Forest Breeding of Conifers in Russia

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The article presents the comparison of plus breeding, individual selection and selection of populations on the basis of the analysis of large experiments on progeny tests in 9 regions, with more than 40 families at the age of 8 years and older. It appeared that excess over control height scores of progenies of plus trees by regions for the Scotch pine changed from-12.7 to +7.0 % (on the average for 549 families -1.1 %). For the Finnish spruce assessments varied from +0.1 to +5.1 % (on the average for 620 families+2.7 %). 3-34 % of the pine families and 4-22 % of the spruce families authentically exceeded control scores. Individual selection resulted to an improvement in height growth from 5 to 33 % in the group of the best families. In selection of the populations the distinction between extreme options is less and makes from 4.6 to 16 %, but this type of breeding has 10 times less cost and less risks of failures, if the work is preceded with estimates of the growth of progenies of populations in 4-5 years. Origins-leaders of spruce can be identified at the age of 4, and they will be in group of 60% best origins

Key words: conifers, forest breeding, populations, plus trees, test cultures.

INTRODUCTION

World experience of forest breeding years 1950-1970. was perceived in the USSR primarily through works Lindquist B., Rohmeder E. and H. Schonbach, and Wright J.W., which have been translated and published in Russian. Were chosen three systems breeding:

- mass selection (plus-breeding, plus-selection);
- individual selection (selection after the results of testing progenies);
- selection of local populations by progenies (breeding of populations).

In the 1980s, the last system in Russia has been reduced to nothing, and it was a big mistake. The summarized results of the tests of plus trees progenies of the main forest species in the republics of the former USSR showed, that a share of the elite families varies from 0 to 90 % in experiments of different researchers; the reasons for different estimates could be use of inappropriate types of control, imperfection of experiment, dependence of productivity on environmental factors [8]. We learned new information on these issues in our monographs [4, 5] and present them below together with their own results.

MATERIALS AND METHODS OF RESEARCH

Research method in this paper was a logical analysis of new information. During the study of the results we separated data, having selected large experiments with 40 and more half-sib families (large statistical sample) at the age of 8 years old and older for evaluating the effectiveness of forest breeding. We also discussed our results of Finnish spruce (*Picea ×fennica* (Regel) Kom.). This data is devoted to the first part of the section results. In the second part of this section analyzes the growth of progeny 453 trees from 12 populations. For these studies, in 1986 we laid the test culture on an area of 11 hectares, on the scheme 2.5 × 1.0 m under typical conditions on the light loamy soil. Measurements were taken at 4, 8 and 21 years. Total was measured 30000 trees. Location of the parent population and geographical coordinates of test cultures and details of methods are shown in the monograph [4, pp. 129-134].

RESULTS AND THEIR DISCUSSION

As a result of generalisation of data on the large experiments we received average data for 549 elite trees of the Scotch pine by 8 experiments in 6 regions, and for 620 spruce trees in 4 regions. The deviation from control scores the height of the progenies from all elite trees by regions varies: for the Scotch pine from-12.7 to +7.0 %, averaging for 549 families -1.1% and for the Finnish spruce from +0.1 to +5.1%, averaging for 620 families +2.7%. 3-34 % of the pine families and 4-22 % of the spruce families significantly exceeded control scores (Table 1).

Table 1 – Results of large-scale analysis of offsprings of plustrees in Russia (number of families is 40 and more, age is 8 years old and older) for 01.01.2012.

Authors	Republic, territory, region	Testing cultures		Deviation from the control options, %	Significantly exceeding control, % of families
		Age	Number of families		
Pinus sylvestris (L.)					
Vidyakin, 2010	KirovRegion; The UdmurtRepublic	20	97	-0.4	2.1
Golikov, 2006	PskovRegion	17-22	71	7.0	34
Demidenko, Tarakanov, 2008	NovosibirskRegion	20	100	1.9	12-22
Turkin, 2007	The KomiRepublic	9	60	-3.2	10
Turkin, 2007	The KomiRepublic	9	129	-12.7	3
Turkin, 2007	The KomiRepublic	8	50	0	6
Sheikina, 2004	The ChuvashRepublic	10	42	-0.5	24
All families			***549***		
Efficiency of plus-selection, average				***-1.1***	***13.9***
Picea×fennica(Regel) Kom.					
Golikov, 2006	Pskovregion	23	72	3.1	22
Vidyakin, 2010	KirovRegion; The UdmurtRepublic	15-17	95	0.1	4.2
Rogozin, Razin, 2012	PermKrai, natural	21	301	2.4	15
Rogozin, Razin, 2012	PermKrai, from ordinary cultures	21	152	5.1	22
All families			***620***		
Efficiency of plus-selection, average				***2.7***	***15.8***

