Assessment of the growth of forest seedlings in new substrates from wood waste and sewage sludge

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Abstract. The morphological parameters of Scots pine (Pinus sylvestris L.) seedlings grown in experimental substrates made from sewage sludge and pine shavings (substrate 1), and pine bark (substrate 2) were studied. The production time of the substrate varied: substrate 1 – 2 months, substrate 2 – 1.5 years. Seedlings of 2-year-old pine were selected for research. To analyze the parameters of seedlings, average values and square deviations were calculated, reliability was determined by Fisher and Student tests. To analyze the length of the root system, one-way analysis of variance was used in MS Excel. For roots of the 2nd order and total root length, the observed values of Fisher's criterion are: 15.42 and 11.27, which exceeds the critical value of 3.18 and indicates a significant difference between seedlings grown in the manufactured substrates. The diameter of the root collar of seedlings grown in peat exceeded that of seedlings grown on substrate 2 by 13%, and in substrate 2 by 4.4%. Maximum root length for seedlings from substrate 1. Substrates from wood waste and sewage sludge can replace fossil peat without losing the quality of growing seedlings and contribute to the emergence of improved quality characteristics of seedlings.

1 Introduction

The issue of reforestation is relevant for researchers and representatives of the forest industry: mandatory restoration of forests after deforestation, careful selection of seeds that make it possible to grow seedlings resistant to soil and natural conditions [4], the problem of degradation of forest soils.

At the state level, it is accepted that sustainable reforestation can be achieved by growing seedlings in containers that cover the plant's root system. Seedlings grown in this way take root better in forest areas and demonstrate stable productivity.

Weathering and degradation of forest soils cause a decrease in the survival rate of forest seedlings, so a number of scientists propose adding fertilizers to their root system, which can be logging waste, which undergoes natural mineralization over several years. However, the authors [2] found that due to long-term leaching, part of the nitrogen passes into the soil and its content in wood decreases. On average, the nitrogen content per unit mass of

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different species is not the same: the highest content is in birch - 0.95%, the lowest in larch - 0.20%. The remaining breeds occupy an intermediate position [6]. Also, to increase fertility, wood waste in the form of bark, which is produced in excess at wood processing enterprises, is added to the soil. The bark contains more nitrogen than the wood itself [5], and it is also rich in potassium, phosphorus, and organic matter, which degrading forest soils lack [1]. However, it has been noted that over the years, the nitrogen concentration in the bark also decreases [10]. The use of wood processing waste such as bark makes it possible to activate the biological productivity of underlying soils for growing seedlings. To obtain high-quality fertilizer from wood waste, it is necessary to speed up the process of humification by the most accessible and simple method of composting. To begin the process, the main component of wood - carbon, must be supplemented with the necessary amount of nitrogen of various natures, available for each case, taking into account logistics, cost and labor intensity. Recently, the production of substrates and soils from sewage sludge has become increasingly popular. As mentioned earlier, the nitrogen content of different wood species differs, so the bark or shavings of softwood and hardwood trees should be sorted and composted separately [9].

Traditionally, the time for biothermal preparation of compost is 2–6 months, and the complete ripening time of compost is up to 1–1.5 years. One of the disadvantages of compost that has a short production time is its unpleasant odor, which disappears within a few months. When used in forested areas, this problem can be neglected. To assess the quality of the substrate obtained in a much shorter time, it is necessary to conduct a trial cultivation of seedlings of one type of plant, for example, Scots pine (*Pinus sylvestris L.*) and determine its growth rates and morphological parameters. Growth rate indicators, which indicate that in prepared substrates germination and growth rate do not differ significantly from the control substrate (peat), are presented in our article [3]. A continuation of this study is the analysis of the morphological parameters of two-year-old pine sprouts growing in the same substrates.

Morphological parameters include measured characteristics: seedling length, trunk diameter and root characteristics: main and lateral lengths, seedling and needle weight, etc. As is known [7], its quality can be determined by the morphological parameters of a seedling. The more developed its root system, the better the sorption of water and nutrients from the soil.

Thus, the purpose of this work is to study the morphology of seedlings grown in substrates produced from sewage sludge, short (2 months) and full (1.5 years) production period.

2 Materials and methods

For research, 102 samples of seedlings of 2-year-old Scots pine (*Pinus sylvestris L.*) were selected, 34 samples for each type of substrate (substrate 1 and substrate 2), a peat substrate was selected as a control.

