Intensification of cultivation of seedlings of Siberian spruce (*Picea obovata* Ledeb.) in the Southern Urals

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Abstract. The study underscores the vital demand for efficient cultivation of Siberian spruce seedlings in reforestation and land reclamation. It delves into diverse peat substrate types, densities, and nutrient additives, providing insights for optimizing growth. The comprehensive approach involves microbiological preparations and mycorrhiza to enhance seedling development. The recommendation is to use high-density peat, introducing microbiological preparations post-emergence for fostering robust Siberian spruce seedlings. The relevance of the research stems from the high demand for large quantities of planting material in reforestation efforts. Siberian spruce, known for shade tolerance and cold resistance, is a significant carbon accumulator. The paper reports 2023 experiments on peat substrates with varying densities and nutrient additives, emphasizing pre-sowing seed treatment with growth stimulants. Results show increased germination energy and germination on denser and more acidic peat substrates. However, superior biometric indicators at the season's end are observed in seedlings grown on substrates with lower density and additives like a complex of humic acids, salts, mineral fertilizers, trace elements, soil microflora, and mycorrhiza. The proposal advocates using high-density peat (at least 0.6 g/cm³) for growing Siberian spruce seedlings, introducing microbiological preparations post-emergence, and regular fertilizing for enhanced first-year development. Keywords encompass recultivation, oil and gas production, Siberian spruce, seedling, closed root system, germination energy, germination, growth dynamics, and biometric indicators. Keywords: *Picea obovata* Ledeb., seedling, closed root system, germination energy, germination, growth dynamics, biometric indicators

1 Introduction

The Siberian spruce (*Picea obovata Ledeb.*) is found in both pure and mixed forests, covering the northeastern regions of the European part of the Russian Federation, the Urals, and Western Siberia [1, 2]. Notable for its shade tolerance and cold resistance [3, 4], this species can reach heights of 20-30 meters, with a conical crown whose diameter and elongation vary significantly based on shading and genetic characteristics [2, 4]. The presence of a surface horizontal root system allows the Siberian spruce to utilize even the weakest atmospheric precipitation [5].

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Siberian spruce stands out as one of the best carbon accumulators, particularly in the middle taiga spruce stands, where carbon accumulation reaches 85.48 tons per hectare, with 95% of the carbon concentrated in Siberian spruce trees [6].

Seedlings of Siberian spruce grown using the closed root system method exhibit high survival rates due to their ecological, biological, and morphological characteristics, requiring minimal ongoing agronomic care [5.

The objective of this study is to examine the influence of different substrates and fertilizers on the germination of Siberian spruce seeds (Picea obovata Ledeb.) in the conditions of the smart greenhouse at Bashkir State Agrarian University in Ufa, Southern Urals.

2 Material and research methods

In order to achieve the set goal, Siberian spruce (Picea obovata Ledeb.) with closed root system was sown in the greenhouse in May 2023.

Seed preparation for sowing was traditional for conifers (snowing, 25 February-April 2023).

Seeds of Siberian spruce of the 3rd quality class were collected in November 2022 in the Askinskiy lesnichestvo of the Askinskiy district of the Republic of Bashkortostan from middle-aged trees of the I class of bonitet. Before sowing, the seeds were soaked in solutions of stimulants, fungicides and phytosporins.

RKL-81 cassettes were used for sowing. Three types of substrate were used to fill the cassettes: **Substrate № 1:** Peat (degree of decomposition 15-25%) pH 5.0, Total nitrogen (NH4+NO3)- 120-200 mg/l ;Phosphorus (P2O5) 100-125 mg/l; Potassium (K2O) 150-200 mg/l; conductivity of water extract1.2-1.5 mS/cm (70%), peat pH 4.5 (Moisture not more than - 60%, acidity - 3.5-4.5, ash content not more than - 10%) (30%), density 0.6 g/cm3. **Substrate № 2:** Peat (degree of decomposition 15-25%) pH 5.0, Total nitrogen (NH4+NO3)- 120-200 mg/l ;Phosphorus (P2O5) 100-125 mg/l; Potassium (K2O) 150-200 mg/l; conductivity of water extract 1.2-1.5 mS/cm (68 %), peat pH 4,5 (Moisture not more than - 60 %, acidity - 3.5-4.5, ash content not more than - 10 %) (29.6 %), feeder mycorrhiza (Mycelium and spores of fungus of genus Glomus, 0.4 %), BiomasterM4 Azofit (nitrogen fixers of the genus Azotobacter vinelandii, 0.02 %), Mycorrhiza for seedlings Green section (0.01 %), Gumi Omi coniferous (0.05 %), 33 Bogatyrya (33 strains of natural soil microorganisms: Bacillus subtilis, B. licheniformis, B. megaterium, B. mucilaginosus, B thuringensis, Azotobacter chroococcum, fungi of Trichoderma genus, 1.8%), Bionex-Kemi (0.13 %), Gumi-90 (0.02 %), density 0.5 g/cm3. **Substrate № 3:** Substrate № 2 (82.4%); agroperlite (17.6%), density 0.3 g/cm3.

