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Long-Term Testing of Aspen Clones in European Russia

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Abstract. The results of 40 years of testing of more than 20 aspen clones selected in various regions of European Russia and the USSR, growing in the Semiluki Tremuletum in the Voronezh Region, are presented. The survival of plants, growth in height, diameter and volume of the stem are shown. A ranked assessment has been given and a selection of promising clones for the creation of highly productive aspen plantations has been carried out. It has also been noted that sexual dimorphism can have different effects on aspen rot resistance in different growing conditions. The testing has been conducted at the Central Research Institute of Forest Genetics and Breeding (currently the All-Russian Research Institute of Forest Genetics, Breeding and Biotechnology). A number of employees of the Institute have been engaged in the selection of the best forms, and then in hybridization, since its organization in 1971. The aim of this study has been to investigate the survival and growth of 21 long-lived aspen clones, as well as their productivity (in terms of stem volume), growing in the Semiluki Tremuletum of the Voronezh Region. It has been revealed that the height variation at the age of 40 has been quite wide – from 17.3 to 31.3 m, diameters – from 28.0 to 50.0 cm, stem volumes – from 0.3 to 2.4 m^3. The top 5 has included 2 aspen clones from the Botanical Garden of the Voronezh State University (clones no. 16 and 17), 2 hybrids introduced from the Baltic States (clones no. 20, 23) and American aspen (clone no. 29). Their average height at the age of 40 has been 26–31 m, diameter – 42–50 cm, stem volume – 1.4–2.4 m^3. This indicates the possibility of selecting promising aspen clones for their further propagation and introduction into plantation forest cultivation. At the same time, male clones (Pzg hybrid and American aspen clone no. 29), also introduced from the Baltic States, can be recommended for landscaping.

Keywords: tremuletum, aspen, clones, hybrids, variety testing, ranking, growth and productivity analysis, sexual dimorphism, selection

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Научная статья

Многолетние испытания клонов осины в Европейской России

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Аннотация. Представлены результаты 40-летних испытаний более чем 20 клонов осины, отобранных в различных регионах Европейской России и СССР. Клоны произрастают на Семилукском тремулетуме в Воронежской области. Показаны сохранность растений, рост по высоте, диаметру и объему ствола. Дана ранжированная оценка и проведен отбор перспективных клонов для создания высокопродуктивных осиновых насаждений. Отмечено, что половой диморфизм может по-разному влиять на гнилеустойчивость осин в различных условиях местопроизрастания. Испытания проводились в Центральном научно-исследовательском институте лесной генетики и селекции (в настоящее время – Всероссийский научно-исследовательский институт лесной генетики, селекции и биотехнологии). Отбором лучших форм, а затем гибридизацией сотрудники института занимаются с 1971 г. Целью данного исследования стало изучение сохранности, роста и продуктивности (по объему стволов) 21 клона осины в многолетнем возрасте, произрастающих в Семилукском тремулетуме Воронежской области. Выявлено, что варьирование высот в 40-летнем возрасте было довольно широким – от 17,3 до 31,3 м, диаметров – от 28,0 до 50,0 см, объемов стволов – от 0,3 до 2,4 м^3. В пятерку лучших выделены 2 клона осины из ботанического сада Воронежского государственного университета (клоны № 16 и 17), 2 гибрида, интродуцированные из Прибалтики (клоны № 20, 23), и осина американская (клон № 29). Их средняя высота в 40 лет составляла 26–31 м, диаметр – 42–50 см, объем ствола – 1,4–2,4 м^3. Это свидетельствует о возможности отбора перспективных клонов осины для их размножения и внедрения в плантационное лесовыращивание. Мужские клоны (гибрид Pzg и клон американской осины № 29), также интродуцированные из Прибалтики, можно рекомендовать для озеленения.

Ключевые слова: тремулетум, осина, клоны, гибриды, сортоиспытание, ранжирование, анализ роста и продуктивности, половой диморфизм, отбор

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Introduction

Aspen is widespread in the forests of Russia and is one of the most important forest species. In terms of area among deciduous trees, it ranks second after birch. Its area is up to 25 million ha with a stand of timber of 3 715 million m³/ha [18].