The plants were dug up, the root system was washed in water for measurement in laboratory conditions. The height of the seedling is determined from the root collar to the apical bud using a ruler, and the diameter of the root collar is measured with a caliper. The root system is straightened out on graduated paper (Figure 1), the number of lateral roots is counted and their length is determined, separately for roots of the first and second order.

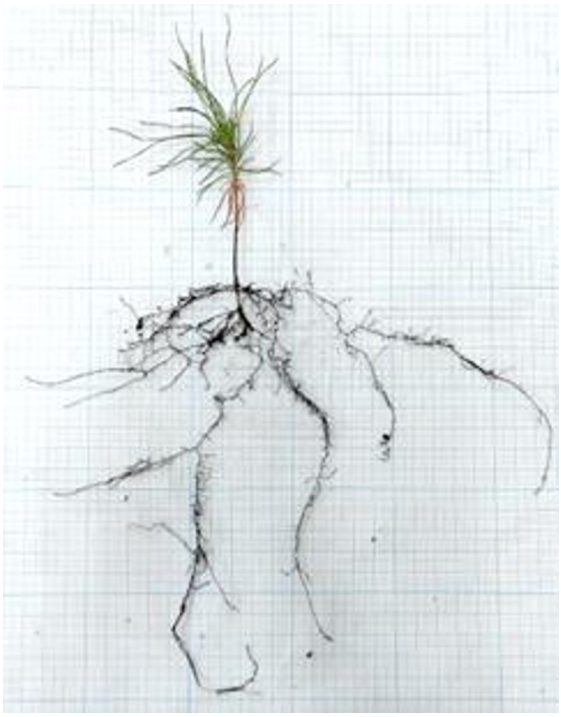

Fig. 1. Experimental sample of Scots pine on graduated paper.

To analyze the dependence of the morphological parameters of the seedling in the studied substrates, the average values and standard deviations were calculated, and the reliability of the results obtained was determined using the Student's t test. Also, to analyze the length of the root system, one-way analysis of variance was used in Excel MS [8]. The type of substrate is taken as a factor; 3 levels of factor are identified: I substrate, II substrate and peat. The dependent variable is the root length in millimeters at each factor level.

The null hypothesis is that there is no influence of the grouping factor "substrate type" on the seedling root length trait. The significance level is taken to be 5%. Due to the fact that root length is subdivided into the length of the main root, 1st order roots, 2nd order root length and total root length, ANOVA was sequentially applied to each respective data set. Thus, for each sample, the values of Fisher's criterion were calculated: observed and critical.

3 Results

The results of studies of the height and diameter of the stems of annual pine seedlings grown on different substrates are presented in Table. 1. The variability of the mean value ranged from 12 to 21%, which is average.

Table 1. Indicators of height and diameter of stems of annual pine seedlings grown in different substrates.

Statistics indicators	1 substrate		2 substrate		Peat	
	Stem height, cm	Barrel diameter, mm	Stem height, cm	Barrel diameter, mm	Stem height, cm	Barrel diameter, mm
Average value	11.5	1.3	9.4	1.2	12.5	1.4
Standard deviation	2.5	0.3	1.8	0.1	1.8	0.2
Reliability of the average value	27	30	30	49	125	36
Average error	0.43	0.04	0.31	0.02	0.10	0.04
Variability, %	21	19	18	12	15	16
Accuracy of experiment, %	4	3	3	2	1	3

The accuracy of the experiment was less than 5%, which also indicates sufficient accuracy of the average value and a sufficient number of measurements.

The average diameters of the root collar and the height of seedlings are presented in Figure 2.

