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Genetic test collections of poplars in the south-eastern part of European Russia for biodiversity preservation.

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Abstract

The relevance of research on biodiversity conservation corresponds to the trends of ideas of the last century, summarized in the Rio Convention (1992) and subsequent international acts. The greatest problem is the preservation of intraspecific diversity. According to the chromosomal inheritance theory of Sutton and Boveri, the number of possible phenotypes of two parents is expressed as 2^n, and genotypes as 3^n, where n is the haploid number of chromosomes in the parents. In particular, for poplars this is ≈ 500 thousand different descendants, and the number of genotypes can be ≈ 4.6 billion. Taking into account the decoding of genome data, these values can be increased many times.
In forest tree breeding researchers try to identify the most useful organisms or their aggregates from the existing varieties. Since its Foundation in 1971 the All-Russian Research Institute of Forest Genetics, Breeding and Biotechnology has been working to create an ex situ field collection fund of practically valuable clones, hybrids and varieties of poplars. The collections were created over the next 50 years, taking into account the recommendations of the field experience methodology.
In different regions of the country the collections of hundreds clones and new hybrids in 5 locations; the variety testing sites in 15 locations; and root cutting plantations in 19 locations were created. Totally, 54.04 ha of poplar experimental objects were created in the South-Eastern part of the European territory of Russia. As a result of many years research, new varieties of poplars have been developed for plantation, protective and reclamation afforestation, as well as for landscaping in the forest-steppe and steppe zones of European Russia.

Keywords: Biodiversity conservation, Genetic resources, Research, Poplar breeding, Poplar varieties.

Introduction, scope and main objectives

In recent decades, the scientific community of the world has been concerned with preserving the biodiversity of organic life. In Russia, one of the first people who pay attention to the decrease in natural diversity of species due to human fault was the author of the book "The Final Evolution" (Kozo-Polyansky 1922). Years passed ... and in 1962, the work "Silent Spring" by Rachel Carson appears with evidence of the carelessness or greed of a human who destroys all living things (Carson 1962). The book has blown up the world, and humanity has become more careful to the available natural wealth.
Finally, at the Earth Summit in Rio de Janeiro on 5 June 1992, the Convention on Biological Diversity was opened for signature, which was enacted on 29 December 1993 (Convention 1992). To date, 193 countries have signed the convention. The Convention provides for the conservation of population, species and intraspecific diversity.

But, if with the preservation of population and species diversity, it is more or less clear what should be preserved and even how, then with the preservation of intraspecific diversity – this is terra incognita. In fact, according to the chromosome theory of inheritance of Sutton and Boveri (Chromosome theory 2020), the number of possible phenotypes of two parents is expressed by a value equal to 2^n, where n is the haploid number of chromosomes in the parents. For example, for a poplar, this is 524,288 ≈ 500 thousand different descendants. And the number of genotypes is 3^n, which theoretically for one parent pair of poplars can be 4,649,045,868 ≈ 4.6 billion of different genotypes.

And it can produce only one pair of the same species without mutations, polyploidization, transgenesis and other external influences, and without taking into account the number of poplar species and the countless number of pairs in intraspecific and interspecific crosses. This is typical not only for poplar, but also for other biological species. Taking into account the decoding of genome data, these values can be increased many times even in the natural course of processes.

With the development of civilization, various human needs arise, to meet which an artificial increase in various genotypes occurs. These processes include the following:

- Selection of individual highly productive trees in natural stands, followed by their testing and selection of specimens with a high overall combinational ability among them (Tsarev 2013).
- Introduction of the best plants from various regions, countries and continents; their testing and selection of the most suitable for various purposes (Poplars... 2014, Tsarev *et al.* 2014).
- Hybridization and selection of individual parent specimens with high general combining ability and parent pairs with high specific combing ability among them. In addition, among the obtained hybrids, it is necessary to distinguish the fastest-growing plants with a straight trunk for forest plantations, as well as producing a large wood stock of biomass at a young age for energy plantations. It is also necessary to identify offspring that are distinguished by a pyramidal crown, have a high aesthetic value and are male for use in landscaping, roadside plantings, fencing gardens, country villages and other applications (Poplars 2014; Stanton 2005; Tsarev *et al.* 2017).
- Creation of new practically valuable genotypes using techniques of polyploidy, mutagenesis, transgenesis, somatic hybridization and other techniques of genetic and gene engineering (Rybchin 1999; Tsarev *et al.* 2014; Inge-Vechtomov 2015).
- Variety testing in different growing conditions, with the required duration of observations and by different cultivation technologies. As a result of the conducted studies, the corresponding zoning of the obtained new breeding and genetic material can be established (Poplars 2014; Tsarev *et al.* 2014).

