

Growth and breeding of aspen in Russia

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Abstract

Researches results are presented that describe variation in natural aspen stands and hybrid collections in Central European Russia. The subject of the study was the selection of the most productive and resistant to heart rot caused by fungus *Phellinus tremulae* (*Fomes ignarius*) stands. Mechanical wood properties, fodder values and other valuable characteristics of aspen are also shown. The valuable stands and hybrids which require conservation were selected for breeding and practical use.

Key words: aspen, heart rot resistant, breeding, hybrids, forms, mechanical properties, fodder value.

1. Introduction

European aspen (*Populus tremula* L.) is the second most common deciduous species after birch (*Betula pendula* Roth) among natural stands of Russia in terms of the extent of their natural habitat and the volume of merchantable volume. European aspen is a multi-purpose species. Its wood is white, flavorless and does not shrink appreciably when dried. Its markets include matches and packing material, construction, and pulp and paper. European aspen is also important as a pollen source for honey production. The vigorous production of root suckers has promoted European aspen as a preferred species for afforesting hillsides and other marginal sites. (YABLOKOV, 1963; WORRELL, 1995; KREMER, 1998; BACHOFER and MAYER, 2007; WÜHLISCH, 2009).

The Russian aspen resource is the largest in the world. The country's natural habitat of European aspen covers 23, 795,000 hectares with a standing volume 3.7 billion cubic meters, not accounting for those stands where it occurs in mixtures with other species. This area has expanded by 9.9 million ha, or 71% during the last 50 years (YABLOKOV, 1963; DISTRIBUTION..., 2011). The increase in aspen stands is owing to two main reasons: 1) Stands of mixed species composition containing as few as three aspens per hectare will regenerate to pure aspen stands due to aggressive root suckering following logging (YABLOKOV, 1963); 2) Lack of artificial regeneration programs for Russia's other commercial species: Scotch pine (*Pinus sylvestris* L.), Spruce (*Picea sp.*) and Oak (*Quercus robur*), where they occur in mixtures with aspen.

The greatest area of aspen stands is situated in the southern part of the forest zone of the European part of Russia, in the forest-steppe and in the south of Western

Siberia, where they replace primary stands of basic trees and form secondary stands replacing the previous climax forests. Aspen stands grow mainly in the *Composita*, *Oxalidosum* and *Myrtillosum* forest types. In general, aspen grows on medium rich and rich soils with normal or wet moisture conditions. It is not found in forests on poor or dry soils (*Cladinosa* forest type). It is seldom found in forests on somewhat poor dry soils (*Vaccinosum* forest type). Aspen grows in forests which are temporarily-flooded or have stagnant soil moisture (*Polytrichosa* forest type) but it forms unmerchantable, short-lived stands as also in forests with high moisture content in soil (*Carex* forest type), where it suffers severely from root rot. Aspen does not grow on peat bogs. It grows in the mixture of all types of broadleaf forests. Aspen stands in the forest zone include an admixture of forest tree species found in primary forests (spruce, fir, pine, oak, linden etc.), and sometimes also birches and alders (*fig. 1*). In small hollows in steppe conditions, aspen can be found in small blocks of pure natural stands called aspen "kolky".

The aspen stands are diverse in composition and structure on normal fresh humus of loamy podzols over blanket loam. Many aspen forests have three layers: the main layer consists of aspen and some birch; the second layer consists of spruce, oak, gray alder; the third layer is presented by the ground vegetation. Live ground vegetation cover in these forests consists mainly of majanthemum, nettle, goutweed, oxalis, fern, and meadow sweet.

Due to its ability to propagate by root suckers aspen quickly captures the area released after cutting. In the second year after cutting, there are a great many root suckers. Because of the very large number of stems on a unit area and light-demanding nature of aspen, its stands undergo intensive natural thinning from an early age. By the age of 10 years, the volume of stem-wood amounts to 40–50 m³/ha; by the age of 30 years it increases by 3–4 times (150–200 m³/ha); and by the age of 70 years the volume reaches 500–550 m³/ha. In stands growing in particularly favorable conditions, the average volume at the age of 70 years may reach 650 m³/ha. The quantitative maturity is registered at the age of 25–30 years, technical maturity – at the age of 35 years. Maximum mean annual increment is reached at the age of 40 years. In top quality stands it may be 2.9–3.9 m³/ha/yr in the centre of the species natural habitat and more than 5-7 m³/ha/yr in the Central Chernozem region (*fig. 2*).

