Biological and economic features of the ‘Voronezh Giant’ hybrid poplar

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Abstract. The purpose of this publication is to generalize the available experimental data on the survival, growth, stability, technical and other characteristics of this hybrid and to clarify proposals for its practical use. Long-term studies have been carried out on the five variety testing sites in various soil and climatic zones of the South-Eastern part of Russia and in Ukraine. The survival rate of this poplar were quite high (from 75 to 96%), on average 81%. The age of economic exploitability in the forest-steppe zone with a 20 m² feeding area per tree was equal to 29 years. To this age the ‘Voronezh Giant’ accumulated stem wood stock of 550-640 m³/ha. The duration of shoot growth was 146 days, and the growing season was 177 days. It was distinguished by high winter hardiness, relative drought resistance, wind resistance, low damage by primary and secondary entomopests, and affection with phytodiseases, but a low straight trunk. It has a fairly high timber density, the length of the wood fiber and the cellulose content, which is important for the pulp and paper industry. The freshly picked green leaves of this poplar are close to the nutritional value of meadow herbs and lucerne. In general, the poplar ‘Voronezh Giant’ is promising for growing wood pulp, introducing into energy, shelter-belts, roadsides, riversides and other reclamation plantings. Given into account its male gender and high decorativeness, it can be also recommended in the greenery landscaping.

1.Introduction
Starting from the 30th of the XX century, domestic and foreign forest tree breeders began to engage not only in the selection of the best trees in natural plantings, but also in the development of new forms by hybridization: Stout et al [1], Stout & Schreiner [2], Pauley [3], Albensky [4], Yablokov [5], Ivannikov [6], Starova [7], Besschetnov [8], Veresin [9], Stanton [10], Stanton et al [11], Tsarev et al. [12]. In this work, the authors attempted to illuminate some biological and economic features of one of the promising hybrids of Russian poplars – the ‘Voronezh Giant’.
Poplar ‘Voronezh Giant’ was obtained by Professor of the Voronezh Forestry Institute (currently: Voronezh State University of Forestry and Technologies named after G F Morozov) M M Veresin in the spring of 1952 from crossing on cut branches. *Populus deltoides* Marsh. was used as a female parent tree. The male parent tree has not been determined yet with sure. According to Professor M M Veresin, a mixture of pollen from *Populus alba* L. and *Populus tremula* L. was used for this pollination variant. However, the obtained and selected hybrid with the original name ‘E.s.-38’ (Elite seedling No 38) was similar in a number of phenotypic features with *Populus balsamifera* L., which was used in the same series for hybridization with other female parent plants. And thus, it was assumed that the paternal plant of the obtained hybrid, named later by its breeder ‘Voronezh Giant’, was *Populus balsamifera* L. [13].

Cytological analysis of this hybrid had showed that it is a mixoploid with a predominance (78.4 %) in somatic cells of a triploid (3n=57) set of chromosomes including 19.6 % of diploid and aneuploidy cells (2n = 38) and 1.9 % of tetraploid cells [14].

The study of the growth and other characteristics of this hybrid by Professor M. M. Veresin [9] and his students and followers (mainly in the collections of the Voronezh region) showed that it can be promising for cultivation [15-18].

The first results on the growth of this poplar in various physical types of forest in Voronezh, Donetsk (Ukraine) and Astrakhan’ regions were based on the growth of 7-11-years old plants [13]. To now date, a number of new data has been obtained in the course of long-term variety testing, which can help to more objectively assess the phenotypic characteristics of this hybrid and the prospects for its use in various types of plantings.

The purpose of this work was to generalize the available experimental data on the survival, growth, stability, technical timber and other characteristics of this promising hybrid, obtained by the authors, and to make more precise proposals for its practical use.

2. Methods and Materials

The study of the surviving and growth of the hybrid ‘Voronezh Giant’ was conducted in the Voronezh, Volgograd and Donetsk (Ukraine) regions. In the Voronezh region, long-term research was conducted on the Semiluky populetum and Zemlyansk variety testing site created by A P Tsarev, as well as on the Khokhol variety testing site laid down by the group of breeders of the Central Research Institute of Forest Genetics and Breeding (currently: All-Russian Research Institute of Forest Genetics, Breeding and Biotechnology). In the Volgograd region the growth and sustainability of the poplar was studied on the testing site in the floodplain of Kumylga river created by employees of Podtelkovsky Forestry under the direction of R P Tsareva. In the Donetsk region the testing sites was created in the Fedorokva forest area of the Mariupol' Forestry under the methodical guidance of A P Tsarev in the floodplain of the Karatysh river.