This species has rapid growth, root-sprouting renewability, and unpretentiousness to growing conditions. Aspen wood is widely used in construction, pulp-and-paper industry, bioenergy and in the manufacture of containers. Sawlogs, veneer, plywood, fiberboard and chipboard are produced from it. In addition, it is considered the main species for ravine and gully detention and can be used as feed additives in animal husbandry [1, 3, 21].

Russian foresters have noted the economic importance of aspen and its use back in the 19th century, and possibly even earlier. Among them we can mention N.S. Nesterov, B.A. Kunitsky, M.K. Tursky at al. But the greatest contribution to the study of the vital activity of aspen, its significance and breeding has been made by A.S. Yablokov (1963) [26].

The largest area of aspen stands is located in the forest zone of European Russia, in the forest-steppe and in the south of Western Siberia, where they replace primary stands of the main forest-forming tree species and form secondary stands replacing the former climax forests. Aspen stands grow mainly in forests of complex types. As a rule, aspen grows in medium-fertile and dry soils with normal or wet conditions. In the forest area, its stands include an admixture of forest tree species found in primary forests (spruce, fir, pine, oak, linden, etc.), and sometimes also birch and alder (Fig. 1).

Fig. 1. The aspen stand with an admixture of pine and spruce in the Republic of Karelia (Konchesero)

In the Central Black Earth Region, the volume of aspen stemwood by the age of 10 is 40–50 m³/ha; by the age of 30, it increases 3–4 times (150–200 m³/ha); and by the age of 70, the volume reaches 500–550 m³/ha. In stands growing in particularly favourable conditions, the average stand at the age of 70 years can reach 650 m³/ha. Quantitative maturity is recorded at the age of 25–30 years, technical maturity – at the age of 35 years. The maximum average annual increment is reached at the age of 40. In high-quality stands it can be 2.9–3.9 m³/ha/year in the centre of the species' natural habitat and more than 5–7 m³/ha/year in the Central Black Earth Region (Fig. 2, 3).

However, it should be noted that aspen in mature and overmature stands is very susceptible to core rot. Earlier studies have been conducted in the Right-Bank Forestry of the Educational and Experimental Forestry Enterprise of the Voronezh State University of Forestry and Technologies [19]. A study of the degree of aspen stands affected by core rot (823 ha of aspen stands have been examined) has shown that the infestation of trees, depending on age, has varied from 0.6 % in age class II, to 16.1 % in age class IV and up to 90.4 % in age class VII (Table 1).

Table 1

The yield of healthy wood in natural aspen forests in the Voronezh Region depending on age classes

Indicators	Age classes						
	I	II	III	IV	V	VI	VII
Stand volume, m^3/ha	15	150	184	238	262	304	301
Infestation with core rot, %	0	0.6	1.6	16.1	31.2	59.6	90.4
Healthy wood yield, m^3/ha	15	141	181	200	180	123	29

It has been established that the maximum yield of healthy wood in the studied aspen stands has been in the IV age class and has amounted to 200 m^3/ha. This age, apparently, should be considered the age of aspen felling. The yield of healthy wood in the older age classes (V and VI) decreases slightly, and in the stands approaching maturity (age class VII) it falls to 10 % and amounts to only 29 m^3/ha.

Fig. 2. The plus aspen stand. Voronezh State Nature Reserve, block 6, sample plot no. 3. On the left – age 45, average height 24 m, average diameter 26.4 cm. March 1967. On the right–age 94, average height 30 m, average diameter 44 cm. August 2014

It should also be noted that male aspen trees are more susceptible to rot than female ones. The study of sexual dimorphism in aspens in the age class V has shown that the infestation of male trees has been 33.7 %, and 22 % in female trees, i.e. in male plots it has been 1.5 times higher than in female ones.

Unfortunately, core rot is very difficult to deal with. Currently, there are several promising ways to obtain healthy aspen wood, and first of all, it is the selection of plus healthy trees in natural stands, in collections of clones and hybrids.