Seed soaking was carried out in 7 preparations for 8 hours: 1.$KMnO_4$ (0.002%) (control); 2. Potassium humate (Barrel and 4 buckets) (Nitrogen (NH4+NO3) 0.9%, Phosphorus (P2O5) - 0.6%, Potassium (K2O) - 1.5%, organic matter 3%, trace elements (Mn, Cu, Zn, B, Mo); 3.Humate with trace elements; (Humic acids 70%, trace elements Mg, S, B, Cu, Fe, Mn, Mo, Zn); 4. Borogum-M (Potassium salts of humic acids, 1%, Phytosporin-M, trace elements with predominance of boron); 5.Kornesil (Humi-20, sodium humates. macronutrients and trace elements); 6. Hyberelon + Cornevin (Sodium salts of gibberellic acids + indolyl butyric acid (IMC), 5 g/kg); 7. Ultramag Boron (Microfertiliser, total nitrogen N : 3.7 %, Boron 11 %); 8. Phytozont (0.00152 g.l L-alanine + 0.00196 g.l L-glutamic acid).

Each substrate was thus sown with 7 experimental variants and one control variant, in which the seeds were soaked in potassium permanganate. Each experimental variant was sown in four cassettes, using 324 seeds, 1 seed per cassette cell.

The seedlings were grown in a greenhouse. The cassettes were mounted on metal frames at a height of 20 cm above the greenhouse floor, with air access to the cells of the cassettes.

During the period of seedling cultivation from May to August, foliar treatments with phytosporin and fertilisation with Borogum-M, Rich Micro, root fertilisation with Bionex-Kemi 18:18:18:18, monocalcium phosphate were carried out.

After the emergence of seedlings, the seed germination energy (percentage of germinated seeds after 10 days), germination (percentage of normally germinated seeds on the 14th day after sowing), dynamics of seedling emergence for one month from the day of sowing were determined. During the vegetation period, the height of the spruce seedlings was measured regularly, and in September the biometric indices (root length, height of the above-ground part of the seedling, absolute root dry weight, weight of the above-ground part of the seedling) were determined.

The methodology of seed germination and processing of the obtained data is carried out in accordance with GOST 13056.6-97.

3 Results

Spruce seeds were sown on 13 May 2023. Germination energy was determined on 23 May 2023 (Figure 1).

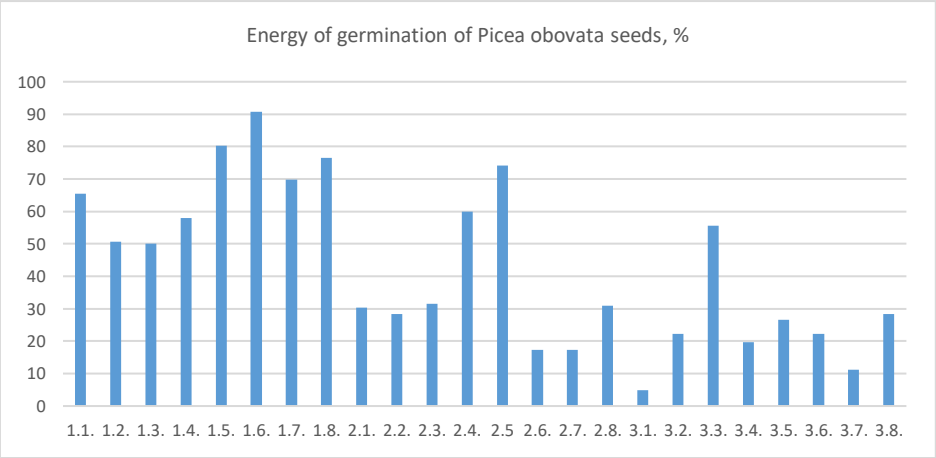

Fig. 1. Energy of germination of Picea obovata seeds in the different variants of the experiments

The highest germination energy was found in spruce seedlings in the variants of experiments: 1.6 (90.7%), 1.5 (80.2%), 1.8 (76.5%), 2.5 (74%), 1.7 (69.8%), 1.1 (65.4%)

The germination of spruce seedlings was determined on 28 May (Fig. 2)

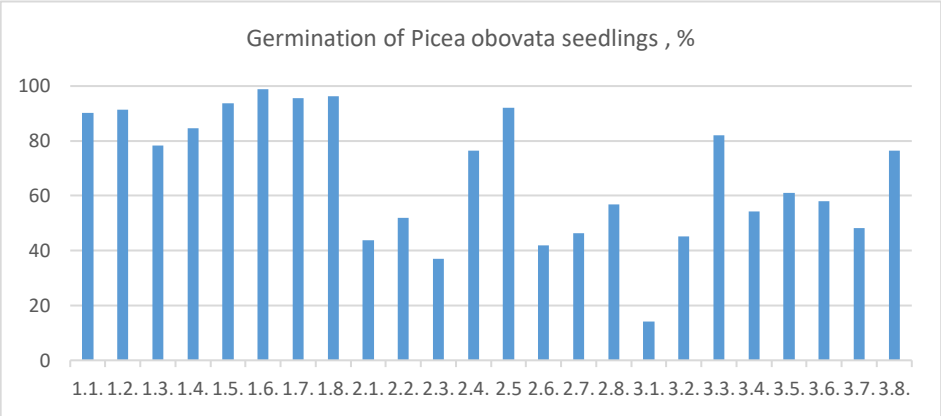

Fig. 2. Germination of *Picea obovata* seedlings in experimental variants

The highest germination rate was found in spruce seedlings in the variants of experiments: 1.6 (98.8 %), 1.8 (96.3 %), 1.7. (95.7 %), 1.5. (93.8 %), 2.5 (92 %), 1.2. (91.4 %), 1.1. (90.1 %), 1.4. (84.6 %), 3.3.(82.1 %), 1.3 (78.4 %), 2.4 (76.5 %), 3.8 (76.5 %), 3.5 (61.1 %).

