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**GROWTH, PRODUCTIVITY AND HERITABILITY OF THE HEIGHT
OF THE SEED PROGENY CLONAL HYBRID SEED PLANTATION
OF SCOTS PINE AT 7 YEARS OF AGE**

Conducted studies on growth and productivity of seed progeny clonal hybrid seed plantation of scots pine in the test cultures. Test cultures of scots pine at 7 years of age have high rates of growth. Of the 20 subjects 9 families of offspring grow better monitoring, indicators 11 families below the height control. On the total volume of the trunks of the differences among the seed progenies were significant. The volume of tree trunks in the compartment in only 2 families were below the control variant (ratio of control to 62.8 and 99.8%). In 17 of the 20 families, the volume of trunks in the compartment exceeds the control by more than 10% (from 111 to 228%). A supply of stem wood of all the families, except two, exceed the control. Also in test cultures determined the heritability of height of seed progeny of scots pine, which amounted to 39.8%.

Key words: pine ordinary, growth, productivity, heritability, seed progeny, hybrid seed plantation, test culture.

Introduction. At present, the possibility of significant increase of forest plantations productivity is considered to be indisputable besides other methods and means, within the existing achievements of forest genetics and selection [1]. According to some researchers, using a seed and planting selection-improving material one can achieve significant (15–25%) increasing of forest stands productivity [2, 3].

According to the results of our researches, obtained earlier [4–6], introduction into silvicultural production practice of distant intraspecific Scots pine hybrids, distinguished by intensive growth in height, allows you to receive by 10 years old plantations of more powerful growth (up 15%) in comparison with the control.

The aim of this study is to evaluate the growth and productivity, as well as to define the difference in the growth and height heredity of clonal hybrid seed progeny Scots pine plantations in Negorelsky-experimental forestry at the age of 7 years old, i. e. at the age of forest plantations transferring to the forested area.

Main part. The researches of growth and productivity of Scots pine plantations were carried out on 15.09.2015 in the quarter 19, plot 36, in Krasnoslobodsky forestry SFI “Starobin Forestry” in the area of 0.6 hectares. History of the object was described by us earlier [7].

More than 20 Scots pine families in all have been studied. To compare growth and productivity indexes as a control seed progeny of Scots pine, grown from the seeds of the first order SFI “Starobin Forestry” seeding orchards.

By actually measured of trees heights and diameters the volume of tree trunks all progenies was determined. The specific number of Scots pine is equal to 0.53 in accordance with the growth course tables of A. V. Tyurin [8].

The tree offspring trunks volumes were expressed in absolute ($\text{m}^3 \cdot 10^{-3}$) and relative (%) values. Scots pine hybrid families stock was found by summering of the actual 40 trees volumes of each tested families in the area with the subsequent transfer of obtained volumes in a stock per unit area, e. d. on 1 ha.

To determine the estimated stem woodstock the following formula was used by us:

$$M = \frac{F \cdot 10,000}{S},$$

where M – the estimated stem wood stock, m^3/ha ; F – the actual stem wood stock on plots, m^3 ; 10,000 – area 1 ha, m^2 ; S – area of the plot occupied by a hybrid family m^2 .

To verify differences in terms of height among the investigated families of Scots pine in the age of 7 years old such a statistical method was applied as ANOVA, allowing not only to compare the growth rates of families with each other, but also to measure height heritability degree of offspring plantations. Studies of Scots pine seed offspring plantations showed that when growing hybrid-seed plantations families are characterized by different growth. Thus, the height rate of 7 years old tree ranges from 286 cm (family 6–3) to 351 cm (family 7–6). In control variant, the average height of the seed progeny in Starobin forestry plantation is 301 cm. 9 from 20 tested offspring families grow better than controls, 11 families have plant growth rates lower than control variant (Table 1).

According to the diameter of the tree, all the tested families grow better than control. According to the total trunks volume on the plot (40 trees per one family), the differences among seed progenies were also significant.