The staff of the Voronezh State University of Forestry and Technologies has begun to select rot-resistant aspen forms in the Central Black Earth Region after the end of World War II. The works of A.V. Tyurin, O.G. Kaper, M.M. Veresin and others are well known [21]. In the following years, the research area has been expanded. Thus, in the Moscow Region (the All-Union Scientific Research Institute of Silviculture and Forestry Mechanization), Kostroma Forest Experimental Station, Kursk Region (Oboyansky Forestry), Novosibirsk Region, Leningrad Region, and others, the selection of the best aspen clones in natural forests has been carried out by A.S. Yablokov (1949, 1963), S.P. Ivannikov (1959), V.T. Bakulin (1966), S.N. Bagaev (1967) et al. [2, 3, 26, 29].

Fig. 3. The stem of aspen tree in sample plot no. 12. Savalsky Forestry of the Savalsky Forestry Enterprise, block no. 3. The Voronezh Region

In the Central Research Institute of Forest Genetics and Breeding (currently the All-Russian Research Institute of Forest Genetics, Breeding and Biotechnology), R.P. Tsareva (1984), A.P. Tsarev (1988), V.P. Petrukhnov (1988) at al. have begun to engage in the selection of the best forms of aspen, and then in hybridization of them (since the establishment of the institute in 1971) [16, 19, 21].

In the last decade, similar work has been actively carried out at the Kostroma Forest Experimental Station of the All-Russian Research Institute of Silviculture and Forestry Mechanization, at the Saint-Petersburg State Forest Technical University, at the Faculty of Forestry, Forest Harvesting, Wood Processing Technologies and Landscape Architecture at the Mytishchi Branch of the Bauman Moscow State Technical University, etc. [1–6, 27–29].

The aim of this research has been to study the survival and growth of 21 aspen clones at the age of 40, as well as their productivity (in terms of stem volume) growing in the Semiluki Tremuletum of the Voronezh Region and to select promising clones for plantation afforestation.

Research Objects and Methods

The best aspen clones have been selected for testing:

in the Right-Bank Forestry of the Educational and Experimental Forestry Enterprise of the Voronezh State University of Forestry and Technologies (clones no. 7 and 9);

in the Savalsky Forestry and in the Botanical Garden of the Voronezh State University (clones no. 11, 16, 17);

in Valuyki and Gubkin of the Belgorod Region (clones no. 14, 15);

in the Oboyansky Forestry Enterprise of the Kursk Region (clones no. 12 and 13)

in the Kostroma Region (clone no. 10).

In addition 10 new hybrids of aspen bred by Ya.Ya. Smilga (clones no. 18–27) and American aspen (clone no. 29), introduced from the Baltic States, have been obtained by way of exchange.

In 1974, V.P. Petrukhnov created a tremuletum from selected aspen clones at the Semiluki Experimental Demonstration Nursery. After his retirement, research at this facility was continued by R.P. Tsareva.

Planting has been carried out using 1-year-old grafted seedlings at a spacing of 5×5 m. 21 aspen clones have been planted. True-rooted seedlings of local aspen (clone no. 6) have been used as a control. The survival and growth of aspen clones in height and diameter have been studied in the tremuletum. The volume of stem wood has been determined (according to the tables by Hadži-Georgiev and Gogušević, 1972) [9].

Results and Discussion

An analysis of the condition of the aspen plants under study have shown that at the age of 40 their survival rate has been 80 %. At the same time, the control sample has had a survival rate of 74 %. The average height of the trees has ranged from 17.3 (clone no. 10 from the Kostroma Region) to 31.3 m (clone no. 17 from the Botanical Garden of the Voronezh State University. In the group of hybrids obtained from the Baltic States, the height has varied from 15.4 (clone no. 24) to 27.3 m (clone no. 20). The average height of the aspen clones tested in the tremuletum has been 24.5 m (Table 2).

The parameters of average diameters have varied in the first group from 28.0 to 50.0 cm, in the second – from 25.2 to 44.3 cm. Overall, the average diameter for the area has been 37.5 cm. The average volume of stems has ranged from 0.30 to 2.4 m^3, and for the entire area it has been equal to 1.06 m^3. The control group has had an average height of 19.5 m, an average diameter of 32 cm, and a stem volume of 0.61 m^3.

