Quality and quantity of poplar plantations on postagrogenic land Northwest region of Russia

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Abstract. A study was carried out at the plantations of the genus Populus in the Leningrad Region, formed on lands previously used in agriculture, on soils underlain by carbonate rocks. It is noted that in the studied stands, stem phytomass is produced, exceeding the natural aspen forests in the studied area. Minor damage by stem rot is noted only in the fragrant poplar forest. An increase in the initial density of forests increases the density of poplar wood, but reduces the total stock of the stand and stem phytomass. The conducted studies have shown the promise of growing.

1. Introduction
The attention of forest scientists and practitioners in many countries around the world is increasingly turning to fast-growing, high-performance tree species. The representatives of the genus Populus can definitely be attributed to such species [1-6]. Growing poplars on plantations is one of the ways to provide raw materials for pulp and paper production. The productivity of plantations of various types of poplars is currently being studied all over the world. Poplar wood is used most intensively in China, India, and in the countries of South America, where poplar plantations have been formed on millions of hectares [5, 7]. In the USA, Canada, Scandinavia, the Baltic States, considerable work has been done to obtain clones of aspen hybrid (P. tremula x P. tremuloides). In the more southern regions, work is focused on obtaining improved clones of poplars and their hybrids, among them the hybrids obtained using P. deltoides, P. maximowiczii, P. trichocarpa, etc. are particularly notable [8, 9]. Special research institutes and experimental stations in Italy, Turkey, Hungary, Bulgaria, the USA, Canada, Poland, Estonia, Sweden, Finland, and Russia are working on solving the problem of increasing the productivity of poplar plantations [1, 3, 5, 6]. The creation of forest plantations of hardwood is a promising direction to ensure the raw material independence of the enterprise. Therefore, the use of innovative technologies reduces the harvesting period to 20 years, and the creation of these plantations on unused agricultural lands solves the issue of their location.

The quality of wood is one of the main indicators of the selective value of new forms, varieties and hybrids and selection work is aimed at improving it. The productivity and quality of the raw wood produced is of primary interest. The density parameters of wood allow us to evaluate the strength,
shrink, mechanical properties of wood, the properties of the resulting paper and chipboard, the caloric value of energy chips and pellets.

When studying the question of the profitability of creating plantations from the genus Populus species for pulp and paper production, a number of criteria are put forward that these species must meet, in particular regarding growth rate, wood density, pulp yield during cooking, etc. [5, 6]. The density of the original wood for the pulp and paper industry should be in the range of 350–450 kg/m³, since at its lower value the transport costs increase, and the productivity of the cooking sections decreases, and at a higher density, the pulp has low strength properties [6, 10]. Therefore, in European countries, great interest from many hardwoods was shown to poplars, which had a high growth rate. Poplars are most suitable as fast-growing species for plantation cultivation.

Taking into account the shortage of wood, there are opinions that due to the reduction of land for agricultural needs in Europe, they should be used to create forest plantations [5, 6, 10, 11]. Thus, the density of the wood of the Populus family is a key indicator, both for foresters and for its consumers. When creating such plantations, it is necessary to know at what age a certain stock of poplar wood accumulates and when this wood has the highest density in order to get the maximum profit from the use of grown wood.

In order to assess the quality of wood and productivity of poplar plantations, forest crops of various types of poplars in the Leningrad region on lands previously used in agricultural circulation were examined.

2. Experimental part

Two plots of hybrid poplar plantations (*Populus newesis* Bogd.) grounded by cuttings on the former haymaking on sod-podzolic soils on the carbonate moraine (No. 1-2) in the Gatchina district of the Leningrad region [12, 13] were studied. The forest crop (No. 3) of the fragrant poplar (*Populus suaveolens* Fisch) on the former arable land on podzolized sod-carbonate soil in the Volosovsky district was also studied [14].