Table 1

**Average growth indexes of 7 years old Scots pine seed progeny
of clone seed hybrid plantation in Negoreloe TEF**

Number of the family	Growth indexes		Sum trunk volume in the plot		Stem wood stock, m ³ /ha
	average height, cm	average diameter, cm	m ³ · 10 ⁻³	ratio with a control, %	
3-6	317.8 ± 4.8	3.2 ± 0.1	55.83	156.9	7.0
6-3	285.9 ± 4.4	2.9 ± 0.1	42.39	119.1	5.3
6-7	324.9 ± 2.8	3.4 ± 0.1	65.09	182.9	8.1
7-3	313.0 ± 4.4	3.2 ± 0.1	56.08	157.6	7.0
7-4	296.9 ± 6.3	3.0 ± 0.1	49.97	140.4	6.3
7-5	337.1 ± 4.9	3.3 ± 0.1	64.98	182.6	8.2
7-6	351.5 ± 3.5	3.7 ± 0.1	81.26	228.4	10.2
7-7	297.0 ± 5.5	3.1 ± 0.1	51.58	145.0	6.5
7-8	319.9 ± 5.6	3.2 ± 0.1	58.44	164.2	7.3
7-9	316.3 ± 5.0	3.1 ± 0.1	51.17	143.8	6.4
7-10	297.5 ± 4.3	3.3 ± 0.1	55.59	156.2	7.0
8-5	279.5 ± 4.8	2.9 ± 0.1	22.33	62.8	2.8
12-3	295.8 ± 2.3	2.7 ± 0.1	39.49	111.0	4.9
12-9	288.5 ± 7.1	3.0 ± 0.1	46.26	130.0	5.8
12-10	297.1 ± 5.6	3.1 ± 0.1	50.28	141.3	6.3
13-1	306.6 ± 5.6	2.9 ± 0.1	46.27	130.0	5.8
13-2	293.8 ± 3.9	2.7 ± 0.1	37.31	104.9	4.7
13-3	297.4 ± 4.5	2.9 ± 0.1	41.95	117.9	5.2
13-4	278.4 ± 4.7	2.7 ± 0.1	35.50	99.8	4.4
13-9	311.0 ± 6.0	3.1 ± 0.1	55.08	154.8	6.9
Control	301.4 ± 7.2	2.6 ± 0.1	35.58	100.0	4.5

Note. To compare growth indexes they took as a control variant a seed progeny of Scots pine, grown from the seeds of the first generation seed plantation in SFI "Starobin Forestry". The diameter of the trees in the 7 years age was measured at a height of 1.3 m with a caliper (accuracy ±1 mm), tree height – using the measuring pole (accuracy ±5 cm).

Thus, the volume of only 2 trunk trees families on the plot was lower than the control variant (ratio of the control is 62.8 and 99.8%).

The trunk trees volume of 17 from 20 families in the plot exceeds the controls of more than 10% (from 111 to 228%). All the families stock trunk wood, except two (2.8 and 4.4 m³/ha), exceed the control variant (4.5 m³/ha) from 4.7 to 10.2 m³/ha. In order to determine the height differences in the clonal seed progeny growth and heritability of Scots pine hybrid seed plantation, contact ANOVA method was used (Table 2).

In order to verify differences in growth among the tested families you need to calculate a number of indexes, following a strict algorithm of calculating the dispersion and variance. Dispersion (C) is the presence of diversity in the group and the primary measure of diversity. The variance is the sum of the squares of the central deviation. Factorial dispersion (C_x) is grand averages quotient dispersion near the grand average. Accidental variance (C_z) is the variance about their private secondary dates. The total variance (C_y) is the variance of dates around their grand averages quotients. Total

variance (δ) is the dispersion divided by the number of degrees of freedom. There are factorial (δ_{2x}) and accidental (δ_{2z}) variances. First, it is necessary to calculate the weighted average square of the general average value by formula.

Further, the factorial variance is calculated by the following formula:

$$C_x = \Sigma H_i - H_\Sigma = \\ = 15,370,551.4 - 15,266,277.1 = 104,274.3.$$

Then, the accidental variance is found out by formula:

$$C_z = \Sigma V^2 - \Sigma H_i = \\ = 15,528,043.0 - 15,370,551.4 = 157,491.6.$$