In different European countries the mean annual increment may vary in the range 4–10 m³/ha/yr (WORRELL, 1995). G. WÜHLISCH (2009) is mentioning that aspen trees can grow to 40 m height with a trunk attaining over one meter in diameter.

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Figure 1. – The mixed composition stand of aspen, pine and spruce in Russia's European middle taiga, Konchezero, Republics of Karelia. Photo courtesy of N. V. LAUR



Figure 2. – Central Chernozem aspen stand in zone Voronezh region. The volume at age 40 is 300 m³/ha. The number of trees infected by heart rot is 25%. Forest site type is D2. Photo courtesy A. P. TSAREV

Harvesting of aspen stands is normally carried out by clear cuttings. The age of stands at clear-cutting varies depending on their state from 41 to 60 years. The normal harvesting rotation provides natural regeneration after clear-cutting. If a viable spruce is present under the storey of aspen stands then cutting of aspen will be undertaken with the objective of coniferous species conservation.

Natural forests with aspen dominant are generally secondary in succession, i. e. they grow after cutting or fire in place of spruce, pine, oak or other broadleaved species. The majority of these forests originate from root suckers and partly from stem shoots. Part of these

aspen stands is seed-originated (TREES..., 1951; YABLOKOV, 1963).

The research in the Central forest-steppe of the European part of Russia has shown that, compared with some other forest species, the productivity of aspen on a given site depends more on soil moisture conditions than on soil fertility (TSAREV, 1970).

Plantations of aspen are established by sowing seed, setting root cuttings and roots or transplanting root suckers. Many investigations were carried out with *P. tremula* in Russia and European countries and with *P. tremuloides* in North America to improve the striking roots of planting materials and growth of trees and to

find the heritability and growth gain in different conditions ((IVANNIKOV, 1958; BÖRSET, 1960; YABLOKOV, 1963; (AHUJA, MUHS, 1982; MUHS, 1987; MUHS, WUEHLISCH, 1990 – cited by WÜHLISCH, 2006); WORRELL, 1995; THOMAS, 1997; DAVID, 2003; DES ROSHERS et al., 2003; TSAREVA, 2003; HEINZE and FUSSI, 2010; TSAREV et al., 2011)).

A limitation to aspen domestication is heart rot. The causative agent of this illness is mushroom *Phellinus tremulae* (Bond.) Bond. et Boriss. (*Fomes ignarius f. tremulae* Bond.). This is included in the Fungi type, *Basidiomycota* division, *Agaricomycotina* subdivision, the class *Agaricomycetes*, *Hymenochaetales* order, *Hymenochaetaceae* family, the genus *Phellinus*.

Fruit bodies look like a narrow hat with the high basis, a keen edge and small longitudinal cracks. Very often they have a prostrate form especially if they appear on branches. Usually they grow in places of disappeared knots. Decay is concentrated in the central part of a trunk, settling down differently. On cross-sections of a trunk the decay has the following appearance: yellow-white strongly destroyed wood in the form of a wrong circle with scattered brownish closed or interrupted thin black lines is located in the central part of a trunk. Decay is separated from the healthy part by a wide – from 2 to 4 mm – brown ring-shaped strip. A ring-shaped green strip of wound nuclear wood up to 1 cm wide circulates the brown strip and is well visible on fresh cuts (VANIN, 1955). More detailed description of its culture and wood affection is given by T. Niemelä, L. Ryvarden & R. L. Gilbertson in Fungal databases (2004–2012).

Damage caused by heart rot can affect up to 100% of the trees within a stand. Consequently the selection of a resistant individuals and stands is a priority task in aspen cultivation. Other traits including productivity and wood, quality of wood are considered as well.

