The effect of seed coat color grading on height of one-year-old container-grown Scots pine seedlings planted on post-fire site

The effect of seed coat color grading on height of one-year-old container-grown Scots pine seedlings planted on post-fire site

A I Novikov[1] and V Ivetić[2]

[1] Faculty of Forestry, *Voronezh State University of Forestry and Technologies named after G.F. Morozov,* 8 Timiryazeva street, Voronezh 394087, Russian Federation
[2] Faculty of Forestry, *University of Belgrade*, 1 Kneza Višeslava street, Belgrade 11030, Serbia

[1]E-mail: arthur.novikov@vglta.vrn.ru

Abstract. The basis for the present research is an alternative hypothesis about the existence of significant differences between morphometric parameters of Scots pine (*Pinus sylvestris* L.) seedlings of different color-seed races. The experiment was established by planting of one-year old Scots pine container seedlings under Kolesov's sword. Ten rows in a 90-fold repetition were planted on 24th October 2017 on the site of the left-bank forestry training Voronezh State University of Forestry and Technologies (coordinates of the nodal point: N 51°49'40.3' E 39°21'49.7', altitude 100.8 m asl). Seedlings were produced from the seeds, previously separated based on seed coat color and size, in the nursery by a standard rotation cycle for Scots pine container seedlings. The planted seedlings were measured for height three times during the first growing season after the field planting on a post-fire site. The results show a significant difference in one-year-old container produced Scots pine seedlings height with white seeds producing the highest seedlings after one year growth in the field. Our results indicate the potential use of seed sorting on seed coat color for improvement of both, production of forest reproductive material and reforestation success.

1. Introduction

The basis for the present research was the previous reports on geographical [1] and genetic [2, 3] variability of seed coat color of Scots pine, and its potential use for seed selection and improvement of production of forest reproductive material. There are many studies of the growth of Scots pine at the juvenile stage [4-9]. There are many methods for improving the seed quality [10-16] aiming to improve seedlings performance (survival and growth), as it is shown for Scots pine [13]. Facing the ultimate goal of improvement of seedling performance after field planting, there is a constant need of improvement of seed quality, resulting with introducing of, among others, innovative biophysical methods [17-20] for assessing the seed quality.

However, there is very little information about the effect of seed coat color on the growth of seedlings after field transplanting. Thus, the purpose of this study was to provide information on the effect of seed coat color and size on the growth of one-year-old container seedlings of Scots pine and to assess future potential in the development of sorting seeds by color.

2. Methods and Materials

Seedlings used in this study were grown in the Voronezh forest nursery between 02nd May 2017 and 23d October 2017 by implementing a standard rotation cycle for the container seedlings of Scots pine

(*Pinus sylvestris* L.). Seeds (harvested from Pavlovsk forestry of Voronezh region, Russia) were divided by the color of the seeds coat, with the help of a photoseparator (Sapsan Series, Smart Grade LLC, Voronezh, Russia), into three seed batches: white (1), brown (2), and black (3). After that, each seed batch was further divided based on the size – seed diameter, by using a sieve unit (BCC AB, Landskrona, Sweden), into two fractions with the maximum seed size of 2.5 mm (small) and 3.25 mm (large), respectively. The 200 seeds for each fraction were then sown by using an automatic seeding line (BCC AB) in HIKO 12 SS 40-cell containers (BCC AB), filled with peat substrate. Containers were installed in greenhouses with automatic temperature and humidity maintenance.

The produced seedlings were planted manually under the sword of Kolesov on 24th October 2017 on the site of the left-bank forestry training Voronezh State University of Forestry and Technologies (coordinates of the nodal point: N 51°49'40.3' E 39°21'49.7', altitude 100.8 m asl). As a total, ten rows in 90-fold repetition were planted. The experimental facility is based on the methodology proposed by Konovalov and Pugach [3], in order to create natural conditions.

a. Viable b. Shrinking c. seedling row

Figure 1. A one-year-old container grown seedlings of Scots pine planted under the Kolesov's sword.

After the field planting, the seedlings height (in millimeters) was measured three times during the first growing season (the year 2018 - May 25, June 28, and July 31) with a ruler, from the ground to the end of the needles (Figure 1). The results were processed by mathematical statistics methods and variance analysis.

