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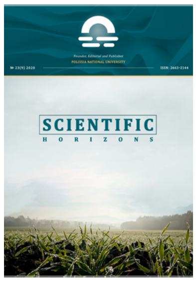

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Growth and Development of Seedlings of Scots Pine and European Spruce Container Seedlings Using Various Materials to Neutralise the Substrate

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Abstract. The article analyses the features of growth and development of seedlings of Scots pine and European spruce on substrates in which various materials were used to neutralise them, affecting the reaction of the environment. According to the research results, the highest germination of seeds of both woody species was established on substrates with a ratio of dolomite flour of 30% and chalk of 70%, while in the case of using pure chalk, seed germination was significantly lower. Scots pine seeds germination in the substrate ranged from 77.6% to 90.1%, and European spruce seeds – from 66.4% to 94.3%. During the cultivation of seedlings of Scots pine and European spruce container seedlings, differences in the content of mobile forms of phosphorus are noted in all variants of the experiment. However, no definite pattern was found depending on the share of participation of various types of lime material. In the substrate of seedlings of Scots pine at the end of the growing season, the content of nitrate nitrogen naturally increases from 1069.1 to 1323.6 mg/100 g of absolutely dry substrate with a decrease in the proportion of dolomite and an increase in the proportion of chalk in the lime neutralising material. Another pattern is manifested when growing seedlings of European spruce container seedlings: the lowest content of nitrate nitrogen (412.1 mg/100 g of absolutely dry substrate) is established in the case of mixing dolomite flour and chalk in equal proportions (option 3). Differences in the content of mobile forms of iron were revealed in all experimental versions of the substrate of both woody species. For the cultivation of Scots pine, its amount ranges from 16.67 to 28.81 mg/100 g of absolutely dry substrate, and European spruce – from 18.40 to 20.99 mg/100 g of absolutely dry substrate. In general, low content of mobile iron was observed in the substrate of growing pine and spruce seedlings in containers. In all experimental variants, the height of seedlings of Scots pine container seedlings exceeds the required average height of the aboveground part in accordance with national standard by 1.3-2.0 times, and for seedlings of European spruce the excess was 1.2-1.5 times. In seedlings of Scots pine and European spruce, according to the variants of the experiment, the average height of the aboveground part rises with an increase in the concentration of dolomite in the mixture of neutralising material from 50% and higher

Keywords: container planting material, container seedlings, substrate composition, peat substrate, medium reaction, seed germination

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INTRODUCTION

Optimal conditions for the growth and development of plants are determined by a whole complex of factors, including the reaction of the environment. Scientific research and practical experience have established that high values of environmental reaction parameters (acidity and alkalinity) have a negative impact on the growth of the root and stem parts of plants [1]. The development of the direction of growing planting material container seedlings (PMCS) dates back to the 60s of the last century, when almost simultaneously in many countries (Scandinavian countries, Northern Europe, South America, Canada, USA) industrial cultivation and research of the growth characteristics of planting material in individual and multi-chamber containers of various types and sizes were started. To date, many types of insulating materials are known – peat and ceramic pots, briquettes, paper honeycombs, plastic bags, and others [2].

At the end of the 1960s, research was started at the St. Petersburg Scientific Research Institute of Forestry and the Latvian Scientific Research Institute of Forestry Problems, as a result of which a technology for growing seedlings using the "Briquette" method was developed. According to this method, the root systems of annual seedlings of coniferous species grown in a greenhouse were placed between two pressed peat plates measuring 2×5×20 cm each. The volume of the root-forming briquette or lump was 400 cm^3. Briquettes were tied, stacked 50 pcs. between two polyethylene tapes, rolled up and placed in containers with a nutrient liquid medium. After impregnation, the rolls were sent to the greenhouse, and then, after a week, to an open area for growing for one year [1].