According to the results of the ranking by height, diameter and volume of stems, the top 5 (ranks 1–5) in terms of growth and productivity has included aspen clones no. 16 and 17 selected at the Botanical Garden of the Voronezh State University, as well as aspen hybrids from the Baltic States (clones no. 20, 23) and clone no. 29 of the American aspen. Among them there are 2 male clones (no. 20 and 29), which do not produce fluff and can be used in landscaping. The worst indicators of growth and productivity in the tremuletum have been found in some hybrids introduced from the Baltic States (clones no. 19, 22, 24, 26, 27) and clone no. 10 (rank 19) from the Kostroma Region. This may be due to the fact that the listed clones have been introduced from more northern and humid latitudes to the south-west of the country, that is, to the more arid Central Black Earth Region. The remaining studied aspen clones and hybrids have occupied an intermediate position in terms of growth and productivity.

Table 2

The rank assessment of growth and productivity of various aspen clones aged 40 growing in the Semiluki Tremuletum (at a spacing of 5×5 m)

Serial No.	Origin	Inventory no.	Average				Stem volume		Sum of the ranks	Overall rank	Sex
			height		diameter						
			m	rank	cm	rank	m^3	rank			
1	Voronezh State University of Forestry and Technologies	7	23.8	9	37.7	9	1.04	10	28	9	♂
2	Voronezh State University of Forestry and Technologies (X_5)	9	21.8	15	35.0	15	0.88	15	45	15	♂
3	Kostroma Region (No. 35)	10	17.3	19	28.0	19	0.42	19	57	19	♂
4	Savalsky Forestry	11	23.3	14	36.8	13	1.05	9	36	12	♂
5	Kursk Region (Drozdy)	12	25.0	6	39.5	7	1.20	7	20	7	♂
6	Triploid Aspen (No. 27)	13	24.4	8	38.5	8	1.11	8	24	8	♀
7	Valuyki (Belgorod Region)	14	25.0	7	39.6	6	1.20	6	19	6	♀
8	Gubkin (Belgorod Region)	15	23.8	10	37.6	10	1.03	11	31	10	♀
9	Botanical Garden of the Voronezh State University (X_1)	16	27.2	3	43.0	4	1.54	4	11	4	♀
10	Botanical Garden of the Voronezh State University (X_2)	17	31.3	1	50.0	1	2.40	1	3	1	♀
11	Baltic Aspen P_{Z13}	18	23.8	13	36.5	14	0.97	14	41	14	♀
12	Baltic Aspen P_R	19	20.0	16	28.7	18	0.51	18	52	18	♀
13	Baltic Aspen P_{zg}	20	27.3	2	44.3	2	1.64	2	6	2	♂
14	Baltic Aspen P_{22}	21	23.8	11	37.3	11	1.01	12	34	11	♂
15	Baltic Aspen P_{gg}	22	19.6	17	32.2	16	0.62	16	49	16	♂
16	Baltic Aspen P_{ns}	23	27.2	4	43.3	3	1.56	3	10	3	♀
17	Baltic Aspen P_{132}	24	15.4	21	25.2	21	0.30	21	63	21	♀
18	Baltic Aspen P_{Sv}	25	23.8	12	36.9	12	0.99	13	37	13	♂
19	Baltic Aspen P_{K43}	26	19.6	18	32.2	17	0.62	17	52	17	♂
20	Baltic Aspen P_{kxg}	27	16.2	20	26.1	20	0.34	20	60	20	♂
21	American Aspen	29	26.0	5	42.2	5	1.42	5	15	5	♂
Average:			**24.5**	**9**	**37.5**	**10**	**1.06**	**10**	**29**	**10**	–
22	**Control** (Local Aspen)	**6**	**19.5**	**17**	**32.0**	**17**	**0.61**	**17**	**51**	**17**	♀/♂

During many years of work at this field object, sexual dimorphism of the aspens has been studied. The greatest interest in this regard is the rot resistance of aspen trees of different sexes. This has made it possible to identify male aspen forms that can be used in landscaping. It has been established that 57 % of the studied forms are male clones and 43 % are female. That is, all male aspen clones (no. 7, 12) and some hybrids introduced from the Baltic States (no. 20, 21, 22, 25, 26, 27) can be recommended for landscaping, as well as a clone of American aspen (no. 29). Highly productive female aspen clones can be recommended for protective, energy and other types of plantations.

Earlier studies carried out in the Voronezh Region among male clones (on an area of 402.1 ha) and female clones (on an area of 91.6 ha) have shown that, overall, the incidence of core rot has been 33 % lower in female aspen stands than in male ones [19, 21].