The Neva poplar obtained by P L Bogdanov in 1934 from a hybrid family - *Canadian × Balsam* poplar [12]. The first plot was grounded in 1963. Cultures were grounded on pre-treated soil with Kolesov’s sword. The planting scheme 6x2 m, density 850 trees/ha. The second plot was grounded in 1972. The planting scheme is 3x2 m, density is 1700 trees/ha.

The third plot was grounded on the former arable land near the village of Tervolovo in 1972 on podzolized sod-carbonate soil. Cultures were grounded by cuttings on the soil treated with agricultural plows by Kolesov’s sword. Double rows, the planting scheme - 2x1x0.4 m, density - 16 thousand trees ha⁻¹. Biometric measurements of forest stands were carried out by the generally accepted taxation method - the diameters were measured at a height of 1.3 m with a continuous count and the heights - at the modal trees. The reference density of wood was measured by the method of maximum moisture on wood samples selected by the Pressler’s borer [10]. For determining the average reference density of poplar wood for the age of 50–60 years (1) and for the age of 30–40 years (2), the previously formulated conversion equations were used [15]:

\[
y = 0.41x + 207.81 \\
y = 1.1
\]

\[
R^2 = 0.70 \\
R^2 = 0.90
\]  

(1)  
(2)

where \(x\) — \(\rho\), reference wood density (kg /m³) at a height of 1.3 meters.

The equations make it possible to determine the density of wood in a tree over the entire height of the trunk by taking only a sample at a height of 1.3 m.

3. Results and Discussion

At the plots of hybrid poplars (*Populus newesis* Bogd.) grounded on the former haymaking, 68% of the planted trees remained in the first plantation at the age of 51 (see Table 1). This plot is characterized by large tree sizes with straight and even trunks. The crown is drying out in 10-15% of the remaining trees. Poplar stand at the plot is in the final stages of active growth. At the second plot in
the plantation of 42 years, the capacity for tree survival is almost 72% (see Table 1). The trees at this plot have mostly straight trunks, but you can observe the slope of the trunk, especially in the upper part. The drying out of the crown is not more than 5%. Poplar stand at the second plot is in the phase of active growth. Comparison of the wood stock at these two plots of poplars in plantations on former agricultural lands showed that the stock of wood in these hybrid populations exceeds the stock in natural aspen stands (Populus tremula L.) on forest land in 1.5-2 times for the boreal zone of Russia [15-17].

**Table 1.** Taxation characteristics of hybrid poplars plantations (Populus newesis Bogd. and Populus suaveolens Fisch).

| Plot | Age, years | Density, st/ha | Average DBH, cm | Average height, m | Standing volume, m³/ha | Steam phytomass, t/ha |
|------|------------|----------------|-----------------|------------------|------------------------|----------------------|
| 1    | 51         | 406            | 40.0            | 34.8             | 474                    | 168                  |
| 2    | 31         | 1111           | 21.6            | 25.8             | 435                    | 152                  |
| 3    | 43         | 3750           | 16.0            | 16.8             | 332                    | 119                  |

At the third plot of the poplar plantations of 16,000 trees / ha of primary plantation, only 3750 pieces/ha remained, that is, only 23.4% of the planted trees remained. The stock at this plantation corresponds to a modal aspen plantation of I b bonitet class at the age of 40 years. The average diameter and average height at this plot are low for the stand of this age. Because of the very high original density, and, accordingly, strong competition, most of the trees died. The same causes uneven growth of the remaining trees and their biometric indicators.

It should be noted that the quantitative representation of trees of medium and large categories up to 75-80% of the total number is observed in the stands of the Populus newesis (plot 1-2). At the plantation of the fragrant poplar (plot 3), 80–85% of the total number of trees have a diameter of 12–16 cm, which, as already noted, is associated with a high original density.