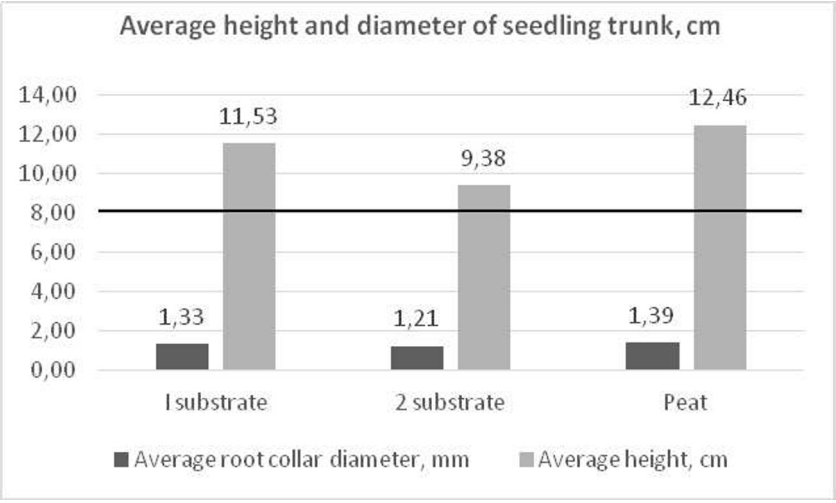

Fig. 2. Average height and diameter of Scots pine seedling trunk, cm.

The values of the variance analysis of the dependence of the morphological parameters of pine on the type of substrate were obtained and are shown in Table 2.

Table 2. Observed and critical values of Fisher's test.

Root Components	F observable	F critical
main root	1.36	3.18
1st order roots	1.34	3.18
2nd order roots	15.42	3.18
Total root length	11.27	3.18

The observed values of the Fisher criterion for the length of the main root and roots of the 1st order were 1.36 and 1.34, and the critical value was 3.18. For 2nd order roots, the observed values of the Fisher criterion are 15.42 and 11.27, respectively, which exceeds the

critical value of 3.18. Therefore, it can be argued that for this type of roots, at the 5% level of significance, there is an influence of the grouping factor on the root length. A histogram was constructed for the total root length, demonstrating the variation in values for each level relative to the average (Figure 3).

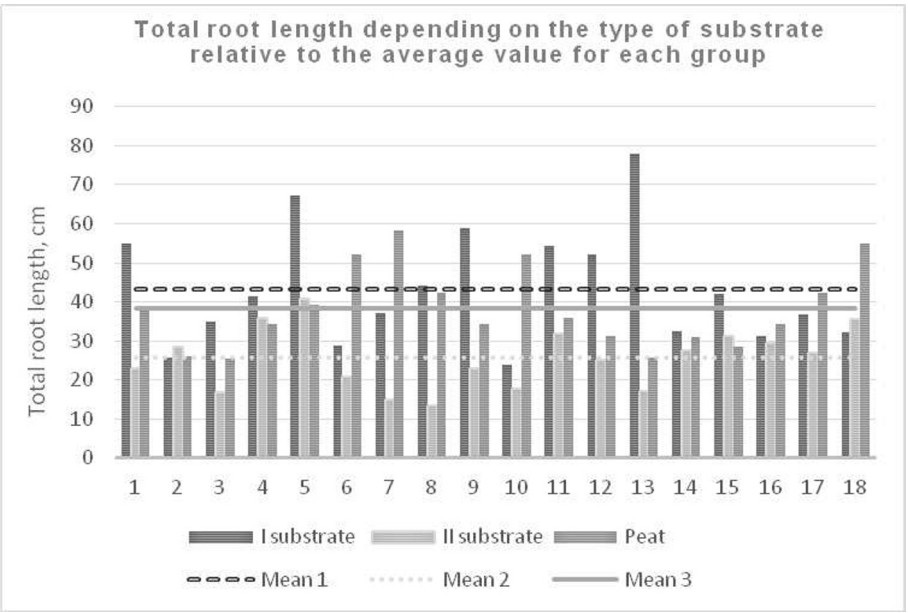

Fig. 3. Total root length depending on the type of substrate relative to the average value for each group.

The differences characterizing the length of the 2nd order roots and the total length of the roots turned out to be significant (Figures 4 and 5).