At the same time, on substrate 1, germination is higher in variants 1.6, (98.8 %), 1.8. (96.3 %), 1.7 (95.7 %), 1.5 (93.8 %), 1.2 (91.4 %), 1.1.(90.1 %), 1.4. (84.6 %), 1.3. (78.4 %). On substrate 2, germination was higher in variants 2.5 (92 %), 2.4. (76.5 %), 2.8 (56 %). On substrate 3, germination is high in variants 3.3 (82.1 %), 3.8 (76.5 %), 3.5 (61.1 %), 3.6 (58 %).

The highest number of spruce seeds germinated per month was found in experiments 1.6 (98.1%), 1.8 (95%), 1. 5 (90.1 %), 1.2 (88.9%), 1.1 (88.3 %), 2.5 (84 %), 1.7 (81.5 %), 1.4 (80.2 %), 1.3 (71.6 %), 3.3 (70.4 %), 3.8 (69.1 %), 2.4 (64.8 %).

Observation of seed germination showed that the maximum number of germinated seedlings was observed on 28-29 May, but subsequently some seedlings died due to the sharp drop in night air temperatures and day-night temperature differences (Fig. 3). Analyses of the extent of abortion according to the treatments (Fig. 4) showed that the lowest proportion of aborted seedlings was recorded in the treatments, mainly on the first and third substrates, and the highest on the second substrate.

The pre-sowing treatment also affected the resistance of the spruce seedlings to lower air temperature and sharp changes in day and night temperature. In the experimental variants: 1.6, 1.8, 3.1, 1.2, 2.6, 3.4, 3.6, 1.1, 1.5 in ascending order, the decrease was from 0.6% to 3.7%. And in the variants of trials 3.3, 3.5, 2.4, 1.7, 2.1, 3.8, 2.2 the decrease was much higher - in ascending order - from 9.3% to 23%.

The highest germination energy was observed in the experimental variants: 1.6, 1.5, 1.8, 1.7, 1.1 (from 90.7% to 65.4%). Germination of Siberian spruce was high in the variants of experiments 1.6, 1.8, 1.7, 1.5, 2.5, 1.2, 1.1, 1.4, 3.3, 1.3, 2.4, 3.8 (from 98.8% to 76.5%). The highest number of spruce seeds germinated for one month, taking into account the dropped seedlings, was found in the variants of experiments 1.6, 1.8, 1.5, 1.2, 1.1, 2.5, 1.7, 1.4, 1.3, 3.3, 3.8 (from 98.1 % to 69.1 %).

Height measurements were taken at 20-30 day intervals to show the growth dynamics of the seedlings. (Table 1).

Spruce seedlings in the experiments 2.3 (84 mm), 2.1 (80.42 mm), 2.4 (78.52 mm), 2.5 (77.13 mm), 2.2 (76.16 mm), 3.3 (75.74 mm) reached the highest height of the above-ground part on 22 September 2023.

Acceleration and deceleration of spruce seedlings growth significantly depends on air temperature [7]. In summer 2023, as already mentioned, there was a significant decrease in temperature from 6 to 13 June and from 18 to 20 June (Fig. 4. Especially night temperatures decreased significantly, which caused a slowdown in seedling growth, especially in the experiments on substrate 1. However, seedlings in the experiments on substrate 2 and 3 showed more stable growth compared to seedlings on substrate 1 (Fig. 5).

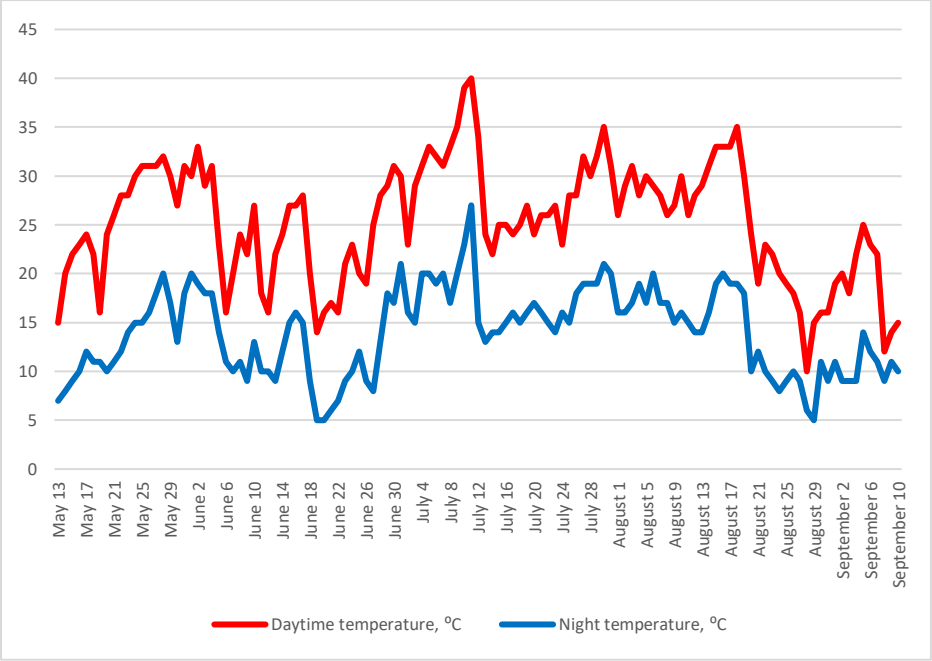

Fig. 3 Graph of day/night temperatures 13 May-27 September 2023

slowdown in seedling growth (especially in Substrate 1 experiments) during this period, but seedlings in Substrate 2 and 3 experiments showed more stable growth compared to seedlings in Substrate 1 (Fig. 5).