In Belarus, Plantek 64F and 35F reusable hard plastic cassettes are used for the cultivation of annual seedlings of coniferous tree species. 64F cassettes, as a rule, are designed for the cultivation of Scots pine for one year, while seedlings of European spruce are recommended to be grown to obtain standard sizes within a 2-year period [3]. The technology of growing PMCS in Belarus began to be used in the late 70s of the last century when a line for obtaining seedlings from the CRS was set up on the basis of the Glubokoe experimental forestry. The next stage of the implementation of this technology was the installation of the line in the Republican Forest Breeding and Seed Production Centre. Currently, the development of technology for growing PMCS is determined by the sectoral program for growing PMCS in the organisations of the Ministry of Forestry of the Republic of Belarus [3], which provides for the construction of four modern and modernisation of two outdated industries.

The production of PMCS is associated with higher costs for growing seedlings, a significant part of which falls on the preparation of the substrate. The size and quality of seedlings depend on the composition and quality of the substrate [3-5], the safety of the substrate coma during transportation [6-8], as well as the growth and development of seedlings in the first years after transplanting to the forest area [9-11]. In foreign countries, over the past more than 20 years, the production of PMCS has been further developed and in practice it has been proven that its production and introduction into forestry production is a more promising direction compared to the use of planting material with an open root system [12-14]. PMCS is increasingly being used in the forestry practice of forest reproduction and afforestation in many countries [15-17].

Indisputable is the fact of the use of various types of PMCS in the forestry production of Belarus, however, the issue of choosing the optimal type of substrate for the production of seedlings of Scots pine and European spruce container seedlings with the selection of the most suitable materials for its neutralisation is still relevant [12].

Many scientists have been engaged in the selection of the optimal substrate for growing plants container seedlings, the selection of various materials for its neutralisation, the evaluation of the effectiveness and prospects of using container plants in forestry production in various countries. In Russia, these studies were conducted by G. Kovalenko and M. Kovalenko [18], in the North-West of Russia – D.S. Burtsev [19], in the North – S.V. Bobushkina and B.A. Mochalov [20], in Karelia – A.V. Zhigunov, A.I. Sokolov and V.A. Kharitonov [16], in Finland – N.V. Landis, R.K. Dumrose, J.R. Pinto [21], in Poland – K. Szabla and R. Pabian [22], in the USA – J.P. Barnett, J.M. McGilvrary, K.D. Howell and T.B. Harrington [23; 24], in Belarus – V.V. Nosnikov [25; 26], O.A. Selishcheva, A.M. Granik, A.V. Romanchuk, A.A. Domasevich, A.V. Yurenia [27], N.I. Yakimov, I.V. Sokolovsky, V.V. Tsai [28], and S.V. Suraviev [29], in Ukraine – V.V. Gupal [15], I.M. Boboshko-Bardin [30], O.I. Lyalin [31].

The purpose of this study is to determine the effect of materials neutralising peat substrate on the growth and development of seedlings of Scots pine and European spruce when growing them container seedlings.

The object of research is the planting material of Scots pine and European spruce container seedlings. *The subject of the study* is the special features of the growth and development of container seedlings of Scots pine and European spruce with the use of various substrate neutralising materials.

MATERIALS AND METHODS

In order to determine the degree of influence of peat-based substrates with the introduction of various combinations of neutralising materials on the growth and development of container seedlings of Scots pine and European spruce an experiment was carried out in the spring of 2020. The substrates were prepared on the basis of separated top peat of a milling billet, into which lime materials (dolomite flour, chalk and their combinations) were introduced to create an optimal acidity regime for these woody species according to national standard [26].

The substrates were thoroughly mixed and moistened with water to a relative humidity of 60-70%, then the cassettes were filled with them and compacted.

The quality of the planting material of coniferous tree species with CRS is determined according to national standard [26]. Planting material should have lignified shoot tips with fully formed dormant buds that are in a dormant state at the end of the growing season.

For growing seedlings of Scots pine and European spruce, were used Plantek 35F and 64F cassettes, respectively, which are widely used for the industrial cultivation of seedlings of these tree species in the Republic of Belarus, as well as in other neighbouring countries with a solid nursery base.