Regular or sporadic measurements on the plots were carried out by complete listing of trees. At the same time, we studied the survival of plants, the dynamics of growth in height (at an early age using a measuring pole, and then – using the German altimeter “Blume Leiss”), the diameter at a height of 1.3 m (using a measuring tape with subsequent translation into diameters). The volume of trunks was determined with growth tables for poplars by Hadži-Georgiev and Goguševski [19].

The wood stock was determined by summing the actual volumes of survived poplar trees on the area of each plot and converting the resulting amount of stock to an area of 1 ha.

In the study of phenological development the beginning of vegetation and growth of shoots, the end of growth of shoots, and the end of vegetation was noted. Within each phenophase plants were evaluated on a five-point scale: 1 –very early start of the phase, 2 –early, 3 – average, 4 – later and 5 – very late start of the phase. Winter hardiness was assessed on the following scale: 1 – highly hardy – did not freeze even in severe winters; 2 – hardy-slightly froze in severe years, and in normal winters did not freeze; 3 – conditionally hardy – significantly froze in severe winters, slightly froze in normal years; 4 – weakly hardy and not hardy – noticeably froze even in normal years, and in severe winters – damaged very much until complete death. A 4-point scale was used to assess drought tolerance: 1 –
highly drought-resistant; 2 – drought-resistant; 3 – medium drought-resistant; 4 – weakly drought-resistant. Damage by primary entomopests was assessed on a 2-point scale: 0 – no damage; 1 – weak damage. Damage by secondary entomopests was assessed on the following scale: 0 – no damage, 1 – weak damage, 2 – medium damage, 3 – strong damage. Phytodiseases incidence: 1 – high-resistant – the percentage of disease development for all years of observation did not exceed 10%; 2 – resistant – the percentage of disease development was 11-25%; 3 – medium-resistant – the percentage of disease development was 26-50%; 4 – low-resistant – the percentage of disease development reached 51-75%; 5 – very low-resistant – the percentage of disease development exceeded 75%.

The straightness of the trunks: 1 point – the trunk is straight from base to apex; 2 points – a trunk before the start of the crown is straight, and in the crown bends, splits, or loses its straightness; 3 points – the trunk is bent or the forks (many trunks) prior to the crown; 4 points – bushy form of the trunk (for clones, strongly affected by the winter frosts).

The density and length of timber fibers were estimated by V K Shyrnin [20] on samples prepared from branches of growing trees. This method was used to avoid destroying trees on the variety testing site.

The conditional timber density was determined by O I Poluboyarinov [21]. The length of the libriform fibers was measured in the last ring of annual growth. In addition, the study of technical timber indices in an adult 40-years old tree from the Semiluky populetum was conducted. In the cut down tree fourcut rings were taken (at root neck of the tree, at a height of 1.3 m, at 1/2 and 3/4 of the height of trees), which were sent for experimental timber pulping in the Innovation and Technology Center of the Northern Arctic Federal University (Arkhangelsk). Samples of aspens growing in the Voronezh and Arkhangelsk regions were used as a control.

The study of the forage value of the tree green mass was conducted on annual terminal shoots from the poplars collection at the age of 18 years and on 1-year shoots from the 10-years old reproductive cutting plantation located in the Semiluky breeding nursery in the Voronezh region grown on typical chernozem soil. In each sample, an integral indicator of feed value – the number of oat feed units was determined [22]. In addition, the amount of raw protein, raw fat, fiber, nitrogen-free extractives (NFE), carotene, sugar, water (sample humidity), and ash was estimated. Additionally, the content of trace elements was also studied: calcium, phosphorus, and potassium.

Standard mathematical methods were used for processing data on various quantitative characteristics [23-25] and Excel electronic program.

3. Results and Discussion
The survival of ‘Voronezh Giant’ poplar plants in various growing conditions is shown in table 1.

| Variety testing sites | Planted plants, examples | Accounting age, years | Survival examples | % |
|-----------------------|--------------------------|-----------------------|------------------|---|
| Ksenevsky (Donetsk region) | 52 | 21 | 42 | 81 |
| Khokhol (Voronezh region) | 24 | 22 | 18 | 75 |
| Kumylga (floodplain at Volgograd region) | 159 | 30 | 133 | 84 |
| Zemlyansk (Voronezh region) | 213 | 25 | 162 | 76 |
| Semiluky populetum (Voronezh region) | 48 | 40 | 46 | 96 |
| Total and average | 496 | 21-40 | 401 | 81 |

From the data in table 1 it can be seen that the survival of the poplar ‘Voronezh Giant’ was quite high at all testing sites, but the highest was observed in the Semiluky populetum on the Chernozem soil. Perhaps this is due to the fact that this site, which is closest to the Institute, had the possibility of regular monitoring and care in the first years after setting up.
The growth and productivity of ‘Voronezh Giant’ poplar in various growing conditions are shown in table 2.