2. Materials and Methods

General characteristics of aspen stands in Russia are based on author's personal research data and partly on literature sources.

Selection of stands resistant to attack of heart rot, investigation of aspen growth depending on forest types, research of physical and mechanical characteristics were carried out in Voronezh region.

The investigation of natural aspen stands was carried out in massifs of the Educational and Skilled Forest Enterprise of the Voronezh State Forest-Technical Academy, the Voronezh State and Hopersky State national parks, and the Savalsky, Hrenovskoy, Tellermanovsky and Anninsky forestry enterprises, all of which are situated in the northeast forest-steppe part of the Voronezh region. These massifs are located on the border of forest-steppe and steppe zones. The latitude is 51–52° of North and 39–42° of East. The total area of aspen forests in these farms accounts for over 17 thousand hectares.

Mean annual precipitation is 450 mm. Mean annual temperature is +5°C. The predominant soil type varies from grey forest soils to chernozems. The depth to the

water table is quite variable. It is allocate three types of ground waters: 1) ground waters of watersheds with a depth from 2–3 to 10–15 m; 2) ground waters of the slopes, which depth depends on a land relief and on the power of the diluvial cover covering radical deposits, which replenishment happens at the expense of an atmospheric precipitation and an underground drain and 3) ground waters of alluvial deposits of valleys. Comparative experiments as described below were carried out in the same or similar environments.

Investigation to identify superior phenotypes was conducted using both basic and advanced techniques. Basic techniques involved usual inventory data (structure, average height, average diameter, stock, age, etc.). The advanced techniques involved in addition to inventory data a value of affecting by heartwood decay and the degree of stem straightness. Stands covering 2,000 hectares were inventoried by the basic method. In contrast, a more sophisticated technique was used in inventorying 675 separate sites totaling 890 hectares in forests of Educational and Skilled Forest Enterprise of the Voronezh State Forest-Technical Academy and 200 hectares in the other forestry enterprises. The procedure involved the collection of data on the relief, soil, heart decay, sex, character of bark, crown, branching of trunks in addition to the standard inventory characteristics.

Thirty-two (32) study plots varying in area from 0.15 to 0.60 hectares were designed to obtain exact measurements of phenotypic characteristics. The distribution of trees within each study plot categorized according to of trunk quality (good, semi-good and firewood), heart rot attack, growth classes – from I (most great) to V (weaken and least) (by Kraft, 1884 – to quoted by M. S. Melekhov, 1980), sex and other characteristics (phenological form, type and color of rind, form and size of crowns, character of branches, cleaning from branches, defeat of diseases and insects). A detailed description of the relief, soil, herb cover, undergrowth was given.

One hundred forty (140) trees were destructively sampled on all plots. Each tree was cut on two-meter sections. The diameter of sound and decay wood were measured in middle of each sections. In addition increment cores were removed from 20–30 trees in each plot to improve the accuracy of heart rot attack evaluation.

Physical and mechanical wood properties were tested in two decay resistant stands of aspen. In total 1321 samples were tested. Density, compression strength along fibers, strengths in static bending and in shock bending was established. Wood density measurements were reported on a dry weight volume basis. Modeling trees and section from them as the testing was taken and made according I. V. Yakimov (1964). The average data of physical and mechanical wood properties of Voronezh region aspen stands (YAKIMOV, 1964) were taken as control.

Studies of aspen hybrids reported in the article were carried out in field trials established in Semiluksky nursery in Voronezh region on chernozem soil by V. P. Petruchnov (TSAREV and TSAREV, 2010). The type of forest environments is D₁₋₂. The design of the experiment did not include repetitions. Each hybrid family consisted