From 3 to 13 July, however, unusually high temperatures were observed. On 10 July, a maximum temperature of +39.4°C was recorded. At the same time, seedlings in the experimental treatments on substrate 1 showed a significant increase in growth rate, while seedlings on substrates 2 and 3 were slightly behind in terms of daily growth. With the drop in temperature at the end of August and beginning of.

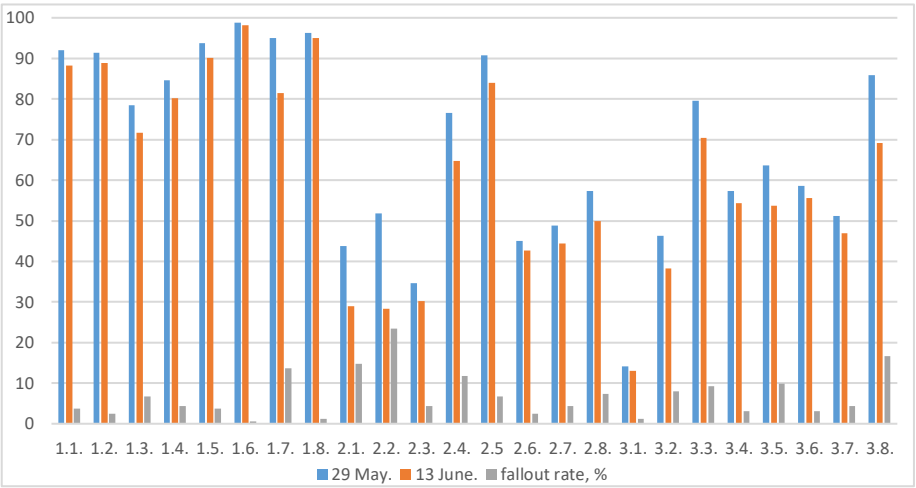

Fig. 4. Change in the number of spruce seedlings due to a sharp decrease in night air temperatures after 30 May in the experiments, % (Decline, %)

September, seedlings on all substrates decreased their growth rate. However, in September, despite the decrease in daylight hours due to the warm weather, the growth rate decreased much slower in the variants of experiments 2.1, 2.2, 2.3, 2.7 than in the other variants.

Table 1. Growth dynamics of the above-ground part of Siberian spruce seedlings

	9 June.			7 July.			8 Aug.			7 September.			22 September.		
	Height, mm	SD	CV	Height, mm	SD	CV	Height, mm	SD	CV	Height, mm	SD	CV	Height, mm	SD	CV
1.1	15.32 ±0.28	3.3	21.6%	24.7 ±0.32	3.7	15.1%	51.51 ±1.01	11.7	22.8%	67.3 ±1.31	15.2	22.7%	69.93 ± 1.32	15.25	21.82%
1.2	15.32 ±0.31	3.6	23.3%	23 ±0.32	3.8	16.6%	52.13 ±1.03	12.3	23.6%	67.94 ±1.34	16.0	23.6%	70.39 ± 1.32	15.73	22.35%
1.3	14.84 ±0.26	2.6	17.3%	21.9 ±0.34	3.7	16.7%	52.7 ±1.13	12.1	22.9%	68.26 ±1.48	15.7	23.0%	70.94 ± 1.5	15.90	22.42%
1.4	14.69 ±0.24	2.7	18.3%	22.17 ±0.33	3.7	16.9%	53.7 ±1.03	11.8	22.0%	67.3 ±1.30	14.8	22.0%	69.45 ± 1.34	15.21	21.89%
1.5	16.65 ±0.22	2.5	15.2%	24.4 ±0.28	3.4	14.0%	57.29 ±1.03	12.3	21.5%	70.17 ±1.17	14.0	19.9%	72.1 ± 1.18	14.10	19.55%
1.6	18.14 ±0.34	4.0	22.2%	25.13 ±0.26	3.2	12.9%	59.84 ±1.05	13.2	22.0%	74.08 ±1.33	16.7	22.6%	75.09 ± 1.29	16.25	21.64%
1.7	15.73 ±0.26	3.0	19.1%	22.6 ±0.36	4.3	18.9%	55.39 ±1.01	12.0	21.6%	69.5 ±1.35	16.0	23.0%	72.43 ± 1.31	15.44	21.32%
1.8	15.6 ±0.18	2.2	14.1%	22.54 ±0.31	3.8	16.8%	59.66 ±0.96	11.6	19.4%	72.38 ±1.28	15.4	21.3%	74.28 ± 1.3	15.62	21.03%
2.1	16.44 ±0.55	3.8	23.0%	29.39 ±1.18	8.2	28.1%	53.96 ±1.8	12.5	23.1%	72.4 ±2.25	15.6	21.6%	80.42 ± 2.33	16.14	20.07%
2.2	15.99 ±0.51	3.4	21.3%	27.54 ±1.25	8.5	30.9%	50.11 ±2.44	16.4	32.7%	68.52 ±3.27	21.7	31.7%	76.16 ± 3.57	23.42	30.75%
2.3	17.62 ±0.56	4.1	23.5%	31.48 ±1.09	7.6	24.1%	57.2 ±1.9	13.4	23.4%	76.7 ±2.45	17.3	22.6%	84 ± 2.78	19.67	23.41%
2.4	17.72 ±0.37	3.8	21.5%	30.63 ±0.74	7.5	24.3%	56.21 ±1.28	12.7	22.6%	75.05 ±1.83	18.2	24.2%	78.52 ± 1.77	17.56	22.36%
2.5	15.63 ±0.21	2.3	14.9%	31.33 ±0.54	6.3	20.1%	56.81 ±1.10	12.6	22.2%	73.73 ±1.39	15.8	21.4%	77.13 ± 1.38	15.67	20.32%
2.6	14.84 ±0.49	4.0	26.8%	29.12 ±0.95	7.3	25.1%	52.64 ±1.62	12.0	22.8%	65.09 ±1.86	13.8	21.1%	68.18 ± 1.86	13.82	20.27%
2.7	15.46 ±0.20	1.7	10.9%	26.75 ±0.82	7.0	26.1%	48.71 ±1.37	11.5	23.6%	65.57 ±1.80	15.1	23.0%	70.07 ± 2.1	17.56	25.06%
2.8	14.34 ±0.28	2.6	17.9%	28.61 ±0.86	7.7	26.8%	51.77 ±1.42	12.6	24.4%	68.1 ±1.92	17.1	25.1%	71.33 ± 1.98	17.63	24.71%
3.1	16.86 ±0.7	4.3	25.4%	31.52 ±1.99	9.1	28.9%	48.1 ±2.57	11.8	24.5%	63 ±3.58	16.0	25.4%	64.25 ± 2.98	13.31	20.71%