3. Results and Discussion

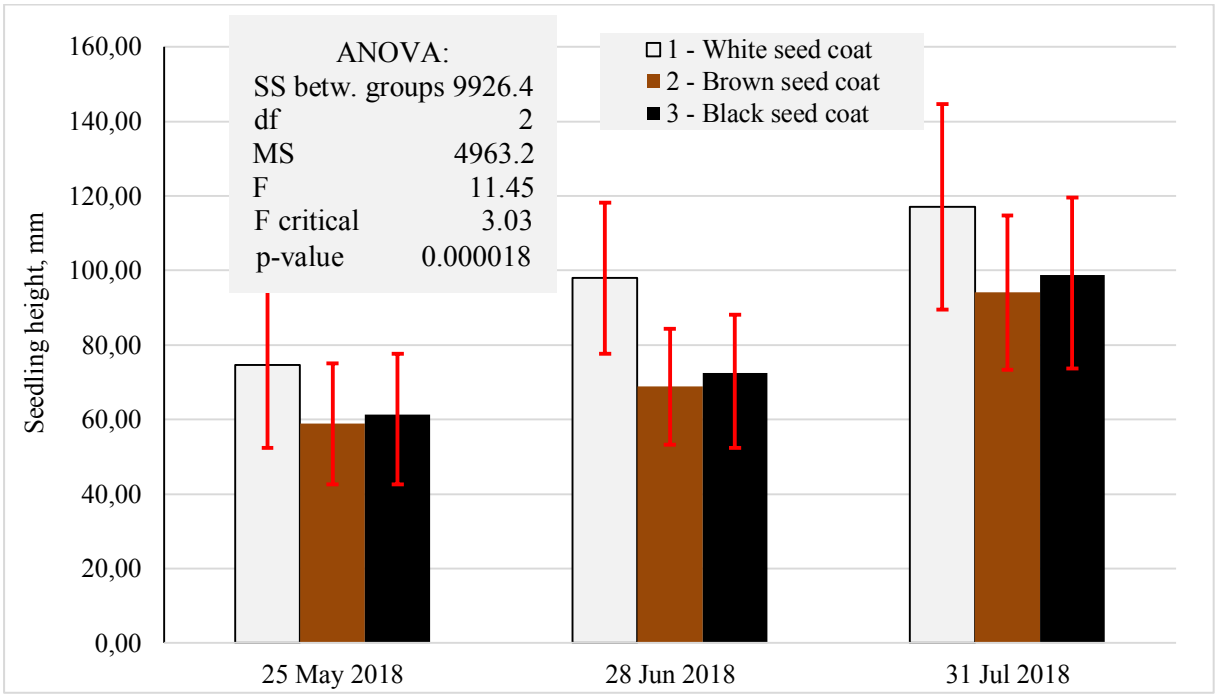
Table 1 shows the height growth dynamics of Scots pine seedlings obtained from seeds sorted by color and size. The table also describes height values and the main statistical parameters: mean deviation, dispersion, standard deviation (SD), coefficient of variation (CV) and survival rate, %.

Table 1. Results of measurements of Scots pine seedlings growth at the first growing season after the field planting on a post-fire site.