of 32–68 hybrid trees. The spacing of trees was 3 x 3 m. Area of that collection is 0.934 ha. That Semiluksky collection includes next hybrid families: *P. tremula* X₁ x *P. tremula* (local), *P. tremula* X₂ x *P. tremula* (local), *P. tremula* (Obojan) x *P. canescens*, *P. tremuloides* x *P. tremula* (local), *P. tremuloides* x *P. alba* var. *bolleana*, *P. canescens* x *P. tremula* (local), *P. davidiana* x *P. tremula* (local), *P. davidiana* x *P. alba* var. *bolleana*, *P. Yablokovy* x *P. canescens* and offspring from open pollinated two species: *Populus tremula* and *Populus davidiana*. *P. tremula* X₁, *P. tremula* X₂, *P. tremula* (local) and *P. canescens* were selected in stands of the Educational and Skilled Forest Enterprise of the Voronezh State Forest-Technical Academy. The *P. davidiana* was taken from Semiluksky arboretum of Central Research Institute of Forest Genetics and Breeding (Voronezh). The *P. tremuloides*, the cultivar *P. Yablokov* and one clone of *P. tremula* introduced from Obojan city of Kursky region. *P. alba* var. *bolleana* Lauche introduced from Astrakhan region. The halfsibs of *P. tremula* (local) and *P. davidiana* were taken as control. Survival, height and basal diameter at height 1.3 m data were collected at age 29. Stems volume was defined according to aspen volumes table reported by TYURIN et al. (1956).

The volume of family stands on the area was defined by summation of the actual volumes of each tree remaining on each plot. Stand volume was expressed on the basis of one hectare. The following formula was used:

$$W = W' \times 10000 / S, \quad (1)$$

where: W – accounted stem wood volume, m³/ha;

W' – actual stem wood volume on plot area, m³;

S – area of the plot, occupied by one hybrid family, m²;

10000 – area of one hectare, m².

Stem wood volume of each hybrid family was defined according to these factors.

Selected components of aspen green mass (leaves, stalks and shoots) that account for its fodder value were quantified by the fodder laboratory of Voronezhsky Regional Agriculture Chemical Station. Data were collected for digestible proteins, nitrogen, calcium, phosphorus, and carotene and were studied. The contents of calcium, carotene, and phosphorus were determined by

the photo colorimetric method, Zirel's method, and the vanadium-molybdenum method, respectively, according to recommendation reported by RAZUMOV (1986).

Besides of that an integral fodder value was obtained as the number of fodder units per 1 kg of food. The Russian fodder unit designed by E. A. Bogdanov in 1922 equals 1 kg of oat or 0.6 kg of starch (ZIPER, 2003). In present work the oat fodder unit was used for estimation of fodder value.

The alfalfa green mass was used as control.

3. The results and discussion

3.1. Selection of aspen stands resistant to heart rot

As it has been said above aspen stands are often subject to heart rot. The problem of distribution of aspen heart decay in European and Russian forests was investigated by many researchers (NILSSON-EHLE, 1936; MELANDER, 1938; JOHNSON, 1942; YABLOKOV, 1941, 1949, 1963; IVANNIKOV, 1952, 1958; BAKULIN, 1966, 1969; TSAREV, 1970, 1985).

The dynamics of heart rot attack in Central forest-steppe is shown in the Table 1. Aspen heart rot begins in age class 2 (11–20 years) – about 0.6%. By the time the stand has matured to 41–50 years of age (age class 5) 31.2% of the trees were found to be affected. In stands of age class 6 (51–60 years) 59.6% of the trees were affected. And in stands of age class 7 (61–70 years) 90.4% of the trees were affected.

The volume growth of sound wood in aspen stands in a given region generally declines up to 35 years, then the merchantable volume is reduced rapidly up to 50 years of age (up to 59%), and in old stands is further reduced to 10% and even to zero. Thus, it is necessary to select aspen resistant to heart rot in order to produce healthy aspen stands with high productivity. Efforts to select aspen have been made in different regions of European and Asian parts of Russia. These resulted in the selection of aspen stands and clones resistant to heart rot (Table 2).

As shown in Table 2 there can be quite significant differences in heart rot attack and productivity in natural stands. So, in spite of similar growth conditions and age the mean infection rate of selected aspen stands is 17 times less than that of the control ones.

Table 1. – Dynamics of heart rot attack in aspen stands and proportion of sound wood in relation to age in Central Chernozem zone.