To create optimal conditions for seed germination and seedling cultivation, cassettes were placed in the greenhouse of the Republican Forest Breeding and Seed Production Centre with controlled microclimate parameters. For an active experiment, 6 cassettes for pine and 4 for spruce were used in experimental versions. In the spring of 2020, seeds of Scots pine and European spruce of the 1st quality class were sown in cassettes filled with substrate. The germination of seeds was established on June 7 – on the 30th day after sowing them in cassettes – by analysing the state of seedlings in all variants of the experiment.

The share of various types of lime fertilisers in the total mass of lime material in the substrate according to the variants was:

1) milling peat + lime material (100% dolomite flour);
2) milling peat + lime material (70% dolomite flour 30% chalk);
3) milling peat + lime material (50% dolomite flour 50% chalk);
4) milling peat + lime material (30% dolomite flour, 70% chalk);
5) milling peat + lime material (100% chalk).

In autumn (September 20), measurements of the main biometric indicators (height of the aboveground part and diameter at the root neck) of container seedlings of the studied tree species were made. Also, at the end of the growing season, pH measurements were carried out.

RESULTS AND DISCUSSION

Seed germination is its ability to produce normal seedlings (in the laboratory) or seedlings (in the field) for a certain period of time. It is affected by the quality of seeds, from which trees they are collected, the conditions of their storage and germination. Indicators of germination of seeds of Scots pine and European spruce according to the variants of the experiment are shown in Figure 1. The germination rate of Scots pine seeds ranged from 77.6 to 90.1%, and European spruce – from 66.4 to 94.3%. With an increase in the share of chalk up to 70% in the composition of lime material, the germination of seeds of both species naturally increases.

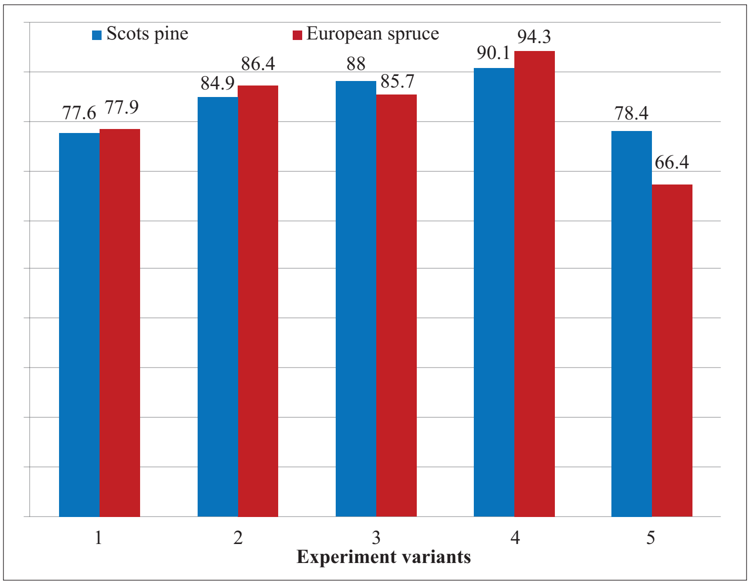

***Figure 1**. Germination of seeds of Scots pine and European spruce in cassettes according to the variants of the experiment, %*

The greatest germination was established in experiments with a ratio of dolomite flour of 30% and chalk of 70%. When using 100% chalk, germination was significantly lower. The results of measurements of biometric indicators of pine and spruce seedlings are presented in Table 1.

***Table 1**. Biometric indicators of seedlings container seedlings on substrates using different materials to neutralise them (in the denominator – statistical indicators for the height of the stem of the seedling (cm), in the numerator – statistical indicators for the diameter at the root neck of the seedling (mm))*