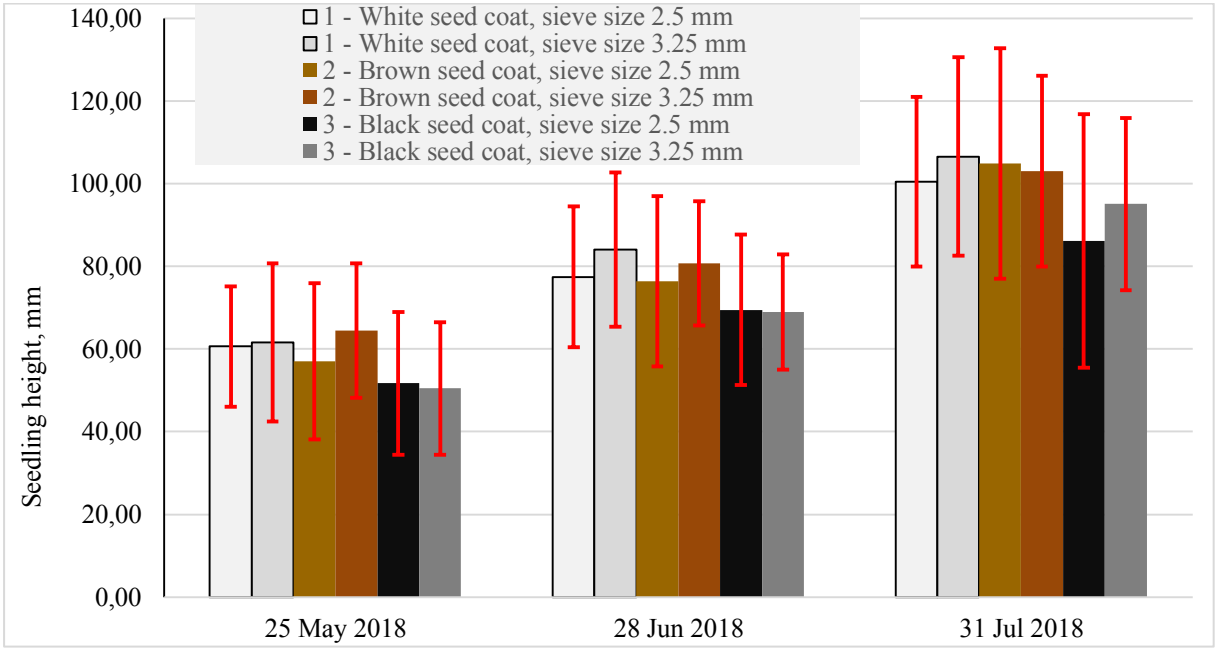
Sample code	Seed characteristics (*a priori)*	Parameters	Date of measurement		
			25 May 2018	28 Jun 2018	31 Jul 2018
1	white	average height, *mm*	**74.63**	**97.93**	**117.08**
		mean deviation, *mm*	16.96	15.74	20.64
		dispersion	498.11	412.31	762.33
		standard deviation (SD)	22.32	20.31	27.61
		coefficient of variation (CV)	0.30	0.21	0.24
		survival rate, %	94.3	83.9	82.8
2	brown	average height, *mm*	**58.85**	**68.83**	**94.10**
		mean deviation, *mm*	14.21	14.47	18.56
		dispersion	352.04	404.27	630.74
		standard deviation (SD)	18.76	20.11	25.11
		coefficient of variation (CV)	0.32	0.29	0.27
		survival rate, %	79.5	75.9	73.5
3	black	average height, *mm*	**61.37**	**72.57**	**98.75**
		mean deviation, *mm*	12.89	11.82	16.39
		dispersion	263.86	241.38	429.69
		standard deviation (SD)	16.24	15.54	20.73
		coefficient of variation (CV)	0.26	0.21	0.21
		survival rate, %	95.3	87.1	84.7
1-2.5	white - small	average height, *mm*	**60.63**	**77.40**	**100.45**
		mean deviation, *mm*	10.88	12.74	15.71
		dispersion	212.11	290.00	418.46
		standard deviation (SD)	14.56	17.03	20.46
		coefficient of variation (CV)	0.24	0.22	0.20
		survival rate, %	89.5	88.2	88.2
1-3.25	white - large	average height, *mm*	**61.64**	**84.05**	**106.53**
		mean deviation, *mm*	14.54	15.05	18.40
		dispersion	366.04	349.78	575.44
		standard deviation (SD)	19.13	18.70	23.99
		coefficient of variation (CV)	0.31	0.22	0.23
		survival rate, %	84.4	82.2	78.9
2-2.5	brown - small	average height, *mm*	**57.04**	**76.35**	**104.89**
		mean deviation, *mm*	14.75	16.45	22.35
		dispersion	358.95	425.77	777.21
		standard deviation (SD)	18.95	20.63	27.88
		coefficient of variation (CV)	0.33	0.27	0.27
		survival rate, %	79.4	70.6	66.2

2-3.25	brown - large	average height, *mm*	**64.44**	**80.75**	**103.04**
		mean deviation, *mm*	12.05	11.85	18.21
		dispersion	265.00	226.49	533.49
		standard deviation (SD)	16.28	15.05	23.10
		coefficient of variation (CV)	0.25	0.19	0.22
		survival rate, %	96.4	88.0	83.1
3-2.5	black - small	average height, *mm*	**51.69**	**69.45**	**86.16**
		mean deviation, *mm*	13.49	14.71	25.90
		dispersion	298.16	331.21	938.51
		standard deviation (SD)	17.27	18.20	30.64
		coefficient of variation (CV)	0.33	0.26	0.36
		survival rate, %	92.5	91.3	86.3
3-3.25	black - large	average height, *mm*	**50.45**	**68.90**	**95.06**
		mean deviation, *mm*	12.95	10.61	14.62
		dispersion	257.81	193.26	433.44
		standard deviation (SD)	16.06	13.90	20.82
		coefficient of variation (CV)	0.32	0.20	0.22
		survival rate, %	98.7	97.5	97.5

