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Forty-five-year monitoring of selection stands of white (Populus alba L.), gray (Populus canescens Sm.), black poplar (Populus nigra L.) and willow (Salix alba L.) in Khoper State Natural Reserve

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Abstract. This paper presents an analysis of forty-five-year dynamics of the main characteristics of white (Populus alba L.), gray (Populus canescens Sm.), black poplar (Populus nigra L.) and willow (Salix alba L.) stands on the territory of the Khoper State Natural Reserve on the basis of the materials of permanent test plots restored and newly established by A I Sivolapov in 1972 for the purpose of selection of the most productive and stable clone micropopulations of these species. The annual changes taking place in the sample plots, and considerable statistical material, make it possible to carry out quantitative and qualitative analysis of the behavior of the existing associations of white, gray, black poplar and willow with great certainty. Selected highly productive genotypes have been uterine trees to create varieties and are recommended for plantation cultivation.

1. Introduction
Khoper State Natural Reserve (16 178 ha) is located in the South-Eastern part of the Oka-Don lowland (southern forest-steppe) in the South-East of the Voronezh region. It borders with the Tellerman forest in the North.

The territory of the reserve includes a section of the floodplain of the Khoper River (in the middle reaches) of the second largest water collecting left bank tributary of the Don River. 74 % of the landscape is the floodplain which extends within the reserve from North-East to South-West and forms two bends (3-6 km), tapering to the North, centre and South up to 1 km. 10% is floodplain terrace, 16 % indigenous right bank of the Khoper River. There are 3 main landscape categories within the floodplain: young, mature and old floodplain, differing in formation time, composition of alluvium and hydrological regime [1].
The territory of the reserve can be considered a forest one. Herbal phytocenoses occupy only about 4% of the total area. Moreover, forested area, according to the surveys, is increasing (5.2% in 60 years) [2]. The flora includes 39 species of trees, 54 species of shrubs and 13 species of semi-shrubs. Floodplain oak forests with lime, ash, elm, poplars or other species (34.2% of the total forest area) are the most common in there. The most common auxiliary species are black alder, Tatar maple, European buckthorn and wild rose. Aspen forests occupies 10.6% of the forest area, ash and 4.3%, willow (several shrub species) -4.2%, white willow - 4.1%, black poplar - about 2.1 per cent, white poplar - 1.8%, elm - 1.4%, lime - by 1.1%. There are highly productive stands of white, gray and black poplar in the mature and old floodplain of the Khoper State Natural Reserve; white willow - in the young floodplain. They are the basis for selection of trees and plantings of these species.

2. Experimental part

The choice of selection system of woody plants depends on their system of reproduction. Poplar and willow have vegetative and seed propagation. Selection must begin with the selection and study of valuable forms of aboriginal species. The possibility of selection of woody plants has been proved for the first time on the poplars, since they easily produce spontaneous hybrids [3]. Many synthetic poplar hybrids were obtained in the middle and at the end of the 20th century [4]. But assortment of valuable forms in nature always occupies a special place in selection. V N Sukachev [5] proposed the study of form reproduction of the most important tree species, selection and reproduction of the best of them as the main direction of forest selection. N I Vavilov [6] also pointed to the maximum use of local material in selection, extracting the most productive, most valuable forms from it.

Material and methods. A I Sivolapov has laid down permanent test plots for the selection and monitoring of the processes taking place in white poplar, black poplar and willow stands of the Khoper State Natural Reserve in 1972: two test plots - in black poplar stands, 2 (4 of which are restored) - in white poplar stands, 1 - in willow stands; in 1976: 1 - in mixed plantations of gray poplar and aspens. The areas were located in the northern and central part of the reserve, 1 trial plot of white poplar (sq. 180) in the southern part of the reserve. The main criterion in the selection of test plots was the desire to cover the largest number of high-yielding, high-quality variants of poplar and willow varieties for the purpose of selection.

The general condition (viability) of plants is in close connection with winter hardiness, drought resistance and immunity to diseases and pests. Accounting is made at the end of summer. Assessment of the general condition was carried out in points for each accounting tree [7]:

0 - excellent condition (tree is healthy, it has normal foliage, strong growth);
1 - good condition (moderate growth, there are weak damage by frost and drought, drying of individual small branches);
2 - weakened condition (tree is significantly weakened by frost, drought or mechanical damage, there is damage to the bark and the main branches, growth is moderate or weak);
3 - weak condition: (tree is sick, most of the crown is lost, and the bark is damaged by frost, burns, it has strong mechanical damage, growth is weak);
4 - tree is very weak due to damage by frost, drought or mechanical damage, and for other reasons is on the edge of death;
5 - trees have died completely.