Variant	χ±m	$\bar{x}$	min	max
Scots pine				
1) milling peat + lime material (100% dolomite flour)	15.4±0.2 / 2.66±0.04	4.2 / 0.66	2.5 / 0.89	29.3 / 5.14
2) milling peat + lime material (70% dolomite flour 30% chalk)	13.2±0.2 / 2.25±0.03	3.2 / 0.56	4.2 / 0.68	24.1 / 3.61
3) milling peat + lime material (50% dolomite flour 50% chalk)	16.1±0.2 / 2.70±0.03	4.1 / 0.59	5.1 / 0.76	30.6 / 5.24
4) milling peat + lime material (30% dolomite flour, 70% chalk)	11.9±0.2 / 2.21±0.03	3.4 / 0.52	3.8 / 0.67	20.5 / 4.05
5) milling peat + lime material (100% chalk)	10.3±0.2 / 2.03±0.04	3.0 / 0.62	2.6 / 0.56	19.2 / 3.82
European spruce				
1) milling peat + lime material (100% dolomite flour)	20.8±0.5 / 2.69±0.05	6.3 / 0.61	4.0 / 0.76	33.0 / 3.90
2) milling peat + lime material (70% dolomite flour 30% chalk)	20.5±0.6 / 2.55±0.05	6.0 / 0.52	4.8 / 0.94	37.5 / 3.69
3) milling peat + lime material (50% dolomite flour 50% chalk)	20.4±0.6 / 2.69±0.05	6.8 / 0.50	4.0 / 1.20	34.3 / 3.88
4) milling peat + lime material (30% dolomite flour, 70% chalk)	17.3±0.6 / 2.48±0.06	6.0 / 0.63	3.9 / 0.72	30.6 / 3.90
5) milling peat + lime material (100% chalk)	18.5±0.6 / 2.74±0.06	5.7 / 0.32	3.2 / 1.13	31.5 / 4.19

***Note**: χ is the average value, m is the error of the average value, x is the standard deviation, min is the minimum value of the indicator, max is the maximum value of the indicator*

Figures 2 and 3 are shown for a visual comparison of seedling height and diameter at the root neck on the different variants.

The height of experimental seedlings of Scots pine exceeds the required average height of the aboveground part according to national standard by 1.3-2.0 times, and the height of annual seedlings of European spruce – by 1.2-1.5 times. The average height of the aboveground part increases with an increase in the concentration of dolomite in the neutralising material from 50% or more (Fig. 2).

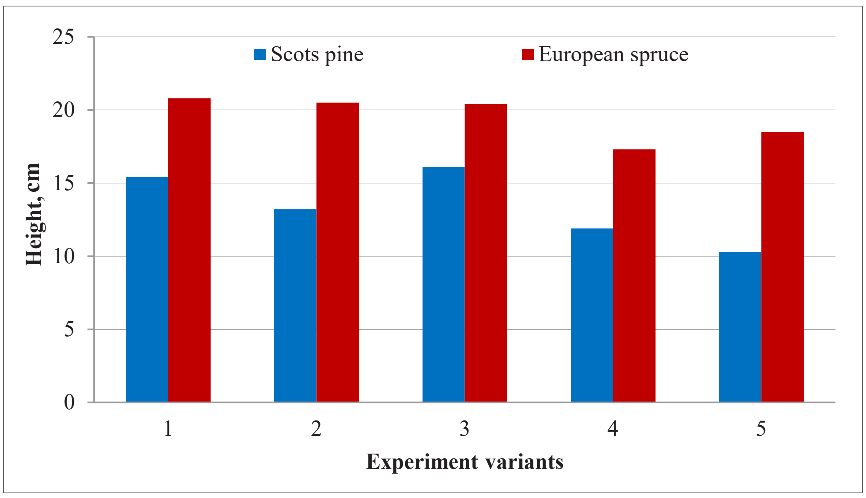

***Figure 2**. The average height of container seedlings of Scots pine and European spruce according to the variants of the experiment*

At the same time, seedlings of Scots pine have the highest average height in variant 1, where the lime material consisted of 100% dolomite flour; seedlings of European spruce in variant 3, where the lime material consisted of dolomite flour and chalk in equal parts.

The best diameter of seedlings of Scots pine was found when using 100% chalk, and European spruce when using dolomite flour and chalk in equal parts. The results of determining the mobile forms of phosphorus and the reaction of the medium in the substrate samples at the end of the growing period of seedlings of Scots pine and European spruce container seedlings are presented in Table 2.

