Results of the intersectional poplar hybrids’ testing in the Central Chernozem region

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Abstract. The main purpose of this work is to summarize the results of long-term variety testing of the intersectional hybrids obtained from controlled crosses of balsamic poplars with black and black poplars with balsamic ones. The research objectives were to study the growth, sustainability and productivity of intersectional poplar hybrids and to select the best of them. The object of research was the collection and testing site (populetum) made in 1974 on Typical Chernozem soil by stem cuttings with arrangement place 5×4 m in Semiluki forest nursery situated in Voronezh region. 13 clones of intersectional poplar hybrids were introduced into the test. The results of 40-year studies of their survival, height and diameter growth, trunk volume and wood stock dynamics are presented, which allowed identifying the most promising poplars’ intersectional hybrids proposed in the assortment for the creation of the most fast-growing and sustainable forest and shelter belt plantations in the region. By the age of quantitative timber maturity of intersectional poplar hybrids (i.e. 25 years) their survival was 83-100 %, and the wood stock – 462-641 m3/ha. Further by the age of 40 their productivity and sustainability also remained quite high (survival 63-96 %, wood stock – 417-764 m3/ha).

1. Introduction

From the whole of the forest tree species poplars possess the easiest crossing ability in the distant hybridization. Usually interspecific and intersection poplars hybrids show the heterosis in their growth and surpass natural poplar species (ancestors of the hybrids) in several times. At the same time interspecific and intersection poplars hybrids distinguish by high plasticity in adaptation to new circumstances and easily acclimatize in various geographic regions and soil-climatic zones. Many of them combine some positive properties of their parental forms and species and surpass them in trunk and timber quality, in entomopest and phytodisease resistance, in winter hardiness, in drought resistance and in other important forestry and economy particularities [1-13].

The wide development of programs and works on introduction, hybridization and variety testing of poplars in Russia was initiated by Soviet scientists-foresters since the 30s of the twentieth century in various forest universities and research institutes. In 1950-1955 there were bred such widely known hybrids of poplars as ‘Leningradsky’, ‘Nevsky’ (Leningrad Forest Technical Academy – originator P L Bogdanov); ‘Pioneer’, ‘Ivanteevky’, ‘Soviet pyramidalny’ (All-Union Research Institute of Silviculture and Forestry Mechanization – originator A S Yablokov); ‘Pyramidalny-osokorevy Kamyshinsky’ (All-Union Research Institute of Agro-Forest Reclamations – originator A V Albensky); ‘Voronezh giant E.s.-38’ (Voronezh Forest Technical Institute – originator M M Veresin), etc. [14]. At
this time, much attention was also paid to foreign researches. As a result, a number of Euro-American poplar cultivars and new poplar hybrids have been introduced to Russia.

In subsequent years (1971-1995) the works by A P Tsarev, R P Tsareva and V P Petrukhnov conducted in the Central Institute of Forest Genetics and Breeding, organized in 1971 in Voronezh, were devoted to issues of poplars hybridization and breeding in Russia. They have received hundreds of new hybrids; some of them are currently obtained patents and copyright certificates (‘Bolide’, ‘Veduga’, ‘Steppe Lada’, ‘Breeze’, etc.) [15, 16].

Having such a wide gene pool of poplar hybrids, there was a need to create a collection of them and testing sites in different zones and regions. The first of such collections, numbering more than 300 species, forms, clones, hybrids and varieties of poplars by domestic and foreign breeding, was created by Professor A.P. Tsarev in the period from 1972 to 1975 in the Central Chernozem forest-steppe zone in Semiluky district of Voronezh region. On its basis 80 best productivity and stability forms were selected, and using them the variety testing site – Semiluksky populetum was created. The results of the white, black and balsam poplars’ variety testing in the Central Chernozem Region were presented earlier [17-19].

The purpose of this work is to carry out under the forest-steppe zone conditions of the Central Black Earth Region of Russia variety testing of poplar intersectional hybrids obtained in different climatic zones of the former Soviet Union and abroad from controlled crosses of balsam poplars with black and black poplars with balsam ones. The main objective of the investigation was to study the growth and productivity of intersectional poplar hybrids, and to select the best of them for making the forest and shelter belt plantations in the region.

2. Methods and Materials

The object of research was the collection and testing site (populetum) created in the Semiluky forest nursery in Voronezh region. 13 intersectional hybrids’ clones were introduced for testing in populetum (table 1).