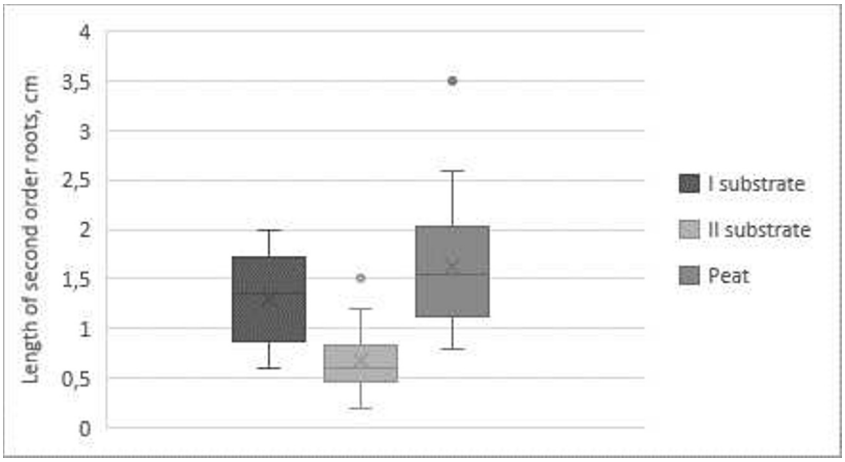

Fig. 4. Length of second order roots, cm.

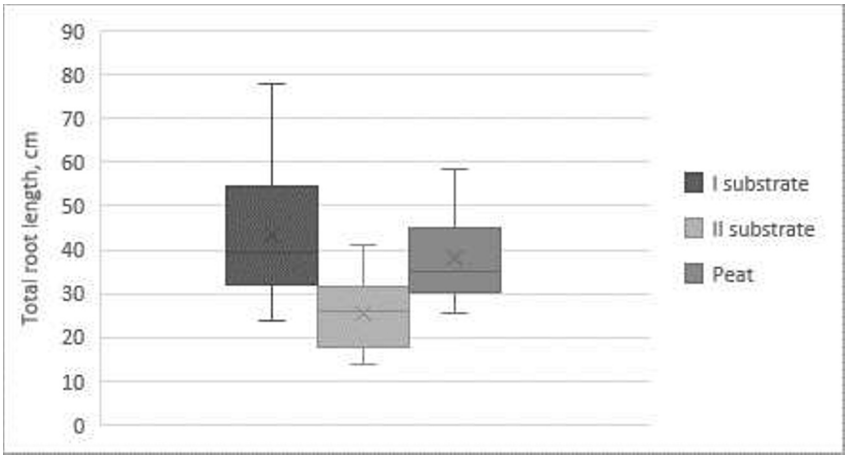

Fig. 5. Total length of roots, cm.

4 Discussion

The maximum height was reached by seedlings grown in peat, which was expected, since it had a lower volumetric weight and looseness of the substrate, and the stem height was 12.5 cm, diameter 1.4 mm. The seedlings grown in substrate 2 had the minimum diameter; their height averaged 9.4 cm, which, however, was higher than the standard for seedlings with a closed root system (8 cm). The reliability of the average value was in all cases more than 4, which is considered reliable values.

The differences in measurements of the height and diameter of the stems between substrate 2 and peat, as well as between substrates 1 and 2, which corresponded to the 100% and 99% significance level, respectively, turned out to be significant. The length of the root system is of great importance for the growth of the root system. The length of the measured roots of different orders turned out to be maximum in seedlings grown on substrate No. 1. Thus, the average length of the main root is 16% greater than the length of the seedling of substrate 2, and the main root of a seedling grown in a peat substrate by 14%. It is important to note that despite the fact that, according to the analysis, the dependence on the grouping factor is not observed for all components of the roots, but for the total root length, which is a summary characteristic, there is an influence on the type of substrate.

For roots of the 2nd order and total root length, the opposite situation is observed: the observed values of Fisher's test are 15.42 and 11.27, respectively, which exceeds the critical value of 3.18 and indicates that the null hypothesis is rejected. Therefore, it can be argued that for this type of roots, at the 5% level of significance, there is an influence of the grouping factor on the root length.

5 Conclusion

The research results indicate the presence of the necessary fertile properties in substrates obtained from sewage sludge and wood waste, which do not differ significantly from the natural traditional peat substrate used and can be used to reduce the economic costs of forestry companies. The diameter of the root collar of Scots pine sprouts grown in peat exceeds those grown in substrate 1 by 4.4%, and seedlings grown in substrate 2 by 13%.

The maximum ratio of the above-ground and underground parts of the seedling was recorded in seedlings grown in substrate 2. The average length of the main root is 16% greater than the length of the seedling of substrate 2, and the main root of the seedling grown in peat by 14%. The length of the measured roots of different orders turned out to be maximum in seedlings grown on substrate 1.

The substrate, produced even within a short time (2 months), can be used for growing annual Scots pine seedlings. On all substrates, seedlings reached standard height sizes.

Acknowledgement

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