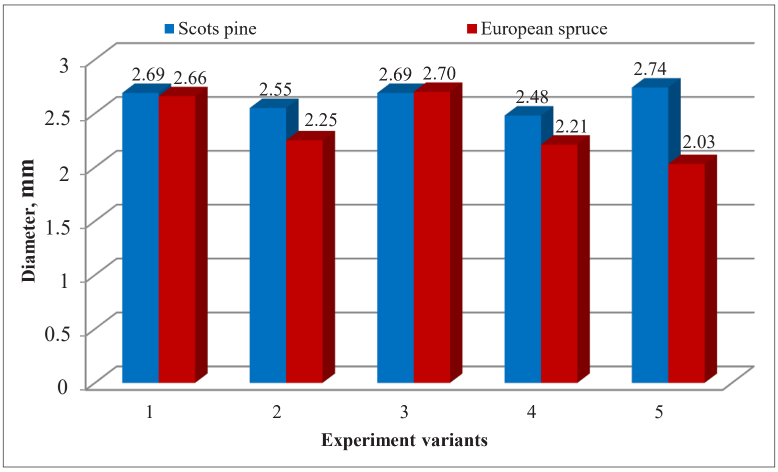

Figure 3. *The average diameter of the root neck of seedlings of Scots pine and European spruce in cassettes according to the variants of the experiment*

Table 2. *The number of mobile forms of phosphorus and the reaction of the medium in the substrate samples at the end of the growing season of the first year of growing seedlings in cassettes*

Experiment variant	P_2O_5 mg/100 g of absolutely dry substrate	Medium reaction (pH kcl)
Scots pine		
1) milling peat + lime material (100% dolomite flour)	446.2	4.34
2) milling peat + lime material (70% dolomite flour 30% chalk)	540.8	4.49
3) milling peat + lime material (50% dolomite flour 50% chalk)	450.2	4.45
4) milling peat + lime material (30% dolomite flour, 70% chalk)	456.8	4.65
5) milling peat + lime material (100% chalk)	474.9	4.40
European spruce		
1) milling peat + lime material (100% dolomite flour)	382.8	4.07
2) milling peat + lime material (70% dolomite flour 30% chalk)	288.8	4.13
3) milling peat + lime material (50% dolomite flour 50% chalk)	345.1	4.27
4) milling peat + lime material (30% dolomite flour, 70% chalk)	338.9	4.23
5) milling peat + lime material (100% chalk)	340.9	4.56

Differences in the content of mobile forms of phosphorus and the reaction of the medium (pH) are noted in all variants of the experiment. However, no definite pattern was found depending on the change in the share of participation of various types of lime material. As a result of the research, the following change in the reaction of the medium in the substrate during the cultivation of Europe-an spruce was established: the pH value increases from 4.07 to 4.56 with a decrease in the proportion of dolomite in the initially added neutralising material and an increase in the proportion of chalk. A similar pattern is manifested in the cultivation of Scots pine, with the exception of the experimental variant 5 using pure chalk, where the pH value decreased to 4.40.

The results of determining the amount of ammonia, nitrate nitrogen, exchangeable potassium and mobile forms of iron at the end of the growing season in substrate samples when growing seed-lings of Scots pine and European spruce with CRS are presented in Table 3.

***Table 3**. Chemical composition of substrates at the end of the growing season*

Experiment variant	Ammonia nitrogen (NH_4+)	Nitrate nitrogen (NO_3–)	Exchangeable potassium K_2O	Iron Oxide Fe_2O_3
	mg/100 g of absolutely dry substrate			
Scots pine				
1) milling peat + lime material (100% dolomite flour)	35.4	1069.1	491.6	28.81
2) milling peat + lime material (70% dolomite flour 30% chalk)	75.3	1170.5	487.9	16.67
3) milling peat + lime material (50% dolomite flour 50% chalk)	65.9	1211.4	603.3	18.24
4) milling peat + lime material (30% dolomite flour, 70% chalk)	83.3	1274.2	489.3	17.18
5) milling peat + lime material (100% chalk)	133.8	1323.6	553.8	21.41
European spruce				
1) milling peat + lime material (100% dolomite flour)	20.4	532.9	327.1	18.40
2) milling peat + lime material (70% dolomite flour 30% chalk)	35.0	459.8	305.5	19.46
3) milling peat + lime material (50% dolomite flour 50% chalk)	106.7	412.1	372.1	18.87
4) milling peat + lime material (30% dolomite flour, 70% chalk)	16.2	464.2	311.2	19.22
5) milling peat + lime material (100% chalk)	10.3	473.1	376.2	20.99

