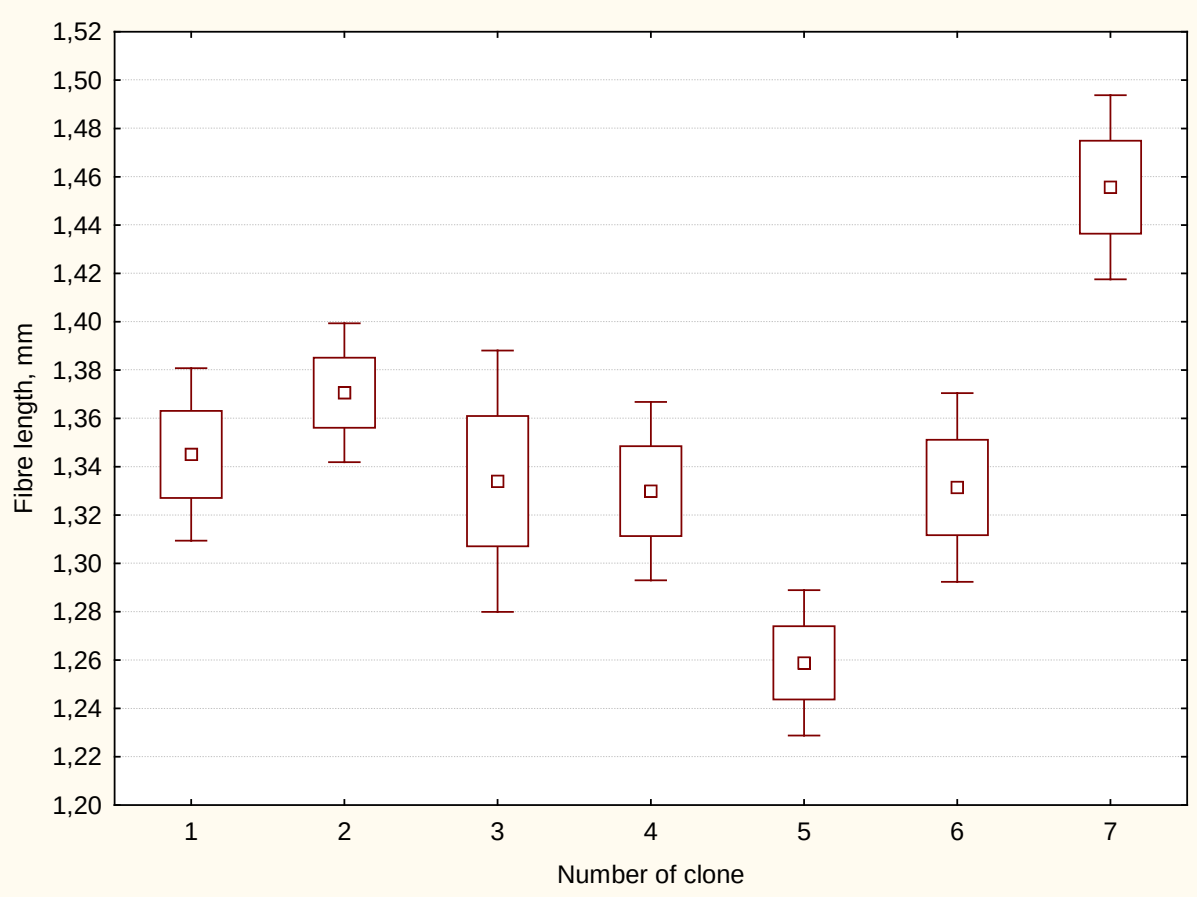

Fig. 2.
Variation of wood fiber length in different white poplar hybrids (1-6) and gray poplar hybrids (7): 1 - 65/81; 2 - 143/82; 3 - 22/83; 4 - 184/82; 5 - 136/82; 6 - 155/83; 7 – Khopersky.

The comparative analysis of the obtained wood quality characteristics shows us that the wood density of all experimental clones except one (clone 155/83) exceeds control data. The best ones are clones 143/82, 65/81 and 184/82, as their wood density has exceeded the control by 13.7; 10.7 and 9.4%. While our study of the structural wood characteristics has shown that the length of the wood fiber of white poplar exceeds the diameter in 42 - 60 times.

Comparing the structural characteristics of poplar wood, we should acknowledge that the clones 143/82 and 65/81 have the best wood quality. Their wood fibers are the longest (1,37±0,15mm and 1,34±0,19mm respectively with the maximum of 1.85mm for clone 65/81) and the thinnest (25±5,2mμ and 23.8±4,8mμ respectively), which indicates their better suitability for paper industry.