It is obvious that it is simply impossible to preserve all existing and artificially obtained intraspecific biological diversity. In breeding, researchers try to identify from the possible inexhaustible variety the most useful organisms or their aggregates for practical purposes, test them for a certain period and offer them for wide use. At the same time, in some cases, at the first stages of selection, it is recommended to select up to 5% of promising plants (Zobel and Talbert 1984). In the future, after the appropriate tests, a more stringent selection will be carried out.

From the beginning of its creation in 1971, the Central Institute of Forest Genetics and Breeding (now All-Russian Research Institute of Forest Genetics, Breeding and Biotechnology) has been working to create a collection fund of practically valuable clones, hybrids and varieties of poplars and to test them.

Special attention was paid to the creation of such ex situ collections in living field plantings. These collections were created not only as individual samples, but taking into account the recommendations of the field experience methodology in such a way that they could be field tested for a long time until the age of economic exploitability to pursue an object.

Collections of clones and new hybrids were created in 5 locations on an area of 5.95 ha; variety testing sites in 15 locations on an area of 35.46 ha and root-cutting plantations in 19 locations on an area of 11.03 ha (Tsarev *et al.* 2019).
In this publication, the authors tried to use the example of one experimental object created to investigate the possibility of preserving intraspecific biological diversity in ontogenesis and using the results obtained for practical purposes.

Methodology/approach

The main studies were carried out on the populetum created by the initiative of A.P. Tsarev in the spring of 1974 in the Semiluky district of the Voronezh region in accordance with the methodology of field experience (Cochran and Cox 1957; Dospekhov 1973). Pre-planting preparation of the soil was winter plowing to a depth of 30 cm. Planting was carried out with stem cuttings of various varieties and clones of poplars. 84 representatives of poplars were introduced into the experiment.
The plot area is 4.6 hectares; the size is 296×155 m. The soil is leached heavy loamy Chernozem. The relief is a weak watershed slope to the Veduga River. The ground water level is 4-5 m. The forest type D_2. Plant placement was 5×4 m. The experiment was carried out in 4 repetitions. The placement of plots in repetitions is randomized. The number of ramets (plants of one clone) on the plot is 6. Each clone and variety is represented by 24 plants on an area of 480 m^2 (20 m^2 × 6 ramets × 4 repetitions).
The studied plants are representatives of six morphological and systematic groups (MSG):
1) white poplars with the pyramidal form of a crown;
2) white poplars with a spreading crown shape;
3) black poplars with the pyramidal form of a crown;
4) black poplars with a spreading crown shape (mainly a group of euramerican hybrids);
5) balsamic poplars and their intra-sectional hybrids;
6) intersectional and complex hybrids of eupopulus L.
The survival and growth of plants were observed for 45 years, the details of which are given earlier (Tsarev *et al.* 2010; Tsarev *et al.* 2019). Economic exploitability occurred in different varieties and clones at different ages: in white poplars about 40 years, in eupopulus with a spreading crown – 26, and in black poplars with a pyramidal crown – in 22-23 years]. In this regard, the analysis of the results is presented in these ages. As a control for each MSG, the average aggregate value of the set of represented genotypes was used (Council directive 2000).
In addition to the survival and growth of plants, winter hardiness, drought resistance, pest and disease damage, physical and mechanical properties of wood, forage value of wood greens, ecological plasticity and stability of individual cultivars according to the Eberhart and Russell method, and some other indices were studied (Eberhart and Russell 1966; Tsarev *et al.* 2019; Tsarev *et al.* 2020).

Results

The data of observations on the growth and survival of poplars are presented in Table 1. As can be seen from the data in this table, the highest average increment in the age of economic exploitability was observed in the MSG of euramerican hybrids of black poplars (more than 18.9 m^3/ha per year), and the lowest – in white poplars with a pyramidal crown. This may have been partly due to the lowest survival in this MSG.