The studied hybrids were received from Bashkirian Forest Research Station of All-Union Research Institute of Silviculture and Forestry Mechanization (Ufa), from Leningrad Forest Technical Academy, from All-Union Research Institute of Silviculture and Forestry Mechanization (Ivanteevka in Moscow region), Voronezh Forest Technical Institute. Three hybrids were introduced from Kazakhstan, Germany and the United States through Ukrainian Research Institute of Forestry and Agro-Forest Reclamations, Amur Forest Research Station and Kazakhstan Agricultural Institute. The originators of the hybrids were A M Berezin, M M Veresin, P L Bogdanov, A S Yablokov, I A Kazartsev, P P Besschetnov, A B Stout & E I Schreiner (USA).

Planting of poplars was carried out by stem cuttings in the spring of 1974 on an entirely prepared and marked area (after complete plowing and spring cultivation) with placement of 5x4 m at 4 times repetition. The placement of the hybrids was randomized. The soil – typical chernozem with groundwater at a depth of 4-5 m. As a control, the average indices of tested intersectional hybrids of the whole set were used, which is acceptable in accordance with the Council of Europe Directive on marketing of forest reproductive material [20].

Observation for the studied hybrids in the first 20 years of growth was annual, then – every 3-5 years. For a more visual and compact representation in this work the 40-years research period results are presented in 5-year intervals.

Measurements of poplar heights were carried out using the ‘Blume-Leiss’ altimeter. The diameters were calculated via the circumferences of the trunk, and the trunk volumes were determined by the formula:

\[ V = \frac{\pi \cdot D^2 \cdot H \cdot f}{10000} \quad (\text{m}^3) \]

where: \( H \) – height, m; \( D \) – diameter, cm; \( f \) – Species number, which for poplar, determined by Houtzagers (G Von Houtzagers) as 0.39 [21].
**Table 1.** The list and the origin of the intersectional poplar hybrids have been testing in Semiluksky populetum in the Central Chernozem Region

| Name of the hybrid | Origin of the hybrid (parent trees) | Author of the hybrid | Region of hybrid’s breeding or selection | Region of hybrid’s introduction and reintroduction |
|--------------------|-----------------------------------|---------------------|----------------------------------------|-----------------------------------------------|
| Berlinsky (inv. No. 130) | spontaneous hybrid *P. berolinensis* Dipp. | no data | Germany, Berlin | Amur Forest Research Station |
| Hybrid 3B (inv. No. 48+134) | not significantly determined | A.M. Berezin | Bashkirian Forest Research Station | No. 48 – from Ukrainian Research Institute of Forestry and Agro-Forest Reclamations, No. 134 – from Amur Forest Research Station |
| Hybrid No. 10 (inv. No. 106) | *P. suaveolens* Fisch. × *P. canadensis* Moench. | P.L. Bogdanov | Leningrad Forest Technical Academy | Leningrad Forest Technical Academy |
| Hybrid No. 30 (inv. No. 102) | *P. canadensis* Moench. × *P. laurifolia* Ledeb. | A.M. Berezin | Bashkirian Forest Research Station | Astrakhan Forest Research Station |
| Hybrid No. 300 (inv. No. 49) | *P. maximowiczii* Henry × *P. rubrinervis* Alb. | I.A. Kazartsev | All-Union Research Institute of Silviculture and Forestry Mechanization | All-Union Research Institute of Silviculture and Forestry Mechanization |
| Ivanteevsky (inv. No. 46) | *P. suaveolens* Fisch. × *P. berolinensis* Dipp. | A.S. Yablokov | | |
| Kzyl-Tan (inv. No. 59) | *PKL-284* Stout&Schrein. × *P. deltoides* Marsh. | P.P. Besschetnov | Kazakh Agricultural Institute | Kazakhstan agricultural Institute |
| Kolonnovidny (inv. No. 103) | *P. laurifolia* Ledeb. × *P. berolinensis* Dipp. | P.L. Bogdanov | Leningrad Forest Technical Academy | Leningrad Forest Technical Academy |
| Leningradsky (inv. No. 104) | *P. canadensis* Moench. × *P. suaveolens* Fisch. | P.L. Bogdanov | Leningrad Forest Technical Academy | Leningrad Forest Technical Academy |
| Nevsky (inv. No. 105) | *P. canadensis* Moench. × *P. balsamifera* L. | P.L. Bogdanov | Leningrad Forest Technical Academy | Leningrad Forest Technical Academy |
| Stratsglas-284 (inv. No. 40) | *P. nigra* L. × *P. laurifolia* Ledeb. | A.B. Stout & E.I. Schreiner | USA | Ukrainian Research Institute of Forestry and Agro-Forest Reclamations |
| E.s.-38 (inv. No. 44+94) | *P. deltoides* Marsh. × *P. balsamifera* L. + *(P. alba* L. + *P. tremula* L.)* | M.M. Veresin | Voronezh Forest Technical Institute | Voronezh Forest Technical Institute |
| E.s.-53 (inv. No. 93) | *P. balsamifera* L. × *P. pyramidalis* Roz. | M.M. Veresin | Voronezh Forest Technical Institute | Voronezh Forest Technical Institute |
Wood stocks were determined by the formula:

\[ W = \frac{V \cdot N \cdot S}{100} \text{ (m}^3\text{/ha)}, \]

where: \( V \) – Average volume of the trunk (m\(^3\)); \( S \) – Survival of the plants (%); \( N \) – Planting density (trees/ha).

3. Results and discussion

The survival dynamics of the studied hybrids for the 40-year research period is shown in figure 1.

![Figure 1. The survival dynamics of the intersectional poplar hybrids.](image)

On early studies hybrid ‘Kzyl-Tan’ (inv. No. 59) introduced from Kazakhstan had completely fallen out. He couldn’t stand the winter frosts of the Central Chernozem Region.

As can be seen from the data in figure 1, after 30 years of growth hybrids ‘Ivanteevsky’ (inv. No. 46) and ‘Leningradsky’ (inv. No. 104) had fallen out due to the low drought resistance, because they’re obtained in the wetter Northern regions of the country (in the Moscow region and in the Leningrad region). Low survival was observed in the American hybrid ‘Stratsglas’ (initially 63% further 38%, and after the drought of 2010 it fell to 17%) and the hybrid ‘E.s.-53’ (25 years – 67%, 35 years – 33% and 40 years – 25%).

The survival of other hybrids during 35 years of research was quite high (75-96%). But after the dry and very hot summer of 2010, some hybrids survival sharply declined in 2013, i.e. in 40 years of age. Survival of the poplars ‘Nevsky’, ‘Hybrid № 10’ and ‘Hybrid № 300’ fell to 33-63%. At the same time, despite the severe drought of this period, survival of hybrids ‘Berlinsky’, ‘Kolonnovidny’, ‘Hybrid 3B’, ‘Hybrid № 30’ and ‘E.s.-38’ remained high (67-96%). So, these hybrids were characterized by high drought resistance and winter hardiness.

In addition to safety, the growth dynamics of hybrid poplars in height, diameter, volume of the trunk and the wood stock were studied at the populetum. Height growth dynamics of poplars is presented in figure 2. As can be seen from the data in figure 2, the height of poplars steadily increased to 25 years of
age. In the subsequent period, the energy of growth in height decreased, and after the drought of 2010 to 40 years in some hybrids growth completely stopped.

Figure 2. Height growth dynamics of the intersectional poplar hybrids.

Earlier studies of the intersectional poplar hybrids growth allowed establishing the age of quantitative timber maturity [17]. The equality of mean and the current increments of wood stock have been in the 25-26 years. This age (25 years) can be recommended as the age of the logging operations for intersectional hybrids’ plantations. And this publication pay more detailed attention to the 25 years planting age.

At the age of 25, the best growth rates in height (ranks 1-5) were observed in hybrids ‘Berlinsky’ (inv. No. 130), ‘E.s.-38’ (inv. No. 44+94), ‘Hybrid No. 10’ (inv. No. 106), ‘Hybrid № 300’ (inv. No. 49) and ‘Hybrid 3B’ (inv. No. 48+134), whose height was 27.8-29.3 m (table 2). The worst indicators of growth in height at the same age (at 23.5-25.8 m) were observed in the hybrids ‘Leningradsky’, ‘Stratsglas-284’, ‘Ivanteevsky’, ‘Nevsky’, ‘E.s.-53’ and ‘Kolonnovidny’ (ranks 7-12).