According to reference data the fiber length of poplar ranges from 0.7 to 1.6mm, (Ugolev 2007). According to Sivolapov (2005), fiber length of Khopersky cultivar in Khopersky natural reserve at the age of 46 years was 1,28±0,02mm, and its fiber diameter was 29,5±0,5mμ, whereas the standard density is 447kg/m^3. According to Tsarev (2002), the wood fiber length of 40-year-old white poplar is 0.64mm, and the basis wood density is 362kg/m^3.

The finding shows that at the age of 29 the hybrids number 143/82 and 65/81 have the best wood quality characteristics (both in density and fibers length) of six studied white poplar clones. However, it should be noted that the gray poplar allotriploid clone Khopersky has still better wood characteristics in comparison with white poplar clones.

The results of the analysis of wood quality of the ramets propagated by *in vitro* culture from triploid white poplar and gray poplar are presented in Table 2 and in Figs. 3-4. Table 2 shows that the clones J (11/83), D (22/83) and A have the highest wood density which exceeds the control by 5.3; 3.9 and 3.3% respectively.

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Table 2

Wood quality characteristics of the ramets propagated by in vitro culture from 18-year-old triploid white poplar and gray poplar

№	Clone number	Tree number	Wood density, kg/m^3						Structural characteristics of wood fibers		
			standard ρ_{12}		oven-dry ρ_0		basic $\rho_{баз}$		fiber length, mm		fiber thickness, mμ
			ρ_{12}	mean ρ_{12}	ρ_0	mean ρ_0	$\rho_{баз}$	mean $\rho_б$	length, mm	mean, mm	mean, mμ
1	G (155/83)	1	375	388	348	363	298	301	1,36±0,09	1,40±0,13	24,9±4,8
2		3	401		378		303		1,44±0,14		
3	J (11/83)	4	463	439	440	414	370	348	1,14±0,12	1,33±0,20	23±5,2
4		5	433		409		344		1,36±0,15		
5		6	420		392		329		1,49±0,13		
6	E (101/83)	7	446	423	423	399	358	335	1,29±0,13	1,38±0,19	25,4±3,6
7		8	437		413		348		1,56±0,16		
8		9	385		361		299		1,27±0,09		
9	A	10	432	433	408	410	346	345	1,54±0,11	1,48±0,16	24,3±3,5
10		11	420		396		335		1,58±0,15		
11		12	447		425		353		1,31±0,07		
12	D (22/83)	24	436	437	414	412	338	347	1,45±0,09	1,47±0,09	22,85±3,7
13		25	438		410		356		1,48±0,09		