3.2	15.23 ±0.37	2.6	16.8%	28.22 ±1.4	10.7	38.0%	51.89 ±2.08	15.1	29.2%	64.83 ±2.44	18.6	28.7%	65.95 ± 2.39	18.20	27.59%
3.3	15.92 ±0.35	3.5	22.0%	30.86 ±0.70	7.4	24.0%	54.41 ±1.21	12.7	23.4%	73.38 ±1.75	18.2	24.8%	75.74 ± 1.77	18.42	24.32%
3.4	15.35 ±0.27	2.5	16.5%	28.36 ±0.74	6.9	24.5%	49.01 ±1.39	12.9	26.3%	65.99 ±1.98	18.3	27.8%	66.28 ± 2.05	19.01	28.68%
3.5	14.34 ±0.33	3.4	23.6%	28.39 ±0.93	8.5	29.9%	51.22 ±1.44	13.1	25.5%	68.72 ±1.71	15.5	22.5%	71.22 ± 1.73	15.69	22.02%
3.6	15.89 ±0.37	3.5	21.8%	29.72 ±0.85	7.9	26.5%	50.72 ±1.3	11.8	23.3%	63.92 ±1.59	14.5	22.7%	65.3 ± 1.62	14.72	22.54%
3.7	14.42 ±0.31	2.3	16.3%	26.68 ±0.69	5.9	22.2%	47 ±1.24	10.4	22.1%	61.71 ±1.84	15.4	24.9%	64.5 ± 2.01	16.86	26.14%
3.8	14.62 ±0.24	2.4	16.2%	29.03 ±0.69	7.2	24.7%	51.36 ±1.22	12.3	24.0%	66.03 ±1.7	17.1	26.0%	67.08 ± 1.7	17.11	25.50%

During seedling growth, the emergence of lateral shoots was recorded (Table 2). The appearance of the first lateral shoots was recorded in late June - early July. At the beginning of September, the highest proportion of seedlings with lateral shoots was observed in the variants of the experiment on substrate 1 (pre-sowing treatment with Giberelon+Kornevin, Phytozont, Kornesil, Borogum-M, potassium humate (Barrel and 4 buckets)), on substrate 2 (Kornesil, Borogum-M), on substrate 3 (humate with microelements).