At the age of 40, almost all of the studied hybrids maintained the same ranks in height as they did at the age of 25, with small variations within the selected groups. The average height of the top five in the 40-year age ranged from 29.3 to 30.5 m (table 3).

The trunk diameters of the studied poplars at the age of 25 varied from 21.5 to 38.8 cm, at the age of 40 – from 27.2 to 43.2 cm, i.e. the amplitude of variation in diameter was much greater than in height. And if the height increments after 25 years had been slightly increasing, the increments in diameter had been more significant. The best growth rates of hybrids in diameter both in the 25 year and in the 40 year age were observed in the same hybrids, which were the best in height (see tables 2, 3). The average height increments over the last 15 years (from 25 to 40 years) had been varied from 0.5 to 2.4 m, and the diameter increments – from 2.0 to 6.2 cm depending on the genotype.
Table 2. Average growth indices of the intersectional hybrids at the quantitative maturity age (25)

| The name of the hybrid | Survival, % | Height, m | Diameter, cm | Volume of the trunk, m³ |
|------------------------|-------------|-----------|--------------|-------------------------|
|                        | H ± m       | rank      | D ± m        | rank                    |
| Berlinsky              | 87.5        | 29.3      | 0.23         | 1                       | 38.0  | 0.87 | 2  | 1.296 | 0.071 | 2  |
| Hybrid 3B              | 83.3        | 27.8      | 0.26         | 5                       | 36.1  | 0.91 | 4  | 1.110 | 0.068 | 4  |
| Hybrid No. 10          | 83.3        | 28.8      | 0.84         | 3                       | 37.0  | 2.68 | 3  | 1.208 | 0.184 | 3  |
| Hybrid No. 30          | 91.7        | 27.0      | 0.27         | 6                       | 30.0  | 0.90 | 6  | 0.744 | 0.061 | 6  |
| Hybrid No. 300         | 95.8        | 28.1      | 0.30         | 4                       | 33.8  | 1.03 | 5  | 0.983 | 0.073 | 5  |
| Ivanteevsky            | 37.5        | 25.2      | 0.42         | 10                      | 25.4  | 1.01 | 10 | 0.498 | 0.045 | 10 |
| Kzyl-Tan               | 87.5        | 25.8      | 0.18         | 8                       | 27.6  | 0.55 | 7  | 0.602 | 0.032 | 7  |
| Leningradsky           | 83.3        | 23.5      | 0.60         | 12                      | 21.5  | 1.20 | 12 | 0.333 | 0.043 | 12 |
| Nevsky                 | 95.8        | 25.3      | 0.38         | 9                       | 26.7  | 0.94 | 9  | 0.552 | 0.044 | 9  |
| Stratsglas-284         | 37.5        | 24.5      | 0.34         | 11                      | 24.1  | 0.87 | 11 | 0.436 | 0.042 | 11 |
| E.s.-38                | 95.8        | 29.0      | 0.22         | 2                       | 38.8  | 0.89 | 1  | 1.337 | 0.081 | 1  |
| E.s.-53                | 66.7        | 25.8      | 0.27         | 7                       | 27.0  | 0.76 | 8  | 0.576 | 0.042 | 8  |
| Aggregate average      | 80.4        | 27.2      | 0.18         | 5.5                     | 32.2  | 0.55 | 5.5| 0.911 | 0.035 | 5.5 |

The ranking of hybrids by the volume of the trunk showed that the ranks of hybrids remained almost the same values as they were in height and diameter. The trunks volume of the best hybrids (ranks 1-5) at the age of 25 years ranged from 0.983 to 1.337 m³, in 40 years – from 1.335 to 1.594 m³. The lowest trunks volumes at the age of 25 ranged from 0.333 to 0.576 m³, and at the age of 40 years – from 0.596 to 0.797 m³ (ranks 8-12 and 8-10 respectively).