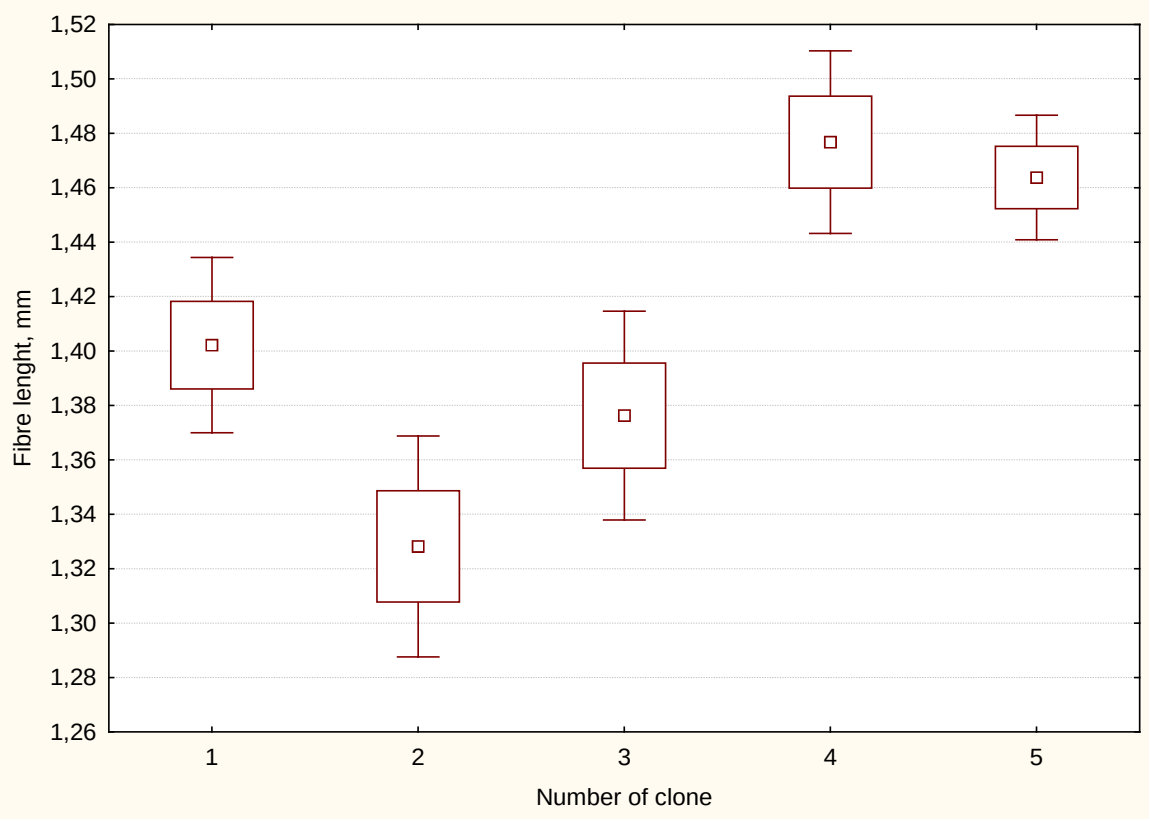

Fig. 3.

Variation of wood fiber length in different white poplar triploid clones (1-3, 5) and gray poplar clones (4): 1 – G (155/83); 2 – J (101/83); 3 – E (101/83); 4 – A; 5 – D (22/83) propagated by in vitro culture.

Fig. 4.
Macerated wood of white poplar clone D (22/83).

The finding shows that the clones A and D (22/83) have the best structural characteristics. The finding also shows that the wood fiber length of white and gray poplar exceeds the diameter in 54 – 64 times.

The A clone of gray poplar and D clone of white poplar (22/83) turned out to be the best ones as they have the longest (1,48±0,16mm and 1,47±0,09mm respectively; with a maximum of 1,85mm for clone A) and the thinnest (24,3±3,5 and 22,85±3,7mμ respectively) wood fiber. A noteworthy detail is that D clone has the length/diameter ratio of 64.

Table 3

Wood quality characteristics of allotriploid hybrids of Populus deltoides × Populus balsamifera at the age of 30 years

№	Clone number	Tree number	Wood density, kg/m^3						Structural characteristics of wood fibers		
			standard ρ_{12}		oven-dry ρ_0		basic $\rho_{баз}$		fiber length, mm		fiber thickness, mμ
			ρ_{12}	mean ρ_{12}	ρ_0	mean ρ_0	$\rho_{баз}$	mean $\rho_б$	length, mm	mean, mm	mean, mμ
1	ES 38	1	432	448	394	409	342	354	1,57±0,17	1,57±0,15	26,4±4,8
2		2	464		424		366		1,57±0,14		
3	3x-2	3	455	460	412	414	357	361	1,71±0,15	1,62±0,15	25,7±4,0
4		4	465		415		364		1,53±0,09		
6	3x-1	5	445	439	403	402	342	341	1,57±0,11	1,64±0,17	23,6±3,5
7		6	432		401		340		1,72±0,19		