These results are important for the strategic assessment of plus-selection. Based on these estimates, it is possible to calculate the intensity of selecting of the "elite" trees, which will be approximately 15%. However, in particular populations and regions its intensity considerably deviates from the average, and this deviation is fundamentally changing the whole strategy of selection. For example, in one of the experiments in the Republic of Komi the pine progeny of 129 families grow much worse in comparison with the control, that is, by 12.7% [7]. However, there are cases when progenys in some regions or from selected cenopopulations (PskovRegion, pine; PermKrai, spruce plus trees from cultures) grow 5-7% better in comparison with the control scores (see Table 1). Thus, efficiency of plus-selection by the regions of Russia gave different results. A possibility of obtaining such results was predicted as early as in the 1970s by many prominent foresters: they always stressed the necessity to test and breeding of parent trees that give the best progeny.

Testing the second system of forest breeding led to better results. For example, in the Perm Krai 15% of the best spruce families, separated (selected) from a group of 152 families, received from plus trees from conventional forest crops, at the age of 21 exceeded the control height scores for 21% [4]. In Kirov Region and Udmurtia the groups of the best pine and spruce families exceeded the control scores by 15-17% [8]. In Pskov Region the average excess of such groups in the spruce offspring was about 25% [3]. At the same time, in other regions the average height excess in the best groups of pine families did not exceed 10% [1, 6, 7].

The positive results of the individual selection mentioned above are usually obtained for a population where there was a better growth of the offspring not only from plus trees, but also from ordinary trees [3, 7, 4].

That is, the population gave in general a fast-growing offspring, and such population may be found by simple testing of an ordinary seed collection. This fact leads us to the third selection system (breeding of populations), which is highly effective for detecting such cases, and here the offsprings give difference between the extreme variants within 4.6-16% of height [4, 5]. Back in the 1980s in the Latvian Republic the selection of populations was considered in some cases even more promising than the selection of plus tree progenies. Apparently, the priorities in selection of conifers in Russia should be changed, too, by developing multivariant forest breeding programs.

In general, the effect of population selection by height is 4.6-16%, and sometimes is two times less in some populations and regions than the maximum effects of individual selection of the best families group (15-33%), but it is often equal to this effect, especially in pine selection, which in some regions has the effect of 5-10%. There fore, the individual selection in the study of unexplored populations has no significant advantages over the breeding of forest populations by progeny, which is ten times cheaper.

To determine the age of the progenies, when is formed by a group of origins leaders, we conducted a comparison of their height in 4, 8 and 21 (Table. 2).

Table 2 - Growth of plus trees progenies spruce different origin in PermKrai (by Rogozin, 2013b)

Origin (cenopopulation)	Количество, шт. Quantity, pcs.		The average height,% of control			The ranks of average height		
	families	plants	4 years	8 years	21 years	4 years	8 years	21 years
Natural stands								
Ocher	13	459	108.7	108.7	108.0 *	1	1	3
Nytva	29	834	106	107.3	105.9 *	2	3	5
Gaiva	74	1898	99.2	95.9	95.4 *	8	11	12
Ilyinsk	32	1010	97	106.3	101.8	9	4	8
Perm	108	2918	96.2	101.2	102.6 *	10	10	7
Kungur	27	785	96.1	102.1	102.7	11	8	6
Chusovoi	18	515	95.2	103.9	100.2	12	6	9
Total	***301***	***8419***	***98.4***	***103.6***	***102.4 ± 0.35****	***7.6***	***6.1***	***7.1***
Forest cultures								
Sepych-I	85	2628	102.1	107.7	107.8 *	7	2	4
Sepych-II	9	239	104.3	104.3	110.4 *	3	5	2
Ocher	16	411	102.8	103.8	110.7*	6	7	1
Vereshagino	19	474	103.5	101.3	97.3 *	4	9	11
lower Kurya	23	595	103.4	93.7	100.0	5	12	10
Total	***152***	***4347***	***102.7***	***104.2***	***105.1 ± 0.47*****	***5***	***7***	***5.6***

* - difference from control authentically

In a sense, it will be the answer to the question of the fundamental possibility of an earlier diagnosis of growth at the macro level - at the level of large communities of plants. In our experiments, the difference in height of 12 origins reached 13.5-15.3%, and there was some preservation ranks of heights with age. Of the first seven ranks, observables in 4 years and 8 years, have kept a high rank to 21 years 5 origins, and they exceed the control at 5.9-10.7% (in the table are darkened). This group includes more than half of the tested variants (7 out of 12, or about 60%) and contains within itself the future leaders. Therefore already in nursery we can choose candidates for the origin-leaders, and further sharply will reduce the area of test cultures.