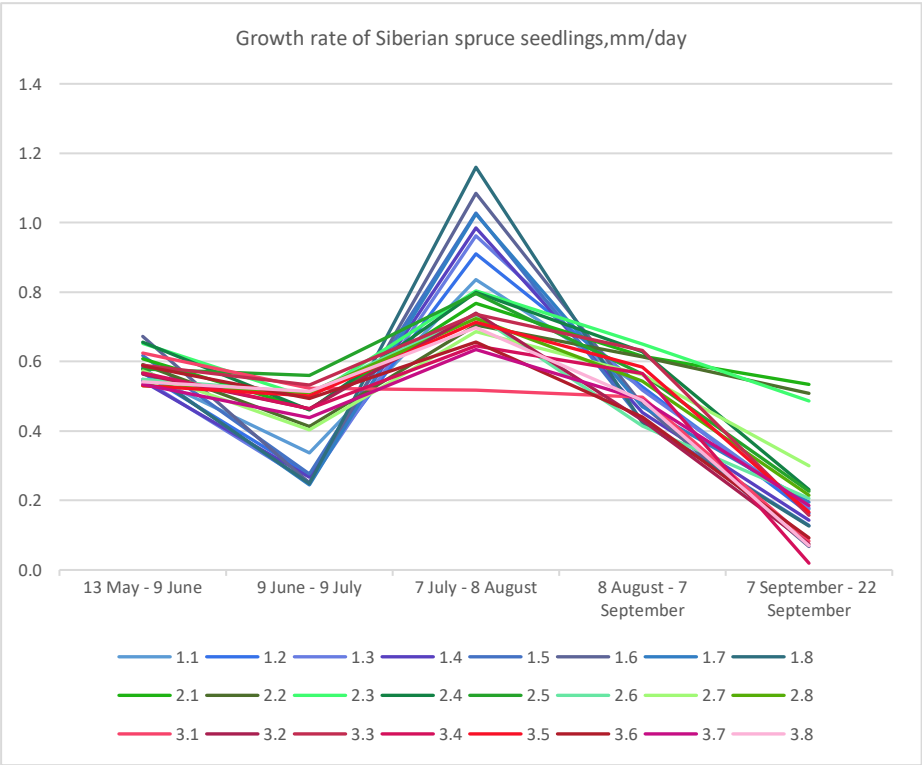

Fig. 5. Siberian spruce seedling growth by experimental treatments

Table 2. Development of lateral shoots in Siberian spruce seedlings according to experiment variants (percentage of seedlings that developed lateral shoots)

№	2 July.	8 Aug.	24 Aug.	7 September.
	Share of seedlings that developed lateral shoots, %			
1.1	1.85	38.89	42.59	43.83
1.2	4.94	41.36	50.00	50.00

1.3	3.09	43.83	45.68	46.91
1.4	11.73	53.09	56.17	56.79
1.5	20.37	67.90	69.14	69.14
1.6	21.60	84.57	84.57	84.57
1.7	20.99	73.46	73.46	74.07
1.8	16.05	67.90	68.52	70.37
2.1	10.49	25.93	25.93	26.54
2.2	12.96	21.60	21.60	24.69
2.3	12.96	21.60	25.93	25.93
2.4	32.10	50.62	51.85	54.94
2.5	34.57	62.96	72.84	72.84
2.6	14.20	27.16	28.40	30.25
2.7	12.35	40.74	41.36	41.98
2.8	12.96	37.04	40.12	44.44
3.1	1.85	5.56	6.79	6.79
3.2	4.94	22.22	23.46	23.46
3.3	13.58	53.70	54.32	54.32
3.4	8.02	38.27	43.83	45.06
3.5	16.05	35.80	38.27	40.12
3.6	16.67	45.06	45.68	45.68
3.7	16.05	37.65	39.51	40.74
3.8	21.60	56.17	56.17	58.64

A selective biometric study of seedlings was carried out after 27 September. Stem height from the hypocotyl to the apical bud and root length were measured on 50 seedlings from each experimental variety (Fig. 6).

On substrate 2 (2.3-13.83 cm, 2.4-13.07 cm, 2.8-12.70 cm), substrate 3 (3.3-13.05 cm, 3.4-12.48 cm) and substrate 1 (1.2-12.58 cm), the highest stem height (from hypocotyl to apical bud) was observed in the experimental variants.

The highest root length was recorded on substrate 1 (1.7 -11.57 cm, 1.4 -10.92 cm, 1.5 -10.75 cm, 1.8 -10.72 cm, 1.2 -10.50 cm) and substrate 2 (2.3 -11.20 cm, 2.5 -10.92 cm, 2.2 -10.29 cm).

The ratio of the stem length to the underground part of the seedlings was between 1:1 and 1:1.3 in most of the treatments (treatments 1.7, 1.5, 1.4, 2.2, 2.5, etc.) and between 1:1.4 and 1:1.5 only in treatments 2.4, 1.3, 3.3, 2.8, 3.7, 2.6.

Absolute dry biomass of the seedling, aboveground biomass and root biomass were also determined (Fig. 7).

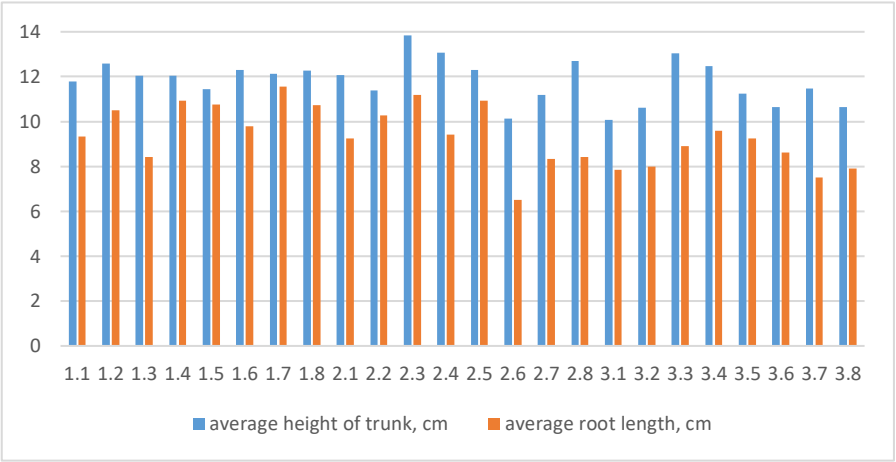

Fig. 6. Average stem height and root length (cm) of Siberian spruce seedlings 27 September 2023.