Table 3. Average growth rates of the intersectional hybrids at the age of 40

| The name of the hybrid | Survival, % | Height, m | Diameter, cm | Volume of the trunk, m³ |
|------------------------|-------------|-----------|--------------|-------------------------|
|                        | H ± m       | rank      | D ± m        | rank                    |
| Berlinsky              | 87.5        | 29.8      | 0.22         | 3                       | 40.0  | 0.86 | 3  | 1.480 | 0.073 | 3  |
| Hybrid 3B              | 66.7        | 29.3      | 0.20         | 4                       | 38.1  | 0.80 | 4  | 1.336 | 0.070 | 4  |
| Hybrid No. 10          | 62.5        | 30.5      | 0.38         | 1                       | 43.2  | 1.52 | 1  | 1.791 | 0.134 | 1  |
| Hybrid No. 30          | 66.7        | 28.3      | 0.33         | 6                       | 34.6  | 1.15 | 6  | 1.070 | 0.084 | 6  |
| Hybrid No. 300         | 62.5        | 29.3      | 0.32         | 5                       | 38.1  | 1.23 | 5  | 1.335 | 0.101 | 5  |
| Ivanteevsky            | 79.2        | 26.8      | 0.30         | 9                       | 29.9  | 0.89 | 9  | 0.754 | 0.054 | 9  |
| Kzyl-Tan               | 79.2        | 26.8      | 0.30         | 9                       | 29.9  | 0.89 | 9  | 0.754 | 0.054 | 9  |
| Leningradsky           | 33.3        | 27.7      | 0.22         | 7                       | 32.3  | 0.71 | 7  | 0.888 | 0.048 | 7  |
| Nevsky                 | 16.7        | 26.0      | 0.47         | 10                      | 27.2  | 1.26 | 10 | 0.596 | 0.064 | 10 |
| Stratsglas-284         | 95.8        | 30.1      | 0.14         | 2                       | 41.2  | 0.61 | 2  | 1.594 | 0.059 | 2  |
| E.s.-53                | 25.0        | 26.9      | 0.72         | 8                       | 30.2  | 2.46 | 8  | 0.797 | 0.176 | 8  |
| Aggregate average      | 54.2        | 29.1      | 0.12         | 5.5                     | 37.6  | 0.43 | 5.5| 1.317 | 0.035 | 5.5 |

The most representative data in the study of productivity are the indices of wood stocks, which take into account both growth rates (height, diameter and volume of the trunk) and rates of stability (survival). From the data of the table 4 and figure 3 it appears that wood stocks of intersectional poplars hybrids in the age of quantitative maturity (in 25 years) ranged from 82 m³/ha (‘Stratsglas’) to 641 m³/ha (‘E.s.-38’). The best hybrids ‘E.s.-38’ (inv. No. 44+94), ‘Berlinsky’ (inv. No. 130), ‘Hybrid No. 10’ (inv. No. 106), ‘Hybrid No. 300’ (inv. No. 49) and ‘Hybrid 3B’ (inv. No. 48+134) had been the most productive by the wood stock at this age (462-641 m³/ha, ranks 1-5).

Lowest productivity (82-265 m³/ha, ranks 8-12) was observed in hybrids ‘Stratsglas’, ‘Ivanteevsky’, ‘Leningradsky’, ‘Kolonnovidny’, ‘E.s.-53’ and ‘Nevsky’, i.e. mostly introduced from more Northern regions. The rest of the hybrids on wood stock occupied an intermediate position.
Table 4. Comparative data on productivity of the intersectional hybrids at the age of quantitative maturity (25) and at the age of 40

| The name of the hybrid | Survival, % | Wood stock, m³/ha | Survival, % | Wood stock, m³/ha |
|------------------------|-------------|-------------------|-------------|-------------------|
|                        |             | 25 years old      |             | 40 years old      |
|                        | W          | ±m               | rank        | W                | ±m           | rank |
| Berlinsky              | 87.5        | 567              | 30.9        | 2                | 87.5         | 647  | 32.0 | 2   |
| Hybrid 3B              | 83.3        | 462              | 28.4        | 5                | 66.7         | 445  | 23.2 | 4   |
| Hybrid No. 10          | 83.3        | 503              | 76.5        | 3                | 62.5         | 560  | 41.8 | 3   |
| Hybrid No. 30          | 91.7        | 341              | 27.9        | 6                | 66.7         | 357  | 27.9 | 6   |
| Hybrid No. 300         | 95.8        | 471              | 35.0        | 4                | 62.5         | 417  | 31.7 | 5   |
| Ivanteevsky            | 37.5        | 93               | 8.5         | 11               |              |      |      |     |
| Kzyl-Tan               |             |                  |             |                  | Fell out     |
| Kolomnovidny           | 87.5        | 263              | 13.8        | 8                | 79.2         | 298  | 21.2 | 7   |
| Leningradsky           | 83.3        | 139              | 17.9        | 10               |              |      |      |     |
| Nevsky                 | 95.8        | 265              | 21.0        | 7                | 33.3         | 148  | 7.9  | 8   |
| Stratsglas-284         | 37.5        | 82               | 7.8         | 12               | 16.7         | 50   | 5.4  | 10  |
| E.s.-38                | 95.8        | 641              | 38.6        | 1                | 95.8         | 764  | 28.3 | 1   |
| E.s.-53                | 66.7        | 192              | 14.1        | 9                | 25.0         | 100  | 22.0 | 9   |
| Aggregate average      | 80.4        | 397              | 18.2        | 5.5              | 54.2         | 500  | 18.6 | 3.5 |