The growth of the forest stand has been carried out for 45 years (1972 – 2017). For aspen the reserve of plantings was determined by the volume tables of AV Tyurin. Volume of trunks beyond the table was determined by the formula: \( V = G HF \), where:

- \( V \) - trunk volume, \( m^3 \);
- \( G \) - cross-sectional area of the trunk at breast height (\( m^2 \));
- \( H \) - height of stem, \( m \);
- \( F \) - tree form factor

Monitoring of the condition and fallout of trees on the sample areas, description of the state of individual trees, measurement of diameters, and description of undergrowth has been carried out by us.
every 5 years. The condition of the tree is estimated on a five-point scale [7], the manifested signs of diseases, damage to the crown and other features are noted. At the same time, the appendix is added to the next list, these are trees of forest forming species that have reached a diameter of 6 cm.

For the analysis of changes in clone micropopulations based on the materials of test plots, the most remote time points have been taken: the data of the first inventory when test plot laying the took place (1972) and the materials of the last inventory (2017).

The main characteristic of communities of different organization levels is species composition. However, this characteristic very illustrative and integrally reflects the relative characteristics of ontogenesis, productivity and state of species in dynamics (Tables 1 and 2).

**Table 1.** Growth and productivity of poplars and willows in the year of plot laying according to permanent test plots.

| No. quar./ No. trial plots coordinates | Type Of forest growth conditions | Composition Of tree stand | Age, years | Average diameter, cm | Average height, m. | Stock, m³/ha |
|---------------------------------------|---------------------------------|---------------------------|------------|----------------------|--------------------|-------------|
| **Populus alba**                      |                                 |                           |            |                      |                    |             |
| 124/1 N:51°11.849′ E:41°42.320′       | D₂                              | 10PA sing.PN              | 40         | 31.3                 | 26.0               | 666         |
| 124/2 N:51°11.849′ E:41°42.321′       | D₂                              | 8 PA2 PN.                 | 42         | 33.8                 | 27.6               | 686         |
| 132/3 N:51°11.329′ E:41°42.656′       | C₃                              | 10 PA sing.Oak.           | 80         | 57.3                 | 33.5               | 1249        |
| 180/4 N:51°7.453′ E:41°37.422′        | D₃                              | 9 PA1Oak                  | 64         | 47.3                 | 28.2               | 709         |
| 93/5 N:51°14.912′ E:41°42.898′        | E₃                              | 10 PA sing.PN             | 95         | 82.2                 | 42.5               | 1513        |
| 123/6 N:51°12.432′ E:41°41.690′       | D₁-C₃                           | 10 PA                     | 80         | 51.4                 | 32.3               | 992         |
| **Populus nigra**                     |                                 |                           |            |                      |                    |             |
| 120/1 N:51°12.834′ E:41°40.889′       | C₂                              | 10 PN sing.PA.            | 70         | 51.1                 | 30.5               | 623         |
| 120/2 N:51°12.834′ E:41°40.888′       | D₂                              | 8 PN 1Oak1PA             | 70         | 51.8                 | 28.0               | 413         |
| **Salix alba**                        |                                 |                           |            |                      |                    |             |
| 122/1 N:51°12.421′ E:41°42.127′       | C₄                              | 10 SA sing.PA.            | 46         | 39.1                 | 24.0               | 554         |

N - Northern latitude; E - eastern longitude; PA- *Populus alba*; PN- *Populus nigra*; SA- *Salix alba*
Black poplar (*Populus nigra* L.) has generally reduced its presence and volume. Both trial plots with its decisive role during the observations have practically destroyed. However, there are areas where black poplar appears by root shoots curtains. Willows stand has also been badly damaged. Accordingly, we see the productivity of these species in the tables. The increase in evenness, that is, more even distribution of poplar trees by number in the 2017 diagram, is explained by an increase in the share of participation in various associations of associated species: linden, Norway maple, elm and ash, growth of functional diversity (Figure 1).

The data in Tables 1 and 2 show that the trees of black poplar and willow over the 45 years of observations at the age of 115 years have worsened their condition and productivity of plantations 2-4 times. White poplar, at the age of 40 - 85 years, have increased productivity 2 times, and planting of 93 years has increased productivity from 1 513 m³/ha to 2 174 m³/ha.