The seeds with white seed coat show the highest growth rate and maintained the advantage in height over the black and brown seeds, respectively, during the first growing season (Table 1 and Figure 2a). The differences between mean values of height for different seed color groups are statistically significant (p=0.000018). This difference in height growth of seedlings from different seeds color, indicates a strong genetic control of both, seed coat color and seedling vigor, having in mind that seed color is not a reliable measure of maturity [21]. In the study [22] of correlations between the germination capacity and selected physical properties of Scots pine seeds, it was found no significant differences between seeds of different colors, although the grey seeds showed in general higher values of measured parameters compared to black and "other" colors. Opposite to this report, similar to findings of Mukassabi et al. [23], that dark seeds of Scots pine exhibited high values of mass and viability, Udval and Batkhuu [24] found a significant differences in germination between different seed colors, with black seed exhibiting the highest germination capacity, followed by brown, and with light color seed showing the lowest germination capacity. The fact that our results show the highest growth of white colored seeds, while other reports show that black and dark seeds are of better quality compared to light colored seeds, indicates the need for further research. Our results also show that brown seeds resulted in the lowest survival rate, much lower than black and white seeds.



a. Growth chart with standard deviation, graded by seed coat color



b. Growth chart with standard deviation, graded by seed coat color and, additional, by seed size

Figure 2. The growth of Scots pine seedlings in the first juvenile period.

Figure 2b illustrates the growth of seedlings over a specified period in the following groups: 1-2.5, 1-3.25, 2-2.5, 2-3.25, 3-2.5 and 3-3.25 (encoding of groups from Table 1). The distribution of the average height for the entire period of time by color groups occurs in decreasing order: from groups (1-2.25; 1-3.25) through groups (2-2.5, 2-3.25) up to groups (3-2.5; 3-3.25). By the end of the period under review, the difference in growth within the groups (1-2.25; 1-3.25) and (3-2.5; 3-3.25) increases, while the one within groups (2-2.5, 2-3.25) is reduced. However, the height of seedlings in groups (2-

2.5, 2-3.25) exceeds the height of seedlings in the group 1-2.5. The greatest oscillation of the elevation values is presented in groups 1-2.5 and 3-2.5.

4. Conclusion

The results of the presented study show a significant difference in one-year-old container produces Scots pine seedlings height after the first growing season in the field conditions, indicating the potential use of seed sorting on seed coat color for improvement of both, production of forest reproductive material and reforestation success. Combining the grading on seed size with sorting on color it is decreased the differences in mean values indicating the potential of using both methods for seed quality assessment and improvement. Further researches need to use more holistic approach to this issue investigating: 1) genetic control of seed color, germination and subsequent seedling growth, 2) relation between seed color and seed quality, 3) relation between seed color and seedling quality in the nursery, and 4) relation between seed color and performance after planting in the field.

Acknowledgments

The research was carried out with the support of the internal grant in Voronezh State University of Forestry and Technologies named after G.F. Morozov (VSUFT).

The authors acknowledged the Voronezh Forest Containerized Nursery (VFN) and Educational-experienced leskhoz (EEL) of VSUFT for the opportunity to conduct research. Special thanks to PhD in Agriculture V. Malyshev (VFN), and PhD in Economics A. Topcheev (EEL of VSUFT) for their constructive feedback. I acknowledged comments and reviews from the editor of FORESTRY-2018 and the reviewer.

References

[1] Pravdin L F 1960 The main regularities of the geographical variability of Scots pine (*Pinus sylvestris* L.) [in Russian - Osnovnye zakonomernosti geograficheskoy izmenchivosti sosny obyknovennoy (Pinus silvestris L.)] *Fundamentals of forest science and forestry* (Moscow: Forestry Publ.) pp 245–50

[2] Ivetić V and Devetaković J 2017 Concerns and evidence on genetic diversity in planted forests *Reforesta* 196

[3] Konovalov N A and Pugach E A 1978 *The basis of forest breeding and varietal seed production [in Russian - Osnovy lesnoy selektsii i sortovogo semenovodstva]* (Moscow: Forest Industry Publishing)

[4] Franke A K, Braeuning A, Timonen M and Rautio P 2017 Growth response of Scots pines in polar-alpine tree-line to a warming climate *Forest Ecology and Management* **399** 94–107

[5] Haapanen M, Hynynen J, Ruotsalainen S, Siipilehto J and Kilpelainen M-L 2016 Realised and projected gains in growth, quality and simulated yield of genetically improved Scots pine in southern Finland *European Journal of Forest Research* **135** 997–1009