Table 1: Survival and growth of plants in different morphological and systematic groups of poplars

Morphological and systematic groups (MSG)	Age, years	Survival, %	Average volume of the trunk, m^3	Average wood stock, m^3/ha	Average increment, m^3/ha per year
White poplars with a pyramidal crown	40	23.0	1.635	206.1	5.1
White poplars with a spreading crown	40	42.0	2.616	535.2	13.9
Black poplars with a pyramidal crown	40	27.1	1.440	217.7	5.4
Euramerican hybrids of black poplars	40	66.4	2.219	758.0	18.9
Balsam poplars	25	89.0	0.760	338.0	14.4

From the data in Table 1, it can also be seen that euramerican poplars had the best survival by the age of 40. Balsam poplars are represented only by 25-year data because after this age, they began to break down. The best indices of trunk volumes by the age of 40 were in white poplars with a spreading crown and in euramerican poplars. But due to the higher survival, stocks were higher for euramerican poplars. They also had the highest average increments by this age.
Within each morphological and systematic group, the best hybrids and varieties were selected. Their brief description is presented in Table 2.

Table 2: Survival and growth of plants in different morphological and systematic groups of poplars

Morphological and systematic groups (MSG)	The best variety or hybrid within MSG	The age of the best genotype, years	Survival, %	Average wood stock, m^3/ha	Average increment, m^3/ha per year
White poplars with a pyramidal crown	'Soviet pyramidal X_1' (bred by A.S. Yablokov)	40	29.0	322	8.1
White poplars with a spreading crown	'Dryada' (bred by A.P. Tsarev and R.P. Tsareva)	40	46.0	672	16.8
Black poplars with a pyramidal crown	'Pioneer'(bred by A.S. Yablokov)	23	59.0	340	14.8
Euramerican hybrids of black poplars	'Regenerata' No. 78 (Alten Sorten)	25	92.0	1 151	46.0
Balsam poplars	P. simonii No. 85	25	100.0	400	16.0

A comparative analysis of the data in Tables 1 and 2 showed that the best genotypes in one or another MSG exceeded their average values. So, in white poplars, these excesses ranged from 1.2 to 1.6 times; in black poplars from 2.4 to 2.7 times, in balsamic poplars – 1.1 times; and in intersectional hybrids – 2 times.

Discussion

It should be noted that in a number of breeding programs it was noted that the most difficult stage of the most breeding programs was the stage of testing the genetic value of selected plus or any other valuable trees and populations by seed progeny (Tarakanov *et al.* 2001; Laur 2012; Besschetnova 2016). At the first stages of breeding seed production in most countries, first-order

seed orchards were created from selected, but not tested for offspring, plus trees. Such seed orchards technologically facilitated the production of seeds, but did not guarantee a genetic and practically significant improvement of the plantations created from them.
Studies conducted with Scots pine in some countries have shown that the use of plus trees without their preliminary tests gave a slight genetic effect. For example, J.W. Wright (1976) cites results obtained in Sweden, Great Britain, and Michigan (USA). In all these trials, the effect was negligible or absent altogether. According to some traite, the genetic gain did not exceed 0.5-1.0%.
On the other hand, E. Rohmeder and H. Schönbach (1959) showed that when testing seed progeny of trees from the same pine plantation, their growth at 17 years of age differed by 34%.
Long-term studies with poplars in European Russia showed that the highest productivity was in the poplar ‘Regenerata No. 78’ (Table 2). Unfortunately, it was characterized by low ecological stability and could show such excellent results only in favorable growing conditions (Tsarev *et al.* 2020).
If we evaluate the results as a whole, it can be noted that in other situations, genotypes with other qualities may come out on top. For example, the aesthetics of white pyramidal poplars, the speed of growth of balsam poplars in the first years of their ontogenesis for obtaining biomass for bioenergy, the development of a surface root system for fixing ravines in aspens and some white poplars, etc. Therefore, when drawing up programs for the conservation of the gene pool, it is necessary to take into account various prospective needs as much as possible.

Conclusions/ wider implications of findings

The existing natural organic including forest gene pool is in danger of destruction and therefore efforts and methods of its conservation are being made in the world.
If it is impossible to preserve everything, when preserving the intraspecific biodiversity of forest woody plants, it is necessary first of all to take care of organisms that are of practical importance for humans.
Among forest woody plants, such organisms include poplars. Since they are valued for their speed of growth, when preserving certain genotypes in vivo, it is desirable to take into account their behavior, growth stability and other qualities in the process of ontogenesis. To explore these indices there are preferably the usual collection of genotypes to be combined with the test objectives.
During long-term studies, the best cultivars and varieties were identified and bred, which to date have turned out to be the best among the tested population.
Note that the priorities of consumption and use of wood and other values of woody plants with time changing so when we’ll breed, select and test of certain genotypes, it must be possible to foresee a shift or expansion needs.

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forest enterprises in forest-steppe, steppe and semi-desert zones of the country, as well as of farm workers and organizations to enforce protection of these trials and care for them.

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