| Table 2. Growth and productivity of the poplar ‘Voronezh Giant’ in various environments. |
| --- |
| Age, years | Survival, % | Height, m | Diameter, cm | Trunk volume, m³ | Wood stock, m³/ha | Increment, m³/ha per year average current |
| --- | --- | --- | --- | --- | --- | --- |
| **Semiluky populetum (placement of trees 5×4 m)** | | | | | | |
| 5 | 100 | 8.1 | 0.11 | 12.9 | 0.16 | 0.06 | 30 | 6.0 | 1.2 |
| 10 | 98 | 18.1 | 0.16 | 24.7 | 0.43 | 0.37 | 181 | 18.1 | 30.2 |
| 15 | 98 | 20.6 | 0.22 | 29.1 | 0.63 | 0.58 | 284 | 18.9 | 20.6 |
| 20 | 98 | 25.3 | 0.25 | 32.3 | 1.05 | 0.81 | 397 | 19.8 | 22.6 |
| 25 | 98 | 28.5 | 0.22 | 36.6 | 0.89 | 1.14 | 569 | 22.8 | 34.4 |
| 30 | 98 | 29.7 | 0.19 | 39.1 | 1.07 | 1.33 | 652 | 21.7 | 16.6 |
| 35 | 98 | 31.6 | 0.17 | 40.5 | 1.41 | 1.48 | 738 | 21.1 | 17.2 |
| 40 | 96 | 32.0 | 0.14 | 41.5 | 0.61 | 1.60 | 764 | 19.1 | 5.2 |
| **Zemlyansk variety testing site (placement of trees 3×3.5 m)** | | | | | | |
| 5 | 81 | 6.7 | 0.10 | 7.8 | 0.18 | 0.02 | 13 | 2.6 | 0.5 |
| 11 | 78 | 14.6 | 0.13 | 21.0 | 0.36 | 0.23 | 144 | 13.0 | 22.8 |
| 16 | 77 | 19.9 | 0.22 | 26.6 | 0.45 | 0.46 | 283 | 17.7 | 27.8 |
| 20 | 77 | 22.0 | 0.18 | 30.3 | 0.48 | 0.62 | 383 | 19.1 | 24.8 |
| 25 | 76 | 23.4 | 0.19 | 32.8 | 0.74 | 0.77 | 475 | 19.0 | 18.4 |
| 42 | 70 | 29.7 | 0.49 | 41.3 | 0.69 | 1.46 | 818 | 19.5 | 19.8 |
| **Ksenevsky variety testing site (placement of trees 3×3 m)** | | | | | | |
| 5 | 98 | 7.5 | 0.10 | 9.6 | 0.30 | 0.03 | 32 | 6.5 | 1.3 |
| 10 | 98 | 16.1 | 0.35 | 19.2 | 1.06 | 1.00 | 216 | 21.6 | 36.8 |
| 15 | 98 | 20.2 | 0.20 | 22.8 | 0.40 | 0.32 | 323 | 21.6 | 24.4 |
| 21 | 81 | 25.5 | 0.24 | 26.2 | 0.48 | 0.52 | 481 | 22.9 | 26.3 |
| **Khokhol variety testing site (placement of trees 3×3 m)** | | | | | | |
| 22 | 75 | 23.7 | 1.31 | 26.3 | 1.87 | 0.53 | 454 | 20.6 | no data |
| **Kumylya variety testing site (placement of trees 4×4 m)** | | | | | | |
| 30 | 84 | 24.5 | 0.36 | 28.1 | 1.04 | 0.55 | 619 | 20.3 | no data |

The data in table 2 shows that the ‘Voronezh Giant’ poplar already by the age of 15 years accumulated reserves exceeding 280 m³/ha. The average increment by this age was 17-20 m³/ha per year. It should be noted that our mainly spread poplar *Populus tremula* L. in 1° stand quality class of native stands had an average increment only 6.5 m³/ha per year at this age [26], i.e. three times less.

The age of economic exploitability was established at the Semiluky testing site, where the most frequent measurements were made (figure 1). From these data, it can be seen that this index at the Semiluky populetum for the poplar ‘Voronezh Giant’ was 29 years old. By this time the ‘Voronezh Giant’ was accumulated the stock of stem wood about 556-641 m³/ha. By this age the 1° stand quality class of aspen stands (*Populus tremula* L.) had a stock of stem wood less than 200 m³/ha [26].