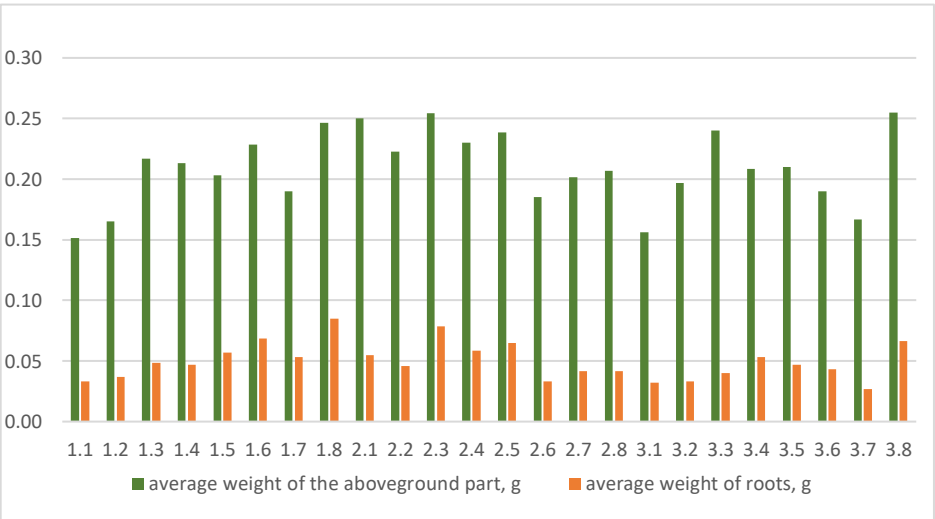

Fig. 7. Average weight of above-ground and underground parts of Siberian spruce seedlings 27.09.2023 (grams)

The highest aboveground mass was found in seedlings on substrate 3 (3.8 -0.26 g, 3.3 -0.24 g, 3.5 -0.21 g, 3.4 -0.21 g), substrate 2 (2.3 -0. 25 g, 2.1 -0.25 g, 2.5 -0.24 g, 2.4 -0.23 g, 2.2 -0.22 g, 2.8 -0.21 g), substrate 1 (1.8 -0.25 g, 1.6 -0.23 g, 1.3 -0.22 g, 1.4 -0.21 g).

Root weight was higher in substrate 1 (1.8 -0.09 g, 1.6 -0.07 g, 1.5 -0.06 g), substrate 2 (2.3 -0.08 g, 2.5 -0.07 g, 2.4 -0.06 g, 2.1 -0.06 g), substrate 3 (3.8 -0.07 g).

Measurement of stem diameter showed that the highest value was found in the experiment variant on substrate 3 (3.8 -2.37 mm, 3.3 -2.03 mm, 3.6 -1.97 mm, 3.4 -1.85 m) on substrate 1 (1.6 -2.07 mm, 1.3 -1.92 mm), on substrate 2 (2.8 -1.98 mm, 2.1 -1.92 mm, 2.3 -1.91 mm).

4 Discussion

Thus, the best substrate for increasing germination of Siberian spruce was substrate 1. The germination energy of spruce seeds was higher in the pre-sowing treatment with the

preparations Kornesil, Phytozont, Ultramag Boron. The germination of spruce seeds was significantly increased in the pre-sowing treatment with the preparations Giberelon + Kornevin, Phytozont, Ultramag Boron, Kornesil, potassium humate, potassium permanganate, Borogum-M, humate with microelements.

The highest number of spruce seeds germinated during the first month of observation was obtained with pre-sowing treatment with Giberelon+Kornevin, Phytozont, Kornesil, potassium humate, potassium permanganate, potassium permanganate, Ultramag Boron, Borogum-M.

The first and third substrates and all substrates with pre-sowing treatment with Giberelon+Kornevin showed the lowest seedling losses at extreme temperature drops and temperature differences.

High growth rate in the first month of observation was shown by seedlings on the first and second substrates under pre-sowing treatment with Giberelon+Kornevin, Borogum-M, Humate with microelements, Potassium manganate, Cornesil, Potassium humate.

The extreme decrease of the air temperature in June 2023 caused a decrease of the growth rate in all the variants of the experiment. However, seedlings on substrates 2 and 3 (pre-sowing treatment with Kornesil, humate with microelements, potassium manganese, Phytozont) showed a less pronounced reduction in growth rate compared to other variants.

On the contrary, in the case of exceptionally high temperatures in July, the seedlings in the variants of the experiment on substrate 1 exhibited an increase in growth rate, regardless of the preparations used in the pre-sowing treatment, but the seedlings treated with Phytozont, Giberelon+Kornevin, Cornesil, Ultramag Boron exhibited a slightly higher growth rate. Irrespective of the preparations used in the pre-sowing treatment, the growth rate of seedlings on substrates 2 and 3 under abnormal heat was significantly lower than that of seedlings on substrate 1. A decrease in growth rate by September was observed in all experimental variants, but on substrate 2 (potassium manganese acid, potassium humate, Barrel and 4 buckets, humate with microelements) the decrease in growth rate was much slower.

The analysis of seedling growth dynamics showed that seedlings on substrate 1 tolerated air temperature decrease worse in the first months of development, but accelerated growth significantly with temperature increase and reduced growth rate equally sharply with autumn temperature decrease.