The verification of these data has been carried out in aspen stands of age class V (41–50 years old) on an area of 267.2 ha. The number of trees with core rot in this class has been 33.7 % in male aspen stands, and 22.2 % in female ones. That is, female aspen stands have been affected 1.5 times less. An analysis of the data obtained on growing conditions has shown that such an advantage is observed in favourable growing conditions (B_3, C_2, C_3, D_2, D_3) (Fig. 4). In unfavorable growing conditions for aspen (B_2) male clones have been found to be more resistant to core rot.

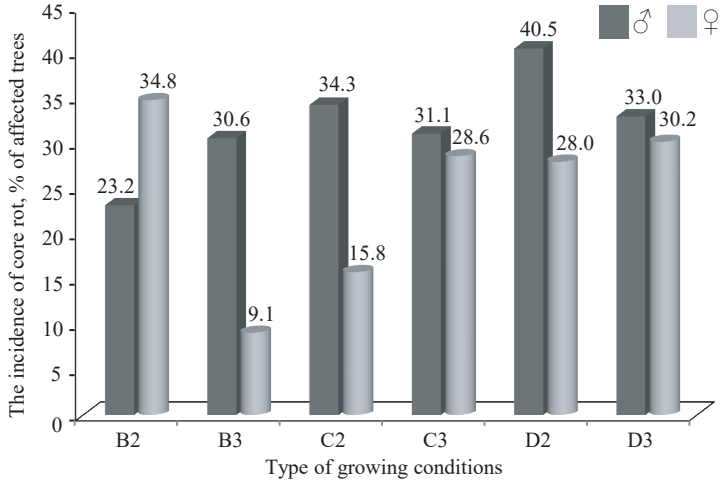

Fig. 4. The incidence of core rot in male and female aspen stands in various growing conditions aged over 30

In the current century, similar studies have been conducted in the Leningrad Region in the Lisinsky Educational and Experimental Forestry on 15 aspen clones and 35 poplar clones. At the age of 10, the height of the clones on the object has varied from 7.7 to 10.5 m, and the diameter – from 3.5 to 16.9 cm. As a result, the best clones have been selected at the site [4, 5, 27, 28].

In 2009, at the Institute of Biology (Syktyvkar) in the Komi Republic, an archive of clones of 42 hybrids and 10 clones of common aspen trees has been established. According to A.L. Fedorkov, at the age of 10, hybrid aspens have had a height of 6.4 m, a diameter of 5.1 cm, and common ones – 4.3 m and 3.1 cm, respectively. That is, at this age, hybrid aspens have exceeded common ones in height and diam-

eter by 61–65 %. The author concludes that use of hybrid aspen trees for plantation forest cultivation in the taiga zone is promising [8].

Aspen breeding has also been carried out abroad: in Germany, Sweden, Norway, Finland, Poland, Czechoslovakia, Scotland, the Baltic States, the USA, Canada, etc. [13–15, 20, 22–25].

If in the 30s of the last century aspen was considered as undesirable species in many countries, significant work is currently underway on its breeding and widespread use [13, 14, 24, 25]. The main method of obtaining healthy aspen wood in these countries is the selection of the best forms, their propagation and cultivation on plantations [7, 10–12, 17, 22].

Conclusions

1. Aspen is one of the fastest growing woody plants, which has been increasingly used in recent decades, both in our country and abroad.

2. A 40-year study of the growth and survival of 21 aspen clones in the Central Black Earth Region has shown that, according to the results of the ranking, the top 5 (ranks 1–5) have included aspen clones no. 16 and 17, selected at the Botanical Garden of the Voronezh State University; 2 hybrids (clones no. 20, 23) and American aspen (no. 29), introduced from The Baltic States.

3. Their growth rates at the age of 40 have been as follows: height – 26.0–31.3 m, diameter – 42.2–50.0 cm, trunk volume – 1.42–2.40 m^3.

4. The selected aspen clones are recommended for reproduction and their wide introduction into plantation forest cultivation in the Voronezh Region.

5. In addition, male clones introduced from the Baltic States (R_{pg} hybrid, and American aspen no. 29), which do not produce fluff, can be recommended for landscaping.

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