[6] Hebda A M, Wachowiak W and Skrzyszewski J 2017 Long-term growth performance and productivity of Scots pine (Pinus sylvestris L.) populations *Acta Societatis Botanicorum Poloniae* **86**

[7] Pliura A, Jankauskiene J, Lygis V, Suchockas V, Bajerkeviciene G and Verbylaite R 2018 Response of juvenile progeny of seven forest tree species and their populations to simulated climate change-related stressors, heat, elevated humidity and drought *Iforest-Biogeosciences and Forestry* **11** 374–88

[8] Silvestru-Grigore C V, Dinulica F, Sparchez G, Halalisan A F, Dinca L C, Enescu R E and Crisan V E 2018 Radial Growth Behavior of Pines on Romanian Degraded Lands *Forests* **9**

[9] Trocha L K, Weiser E and Robakowski P 2016 Interactive effects of juvenile defoliation, light conditions, and interspecific competition on growth and ectomycorrhizal colonization of Fagus sylvatica and Pinus sylvestris seedlings *Mycorrhiza* **26** 47–56

[10] Edwards D G W and Wang B S P 1995 *A Training guide for laboratory analysis of forest tree seeds* (North American Forestry Comm.)
[11] Adams M J, Groot A, Crook G W, Fleming R L and Foreman F F 2005 Direct Seeding Black Spruce and Jack Pine: A Field Guide for Northern Ontario 528
[12] Grzywacz A P and Rosochacka J 1980 The colour of Pinus silvestris L. seed and their susceptibility to damping-off. I. The colour and quality of seeds and fatty acids content of the seed coat *Forest Pathology* **10** 138–44
[13] Winsa H and Bergsten U 1994 Direct seeding of Pinus Sylvestris using microsite preparation and invigorated seed lots of different quality: 2-year results *Canadian Journal of Forest Research* **24** 77–86
[14] Novikov A I 2017 *Disc separators in forest seed production [in Russian - Diskovye separatory semyan v lesohozyajstvennom proizvodstve]* (Voronezh: VSUFT)
[15] Novikov A I 2002 *Substantiation of the technological scheme, design and parameters of the disk separator of forest seeds [in Russian - Obosnovanie tekhnologicheskoy skhemy, konstruktsii i parametrov separatora lesnykh semyan diskovogo tipa]* (PhD Thesis, Voronezh State University of Forestry and Technologies named after G.F. Morozov)
[16] Rakshit A 2018 *Advances in Seed Priming* ed A Rakshit and H B Singh (Singapore: Springer Singapore)
[17] Gislum R, Nikneshan P, Shrestha S, Tadayyon A, Deleuran L C and Boelt B 2018 Characterisation of Castor (Ricinus communis L.) Seed Quality Using Fourier Transform Near-Infrared Spectroscopy in Combination with Multivariate Data Analysis *Agriculture-Basel* **8** 10
[18] Qiu G J, Lu E L, Lu H Z, Xu S, Zeng F G and Shui Q 2018 Single-Kernel FT-NIR Spectroscopy for Detecting Supersweet Corn (Zea mays L. Saccharata Sturt) Seed Viability with Multivariate Data Analysis *Sensors* **18** 16
[19] Ambrose A, Lohumi S, Lee W-H and Cho B K 2016 Comparative nondestructive measurement of corn seed viability using Fourier transform near-infrared (FT-NIR) and Raman spectroscopy *Sensors and Actuators B: Chemical* **224** 500–6
[20] Novikov A I and Saushkin V V 2018 Infrared range spectroscopy: the study of the pine seed coat parameters *Forestry Engineering Journal [Lesotekhnicheskiy zhurnal - in Russian]* **8** 30–7
[21] Cram W H and Lindquist C H 1979 Maturity of Scots pine cones *The Forestry Chronicle* **55** 170–4
[22] Kaliniewicz Z, Tylek P, Markowski P, Anders A, Rawa T, Jóźwiak K and Fura S 2013 Correlations between the germination capacity and selected physical properties of scots pine (Pinus sylvestris L.) seeds *Baltic Forestry* **19** 201–11
[23] Mukassabi T A, Polwart A, Coleshaw T and Thomas P A 2012 Does Scots pine seed colour affect its germination? *Seed Science and Technology* **40** 155–62
[24] Udval B and Batkhuu N-O 2013 Seed and cone characteristics of Scots pine (Pinus sylvestris L.) from diverse seed sources in northern Mongolia *Eurasian Journal of Forest Research* **16** 57–62