In some trial plots, they, as well as maple, have gone out or increased their presence in the upper tier. Other species: aspen, pear, apple, bird cherry are minor impurities. Moreover, aspen is classically the most dynamic, unstable component, periodically penetrating into the community, and retreating under adverse conditions. Its low competitiveness and high susceptibility to diseases is balanced by well-pronounced reactivity. A clonal strategy implies a quick seizure of vacated (for various reasons) areas with a great deal of coppice activity, regardless of the degree of overgrowth of their grassy species. However, it is also a weak point of the species, explaining the epidemic nature of various pathologies, sometimes, almost instantaneous, character of aspens drying out.

**Table 2.** Growth and productivity of poplars and willow in 45 years after laying according to the data of permanent test plots

| No. quar./No. trial plots | Type Of forest growth conditions | Composition Of tree stand | Age, years | Average diameter, cm | Average height, m | Stock, m³/ha |
|---------------------------|---------------------------------|--------------------------|------------|----------------------|------------------|-------------|
| **Populus alba**          |                                 |                          |            |                      |                  |             |
| 124/1 D₂                  | 1⁰PA+Elm                       | 85                       | 51.2       | 29.5                 | 1276             |             |
| 124/2 D₃                  | 8 PA.1⁰PN 1⁰Elm                | 87                       | 53.7       | 31.0                 | 1273             |             |
| 132/3 C₃                  | 1⁰PA sing.¹Elm                | 125                      | 78.3       | 34.0                 | 1105             |             |
| 180/4 D₃                  | PA1Oak+Elm                    | 109                      | 72.4       | 30.3                 | 747              |             |
| 93/5 E₃                   | 1⁰PA+Elm, sing.L              | 140                      | 111.3      | 42.5                 | 2174             |             |
| 123/6 D₃-C₃               | 1⁰PA                           | 120                      | 56.3       | 32.8                 | 748              |             |
| **Populus nigra**         |                                 |                          |            |                      |                  |             |
| 120/1 C₂                  | 1⁰PN sing.PA                  | 115                      | 73.8       | 31.0                 | 203              |             |
| 120/2 D₂                  | 8 PN1Oak1PA                   | 115                      | 75.3       | 29.0                 | 103              |             |
| **Salix alba**            |                                 |                          |            |                      |                  |             |
| 122/1 C₄                  | 9⁰SA1Elm                      | 90                       | 63.5       | 28.0                 | 220              |             |

The most moving category for this indicator is black poplar stand. Next, close values are demonstrated by white poplar stands. The destructive test area of white willow is somewhere behind. Here, in the struggle for liberating resources in the conditions of small floodplain, woody species clearly lose to herbaceous and semi-shrubby species [1].

The activity of the processes of species change occurring in the white, black poplar and willow stands reserve is characterized by a histogram of tree stands additions on the test plots by association (Figure 1).
The triploid form of the poplar growing together with aspen has replaced aspen almost completely [8]. In willow stand, there is no restoration of the main species or change in varieties when thinning damaged stand. Although willow actively inhabits the neighboring riverbed ramparts, sandbars, forming new plantings.

Modern species composition on the test plots characterizes willow stands as the poorest in the species composition (Table 2). The only difference is that forest communities have not yet formed on the near-river banks of the small floodplain, and they are in the stage of edaphic climax in the "pockets" of the middle floodplain [2].

In white poplar stands, there is a formation of the second tier of a number of species along with a slight decrease in the proportion (by the number) of the main species; elm and ash are the most active among which. But in terms of volume, primacy still remains to the main species. As a result, the change in indicators common to the tree stand here has a pronounced positive balance. White poplar is able to increase them up to 145 years of age having the growth rate, size and productivity exceeding all other species [9, 10], and, apparently, this is not the limit (Figure 2). In the 93rd quarter, such giants of the forest have survived: almost 150-year-old 44-meter white poplar trees with a trunk diameter of more than a meter give an annual increase of 20 m3/ha and grow on light gray flood plain layered soils with a buried 0.5 m humus horizon at a depth of 113 cm and below.

Non-stable nature of the dynamics of the fallout in poplars and willows is distinguished. Samples even within one category behave ambiguously; however, the fallout rates are summarized for all trial plots (Figure 3).