Figure 3. Wood stock productivity dynamics of the intersectional poplar hybrids

The wood stock ranking distribution of the first five best hybrids remained in 40 years, but the rate of wood stock accumulation by this age had been decreased. As above noted, the severe drought of 2010 had an especially significant influence on the accumulation of trunks timber, after which some hybrid trees began to dry out, and the total stock of live timber had been decreased significantly due to low survival.
So, for example, if the wood stock of ‘Hybrid 3B’ (inv. No. 48+134) at the age of 25 years was 462 m³/ha, in 40 years due to the loss of trees and reduced survival after the drought in 2010 it fell to 445 m³/ha. A more significant reduction in wood stocks was observed in ‘Hybrid No. 300’ (from 471 to 417 m³/ha), ‘Nevsky’ (from 265 to 148 m³/ha) ‘E.s.-53’ (from 192 to 100 m³/ha) and ‘Stratsglas’ (from 82 to 50 m³/ha). Their wood stocks to the age of 40 had decreased by 11-48 %. This is clearly seen in figure 4.

Figure 4. Productivity of the intersectional poplar hybrids by wood stock in 25 and 40 years

In comparison with the control (aggregate average) significantly better by the wood stock in the age of quantitative maturity (25 years) were hybrids ‘E.s.-38’ (inv. No. 44+94), ‘Berlinsky’ (inv. No. 130), ‘Hybrid No. 10’ (inv. No. 106), ‘Hybrid No. 300’ (inv. No. 49), and ‘Hybrid 3B’ (inv. No. 48+134). These clones were also significantly better in productivity at the age of 40.

It should be noted that the hybrid ‘E.s.-38’ is a male clone. According to M M Veresin and A I Sivolapov, it is characterized by high tolerance to drought and frost, resistance to weak soil salinization and has highly growth energy not only in the Central Chernozem Region, but also in the more southern regions (in the floodplain of the Volga river in Astrakhan region) and abroad (Ukraine) [22, 23].

It has those phenological characteristic features: the early leaves coming-out in the beginning of the vegetative period (April) and the late leaf-losing in the end of the growing season (October). At the same time, no damage was noted by frost. In Ukraine it has high resistance to flooding under the floodplain conditions – up to 60 days. Due to its bio-ecological features ‘E.s.-38’ is well cut and shows high survival and resistance in cultures.

The cytological analysis of the hybrid showed that ‘E.s.-38’ is an allotriploid with a triple set of chromosomes (2n = 57), or rather a mixoploid with a predominance of cells having a triploid set of chromosomes – 78.4 %. Diploid and aneuploid cells are 19.6 %, tetraploid – 1.9 % [22].

Plantings with poplar ‘E.s.-38’ in all investigated experimental sites distinguished by strong growth and high productivity. In the Educational-Research Forestry of Voronezh State Forest Technical University on the dark-gray loam high plateau with the density of approximately 500 pieces per 1 hectare the wood stock in 10 years was 126 m³/ha [22].

Under the conditions of the Semiluksky populetum on Typical Chernozem soil with the same placement (4×5 m) during all 40 years of growth ‘E.s.-38’ had been showing the highest wood stocks,
steadily occupying the highest rank on productivity. At the age of 10, its wood stock was 166 m$^3$/ha or in 1.5 times higher than control (111 m$^3$/ha), at the age of quantitative maturity (25 years) – 641 m$^3$/ha which in 1.6 times higher than the aggregate average wood stock (397 m$^3$/ha), and at the age of 40 its wood stock reached 764 m$^3$/ha which is also in 1.5 times higher than control (500 m$^3$/ha).