Spruce seedlings on substrate 2 and 3 with pre-sowing treatment with Humate with microelements, Borogum-M, Potassium Humate (Barrel and 4 buckets) more easily tolerate extreme temperature reductions in the first month of development, but significantly reduce growth rates at abnormal temperature increases compared to seedlings on the first substrate.

In autumn, when the temperature decreases, seedlings on substrate 2 relatively slowly reduce growth rates compared to other variants.

The final height of seedlings was higher on substrate 2 (pre-sowing treatment: Humate with trace elements (8.4 cm), Potassium Manganese (8.04 cm), Borogum-M (7.35 cm), Cornesil (7.71 cm), Potassium Humate (Barrel and 4 buckets) (7.6 cm).

Stem height of Siberian spruce seedlings in these variants of experiments (12.58-13.83 cm) was higher than the recommended values for two-year-old seedlings (8 cm). Also, the experimental seedlings were significantly higher than the parameters of first-year Siberian spruce seedlings in natural germination conditions. There they are uniaxial plants 3-4 cm high, having hypocotyl, 6-7 seedlings up to 15 mm long and apical bud [8].

The average root length of seedlings was higher in experiments on substrate 1 (Ultramag Boron, Borogum-M, Cornesil, Phytozont, potassium humate (Barrel and 4 buckets), on substrate 2 (Humate with microelements, Cornesil, potassium humate (Barrel and 4 buckets)).

In seedlings on substrate 3 (pre-sowing treatment with preparations Phytozont - 0.26 g, Humate with trace elements - 0.24 g, Borogum-M - 0.21 g), on substrate 2 (Humate with

trace elements - 0.25 g, potassium permanganate - 0.25 g, Kornesil - 0.24 g, Borogum-M - 0.23 g, Potassium Humate (Barrel and 4 buckets) - 0.22 g, 2. 8 -0.21 g), on substrate 1 (Phytozont - 0.25 g, Hyberelon +Kornevin - 0.23 g, Humate with trace elements - 0.22 g, Borogum-M - 0.21 g) revealed the highest average above-ground weight. The average root weight was higher on substrate 1 (Phytozont - 0.09 g, Giberelon + Kornevin - 0.07 g, Kornesil - 0.06 g), substrate 2 (Humate with trace elements - 0.08 g, Kornesil - 0.07 g, Borogum-M - 0.06 g, potassium permanganate - 0.06 g), substrate 3 (Phytozont - 0.07 g).

5 Conclusion

Siberian spruce can play a significant role in forest restoration and the reclamation of disturbed lands due to its morphobiological qualities. Rapid cultivation of spruce planting material can contribute to this role.

Experimental cultivation of Siberian spruce on different substrate types and pre-sowing treatment with various preparations revealed that the best substrate for increasing germination energy and seed viability is substrate 1, with a relative density of 0.6 g/cm3 and pH 4.7-5. Pre-sowing treatment with preparations such as KorneSil, Fitozont, Ultramag Bor, Gibberellin + Rootwin, and Potassium Humate resulted in higher germination energy and seed viability on the first substrate. Seedlings in experiments on substrates 2 and 3 exhibited lower germination energy and viability due to less dense substrate and the addition of humic and organic preparations, raising the pH (Gumi Omi conifers, Bionex-Chemi, Gumi-90) [9]. Optimal pH for the germination of Siberian spruce seeds is in the range of pH 4.7-5.3. Increasing pH leads to a decrease in seed viability [10].

However, the best biometric indicators (greater stem height, total and above-ground biomass, stem diameter) in September were observed in seedlings grown on substrates 2 and 3, differing only in density, thanks to the addition of agroperlite in substrate 3. Both substrates, besides peat, contain a complex of humic acids and salts, mineral fertilizers, microelements, strains of friendly soil microflora, and mycorrhiza. The density of substrate 2 is 0.5 g/cm3, and the density of substrate 3 is 0.3 g/cm3. The acidity of these substrates at the beginning of cultivation was pH 5-5.5, decreasing to 4.8 by the end of the growing season.

Despite the optimal germination in a denser peat substrate with pH 4.7-5, for the more intensive development of seedlings, it is suggested to introduce a complex of microbiological and humic preparations into the initial substrate through mulching and watering. Subsequent regular fertilization is recommended for their enhanced development in the first year.

Extreme temperature fluctuations in the summer of 2023 resulted in a growth rate reduction for Siberian spruce seedlings. Seedlings on substrates 2 and 3 proved more resistant to temperature drops, attributed to strengthened immunity under the influence of microbiological additives. However, excessive temperature increase (above 30 degrees) caused growth rate setbacks compared to seedlings on substrate 1, due to lower substrate density, quickly losing moisture. High temperatures also reduced the activity of friendly microflora. Seedlings grown on a denser substrate 1, retaining moisture longer, effectively endured extremely high temperatures, enhancing their growth rates.

In summary, Siberian spruce seeds germinate better in a denser peat substrate with pH 4.7-5. However, for their more intensive development, introducing a complex of microbiological and humic preparations into the initial substrate through mulching and watering is necessary [11]. Regular fertilization with preparations such as Gumi Omi conifers, Bionex-Chemi, Gumi-90, and Monopotassium Phosphate is recommended. The impact of microbiological preparations on seed germination may require further investigation, but their positive influence on seedling growth intensification is evident.

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