The study showed that the damage caused by butt and stem rot in result of various wood-destroying fungi activities in the studied plantations near the Populus newesis is not currently observed; this was revealed through the selection of wood cores along the entire length of the trunk of modal trees. The variability of wood density in thickness steps in plantations at the age of 31 years ranges from 338 to 357 kg/m³ and increases by the age of 50 years from 338 to 370 kg/m³.

At the age of 43 in the fragrant poplar plantations, there is a large variability in the density of wood in thickness steps from 316 to 478 kg/m³, which is probably due to the greater density of the stand. It is also necessary to note the presence of stem rot in 10-15% of trees of small thickness steps (12-16 cm at a height of 1.3 m). In terms of physic-mechanical properties, the forms of poplars that are resistant to core rot have more dense wood, predominantly of mechanical tissue (libriform), which is 64% or more. Weakly resistant forms of poplars have crumby, soft wood, in which the libriform is 50% [10, 16, 17, 19].

The data obtained as a result of the study on the density of the Populus newesis wood shows that at different age stages the most dense wood is formed in the thickness steps of different dimensions along the distribution of tree trunks (Figures 1-2).

In the fragrant poplar forests, there is a decrease in the density of wood from smaller to larger thicknesses of trees, in contrast to plantations of the Populus newesis, where this indicator does not have such a pronounced dependence on tree trunk size categories (Figure 3). The magnitude of density indicators of the fragrant poplar wood in steps of the stand thickness is higher than in the stands of the Populus newesis forests at different age stages. This is probably due to the higher density of this forest than the Populus newesis plantations. It is possible to note the obvious regularity that with an increase in the density of trees at a plantation, the density of wood increases, but the stem stock decreases and, consequently, the stem phytomass of the plantation as a whole decreases (see Table 1).
Figure 1. Reference density of the Neva poplar (*Populus newensis* Bogd.) at the age of 31 years.

Figure 2. Reference density of the Neva poplar (*Populus newensis* Bogd.) at the age of 51 years.

Figure 3. Reference density of the fragrant poplar (*Populus suaveolens* Fisch.) at the age of 43 years.
In aspen (*Populus tremula* L.), relatively dense wood is formed by the age of 20–25, then its decrease is observed to 35–40 years. The maximum density of these species is observed at the age of 60-70, then again a slight decrease follows [5, 10, 16, 18, 19, 21]. In general, the average reference density of the *Populus newesis* wood in the studied plantings is 350-354 kg/m³, and in the fragrant poplar is 360 kg/m³, which is lower than that of aspen (*Populus tremula* L.) - 400-410 kg/m³ in the studied region. However, it should be noted that the damage caused by butt and stem rot in result of various wood-destroying fungi activities in the studied plantations is actually either not observed, or affects a small number of trees (5-10%); this was revealed through the selection of wood cores for the length of the modal tree trunk. In aspen stands in the studied region, there is a widespread damage by the tinder conk and false tinder conk (*Fomes fomentarius, Phellinus tremulae* Bond.) from the age of 20-25 years, depending on the origin of the stand [5, 20]. In order to create plantations for the accelerated production of biomass for the needs of bioenergy and pulp and paper and wood chemical production, these poplar hybrids are of undoubted interest and it is necessary to continue to conduct clonal selection for growth rate and wood density.

4. Conclusion
The conducted study allows making the following conclusions:

1. The studied poplar plantations (*Populus newesis* Bogd, *Populus suaveolens* Fisch.) at this age have the stock of wood exceeding the stock of modal aspen stands in the studied region.
2. The density of poplar wood in plantations is lower than the average density of aspen wood in natural forest stands.
3. A little damage by the stem rot in the studied plantations is observed only in the plantations of the fragrant poplar (*Populus suaveolens* Fisch.).

In order to obtain a wood of good value, it is necessary to reduce the density in poplar plantations in the forest crops on the postagrogenic lands in a timely manner.

4. The studied plantations can be a source of further work on selection of the resistant to stem rot tree forms and trees with high density wood.

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