Hybrids of P.L. Bogdanov obtained from crossing P. canadensis (♀) with P. balsamifera (♂) and P. suaveolens (♂), ['Nevsky' (P. newesis Bogd.) and 'Leningradsky' (P. leningradensis' Bogd.)], according to A.K. Boytsov, A.V. Zhigunov et al., still serve as standards of productivity in the North-West of Russia [24]. In 7 years they had a height of 10-11 m, diameter – 13 cm and were quite frost-resistant. In the conditions of the Leningrad climate they are recommended both for massive (for timber materials) and for greenery landscaping plants (both clones are male) [25].

In the conditions of the Central Chernozem Region at the age of quantitative maturity (25 years) they reached a height of 23 and 25 m, diameter – 21 and 27 cm, survival – 83 % and 96 % respectively. Wood stock – 139 and 265 m$^3$/ha which in 3 and 1.5 times lower than control (397 m$^3$/ha). After 30 years of age P. ‘Leningradsky’ ‘in the forest-steppe zone completely fell out, and the survival of P. ‘Nevsky’ decreased to 33 %. I.e. both of these hybrids in more southern conditions don’t withstand the lack of moisture and cannot be recommended for artificial afforestation in the Central Chernozem Region.

The same trend was observed with the poplar ‘Ivanteevsky’ which was characterized by rapid growth, good winter hardiness and decorative in the Moscow region [26], but under the conditions of the Central Chernozem Region it was also not drought-resistant. Since the age of 10 it had one of the worst indices of growth, survival and productivity. At the age of quantitative maturity (25 years) its wood stock was 93 m$^3$/ha, which is more than in 4 times less than control (397 m$^3$/ha), and by the age of 35 it completely fell out of the plant.

Conclusions

Thus, long-term testing of intersectional hybrids under conditions of the Central Black Earth forest-steppe zone allowed drawing the following conclusions:

In the variety testing in the Semiluksky populetum 13 intersectional hybrids obtained in different regions of the natural habitat of poplar (Leningrad region, Moscow region, Bashkirian Republic, Central Chernozem Region, Germany, USA and Kazakhstan) were included. In the first phase of testing at the age of 7 years not winter-resistant south hybrid ‘Kzyl-Tan’ introduced from Kazakhstan fell out from the plantation. To 35 years the hybrids with low drought resistance – ‘Ivanteevsky’ and ‘Leningradsky’ had completely fallen out of plantation, and the survival of the hybrid ‘Stratsglas’ fell to 17 %.

The age of timber technical maturity in cross-section hybrids, determined by the dynamics of average and current increments of wood stock, was observed at 25-26 years. And under these conditions, with arrangement place of 4×5 m, the age of 25 years can be taken for the age of the main logging operations for intersectional poplar hybrids.

The highest survival, highest growth energy and the maximum accumulation of wood stock at the age of 25 were observed in the hybrids ‘E.s.-38’, ‘Berlinsky No. 130’, ‘Hybrid No. 10’, ‘Hybrid No. 300’ and ‘Hybrid 3B’. At this age their survival was 83-96 %, the average height varied from 27.8 to 29.3 m, the average diameter – from 33.8 to 38.8 cm, the average trunk volume – from 0.983 to 1.337 m$^3$, and wood stock – from 462 to 641 m$^3$/ha. To 40 years the wood stock of the most productive intersectional hybrids made up to 417-764 m$^3$/ha while the wood stock of local poplar (P. nigra L.), widespread in the research region, at the age of 25 years was 401 m$^3$/ha, and by 40 years due to a sharp decrease in the survival its wood stock decreased to 261 m$^3$/ha.

Growth energy and timber accumulation of intersectional hybrids after 25 years were significantly reduced, and keep them in plantations over this age is economically unreasonable.

In the prospective assortment for creation of fast-growing and sustainable poplar plantations in the forest-steppe zone of the Central Chernozem Region the following intersectional hybrids ‘E.s.-38’ (inv. No. 44+94), ‘Berlinsky’ (inv. No. 130), ‘Hybrid No. 10’ (inv. No. 106), ‘Hybrid No. 300’ (inv. No. 49) and ‘Hybrid 3B’ (inv. No. 48+134) can be recommended.
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