Whereupon the general dispersion is determined by the following formula:

$$C_y = C_x + C_z = \\ = 104,274.3 + 157,491.6 = 261,765.9.$$

Factorial variance is calculated by the formula:

$$\delta_x^2 = \frac{C_x}{R-1} = \frac{104,274.3}{11-1} = 10,427.43.$$

Table 2

Validity determination of growth differences of 7 years old Scots pine seed progeny of clonal hybrid seed plantation in Negorelsky TEF using a single factor ANOVA graduations investigated trait for seed progeny number graduations

V	Features undertest gradation for seed progeny											Number of graduations R = 11
	7-6	7-5	6-7	7-9	Control	12-3	13-2	12-9	6-3	8-5	13-4	
	1	2	3	4	5	6	7	8	9	10	11	
n	15	15	15	15	15	15	15	15	15	15	15	N = R · n = = 11 · 15 = = 165
ΣV	5,284	5,104	4,903	4,770	4,547	4,462	4,360	4,264	4,264	4,137	4,124	ΣΣV = = 50,189
ΣV ²	1,869,404	1,750,838	1,607,221	1,514,700	1,412,765	1,330,328	1,275,696	1,242,616	1,224,938	1,153,599	1,145,938	ΣΣV ² = = 15,528,043
H _i = (ΣV) ² / n	1,861,377	1,736,721	1,602,627	1,497,840	1,378,347	1,327,296	1,267,304	1,212,113	1,212,113	1,140,985	1,133,825	ΣH _i = = 15,370,551

Note. R – the number of the experimental groups graduations; n – number of measurements in dates; N – the product of the number of graduations per the number of measurements in dates; V – the dates (measurements); n – the number of dates; Σ – sum sign; ΣV – the amount of dates; ΣΣV – the sum of the amount of dates; ΣV² – the sum of the squares of the dates; ΣΣV² – the sum of the sum of squares of dates; (ΣV)² – the amount of dates, squared; H_i – the weighted square of quotient average value of central deviations; ΣH_i – weighted sum of the weighted squares of quotient average value of central deviations.

Accidental variance is calculated by the following formula:

$$\delta_z^2 = \frac{C_z}{N - R} = \frac{157,491.6}{165 - 11} = 1,022.67.$$

Validity of differences according to Fisher (F) is determined by comparison of the actual values (F_{fact}) with a standard table value (F_{st}) and is determined by the formula:

$$F = \frac{\delta_x^2}{\delta_z^2} = \frac{10,427.43}{1,022.67} = 10.2$$

$$\text{by } F_{st} = \{5.1; 3.4; 2.3\}.$$

ANOVA also allows us to estimate the power of feature manifestation, or strength of feature influence, i. e. height heritability coefficient (η_{2x}).

Coefficient of heritability of height is calculated according to the formula:

$$\eta_x^2 = \frac{C_x}{C_y} = \frac{104,274.3}{261,765.9} = 0.39835,$$

$$\text{or } 39.8\%.$$

The error of height heritability coefficient is found out by the formula:

$$m_{\eta_x^2} = (1 - \eta_x^2) \cdot \frac{R - 1}{N - R} =$$

$$= (1 - 0.39835) \cdot \frac{11 - 1}{165 - 11} = 0.03907.$$

Thus, the height heritability coefficient (η_{2x}) of Scots pine seed progeny and its error made η_{2x} = 0.39835 ± 0.03907. The reliability of heritability coefficient by Fisher (F) is determined by comparison of the actual values (F_{fact}) with a standard table value (F_{st}) and is determined by the formula [9]:

$$F = \frac{\eta_x^2}{m_{\eta_x^2}} = \frac{0.39835}{0.03907} = 10.2$$

$$\text{by } F_{st} = \{5.1; 3.4; 2.3\}.$$

Thus, the height heritability coefficient of 7 years old Scots pine progeny seed of clonal hybrid seed plantation is η_{2x} = 0.39835 ± 0.03907, or 39.8%.

Conclusion. The following conclusions can be drawn from the research: test plants of the 7 years old Scots pine clonal hybrid seed plantation in Negorelsky educational experimental forestry are characterized by high rates of growth; from 20 families put to the test, 9 progenies have height index of plants more than control, 11 families have the average height of trees lower than the control variant; height heritability coefficient (η_{2x}) of Scots pine seed progeny in the test 7 years old plants was 39.8%; the validity of height heritability coefficient is confirmed by the calculated Fisher standard (F = 10.2 at F_{st} = 5.1).

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