Studies in the floodplains of the Khoper and the Don Rivers, where white poplar and aspen grow together, confirm the emergence of a spontaneously-hybridogenic species, which has all intermediate transitional forms from white poplar to aspen. This form is called gray poplar [10, 13]. The greatest diversity of gray poplar is found in the floodplain of Khoper State Natural Reserve (KSNR) and the floodplain of the Don – Bogucharsky forestry [12].

Gray poplar and white poplar is represented by male and female trees in the forests of the Central Chernozem Region. Determining the sex and other signs of trees on plots shows that clumps and sections of these poplars are most often represented by clones or clonal micropopulations [10, 13, 14].

Figure 1. Ratio of trees of the main stand and additions on associations at inventory of trial plots in 2018
On the gray poplar gray (*Populus canescens* Sm.) a system of genetic and selection studies aimed at the implementation of their basic theoretical and practical values in the forest growing conditions of The Central Chernozem Region has been worked out. And a similar system-methodological approach to the study of other forest species in different regions of the country has been shown on 45-year own experience. Modern increased role of fast-growing species in covering existing and projected shortage of wood has been highlighted [11, 13].

Spontaneous hybridogenic species - gray poplar has originated from the crossing of white poplar and aspen. Among clonal micro-populations of this polyploid poplar, we meet mixoploidy forms, relevant to the theory of introgressive hybridization and speciation, the theory of mixoploidy and epigenetics, spontaneous mutagenesis and polyploidy in woody plants, to the study of sterility allotriploid biotypes, to the study of withspecific molecular DNA markers, the possibility of valence crosses [8, 10].

Selected in the floodplain of the river Khoper (Khoper Reserve) large-leaf, allotriploid form of gray poplar was the ancestor of the new variety of Khoper poplar 1 by improving it, using the methods of vaccination and reproduction *in vitro*. The female clone of this variety is of great interest for industrial plantations as a long-fiber form [10]. It is one of the few species that do not give valence crosses. Seeds from free crossing are not viable, individual shoots die in the first days of life. Abnormalities in the process of its formation are noted as a result of embryological studies of the embryo sac. High ecological lability of t poplar is noted, i.e. this poplar shows good growth in a wide range of environmental conditions: it adapts and grows in certain environmental conditions due to a change in the number of cells with triploid chromosome set [15].

Gray poplar triploid is registered as a variety for industrial species (Patent for selection achievement No. 118, [16]). Dynamics of growth and productivity of allotriploid form of gray poplar in quarter 92 of KSNR is shown in Table 3.

Along the Khoper River on the left bank of this 78-year-old plus graywood tree, a curdling of 55-year-old spring grass trees is spread on a dark gray loam of chernozem type with an area of approximately 0.3 hectares. On the north side, aspen (in the second tier) comes in this curdling of poplar trees. In 20 years on the trial area of aspen there were 150 aspen trees, and in 55 years there was only 1 aspen tree (Figures 2 and 4).

![Figure 2. Dynamics of mortality of aspen when sharing habitat with gray poplar in quarter 92 of KSNR.](image-url)
Figure 3. Unique stand (clonal micro-population, female) white poplar in square 93 HGPS, age 135 years.

Figure 4. The micro-population clonal poplar serushago in quarter 92 HGPS. The age of 55 years. Gender: women's.

Table 3. Dynamics of growth and productivity of allotriploid form of gray poplar in quarter 92 of KSNR.

| Species          | Age, years | Average diameter, cm | Average height, m | Bonitet | Density | Stock, m³/ha |
|------------------|------------|-----------------------|-------------------|---------|---------|--------------|
| Gray poplar      | 20         | 21.5                  | 20.6              | I       | 0.54    | 163.0        |
| Aspen            |            |                       |                   |         |         |              |
| Gray poplar      | 46         | 58.0                  | 34.5              | I       | 0.59    | 427.0        |
| Aspen            |            |                       |                   |         |         |              |
| Gray poplar      | 55         | 72.0                  | 39.0              | I       | 0.59    | 587.0        |
| Aspen            |            |                       |                   |         |         |              |

The state of the forest stand is good, however, it should be noted that, the size of the leaves have decreased, perhaps, in our opinion, the number of triploidic cells have decreased after the abnormal heat of 2010 [10], but this number is restored in favorable years. A genetic passport has been compiled.
based on microsatellite analysis and a variety has been registered for the preservation and selection of the valuable allotriploid genotype of gray poplar [8].