According to Table 3, it follows that when growing Scots pine, the content of ammonia nitro-gen increases from 35.4 to 133.8 mg/100 g of absolutely dry substrate with a decrease in the propor-tion of dolomite and an increase in the proportion of chalk in the composition of lime material. A different pattern was established when growing European spruce: the highest content of ammonia nitrogen (106.7 mg/100 g of absolutely dry substrate) is observed when mixing dolomite flour and chalk in equal proportions (experiment version 3).

Regarding nitrate nitrogen in the substrate, the following has been established: when growing Scots pine, its content naturally increases from 1069.1 to 1323.6 mg/100 g of absolutely dry sub-strate with a decrease in the proportion of dolomite and an increase in the proportion of chalk in the lime material. When growing European spruce, the lowest content of nitrate nitrogen is observed when mixing dolomite flour and chalk in equal proportions (experiment variant 3), and the highest – in the absence of chalk in the substrate (experiment variant 1).

Analysis of the content of nitrate nitrogen in substrates at the end of the growing season showed that the substrate in which seedlings of Scots pine are grown contains a much larger amount of it (2-3 times more) compared with the substrate where the seedlings of European spruce were grown.

According to the content of exchangeable potassium in Scots pine, the highest value is at an equal dose of chalk and dolomite flour, and the lowest – at 30%

dolomite flour and 70% chalk. For European spruce, the situation is different, exchangeable potassium is presented to a greater extent in the variant with 70% dolomite flour and 30% chalk, and the least – in the variant with 100% chalk. The situation is reversed only with iron oxide being higher at 100% dolomite meal and the lowest at 100% chalk.

On the contrary, iron oxide had a higher value with a content of 100% dolomite flour and 30% chalk. This, in turn, suggests that with an increase in the iron content, the seedlings of Scots pine have a better height and diameter of the root neck.

CONCLUSIONS

At the initial stage of germination of seeds of Scots pine and European spruce, the main nutrition of seedlings is provided by the endosperm of seeds. The obtained results of the influence of substrates of different structural composition and using various neutralising materials, such as dolomite flour and chalk, indicate high seed germination rates. Germination of Scots pine seeds in substrates using various neutralising materials ranged from 77.6% to 90.1%, and seeds of European spruce – from 66.4% to 94.3%. In experimental versions using different neutralising materials, the average height of seedlings of Scots pine exceeds the required average height of the aboveground part according to national standard by 1.3-2.0 times, and seedlings of European spruce – by 1.2-1.5 times. In seedlings of Scots pine and European spruce, according to the variants of the experiment, the average height of the aboveground part rises with an increase in the concentration of dolomite in the mixture of neutralising material from 50% and higher. It should also be borne in mind that the European spruce should reach standard indicators (in accordance with the technical conditions) in the second year of cultivation, while in the experimental versions, plants of one-year age were measured.

The content of nitrate nitrogen increases from 1069.1 to 1323.6 mg/100 g of absolutely dry substrate with a decrease in the proportion of dolomite and an increase in the proportion of chalk in the lime material. Analysis of the content of nitrate nitrogen in substrates at the end of the growing season showed that the substrate in which seedlings of Scots pine are grown contains a much larger amount of it (2-3 times more) compared with the substrate where the seedlings of European spruce were grown.