According to Table 2 can be determined and efficacy for plus-breeding spruce in Perm Krai. At the age of 21 origin were significantly higher than the control, in five cases out of 12 (42%) and plus-selection has been effective; in a similar number of cases (42%) of their height were very close to the control, and two origin (16% of cases) were growing authentically worse than the control.

The next stage of work on early diagnosis of growth was the question of the minimum age when possible selection of families with height at age 21 110% of the control and more – families-leaders. We used families from plus trees from natural stands and from forest cultures (301 and 152 families) in two age states: 4 years and 8 years, and have compared height of the families in these ages, with heights at age 21. Correlation to heights of 4 and at age 21 were still unreliable, but at 8 and '21 autocorrelation was already sufficient ($r = 0.48 \pm 0.03$) for the selection of candidates in a group of families leaders. For forming of this group, family at the age of 8 years old must have a height of 101% or more of the height of control; the share of such families is 50-60% [5]. Thus, early diagnosis of growth between the origin of spruce is more successful than diagnosis rates among her families.

A study on early selection of the origins of pine in Siberia [2] showed that high correlation ($r \approx 0,8$) to the heights of climatypes at the age of 30 years starts at the initial period of growth, which is10-12 years old, however, at the age of 4-5 there is reliable low correlation with their sizes. This completely confirms our idea of the"soft" selection among origins with intensity of 60% at the age of 4.

The next relevant issue of forest breeding is division of progeny tests into two phases: testing for growth speed and testing for biomass productivity. In the first case, we measure the growth of individual trees experimental plots, and then we sum the figures of their growth to determine the average value. In the second case we study a much more complex parameter, which is the form of crop biomass (wood volume) per area unit.

At the first stage of testing competition between plants is weak and has little effect on the development of trees, whereas at the second stage this competition strongly affects the further growth of the origin and reduces or increases two or more times productivity of biomass depending on the initial density of forest stand [5].

For the first case, it was proved that the sample size for a family in one test may be reduced to 20-30 plants [5, 7]. In this case the breeder takes at least three or four trials using seeds of several harvests, and combines results of these tests. As a result, the total sample size quite large. After evaluation of the progenies of the first harvest, which is about 5 years, in accordance with the periodicity of fruiting of conifers the second harvest is expected, and in following 5 years, the third one, and during the series of these three experiments we may gradually reduce the number of populations each time for approximately 40%, according to the results of earlier growth evaluation. After such moderate "separation" of the best origins we are already able to check their progenies for accumulation of timber stock by limited number of forest stands, that is, implement individual selection.

In our view, breeding for any breed should be started, first of all, with a study of progeny of cenopopulations, as the earliest estimates of growth will reduce the cost of other selection systems. Russia’s sad experience convinces us that lack of study of cenopopulations’ progeny may stall the whole system of forest selection, if it has only one direction of selection, that is, plus-breeding, especially a highly abridged version of it when breeders were suggested selecting plus trees without testing their progeny.

The analysis shows that in order to avoid the accidental hits on weakly growing offspring, it is necessary to test offspring populations within forest seed areas just before the beginning of the selection of plus trees. This will prevent from receiving a large number of close to neutral results. The best origins, after evaluation of their offspring at the age of 4-5, can be immediately used just by harvesting seeds and creating forest seed orchards made of them. This will be both a strategically correct choice and simultaneously fast innovation of results of selection for seed growing of conifers with the lowest expenses.

CONCLUSION

Thus, the comparative analysis of plus selection, individual selection and selection of populations showed that height growth of plus trees progenies by regions compared with control scores changed for Scots pine from -12.7 to +7.0 % (on the average for 549 families -1.1 %). For the spruce tree assessment varied from +0.1 to +5.1 % (on the average for 620 families +2.7 %). 3-34 % of the families of pine and 4-22 % of the families of spruce authentically exceeded the control scores. Individual selection gives a shift in height from 5 to 33 % in the group of the best families. In selection of populations distinction between extreme options is less and makes from 4.6 to 16 % for height, but this type of selection is several times cheaper and has less risks of failures for plus selection and individual selection, if estimates of growth of progenies of populations in the periods of 4-5 precede. It is obvious that it is necessary to develop programs of breeding conifers based on multi-stage series of testing progeny of populations. According to such estimates it is possible to breed up to 60% of origins having great potential for next generations of seeds. Finnish spruce in PermKrai plus breeding is effective in 42% cenopopulations; in other cases its effect is neutral (42%) and negative (16%). Therefore plus breeding continues to be a hypothesis, which requires checking in each population.

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