The study of the phenological development of the ‘Voronezh Giant’ hybrid in the forest-steppe zone showed that it characterized by the early start of vegetation and growth of shoots and by the average finish of vegetation. On average, the duration of growth of shoots is 146 days, and the duration of vegetation is 177 days.

It belongs to high-hardy (score 1) and drought-resistant varieties (score 2). In terms of wind resistance, it is inferior to white and black poplars, but significantly exceeds this indicator for balsamic poplars. So, in the forest-steppe, the number of wind-damaged ‘Voronezh Giant’ poplar trees was 4.2-13%, while the number of wind damaged balsam poplars in some years reached 30-90%.
Damage by primary and secondary entomopests of this hybrid was weak or absent. Damage by leaf rust was high (up to 5 points). The incidence of other diseases was low (1-2 points). However, it should be noted that leaf rust did not significantly affect the growth and productivity of this hybrid.

The straightness of the trunks of this poplar is low (2-3 points). Therefore, it is preferable to use it in greenery landscaping, land reclamation and energy mini-rotation plantations.

The technical timber properties evaluated both on cut branches and on an adult plant, allowed us to obtain new results. The timber density determined by V K Shyrnin [20] on cut branches was 461±6.2 kg/m³, and the length of timber fibers ranged from 864±19.8 to 875±87.5 microns. Experimental timber pulping from a 40-year-old tree of this poplar revealed the percentage of cellulose yield, which varied from 57.5 % to 61.9%. This indicator was higher than that of the green-bark aspen growing in the Voronezh region and the aspen from the Arkhangelsk region by 7.4-15.2%.

The average length of the timber fibers of the ‘Voronezh Giant’ hybrid before grinding varied from 1.138 to 1.144 mm, and after grinding – from 1.014 to 1.027 mm. The average width of the timber fibers before grinding was 29.9-30.0 microns, and after grinding – 30.4-30.5 microns [27].

The results of the study of the feed value and chemical composition of freshly harvested ‘Voronezh Giant’ poplar leaves showed that one kilogram contains 0.24±0.003 oat feed units/kg. The content of digestible protein was 28.7±2.8 g, calcium – 4.9±0.6 g, phosphorus – 0.7±0.05 g, carotene – 77±12.5 mg. At 72% humidity, the content of crude protein ranged from 4.38 to 6.13%, crude fat – 0.32-0.41%, crude fiber – 3.49-3.59%, nitrogen free extractives – 16.2-17.7%, ash – 2.3 – 2.5%.

Comparison of the nutritional value of freshly harvested leaves with similar samples of herbaceous vegetation showed that the fodder value of ‘Voronezh Giant’ poplar leaves is close to the indices of grass in flood plain meadows and even lucerne.
4. Conclusions
Long-term studies of biological and economic characteristics of M M Veresin’s hybrid poplar ‘Voronezh Giant’ in various soil and climatic environments of South-Eastern part of Russia and Ukraine allowed us to make the following conclusion.

The survival of this poplar throughout all the years of research (from 21 to 40 years) was quite high and ranged from 75 to 96%, averaging 81% for 5 studied testing sites.

The study of growth dynamics allowed us to establish that by the age of 15 years this poplar hybrid accumulated a stock of stem wood exceeding 280 m³/ha, with a variation in the average increment from 17 to 20 m³/ha/year, which is three times higher than the average increment of native aspen stands at the same age.

The age of economic exploitability in the forest-steppe zone with a feeding area of 20 m² per tree was equal to 29 years. By this time, the Voronezh Giant was accumulating wood stock of 550-640 m³/ha. Native Iº stand quality class of aspen stands (Populus tremula L.) in the forest-steppe zone had a wood stock less than 200 m³/ha by this age.

The duration of growth of its shoots was on average 146 days, and the duration of vegetation was 177 days.

It is characterized by high winter hardiness, acceptable drought and wind resistance, low damage by primary and secondary insects and plant diseases. But it is characterized by a low straightness of the trunk.

‘Voronezh Giant’ has a fairly high timber density, length of timber fiber and cellulose content, which is important for the pulp and paper industry.

The study of the feed value of wood greens by a set of characteristics (feed units, the amount of raw protein, raw fat, fiber, nitrogen-free extractives, carotene, sugar, calcium, phosphorus, potassium, etc.) showed that the freshly harvested green leaves of this poplar are close to the feed value of meadow grasses and lucerne and can be used in animal husbandry when there is a shortage of feed.

In General, ‘Voronezh Giant’ poplar is promising for growing wood pulp, introducing to energy, protective, roadside, riverside and other reclamation plantings as well as, given into account its male gender and high decorative value, in greenery landscaping of cities and other localities.

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