The exchange potassium for Scots pine has the highest value with an equal dose of chalk and dolomite flour, and the least – with 30% dolomite flour and 70% chalk, the situation is quite different for European spruce – the content of exchange potassium is higher in the variant of 70% dolomite flour and 30% chalk, and least of all – with 100% chalk. The highest iron oxide content is in the 100% dolomite flour variant, and the lowest is at 100% chalk. The iron oxide content is higher with 100% dolomite flour and 30% chalk. This, in turn, suggests that with an increase in the iron content, seedlings of Scots pine reach higher height and diameter at the root neck.

When growing seedlings of Scots pine and European spruce container seedlings in variants with pure chalk with equal proportions of chalk and dolomite flour, the content of exchangeable potassium was 13-24% higher than in other experiments. The content of exchangeable potassium in the substrate when growing Scots pine is 1.6 times higher on average compared to the substrate when growing European spruce. According to the content of mobile forms of iron in the substrate, there are absolutely insignificant differences in all variants of the experiment. The iron content in the substrate when growing Scots pine is from 16.67 to 28.81 mg/100 g of absolutely dry substrate, in the substrate when growing European spruce – from 18.40 to 20.99 mg/100 g of absolutely dry substrate. In general, low content of mobile forms of iron in substrates is observed when growing seedlings of the tree species under study.

The obtained research results show that these requirements for growing container seedlings of the studied coniferous species in the closed root system in the Republican Forest Breeding and Seed Production Centre are observed with a slight deviation for seedlings of Scots pine.

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Ріст і розвиток сіянців сосни звичайної і ялини європейської із закритою кореневою системою за використання різних матеріалів для нейтралізації субстрату

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Анотація. У статті проаналізовано особливості росту і розвитку сіянців сосни звичайної та ялини європейської на субстратах, у яких було використано різні матеріали для їх нейтралізації, що впливають на реакцію середовища та хімічний склад. За результатами досліджень найбільша схожість насіння обох деревних видів встановлена на субстратах із співвідношенням доломітового борошна 30 % і крейди 70 %. Однак у разі застосування чистої крейди схожість насіння була значно нижчою. Схожість насіння сосни звичайної в субстраті становила від 77,6 % до 90,1 %, а насіння ялини європейської – від 66,4 % до 94,3 %. Під час вирощування сіянців сосни звичайної та ялини європейської із закритою кореневою системою по всіх варіантах досліду відзначаються відмінності у вмісті рухомих форм фосфору. Однак певної закономірності залежно від частки участі різних видів вапняного матеріалу не виявлено. У субстраті сіянців сосни звичайної в кінці періоду вегетації закономірно підвищується вміст нітратного азоту від 1069,1 до 1323,6 мг/100 г абсолютно сухого субстрату при зниженні частки участі доломіту та збільшенні частки крейди у вапняному нейтралізуючому матеріалі. Інша закономірність проявляється за вирощування сіянців ялини європейської із закритою кореневою системою: найменший вміст нітратного азоту (412,1 мг/100 г абсолютно сухого субстрату) встановлено у випадку змішування доломітового борошна та крейди в рівних пропорціях (варіант 3). Відмінності за вмістом рухомих форм заліза виявлено по всіх дослідних варіантах субстрату обох деревних видів. За вирощування сосни звичайної його кількість коливається від 16,67 до 28,81 мг/100 г абсолютно сухого субстрату, а ялини європейської – від 18,40 до 20,99 мг/100 г абсолютно сухого субстрату. Загалом можна говорити про низький вміст рухомого заліза в субстраті вирощування сіянців сосни і ялини в контейнерах. У всіх дослідних варіантах висота сіянців сосни звичайної з із закритою кореневою системою перевершує необхідну середню висоту надземної частини по національному стандарту в 1,3–2,0 рази, а висота сіянців ялини європейської – в 1,2–1,5 рази. У сіянців сосни звичайної і ялини європейської по варіантам досліду збільшується середня висота надземної частини із збільшенням концентрації доломіту в суміші нейтралізуючого матеріалу від 50 % і більше

Ключові слова: посадковий матеріал із закритою кореневою системою, контейнерні сіянці, склад субстрату, торф'яний субстрат, реакція середовища, схожість насіння