Parameters	Age class*						
	I	II	III	IV	V	VI	VII
Stems attacked by heart rot, %	0	0.6	1.6	16.1	31.2	59.6	90.4
Sound wood, % of total volume	100	95	85	75	59	20	10

* I age class of stands is 1–10 years old; II age class of stands is 11–20 years old; III age class of stands is 21–30 years old; IV age class of stands is 31–40 years old; V age class of stands is 41–50 years old; VI age class of stands is 51–60 years old; VII age class of stands is 61–70 years old.

Table 2. – Mean characteristics of plus aspen stands selected in the Voronezh region and usual aspen stands.

Experimental stands	Values	Age, years	Total volume, m ³ /ha	Heart rot affection ^{*)}	Sound wood volume, m ³ /ha	Part of sound wood, %
Plus stands	mean	45	370.0	3.8	244.8	66.2
	limits	43-46	341-391	0 – 6.1	186-295	
Usual stands (control)	mean	41	367.2	63.2	46.1	12.6
	limits	39-46	274-475	21.3-91.1	9.5-82	

* Percentage of stems on which fruiting bodies of heart rot occurred.

This leads to the fact that when general wood volume in natural stands is similar or equal the volume of sound (merchantable) wood it is many times greater in selected aspen stands than in usual ones. The comparison of mean volume of sound wood on three plots of plus stands and that on three plots of control usual stands showed that the quantity of sound wood in plus stands was 5.2 times more than that in control stands (Table 2). Determination of the degree of genetic and environmental controls of this difference can be obtained by special testing research of offspring.

3.2. Physical and mechanical wood properties of different aspen stands

The sapwood of aspen is diffuse porous in structure, white in color with a greenish shade, light in density,

and mild. Physical-mechanical parameters for two fast-growing and heart-rot-resistant stand and for control stands in the Central forest-steppe are given in Table 3.

As it is shown in Table 3, the wood density of selected stands of *Populus tremula* L. and usual ones, in which no selection have been made, differ insignificantly (0.502 and 0.500 g/cm³) for the first pair of the test areas and differ significantly (0.498 and 0.450 g/cm³) in the second ones. It is interesting, that these figures are higher than those generally reported for the North-American species *Populus tremuloides* Michx. (0.39–0.42 g/cm³) growing in its native environment (SCHREIBER et al., 2011).

The compression strength along fibers and the strength at static bend of the selected stands and usual ones differ significantly ($t = 1.8-9.2$) in favor of selecting

Table 3. – Physical and mechanical wood properties of different aspen stands (at 15% moisture content).

Properties	Selected heart-rot-resistant stands of aspen (from A. P. Tsarev)	Usual stands of aspen (from I. V. Yakimov (1964))	Coefficient of significance, $t^*)$
	$X \pm s_x$	$X = s_x$	
	Experimental plot № 3, forest site type^{**) C₂}	Control, forest site type C₂	
Density of wood, g/cm ³	0.502±0.003	0.500±0.004	-
Compression strength along fibers, kg/cm ²	359.0±2.63	331.0±3.3	6.7
Strength at a static bend, kg/cm ²	673.0±9.55	653.0±4.7	1.8
Specific work at a shock bend, kgm/cm ³	0.40±0.01	n. d. ^{***)}	n. d.
	Experimental plot № 12, forest site type E₁	Control, forest site type D₁	
Density of wood, g/cm ³	0.498±0.003	0.450±0.003	11.4
Compressing strength along fibers, kg/cm ²	355.0±2.5	300.0±5.4	9.2
Strength at a static bend, kg/cm ²	655.0±10.8	613.0±5.7	4.3
Specific work at a shock bend, kgm/cm ³	0.47±0.016	n. d.	n. d.