The taxation indices of large-leaf triploid gray poplar form considerably exceed growing aspen of the same age. At 20 years of age, the diameter of the poplar is 20 cm longer than the diameter of an aspen, at 55 years old - 27 cm longer. The height of the gray poplar at 20 years exceeds that of aspen by 4 m, and at 55 years - by 9 m.

Thus, the large-leaved form of gray poplar is characterized by powerful somatic and adaptive heterosis.

3. Conclusion

Forest processes in white and black poplar stands and willow forests, in our opinion, do not go beyond the natural processes on the territory of KSNR. There is a significant differentiation of niches and differences in the nature of changes by association in the initial stages of floodplain succession of a small floodplain.

The stability of mature forest communities in mature and middle floodplain is largely due to reactive species (elm and aspen). These species, regardless of their individual strategies, are characterized by lethal epidemics and epizootics.

In other tracts of the middle floodplain, the dynamics of plant communities goes on with varying success, and, apart from forests, wedges, grass-shrub or meadow associations often form overgrowing tree species over time.

Selected stands of white and black poplar and willow forests are related to the category of winners. The best trees for further propagation are selected among them. In inoculation from centenary uterine trees, the topophysis was observed for about 10 years, and they died. The inoculation from the plus tree of gray poplar is found in 20 years after reproduction in vitro was registered as a variety (Kopersky poplar 1) and it is used to create plantation stands.

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References

[1] Tsvelev N N 1988 Flora of the Khoper State Natural Reserve Nauka 191
[2] Bugaev V A, Musievski A L 2005 State forest Fund of Khoper reserve State natural areas of the European part of Russia. The 70-th anniversary of KSNR VSU 203-206
[3] Romeder E, Schönbach G 1962 Genetics and selection of forest species (Publishing house of foreign literature) 268
[4] Tsarev A P, Pogiba S P, Laur N V 2014 Selection of forest and decorative tree plants: textbook (MSFU) 552
[5] Sukachev V N 1933 The main installation of selection of forest tree species in the Soviet forestry Soviet botany 1 23 – 34.
[6] Vavilov N 1935 Botanical-geographical bases of breeding Selkhozgiz 60
[7] Alekseev V A 1989 Diagnostics of vital condition of trees and forest stands Forest science 4 51-57.
[8] Sivolapov A I, Politov D V, Mashkina O S, Belokon M M, Sivolapov V A, Belokon Y S, Tabatsca T M 2014 Cytological, molecular and silvicultural-selection research of polyploid poplars collection Journal of Siberian forest 4 50-58
[9] Sivolapov A I, Biryukov V I 2005 Productivity and status of selected forest stands of gray and white poplar in floodplains of the Khoper and Don rivers State specially protected natural areas of the European part of Russia The 70-th anniversary of KSNR VSU 252-257
[10] Sivolapov A I 2005 Gray poplar: genetics, selection, reproduction VSAFT monograph VSU 157
[11] Sivolapov V, Sivolapov A, Blagodarova T 2014 Short term plantations of birch, alder and poplar using biotechnology in vitro Saarbrücken, Germany (LAP Academic Publishing LAMBERT) 120 E-book. http://dnb.d-nb.de.
[12] Sivolapov A I, Blagodarova T A 1993 Importance of cytogenetic investigations in Populus and Alnus selection IUFRO cytogenetics. Working Party Symposium. September 8 Drijuni National Park Croatia 18
[13] Sivolapov A I 2008 Theory and Practice of System Research of Genetics, Selection and Reproduction of Poplars in Forest-Steppe Zone of Central Chernozem Area in Russia Forest Journal 80-82
[14] Vanden Broeck A, Villar M, Bockstaele E Van, Slycken J Van 2005 Natural hybridization between cultivated poplars and their wild relatives: evidence and consequences for native poplar populations Ann. For. Sci. 601 – 613
[15] Sivolapov A I 2011 Structure of Clonal Populus Alba Micropopulations in Floodplains of Khoper and Don Rivers Conservation of Forest Genetic Resources in Siberia Proceedings Krasnoyask 160
[16] Patent on selection achievement No. 1187 R. F. Topol (Populus L.) Khopersky 1 A I Sivilapov; applicant and patent holder of VSAFT. – No. 9908269; declared. 06.12.2000; registered in the state register of protected selection achievements 17.12.2001