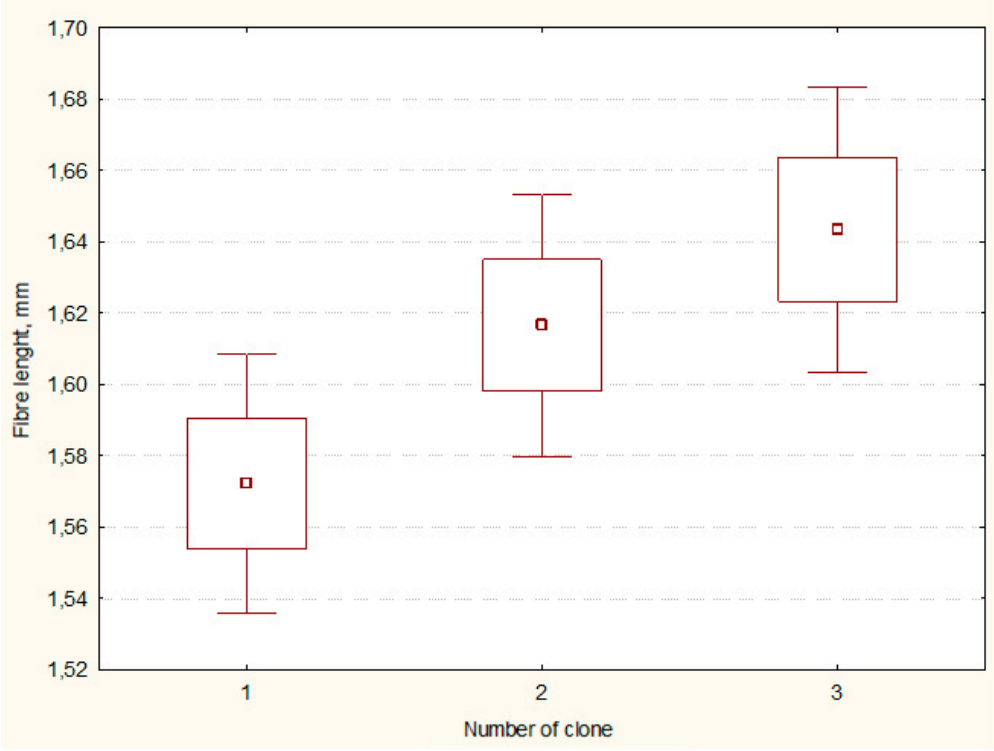

Fig. 5.
Variation of wood fiber length in allotriploid hybrids (Populus deltoides × Populus balsamifera): 1 – ES-38; 2 – 3x-2; 3 – 3x-1.

According to Sivolapov (2005), gray poplar from Boguchar forestry station (Voronezh region) has wood fiber length of 1,27±0,02mm and standard density of 533kg/m^3 while a large-leaved poplar form from Khopersky natural reserve has wood fiber length of 1,54±0,02mm and standard density of 529kg/m^3.

In summary, A clone of gray poplar (Khopersky cultivar) and D clone of white poplar (22/83) turned out to have the best wood quality characteristics at the age of 18 years among five studied poplar clones propagated by *in vitro* culture.

The results of the wood quality analysis of artificially obtained productive allotriploid hybrids of *Populus deltoides Marsh* × *Populus balsamifera L*. at the age of 30 years are presented in Table 3 and in Fig. 5.

The finding shows that all tested specimens of clones 3x-2, ES-38 and 3x-1 have exceeded the control. Their standard density is 361kg/m^3, 354kg/m^3 and 341kg/m^3, that exceeds the control by 8.1; 6.0 and 2.1% respectively. Our study on their structural wood characteristics has shown that the wood fiber length here exceeds the diameter in 59 – 69 times. The clones 3x-1 and 3x-2 have the longest (1,64±0,17mm and 1,62±0,15mm respectively; with a maximum of 2,10mm for clone 3x-2) and the thinnest (23,6±3,5 and 25,7±4,0mμ respectively) wood fiber.

There is a correlation between wood quality characteristics of the parent trees and their progeny. In particular, the study of the wood quality of the valuable ES-38 clone's progeny has shown that the progeny has exceeded the parent ES-38 tree in density as well as in other structural characteristics.

The comparative analysis allows us to determine the most perspective clones which are expected to give the best results in the target region. Five of the six artificially obtained 29-year-old allotriploid and diploid white poplar hybrids have shown the best results in density as well as in other structural characteristics. The finding also shows that wood quality of these hybrids is highly competitive with naturally selected highly productive 30-year-old triploid gray poplar clone (cultivar Khopersky).

Our study of the wood quality characteristics has shown that all our specimens of artificially obtained 30-year-old allotriploid poplar hybrids (3x-1, 3x-2 and ES-38 – Voronezh giant) have high quality. The 3x-1 and 3x-2 clones have the best structural characteristics among all tested clones.

Among the white and gray poplar clones propagated by *in vitro* culture from the Semiluki forest breeding nursery in Voronezh region at the age of 18 years one promising clone was selected – D rameta clone of the clone 22/83 – with high wood density and long and thin wood fibers.

CONCLUSIONS

The study on wood quality characteristics of promising heteroploid poplar hybrids and clones (including propagated by *in vitro* culture clones) has been achieved. As a part of the study the density, length

and thickness of the wood fiber have been examined. A number of promising clones expected to give the best results in the target region were selected. The finding confirms the possibility of wide use of poplar wood as raw material for various purposes in the timber industry.

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