*) At 0.05 level of significance;

**) Forest site types were determinate by P. S. POGREBNYAK (1968);

***) n. d. – no data.

stands. It is mention that these data are average between minimal and maximal value of that characteristics. S. Eliseev and B. Ermolin (2008) were showed that in *P. tremula* the compression strength along fibers varied from 30.0 to 44.8 MPa while in our research it varied from 35.5 to 35.9 MPa at heart-rot resistant stands and from 30.0 to 33.1 MPa at usual stands. The strength at static bend of the aspen stands as a full varied from 53.2 to 83.2 MPa while in our research it varied from 65.5 to 67.3 MPa at heart-rot resistant stands and from 61.3 to 65.3 MPa at usual stands.

3.3. Growth and resistance of aspen hybrids

The best hybrid families of the Semiluksky aspen collection at 16 years of age had mean growth parameters of 14.6–15.1 m in height and 16.8–20.1 cm in stem diameter and stem volume 145–214 m³·10⁻³; these parameters exceed the control trees by 1.3–1.9 times (TSAREVA, 2003).

As the result of the long-term trialing of the genotypes in the collections many proven hybrids have been selected both for industrial plantations and as breeding material for further complex crossings and development of new cultivars (TSAREV and TSAREV, 2010).

Among hybrid offspring of the aspen it was possible to select five best productivity families (Table 4).

Two of them were obtained by crossbreeding of local plus trees [*P. tremula* X₂ x *P. tremula* (local), *P. tremula* X₁ x *P. tremula* (local)] and three – by remote hybridization [*P. tremuloides* x *P. tremula* (local), *P. tremuloides* x *P. alba* var. *bolleana* and *P. tremula* (Obojan) x *P. canescens*]. The average volume of stem wood determined in these families at the age of 29 years varied from 223 to 508 m³/ha. Heart-rot infected trees at this age were not evident. More than 60 perspective hybrids were selected. Their height at this age varied from 19 to 25 m, average diameter – varied from 25 to 40 cm, and

stem volume varied from 0.4 to 1.1 m³. These hybrids did not culminate merchantable growth and their wood volume was projected continue to increase. Thereby, the hybrid aspen stands could supply about 500 m³/ha of wood already at the age of 30 years. All trees at this age were sound.

Similar experiments conducted in Germany also report that the aspen hybrids are superior to pure species selections (WÜHLISCH, 2006, 2010; UNSELD and WÜHLISCH, 2012).

3.4. Fodder value of aspen

Analyses of food value of aspen green mass in forest-steppe region of the European part of Russia showed that it contained 0.14–0.35 fodder units per kg depending on its composition (leaves, stalks or branches) and moisture. The greatest quantity of fodder units was in shoots of young aspen scions (0.29–0.35 fodder units per kg). Leaves contained 0.25–0.29 fodder units/kg, and the lowest quantity was in stalks: 0.14–0.24 fodder units/kg. The food value of alfalfa varied from 0.24 (field moisture) to 0.49 (hay) fodder units/kg (Table 5).

The content of digestible protein varied from 9.0 g/kg in stalks to 32 g/kg in leaves. It was less than that of alfalfa (34–40 g/kg). The calcium content did not differ significantly from that of alfalfa. The concentration in fresh green mass of aspen was 3.15–14.92 g/kg, while in fresh mass of alfalfa it was 4.5–5.04 g/kg. But the content of this ingredient in absolutely dried alfalfa reached 19.3 g/kg. The aspen content of phosphorus varied from 0.59 to 1.52 g/kg. It was more than in fresh alfalfa (0.64–0.70 g/kg) but less than in absolutely dried alfalfa (2.5 g/kg) or in alfalfa hay (2.21 g/kg). The content of carotene in aspen green mass was 28–75 mg/kg. In fresh alfalfa it was 29–96 mg/kg and in alfalfa hay – 20–86 mg/kg.

So the aspen green mass is comparable with alfalfa green mass.

Table 4. – The average growth indices of aspen hybrid families in Semiluksky collection of Voronezh region at age 29 years.

Hybrid families of aspen	Planted, seedlings	Survival, %	Growth indices		Mean stem volume		The size of family plots, m ²	Wood volume, m ³ /ha	Wood volume,	
			Mean height, m	Mean diameter, cm	m ³	rank			rank	%
<i>P. tremuloides</i> x <i>P. tremula</i> (local)	147	49.7	18.5	24.3	0.42	4	1150	267	3	156
<i>P. davidiana</i> x <i>P. tremula</i> (local)	168	41.1	16.8	21.2	0.29	8	1300	156	9	91
<i>P. davidiana</i> x <i>P. alba</i> var. <i>bolleana</i>	89	44.9	16.3	20.3	0.26	10	810	129	10	75
<i>P. tremula</i> , X ₁ x <i>P. tremula</i> (local)	148	81.8	17.5	22.4	0.34	6	1550	266	4	156
<i>P. tremula</i> , X ₂ x <i>P. tremula</i> (local)	50	80.0	19.2	25.9	0.50	2	390	508	1	297
<i>P. tremuloides</i> x <i>P. alba</i> var. <i>bolleana</i>	32	43.8	18.0	23.3	0.38	5	160	331	2	194
<i>P. canescens</i> x <i>P. tremula</i> (local)	150	43.3	17.0	21.6	0.31	7	1010	199	7	116
<i>P. 'Yablokovy'</i> x <i>P. canescens</i>	60	46.7	18.6	24.3	0.42	3	580	204	6	119
<i>P. tremula</i> , Obojan x <i>P. canescens</i>	40	42.5	20.1	28.0	0.60	1	460	223	5	130
<i>P. tremula</i> (local, halfsibs, control)	136	54.4	16.7	20.9	0.28	9	1230	171	8	100
<i>P. davidiana</i> (halfsibs)	73	41.1	15.6	18.4	0.21	11	700	88	11	51
Total and average	1093	52.2					9340			

Table 5. – Compositional analysis of aspen green mass for fodder value.

Fodder Source	Number of analyzed samples	Content in one kilogram of natural moisture fodder					Moisture Content %
		Fodder units, kg	Digestible protein, g	Calcium, g	Phosphorus, g	Carotene, mg	
Aspen leaves	13	0.25-0.34	17.0-32.0	3.83-14.92	0.68-1.52	28-75	51.4-63.1
Aspen stalks	11	0.14-0.24	9.0-19.0	3.15-10.26	0.59-0.95	n. d.	47.5-58.3
Shoots of young aspen scions (stalks + leaves)	8	0.29-0.35	18.25-28.88	3.86-6.47	0.86-1.24	33-64	57.2-64.5
Alfalfa**	n. d.	0.17-0.22	38-40	4,5	0,7	29-96	n. d.
Alfalfa***	n. d.	0,24	34,0	5,04 /19,3*	0,64 /2,5*	46,0 ±4,2	74,2
Alfalfa hay****	n. d.	0,49	87-101	14,37	2,21	20-86	17,0

*) Under absolutely dry moisture.

**) SHCHEGLOV, BQYARSKY, 1990; ZIPER, 2003.

***) TSAREV, MIRONENKO, 1993.

****) AVRAMENKO, 2003; ZIPER, 2003.

n. d. – no data.

4. Conclusion

– The aspen is a widely distributed and important deciduous forest species in Russia.

– It is very sensitive to attack of heart rot so the main object of its domestication is the selection of the most productive and resistant forms.

– Some of the aspen stands selected in Central Chernozem zone showed high resistance to heart rot attack. The mean volume of sound wood of these stands was many times larger than that of the usual stands. More accurate data can be obtained in the course of research including special progeny tests.

– The wood density of selected heart rot resistant stands didn't differ from that of usual control ones. The other mechanical wood properties (the compression strength along fibers and the strength at static bend of the heart rot resistant stands) were average between minimal and maximal value of that characteristics.

– The local aspen hybrids in Voronezh region had the volume of wood of 300-500 m³/ha at the age of 29 years with very high output of sound wood.

– The food value of aspen leaves was close to that of fresh mass of alfalfa.

– As a whole, the aspen presents a valuable resource of wood and possesses other useful characteristics. Rational use of this aspen potential can bring in an essential contribution to transformation of forest cultivation in this high revenue branch of the country economy.

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